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AN ANALYTIC STUDY OF THE MEMORY IMAGE AND THE PROCESS OF JUDGMENT IN THE DISCRIMINATION OF CLANGS AND TONES.

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INTRODUCTION.

During the winter of 1897-98, the writer, then a student at Clark University, was attracted to the problem with which the present investigation deals by the observation of several rather unusual instances of 'pitch memory.' These observations led to an experimental investigation which was instituted with a view of analyzing qualitatively the structure of such processes of discrimination. The tests were, however, of an unsystematic nature, and were mainly restricted to personal observations conducted with the aid of a piano.

The more detailed and systematic study of the problem, the results of which are embodied in the present paper, was undertaken in the Psychological Laboratory at Cornell University during the academic years 1898-99 and 1899-1900. An added interest was given to the problem, and a favorable setting secured for the necessary experimentation, by the fact that there had just been completed in the same laboratory an essentially similar study in the domain of vision.¹

Since this article fully discusses the general bearing of the problem in hand, the present paper needs but little introduction. It may be well, however, to recount briefly the features of the preceding work which bear especially upon the prob-

¹ I. M. Bentley: The Memory Image and its Qualitative Fidelity, this *Journal*, XI, 1899, 1-48.

lem, and also to make preliminary mention in this place of certain previous publications upon pitch memory which must necessarily be handled in some detail in the discussion of our results.

Setting out from Kuelpe's contention that much of the work on memory has assumed without sufficient cause the presence of a memory image, and that the term has been too loosely applied, Bentley has given a review of the literature bearing upon the memory image and the methods of its investigation, has discussed its genesis and function, and conducted an experimental study of the qualitative fidelity of memory images of color and brightness. He points out that the modern laboratory researches in this field have been chiefly pedagogic and popular rather than analytic in nature.¹

The chief methods for the study of the image are those of reproduction, recognition, comparison, and description. In view of the schematic nature of the reproduced elements, an important analytic problem is afforded if we seek to determine not how much of a given impression can be reproduced, but what is the nature of the centrally excited processes which form the basis of the act of reproduction or of recognition.

Both Wolfe² and Lehmann³ assumed the presence of a memory image in the recognitory consciousness; Hoeffding⁴ posited an unanalyzable 'quality of knownness' which had its physical substrate in a certain ease of molecular movement in the cortex; Washburn⁵ has advanced the hypothesis that recognition is a peculiar property of centrally excited sensations, possibly mediated by the excitation of connective brain tracts; Kuelpe⁶ has mentioned effectiveness for the arousal of centrally excited sensations *plus* a mood of familiarity; Baldwin⁷ the ease of motor adjustments of attention; and Wundt⁸ a feeling of recognition supported by a background of ideas.

Perception, like recognition, does not necessarily include reproduction, although it involves the past experience of the individual. We may arrange a schema of types of meaning-consciousnesses which shall show at a glance the part played by the image. Such a schema is given herewith:

1. Cognition (perception): no image introspectively discoverable.

¹ The articles of Philippe, *Rev. phil.*, Vol. XLIII, 1897, 481-493, *ibid.*, Vol. XLIV, 1897, 508-524, by their emphasis of the analytic study of the image for its own sake, form a pleasing exception to this tendency.

² *Phil. Stud.*, III, 1886, 556-558.

³ *Phil. Stud.*, V, 1889, 118-119.

⁴ *Vierteljahrsschrift*, 1899-90.

⁵ *Phil. Rev.*, VI, 1897, 267.

⁶ *Outlines of Psychology*, 1895, p. 172.

⁷ *Mental Development*, 1895, 313 ff.

⁸ *Phil. Stud.*, VII, 1892, 344 ff.

2. Recognition.

- A. Direct recognition: no image is necessary (whether the process be conducted with active or passive attention) save in the form of direct recall (memory in the narrow sense).
- B. Mediate recognition: when it involves conscious comparison an image is implied, but otherwise auxiliary ideas or other motives may be sufficient.

Bentley's experimental tests were conducted mainly by the method of recognition, with special precaution to secure knowledge of the presence or absence of the image just at the end of the time-interval. In the first series, conducted with open eyes, the observers did not try to hold the brightness image. Images were present in five-sixths of the tests. They could be recalled better at the end of five minutes than at the end of one minute. On the other hand, there were frequent instances of flash-like, absolutely certain judgments, where there is no trace of comparison and no vestige of an image,—judgments in which "the work seems to have all been done for consciousness."¹ There was a constant tendency toward lightening of the imaged brightness. The second series proceeded by a continuous change method. The results showed that the method hindered the employment of the image in processes of comparison, and that the individual variations were large. Although the standard was approached from two directions, yet a large amount of expectation might obscure any constant memory error. The quantitative results exhibited large mean variations.²

The third series reported by Bentley was made by the method of right and wrong cases, with special regard to the stimulation of the retina during the interval (2-60 secs.). In these tests the observer was asked to hold the image actively. The result of non-stimulation of the retina during the interval was to darken the brightness image. The amount of darkening and consequent loss of accuracy increased slowly from 2 to 60 seconds, but without the peculiar periodicity asserted by Wolfe and others.

In conclusion Dr. Bentley adds: "Simple recognition stands much nearer positive or negative identification (expressed by affirmative or negative judgments) than it does to pure memory, and the alleged act of comparison with a memory image is rather a logical formulation, suggested by the judgments 'like' and 'different,' than a psychological statement of fact. Where the image is available memory is slightly more accurate," but recognition may be sure and precise when the image plays no part.

The experiments of Wolfe³ by the method of right and wrong cases

¹ Chronoscopic measurements of such immediate judgments, in the case of recognition of tones, will be given later.

² A detailed discussion of the application of this method to the problem in audition will be given later.

³ *Phil. Stud.*, III, 1886, 534-571.

are, as regards the materials (clangs of the Appunn tonometer) and the intervals employed (mainly 2 to 60 seconds), more in accord with those of the present investigation than the experiments upon the fidelity of the visual memory image just reviewed, although in their essential purpose, since they were concerned with a functional investigation (the capacity for tonal recognition as conditioned by time interval), they are not at all closely allied to our experiments. More especially, Wolfe, as has already been mentioned, assumed that the quotient r/n (method of right and wrong cases) measured the fidelity of the memory image. This assumption depends in turn upon the hypothesis that the image is always actively present in the judgment. Thus he says (p. 556): "Gehen wir naeher auf das Verfahren beim Vergleichen zweier durch einen Zeitraum getrennten Toene ein, so ist klar, dass ohne ein Erinnerungsbild des ersten Tons eine Vergleichung ueberhaupt unmoeglich ist. Dieses Erinnerungsbild ist gewissermassen der Masstab, an welchem der zweite oder Vergleichston gemessen wird." This quotation should be qualified by the following (p. 558): "Es ist aber bekanntlich nicht noetig ein bleibendes Bild im Bewusstsein zu behalten, um eine Vergleichung zu vollziehen. Selbst wenn keine bewusste Spur des ersten Tones zurueckbleibt, ist ein Urtheil oft moeglich, indem der zweite Ton sofort ein Bild des ersten hervorrufft."

The tone differences employed by Wolfe were 4, 8, and 12 vibrations;¹ the categories of judgment were 'same,' 'different' (higher or lower) and 'doubtful.' The results of the series with 4 vibs. D showed that there were more right cases with $D=0$ than with $D=\pm 4$ vibs. The series with $D=8$ vibs. showed that the comparison of different tones ($D=\pm 8$) was less influenced by time-interval than was the recognition of the same tone as 'same' ($D=0$). In the series with $D=12$ vibs. there were still instances, even at four seconds interval, in which difference was recognized, but not the direction of the difference.

The discussion of the dependence of the results upon time-interval brings out the following statements. Despite many disturbing individual factors, more especially that of practice, it may be said that, in general, fidelity of the memory image for pitch decreases in such a manner that the time-interval must increase approximately in geometrical progression in order to effect equal amounts of decrease of retentiveness.² The optimal time for judgment is at 2 secs. At between 10 and 20 seconds (depending upon the observer) there is a rise in the number of right cases which may indicate, according to Wolfe, not only a cessation of the disintegration, but a positive renewal of the image. Whether the explanation be in terms of large periodic variations of apperception (attention to the image) or of the influence of

¹ In every case $D=0$ was included.

² This law is based upon the results for $D=0$.

tonal after-images,¹ the periodicity, as evinced by the curve of right cases, remains an assured fact. The phases of clearness in the image may be assumed to be approximately constant for the same individual and the same degree of effort. The periodicity, therefore, points to a like periodicity in the attention, since clearness of memory is assumed to be dependent upon the attention.

Other general results are that $D=0$ is oftener judged higher than lower; higher is oftener judged correctly than is lower, and lower is oftener judged higher than higher is judged lower. These results are due to the fact that there is a tendency to estimate the memory image owing to its lessened intensity, as lower than an actually heard tone of the same pitch. Practice effects are prominent in the early stages especially in the case of unmusical subjects. Such practice effects seem to be rather restricted in their application; thus Wolfe, who was unmusical, became able to discriminate higher from lower with considerable exactness with a $D=4$ or 8 vibs., but curiously enough was then far less certain with a D of 30 or 40 vibs.

Our general criticism of the work of Wolfe can be well emphasized at this point by a quotation from the recent monograph by Martin and Mueller.² It is a source of satisfaction to find that these authors, whose general purpose, as indicated by the title of their work, is identical with our own, have made express mention of the desirability of investigations along lines which our experiments have attempted in part to cover. After referring to the experimental setting of Wolfe's work they say (pp. 230-1): "Man hat nun die Ansicht ausgesprochen, dass die Resultate derartiger Versuche ohne Weiteres geeignet seien, uns Auskunft darueber zu geben, wie die Treue der Erinnerung an den Normalton (oder sonstigen Normalreiz) im Verlaufe der Zeit abnimmt. Diese Behauptung laesst die erforderliche Vorsicht des Denkens vermissen. Aus Resultaten von Versuchen der soeben erwaehten Art kann man betreffs des Ganges, den die Treue der Erinnerung im Verlaufe der Zeit nimmt, offenbar nur dann etwas erschliessen, wenn man zuvor in wissenschaftlicher Weise etwas Sichereres ueber die Beziehung ausgemacht hat, in welcher die Resultate derartiger Versuche zu der Treue der Erinnerung stehen, also zuvor den Vorgang, welcher bei Vergleichung eines Sinneseindruckes mit einem vorausgegangenen Sinneseindrucke stattfindet, nach allen wesentlichen Seiten hin sicher aufgeklaert hat. Zur Zeit liegt aber ein ernstlicher Versuch, eine Aufklaerung ueber das Wesen dieses Vorganges zu erlangen, . . . ueberhaupt nicht vor."

While it is scarcely desirable to recount the experiments of Martin and Mueller, because of the disparity between their materials (lifted weights) and tones,—a disparity which is accentuated by the introduc-

¹ "Eine periodische Tendenz zur Erneuerung einer Tonempfindung eine Zeit lang nach dem Aufhoeren des Reizes fortexistiert" (p. 557).

² Zur Analyse der Unterschiedsempfindlichkeit, Leipzig, 1899.

tion of an important and complicated factor, that of active movement upon the part of the observer,¹—yet it seems fitting to make specific reference here to this monograph as a noteworthy contribution to the analytic study of the judgment process. This emphasis of analysis as the ultimate problem of the psychologist is well expressed upon page 225: "Man wird mit uns darueber uebereinstimmen, dass fuer die Psychologie nicht die Untersuchung jener irgendwie definirten Unterschiedempfindlichkeit die letzte Aufgabe ist, sondern die Untersuchung der Factoren, auf deren Wirksamkeit die Urtheile ueber die zu vergleichenden Sinneseindruecke und die Besonderheiten dieser Urtheile beruhen. Jeder jener Factoren ist, so weit es eben geht, hinsichtlich seiner Natur und Wirkungsweise und hinsichtlich seiner Abhaengigkeit von den Versuchsumstaenden zu untersuchen." Such of the detailed results of this monograph as are applicable to the sphere of audition will be discussed later.

In an article upon the "Experimental Investigation of Memory,"² Kennedy has entered a plea for the analytic study of the memory image. Thus he says (p. 484): "The general problem of memory, as it is now conceived, is that of tracing the transformations which take place in each content as it passes through time." But it is evident that Kennedy still holds to the necessity of an image in the judgment process. We quote from page 485. "In order that a certain object be remembered it is necessary . . . that some image of it be retained after it has gone." The words "some image of it" leave, perhaps, room for misinterpretation: still this author has apparently not considered it possible for a content to be recognized without the use of a memory image; nor, what is more, has he considered it possible for elementary contents, such as tones, to be recognized without the aid of a memory image of their own kind. This criticism is, I think, justified by a statement on p. 482, when, after having distinguished 'immediate' from 'mediate' (conceptual) memory, he says: "If what we are to remember is some delicate shading of color or some fine variation of pitch, it must be recollected immediately." Bentley's experiments with finely graded visual qualities³ and our own with finely graded tonal qualities show that recognitory judgments in which there is no memory image of the original stimulus are not only possible but frequent. This same objection to Kennedy's treatment arises as one reads his discussion of the fading of the image (p. 492). He urges that, until possible qualitative and quantitative (intensive, temporal, spatial) variations of the image are excluded, we

¹ The disparity extends also to many of the detailed conditions of experimentation. For example, our use of a number of irregularly placed standard stimuli makes a distinct difference between our tests and those of Martin and Mueller. Thus there is no evidence in our experiments of anything analogous to the judgments passed absolutely upon an isolated weight.

² *Psych. Rev.*, V, 1898, 477-499.

³ See especially pp. 39-40.

cannot be sure that r/n measures this fading. We prefer to say that r/n does not necessarily tell us anything at all about the condition of the image.

In view of this criticism, we fail to see how any amount of tables can furnish data for the plotting of curves of qualitative or quantitative change in the image. The only reliable guide to the transformation of the memory image in time is the careful introspection of the observer himself.¹

There remain to be mentioned the experiments of Angell and Harwood,² which are essentially similar to ours in Part I. They involve a study of the discrimination of tonometer clangs (512-1024 vibs.) under varying conditions of time-interval (1-60 secs.) with reference to the presence and function of the memory image. One-half of the judgments, however, are obtained under conditions of distraction. In their summary of results Angell and Harwood assert that "no law can be laid down in regard to a decrease in accuracy of the so-called tone-memory for intervals up to 60 seconds; the most that can be said is that there is a small and irregular falling off for some [observers] and no falling off for others." On the other hand, there is a very marked falling off in accuracy of judgment with increase of time interval for $D=0$. This latter finding is, of course, in agreement with Wolfe.

In the second paper (p. 58) Angell discusses the results gained by the use of various distractors: adding, counting metronome beats, reading backwards, listening, and clang discrimination. Their outcome may be gleaned from the following quotation: "The main conclusion to be drawn from the distraction experiments is that judgments of tone discrimination can take place, and in the majority of our experiments did take place, without conscious comparison between the present sensation and a memory image of a past sensation."

One can but regret that Angell did not pay more attention to the introspective evidence. The excuse offered, viz., that too much stress upon the introspection would have invalidated the quantitative results, seems to us to be negated by the evidence of our own experiments. In the short intervals one can formulate the introspective report entirely by 'post mortem' examination. In the longer intervals the introspection formulates itself in verbal phrases as the test proceeds. Only rarely does this process distract from the decision at the end of the interval. The cases reported read something like this: "Image fluctuated with my breathing. Got thinking about this and lost it." As was natural, this sort of self-consciousness about the experiment occurred most often in the writer's own observations. That it is not a prominent source of error may therefore be inferred from the fact that his right cases exceed in number those of any of the other observers.

¹ For further discussion of these and cognate points in Kennedy's article, see Bentley, *op. cit.*, p. 13.

² This *Journal*, XI, Oct., 1898, 67; *ibid.*, XII, Oct., 1900, 58.

CHAPTER I.
EXPERIMENTAL.

The following experiments were conducted in the acoustic room¹ of the Cornell laboratory.

For convenience in discussion and tabulation the course of experimentation is divided into two parts, the second of which is further subdivided into four series. Each section will be treated in general as a distinct line of investigation.

PART I.

The experiments comprised under Part I are in a certain sense a repetition of one of the series published by Wolfe in 1886,² but, as we have already pointed out, our purpose is quite different; we wish to trace introspectively the nature and course of the tonal memory image,³ and to analyze the processes of judgment. For this reason our experiments are fewer in number for each observer, but especial emphasis is laid upon each individual test.

Instrument. All the tones in Part I are given by an Appunn tonometer (512-1,024 vibrations) actuated by the Appunn bellows. A weight of 4.7 kg. upon the main bellows and a weight of 1 kg. upon the lid of the tonometer give satisfactory duration and intensity.⁴ On the other hand we have found it very difficult to obtain a sufficient number of series of tones of similar clang tint.⁵ The tones finally chosen as standards are 612, 724, 832, 928 and 984 vibrations, denominated *a*, *b*, *c*, *d* and *e* respectively. The difference (D) amounts to 0 or to ± 8 vibs., so that, besides the standards, there are used the reeds giving 604, 620, 716, 732, 824, 840, 920, 928, 976, and 984 vibrations.

The choice of these tones must be made by laborious testing of the whole tonometer. It is obviously important that at least within a given group (N, N+8, N-8)

¹ This room is not intended to be sound-proof, but it offers distinct advantages for the prosecution of such studies as the present, in view of (1) its isolation by heavy walls from the other parts of the laboratory, (2) its length, which enabled the observers to sit 9 meters from the instrument, where they were not distracted by the noises incident to its manipulation, (3) the adjustable hanging curtains for the elimination of echoes, and (4) the complete electrical connections with other rooms, more especially with the 'registration room,' which enabled chronometric readings to be taken without disturbance to the observers. Practically the only distraction to the experiment came from sounds external to the building. Whenever such distractions were reported the test was thrown out.

² *Op. cit.*, especially p. 542.

³ We include both the memory image proper and the memory after-image. See Fechner, *Elemente der Psychophysik*, Leipzig, 1889, 2nd ed., II, 468 ff., and Bentley, *op. cit.*, p. 15.

⁴ More especially as it is thus unnecessary to operate the bellows during the clang. A single downward thrust of the foot is made simultaneously with the 'ready' signal. This suffices to produce a steady tone of one second's duration beginning two seconds after the signal.

⁵ Cf. Stumpf and Meyer, *Zeits. f. Psych.*, XVIII, 1898, 330.

the qualitative variation of the stimulus shall predominate, and that the 'color' variation shall be minimal; otherwise there may result a judgment based upon the difference of color and not upon a true qualitative discrimination.

While the groups selected are of uniform color, they do not all furnish exactly the D (8 vibs.) desired.¹ We prefer, however, to use these reeds, since their color is uniform and their deviation from the desired D can be computed and properly distributed in the evaluation of the results.

The computation of the actual differences, *plus* and *minus*, from the five standard tones of the instrument was effected by counting the beats between the standard and the next reed above or below (*i. e.*, 4 vibs.), and then the beats between the latter and the reed supposed to give the D required (8 vibs.). In every case we made four counts of the beats, grouping by fours, and with a stop-watch took the time consumed by 56 beats. In order to avoid the irregularities of intensity which would ensue were one to actuate the reeds by the bellows for so long a time (circa 14 secs.), we applied to the tonometer a compressed air device which furnished a steady and adequate air supply at the proper pressure for over 20 seconds. The results obtained by this method showed the actual D's to be as follows:

D for a+	7.678 vibs.
D " a-	7.771 "
D " b+	8.000 "
D " b-	6.815 "
D " c+	8.415 "
D " c-	8.664 "
D " d+	8.271 "
D " d-	8.456 "
D " e+	10.212 "
D " e-	7.875 "

Average, 8.215 \pm .587 vibs.

Inspection of this list shows that the average D used is 8.215 vibs.; the mean variation, 0.587 vibs.; the average *plus* D is 8.515 vibs.; the average *minus* D, 7.916 vibs. The influence of each particular D on the results will be mentioned later, when the influence of absolute pitch is discussed.

Method of Procedure and General Arrangement of Tests in Part I. During a large part of the experimentation we have found it both economical and entirely feasible to work with three observers at each sitting of one hour weekly. The observers are isolated from one another by large cardboard screens, and provided with prepared blanks upon which they record at the end of each test, their judgment, -equal (=), plus (+), minus (-), or doubtful (?),² -their certainty, and detailed introspection as to the course of the image and the process of judgment.

The experimenter gives the usual 'ready' signal two seconds before the first or standard stimulus (N).

For the determination of the length of the intervals and of the tones there is fastened to the framework of the bellows immediately behind the tonometer, an upright provided with a horizontal arm from which hangs a simple pendulum. This pendulum consists merely of a thread and lead bob so adjusted as to swing in seconds. We prefer, for various reasons, a silent metronome of this sort to the ticking metronome employed by Wolfe.

¹ Stumpf and Meyer, *loc. cit.* p. 327.

² In the second half of the experimentation, doubtful tests are repeated until the observer makes satisfactory judgment, but the number and distribution of these cases are recorded.

After waiting for an interval of 2, 4, 6, 10, 15, 20, 30, 40, or 60 seconds, the experimenter gives the variable or comparison stimulus (V), which is either the same as N ($D=0$), or higher ($D=+8$), or lower ($D=-8$). No ready signal is given before V, even in the long intervals. The reasons for this are: first, that the *speaking* of a 'ready' or 'now' at the end of the interval, when the subject is attending 'with might and main' to the memory image, proves to be a distraction rather than a help; while, secondly, the slight but unavoidable noise of pumping the bellows for V, which the experimenter soon comes to produce quite uniformly and at a constant time before V, affords an entirely adequate and yet unobtrusive signal for the attention of the subject to the second tone. Both stimuli last one second, as nearly as the operator can manipulate the stops in time to the swing of the silent metronome.

The further arrangements of the tests of Part I may be summarized as follows. In each hour of experimenting, each observer is given each one of the standard tones, *a, b, c, d, e*, three times; once followed by $V=N$, once by $V=N+8$ vibs., once by $V=N-8$ vibs. The order is, of course, quite irregular, though the same for each observer in a given test, and care is taken that the same N is never given twice in succession; for our preliminary tests show that many observers, even after spending two or three minutes in writing their introspection, are able to identify a repeated N as identical with that of the preceding test.¹

Several weeks were given to preliminary determinations² both for the sake of practicing the observers and in order to settle upon favorable detailed conditions of procedure. After this practice period, to the results of which we shall make incidental reference, the experiments proper of Part I began.

Part I is practically subdivided in point of time into a first and a second half. In the first half the intervals (time elapsing between N and V) are taken up in the order 2, 60, 4, 40, 6, 30, 10, 20, 15; in the second half exactly the reverse order is maintained. The object of this arrangement is to distribute as evenly as possible whatever practice effects might persist after the termination of the preliminary period especially designed to familiarize the observers with the work. The results later to be discussed show that the practice curve does gradually rise during at least the first half of Part I.

It is obvious that the number of tests for each interval is

¹ The extent to which the constant use of one or a very few standards may affect the observer's judgments is well exhibited in the analyses of Martin and Müller, *op. cit.*, 43 ff.

² These include tests with 4 and 8 vibs. D at 10 and 20 secs. interval, and tests of distractors, especially reading.

doubled by the arrangement just mentioned. Accordingly each of the six observers passes $15 \times 2, 30$ judgments upon each one of the nine intervals, so that the total number of tests represented in Part I, for all subjects and all intervals, is 1,620. The number of cases for each time-interval, 180, is relatively small as compared with the enormous number of tests which many investigators have employed when working by the method of right and wrong cases, but we do not wish to place any high degree of insistence upon the generalizations which we shall base upon purely quantitative results, since our immediate purpose is analytic. We are interested rather in the structure of the conscious processes which run their course during the time-interval and during the formation and expression, whether by word of mouth or reaction movement, of the judgment which terminates each test. We insist that, from this point of view, mere numbers are not an essential to the legitimate conduct of the psychological experiment; on the contrary, given the proper, the optimal conditions (of practice, attention, etc.), each test which includes the careful introspection of a trained observer has a right to demand for itself a hearing, to be regarded as a datum. Every such test counts for one experiment.

Subjects. The subjects in the experiments of Part I are all students in Cornell University who have had training both in general psychology and in the introspection of laboratory drill work. Since the investigation of any such problem in acoustics as the one here presented must take into account, in a rather detailed manner, the musical training of the persons concerned, it seems too vague to classify the subjects roughly as 'musical' or 'unmusical'; hence there follows a brief 'musical history' of the six subjects who participated in Part I.

1. *M.* (Miss M. F. McClure), a few piano lessons; has studied harmony; a slight acquaintance with the banjo and mandolin; sings alto or low soprano parts; carries airs very easily; generally fond of music, especially of church-organ or orchestral effects, which often incite brilliant phosisms.¹ Introspection painstaking and detailed, but liable to be influenced at times by suggestion. Generally alert mentally.

2. *W.* (Mr. J. H. Wilson). Non-musical family; no lessons in singing or upon any musical instrument; very fond of music; prefers piano to any single instrument, the orchestra to the brass band; whistles and hums popular airs a great deal. Despite certain of these indications *W* must be classed as strictly unmusical, as will be shown by many features of his introspection. Unfortunately his absence during the second year of experimentation forestalled a series of subsidiary tests which had been planned to elucidate some of his peculiarities. Tendency to retain N by aid of articulation.² Very slow and cautious in judgment; of a distinctly phlegmatic type.

¹ For a detailed account of the phosisms and allied phenomena of *M*, see this *Journal*, X, 1900, 318.

² Actual articulation or humming was, of course, excluded.

3. *S.* (Miss Claire Seymour). Unmusical, as were her parents; piano lessons when from 12 to 15 years old, including moderately difficult selections, but these were invariably acquired by committing to memory the appropriate keys; cannot recall at will more than a dozen notes of any selection however many times it has been heard. One term singing lessons; sings soprano, but only when in a loud chorus and 'carried along' by the others. Very fond of music; prefers church organ, orchestra, and male voices. Strong liking for all low tones on account of their fullness and cool soothing character. When a child, emotional, thrilling music, —especially that in which low tones predominated,—aroused photisms which formed quite an important mental feature for about two years. Early in the course of these experiments *S* developed visualizations which came to be uniformly present, and which at times served as a basis for judgment. These will be discussed later. *S*, as above mentioned, also associated temperatures with tones. High tones were warm and unpleasant, low tones cool and pleasant (like the bathing of hands and face in cool water). Tests of *S*'s photisms revealed nothing worthy of detailed mention. Introspection good, though occasionally restricted by a spirit of competition; *S* worried to think other observers might be getting more right cases.

4. *F.* (Mr. H. H. Foster). Distinctly musical. Training: the usual vocal instruction in public schools supplemented by about six years private lessons. Voice, bass (*E* to *e'*); uses solmization. Occasional obsessions of 'tunes in the head.' Plays violin often, piano less often. Strong tendency to fix the pitch of *N* by humming. Introspection quite good, but of a general sort, lacking finer details; constitutionally tired.

5. *L.* (Mr. E. T. Lies). Mother musical; father fond of music, but not a musician. *L* took piano and organ lessons for eight years; early taught to sing; has done a large amount of singing in choirs and choruses, for a time being organist and chorister. Voice baritone (*G* to *d'*). Cannot commit to memory easily; prefers orchestral music in general, and always harmonic music to solos of any sort. Frequent obsessions of 'tunes in the head,' mostly instrumental music; a single selection is apt to prevail for one or two days. Introspection rather scanty, stereotyped, and subject to logical bias, *e.g.*, that judgment was impossible without conscious comparison.

6. *Wh.* (the writer).¹ Distinctly musical; plays piano, banjo, mandolin and guitar; sings baritone; has had vocal instruction. Auditory imagery generally prominent; centrally excited tonal imagery, both vocal and instrumental, melodic and harmonic, very prevalent, especially when incited by any sort of rhythmic action, such as walking or eating. The presence of so much auditory imagery is, as might be expected, the correlate of a well developed capacity to reproduce all sorts of music at will. From continual service as experimenter as well as observer, *Wh* naturally obtained a very high degree of practice. There is no vestige of memory for absolute pitch.

(To translate this classification of the subjects for comparison with the German standards, we should say that *W* and *S* are hopelessly 'unmusikalisch,' *M* is also strictly speaking 'unmusikalisch,' though possibly ranking as 'wenig musikalisch.' *L*, *F*, and *Wh* would be 'musikalisch' in any German monograph, but they have perhaps none of them been favored with so many opportunities to listen to good music as would be implied by the connotation of the German adjective.)

Results of Part I. It follows, both from the general object and nature of these researches, as well as from the wide variation of the capacities of the observers to image tones, that the general crude results of the experiments are of relatively less importance than the more distinctly analytic data which we shall present for the most part under the heading "dependence upon the individual." Yet the individual variations must be

¹ Our thanks are due to Mr. W. B. Secor for serving as operator for *Wh.* during Part I, and to Dr. W. C. Bagley for a similar service in Part II.

discussed in the light of the general and average results, and, moreover, despite the smaller number of cases, we believe that the numerical results are worthy of consideration as regards their relation to the Tables obtained under similar conditions by Wolfe and by Angell and Harwood.

TABLE I.* (1620 tests.)

Inter-val.	D = 0			D = + 8			D = - 8			Doubt-ful.	Total right cases.
	r	+	-	r	=	-	r	=	+		
2	51	6	3	39	8	13	40	8	12	0	130
4	48	6	6	43	10	7	35	15	9	1	126
6	45	6	9	42	9	9	32	20	8	0	119
10	45	7	8	39	10	10	38	17	5	1	122
15	49	6	5	42	6	12	37	14	9	0	128
20	40	14	6	38	14	8	31	17	11	1	109
30	30	20	10	37	14	9	34	18	8	0	101
40	34	9	16	31	20	8	40	11	9	2	105
60	29	12	19	32	12	14	36	14	8	4	97
Total,	371	86	82	343	103	90	323	134	79	9	1037

*r denotes the number of right cases, + the judgment 'higher,' — the judgment 'lower,' and = the judgment 'equal.' The nine doubtful cases are, for convenience, given in a single column. For their distribution, see below.

Table I gives the distribution of the judgments of all six observers for the tests of Part I. Attention is called to the following numerical features:

1. *The right cases:*

(a) Increase of time-interval causes a general decrease in the total number of right cases. At two points, however (15 and 40 seconds), the curve is peaked.

(b) Both the general decrease and the two points of resurgence in the total number of right cases are traceable practically to the results for $D=0$ alone.

(c) Increase of time-interval effects a very slight but fairly uniform decrease in the right cases for $D=+8$.

(d) Increase of time-interval has practically no effect upon the number of right cases for $D=-8$.

The fact that the cases for $D=0$ suffer most as time elapses is in accord with the results both of Wolfe and of Angell and Harwood. The rise in this curve at 15 and 40 seconds appears to corroborate strongly Wolfe's contention for a periodic renewal of the tonal memory image. We shall see how further analysis of the results bears out this hypothesis.

(e) The total number of right cases is greatest for $D=0$, less for $D=+8$, least for $D=-8$.¹ A similar result is reported by

¹ The precedence which $D=+8$ takes over $D=-8$ may possibly be

Wolfe (p. 556). We may be inclined to doubt, however, whether this fact signifies that judgments are passed with any greater accuracy and confidence when $D=0$. For, leaving introspective evidence out of account, the Table shows that, with $D=\pm 8$, the most frequent error is the judgment 'equal.' We may, therefore, suspect that there exists a general tendency to give this decision in certain conditions of doubt,—conditions in which the degree of uncertainty is not sufficient to cut off the process of judgment entirely, *i. e.*, not sufficient to be actually registered as 'doubtful.' From data to be presented later, we find that of the correct judgments of 'equal' and 'higher,' the same percentage, 76, are certain: only 66 per cent. of the correct 'lower' judgments are also certain.

2. The errors.

(a) *The errors in the order of their frequency are $- =, ^1 + =, + -, = +, = -, - +$: the last four in nearly the same frequency.* We have just remarked upon the relatively great frequency of the first two errors, due to the tendency to pronounce two impressions alike when the difference between them is not clearly made out. We shall see the force of this point when we discuss the introspection of the subjects.

(b) *The frequency of the error $= -$ increases nearly uniformly with the time-interval employed. It is the smallest source of error at 2 seconds, the greatest at 60.* It is very difficult to see how this fact could be explained by Wolfe's theory² that the memory image, as it declines in intensity and clearness, is underestimated in pitch. Now it is true that our total $= +$ error is 86 as against 82 for $= -$, but the former error exhibits no gradual increase with time, although it is entirely reasonable to suppose³ that increase of the time-interval would emphasize gradually any such error of underestimation. The possible solution that the observers, fearing that the image was flattening as well as losing in intensity, made, as time passed, an increasingly strong effort to hold it to pitch, and thereby actually sharpened it, is shown by our tests to be the true solution in the case of some observers.

(c) *The error $+ -$ is somewhat more common than the error $- +$; neither is noticeably affected by the lapse of time.*

3. *The nine doubtful cases are contributed one each from M,*

ascribed to the fact that, as is pointed out above (p. —), the average plus D is really greater than the average minus D. Wolfe assigns the precedence to underestimation of the image.

¹ That is, the judgment 'equal' is given when D is -8 , etc. When $=$ precedes, it means that $V=N$, *i. e.*, $D=0$ is given.

² *Op. cit.*, p. 556.

³ Wolfe's Table (p. 562) unfortunately does not show the distribution of errors by time-interval.

W, and S, two from L, and four from F, the standards being once e, twice c, and six times d. There are 14 doubtful cases in the second half, not indicated in Table I,¹ one from F, four from L, nine from S. Then the standards were three times a, once b, once c, six times d, and three times e.

4. *Dependence upon practice.* By comparing the results of the first and second half of the work which is represented *in toto* by Table I, it can be shown that, despite the preliminary period designed to familiarize the observers with the experiments, practice does lessen the total number of errors of each type (save that of $+ =$, which is increased in the second half of the year's experimentation). The error $+ -$ is reduced nearly one-half. The total number of right cases is increased for every interval except 20 seconds. This exception is due to extraneous conditions, being directly traceable to the fact that, on the second occasion of this test, one observer was "very hungry," another "tired, cross and sleepy." The practice effect is almost entirely confined to the unmusical observers,² thus, the total number of right cases for M, W and S increases from 198 in the first half to 238 in the second, *i. e.*, about 20%; whereas the total number of right cases for F, L and Wh increases only from 298 to 303, *i. e.*, less than 2%. There is no uniformity as regards the nature of the improvement. The chief gain during the second half is for M, with $D=+8$; for W, with $D=0$; for S, F and Wh, with $D=-8$ (F, by decreasing the error $= -$, S and Wh by decreasing both the errors, $= -$ and $- +$). L shows no practice effect; on the contrary, he loses ground slightly for every type of D. We believe that in so far as regularity of quantitative results is desired, it would be advisable to train unmusical subjects by systematic coaching in *sensible* discrimination; *i. e.*, by a series of preliminary tests in which any erroneous judgment is immediately corrected.³ We did not adopt this course, because it threatened to interfere with the natural development of the judgment consciousness which it was desired to observe.

5. *Dependence upon absolute pitch.* Within the octave employed (512 to 1,024 vibs.) there is no observable dependence upon pitch. This is clear from a glance at the 'total' column of Table II. It is more difficult to assign the effect of the variations in the various values of D from the 8 vibs. theoretically given (see p. 417). Apparently the low value of b— (6.815 vibs.) does diminish the number of right cases, for in 108 trials it is correctly judged but 52 times; and, what is more

¹ See footnote p. 417.

² C. Stumpf: *Tonpsychologie*, I, 321.

³ On the effect of such a training by the method of partial knowledge, see Martin u. Müller, *op. cit.*, 195-6.

TABLE II.
(Right cases by pitches. (108 cases each.)

STANDARD.	D=0.	D=±8	D=-8.	TOTAL.
<i>a</i>	69	82	69	220
<i>b</i>	77	77	52	206
<i>c</i>	81	60	65	206
<i>d</i>	66	54	69	189 ¹
<i>e</i>	78	70	68	216
Average,	74.2	68.6	64.6	207.4

significant, the error — = is recorded 40 times, that of — + but 16. In other words, the uncommonly small objective value of D in this instance favors the judgment 'equal.' On the other hand, the rather large D in the case of *e*+ (10.212 vib.) does not increase the number of right cases: there are even 12 more right cases with *a*+ (7.668 vib.) than with *e*+.

6. *Dependence upon the individual,—the introspection.* The individual variations in the numerical results can be properly understood only in the light of the introspective data, for the variations in the methods of judgment and capacities for retention of different observers lead to widely divergent results under different conditions of experimentation. We shall, therefore, consider in this place not only the quantitative dependence of the results upon the individual observer, but also those questions which can be answered only by the aid of introspection. The two chief questions are: (1) what is the nature and the course of the tonal memory image, and (2) what is the nature of the judgment process?

In order to facilitate the introspection generally, to avoid stereotyping, and to direct the attention upon all the points at issue, a placard containing a full list of these points was hung before the observers, and they were requested to glance over it from time to time between the tests. We believe that the wide range of the topics thus presented accomplished the object intended without introducing the error of 'suggesting' any particular introspective verdict whatsoever. The card read as follows: Image: beginning, timbre, localization, constancy (pitch, intensity, clearness), muscular strains, associations (colors, words, etc.), attention strains. Judgment: time, certainty, terms (tonal, verbal, muscular, affective, spatial). It was, of course, not to be supposed that any large number of these points could be noted in a single introspective report, but they could all be noted in the course of three or four tests. Further, during the larger part of the experimentation, a consultation was held with each observer immediately at the close of the hour's work: his reports were carefully examined, and he was questioned upon the obscure details. Here, also, the utmost care had to be used to coach the observers without 'suggesting' the results to be found. Thus, after hinting at the possibility of a purely 'verbal' type of judgment, *M* reported eight of this sort in the next set of 15. Suggestibility of this kind must be met by counter-suggestion. Three general sources of difficulty were encountered in the early course of the investigation, but they were successfully eradicated. These were (1) a tendency to stop to introspect during the time-interval, (2) a tendency to too long after-introspection, and (3) a tendency to anticipate the relation of the coming V to N, *e. g.*, "This will be 'plus.'"

¹ Compare the large number of doubtful cases with *d*, p. 423.

A. THE MEMORY IMAGE.

Observer M.

The following propositions may be laid down concerning the origin and course of the image in the case of *M*:

1. The standard (N) usually arouses either (*a*) photisms,¹ (*b*) strain sensations, or (*c*) associations (commonly personifications).

Examples are: (*a*) purple, dark rich blue, thin steely blue, horrid yellowish green, "darkness of the field stirred." (*b*) "Both tones seemed to be felt in brows." "N high and thin: strain in my head as if trying to reach it." (*c*) "Far away as if coming through a fog." "Like a tall, well-built woman with dark hair and clean-cut features."² "Made me cross, like a gruff, disagreeable old man." "Sharp like a butcher's knife" (visualized). "Extremely smooth and pleasant like a still pond in warm sunshine in summer."

2. After the cessation of N there is a short interval (about one second) devoid of auditory filling. The image then "emerges."

3. The image is almost invariably of the timbre of the tonometer.

The three exceptions noted are: "Image in terms of my voice supported by movement and strain in throat." "Effort to remember N by translating it from tone of instrument to tone of my own voice; strain in throat."³ "Image had timbre of instrument and my voice."

4. The image is localized (*a*) commonly at the back of the room, *i. e.*, at the actual source of sound; (*b*) very frequently, however, somewhere in the head; (*c*) occasionally, N seems to affect one ear only, and then the image is apt to be localized there.

Illustrations: "Through middle of head." "Just above eyes, inside." "In ears: thought of ears when trying hard to recall it." "N especially strong in right ear, and image rang in right ear all the time. The memory of N seemed to be all in the right side of my head." "N filled both ears as a cork would fill a bottle. I felt as a bottle must when the cork is put in."

5. Variation in the image.

(*a*) Qualitative variation is but once noted.

"During the interval an 'after-image' of the tone of the previous test returned, and I got mixed up, but at V the real image of this test appeared." A quasi-qualitative shift is thus indicated: "Image almost lost once, but recalled by slight muscular strain and visual aid (eye feeling as if it were going down the scale and running over two or three notes as it neared, passed and returned to the right note)."

(*b*). (1) Variation in intensity ('fluctuation') is first noted in the six-second interval; it is quite common at 10 seconds. (2) From two to four fluctuations (periodic increase and decrease of intensity) are recorded at 10 seconds, from four to seven at 20 seconds, etc. (3) At

¹ *M* was seated before a window screened by a yellowish green shade, so that the closing of the eyes for each test may have induced a positive or negative after-image which suggested these photisms. The colors observed are, however, too varied in quality and too uniform in their temporal connection with N to be fully explained in this way. While the color clouds rarely play any part in the judgment, other visualizations do so. At times V arouses a photism different from that of N. For a detailed investigation of *M*'s photisms, see this *Journal*, XI, 1900, 377 ff.

² In this instance V had the same 'feeling,' and the judgment was based upon these associations.

³ Here the judgment was made "by throat and vocal feeling."

15 seconds image-less gaps begin to be noted. (4) At 30 seconds the image may have lost so much of its intensity as to be unserviceable. (5) At 60 seconds the image is often gone beyond recall. (6) In order to keep the image at maximal intensity recourse must be had in intervals from 10 seconds up to muscular contraction (attention strains) in increasing degree.¹

"Great strains in face and neck to hold image" (15 secs.). "Held breath to hold image." "Breathing interferes and causes fluctuation, as it loosens attention to have to breathe" (30 secs.). "Could remember N better when I was not breathing; better after taking a breath than after expiring."

(c). Variation in clearness is easily confused with variation in intensity, but in the longer intervals the obscuration of the image is readily noted.

"The image fluctuated, and each time of its return seemed dimmer and dimmer."

6. Relation of the image to N and V.

(a). A good image may be constructed from a (subjectively) unsatisfactory N. "Image good and strong for such a thin and disappointing tone."

(b). The sounding of V may either (1) revive or (2) dispel the image of N.

"Image disappeared frequently and was faint, but V recalled it stronger than it was during the last half of the interval." "Image driven away by the greater loudness of V."

Observer W.

The cue to the radical difference between the nature both of the image and of the judgment of *W*, as compared with *M*, is to be found in the difference in the type of the two individuals. *W* is phlegmatic, *M* vivacious; *W* is distinctly unmusical, *M* rather musical. For *W* the course and nature of the image may be summarized thus:

1. The standard (N) usually arouses (a) pleasantness or unpleasantness, or (b) an organic 'set,' much less frequently, (c) a visualization² (never photisms), and very rarely (d) miscellaneous associations (never personifications).

Examples are: (a) "Pleased at N, and said 'now it will not be so hard to distinguish the next one,'" (b) "N caused a sort of shudder, but yet it was not unpleasant." "Caused a twitch in my ear."³ (c) "Visualized the tonometer." "Saw indistinctly a big round vortex ring with waving circumference, back of me over the tonometer." (d) "Like a whistle." "Verbal association, 'clear as a marriage bell.'"

2. The image never appears at once. The image-less period is ordinarily estimated at one second, but it may be somewhat longer (five seconds), and the formulation of the image takes place so slowly that

¹It seems very probable that the large increase of the error — at 30, 40 and 60 seconds is due to an unconscious sharpening of the image during this active effort to hold it.

²In contrast to *M*, *W* never has a visualization with V, and has no sort of visual element in the judgment process.

³*Cf.* Stumpf: *Tonpsychologie*, I, 168 f.

with the two-seconds interval there is frequently no image during this time.

A curious filling of the image-less gap is once reported: "At cessation of N, I heard the operator say 'ready,' visualized him pulling the stop, then the image appeared," *i. e.*, the image appeared only after a recapitulation of the whole experience of its production.

3. The image is always of the timbre of the tonometer.

4. The location of the image is invariably at the back of the room, and is often maintained there by the visualization of the instrument, as above mentioned.

5. Variation in the image.

(a). Qualitative variation is but once reported, and in this case there is rather uncertainty from the beginning than a shift during the period.

"Did n't get first tone well in mind. I had an argument with myself whether it was a certain tone or not, and then I got more and more certain of it as time went on. I used the image in the judgment" (which was incorrect).

(b). (1) Variation in intensity appears as soon as an image appears, *i. e.*, in the four-second interval. (2) The image may be entirely gone at the end of the six-second interval. (3) Image-less gaps of five seconds duration are reported in the 30 second interval. (4) At 40 and 60 seconds images are almost always said to be present,¹ but the greater part of them are rated as 'bad.' (5) Attention strains appear at 10 seconds, and are characteristic of all intervals longer than that.

"Held breath to keep image." "Great frowning to hold image." "Tendency to produce sound in my throat when I wanted to bring back image." "Fluctuation seemed to go about with my breathing."

(c). Two cases of shift in clearness appear to refer to an illusory bettering of the image with time.

"After a period of fluctuation, image seemed to get clearer, more distinct." (40 secs.).

6. Relation of the image to N and V.

(a). V often (1) dispels the image, but (2) more frequently it 'recalls' it.

"Second tone broke up the image." The recall is noted, *e. g.*, in the two seconds interval when no image had formed. Here the sounding of V is said to make an image of N appear. The recall is also noted very frequently in the long intervals when the image has practically disappeared in the meantime. The excellence of a 'bad' (during the interval) image which is recalled at the end of 60 seconds by the variable tone may be questioned. How shall we estimate, for example, the value of the use of the image thus described: "Had an image of the tone pretty well at first, but it fluctuated and I could hear only the high part of it, and could not tell its timbre until I heard V. Then I remembered about how N sounded, and made a judgment by comparing the two tones?" This instance bears out our previous supposition,¹ for it leads one to suppose that the auditory elements ("timbre") of the

¹There is reason to believe, as will be shown later, that *W* overrates the excellence of his images in these cases, and that he may consider an image to be present when there is little or no trace of the auditory core, but perhaps simply an organic complex, strain in throat, forehead, etc.

original complex have disappeared, while the organic or strain sensations ("the high part of it") remain and are attended to as the image.

Observer S.

1. N usually arouses either (a) photisms,¹ (b) pleasantness or unpleasantness, or (c) associations (largely of visualized geometrical forms, less often personifications).

Examples are: (a) heliotrope, pale green, reddish brown, yellow line on a dark background. (b) "Low and strong and pleasant." Low tones are uniformly pleasant, high ones mostly unpleasant. (c) "Like two curved lines or rather what was contained between them; much clearer in center and growing fainter along edges." "Soothing like cool water, and more like a round ball than a line." "Image seemed like a woman, perhaps a woman's voice." "Visualized a boy blowing a 'squawker,' quite amused."²

2. There is always an interval without any auditory filling immediately after N. Its length is variously estimated from a fraction of a second to three seconds, usually at two seconds.

3. The image almost always has the timbre of the instrument.

Once it "seemed in terms of a horn" (with visualization of the brass mouth of a horn). It should be remembered that S usually carries over into the image those phenomena which are aroused at N, so that it would be, perhaps, misleading to describe the image as a merely auditory representation of the clang, *e. g.*, "the image had something spatial about it which grew larger and smaller each time the auditory part fluctuated." Similar illustrations are given later.

4. The location of the image is either (a) in space in front of the head,³ (b) somewhere within the head, or (c) very rarely, close to the head, but behind it.

(a) "Outside on a level with my forehead, having thus a location but no form." (b) "Felt in throat." "In ear and head." The following is a peculiar combination of (a) and (b) which is frequent. "Auditory image within my head, but at same time a spatial position for it outside." (c) "Back, behind left ear."

5. Variation in the image.

(a) Qualitative variation is extremely frequent with S, the variation being in every case declared a flattening in pitch.

"Image fluctuated with breathing, and flattened slightly. Did not attempt to bolster it up, simply recognized that it was too low and made allowances in the judgment." (D = -8 given; judgment 'equal.') "Pitch fluctuated a little, but I managed to bolster it up just before V came." (Judgment correct.) A quasi-qualitative varia-

¹ Unlike M, S makes these ascriptions with considerable constancy, *e. g.*, standard a is nearly always heliotrope; b is green, etc. On the other hand, S does not experience photisms outside of these tests. She does occasionally make use of them in the judgment process.

² These associations are obviously, like the photisms, determined by the general organic reaction or affective result of the standard. Like the photisms, too, they exhibit rather remarkable constancy, so that, while totally unable to identify the five standards tonally, S did possess a rough knowledge of the identity of the standard by dint of these associations, thus, standard a is always strong, cool, round, or heliotrope. It must be added that this rough classification of the five tones did not avail in making the finer discriminations required in the tests, with the exception of the instances to be found below.

³ When the relation of V to N is based upon 'spatial' relations, V is placed with reference to this situation of the image.

tion in quality occurs once. "Image seemed alive and trying to baffle me. I became very angry and determined to get ahead of it. It danced up and down, to and fro, and I tried to make it keep the place assigned to it."

(b). (1) Fluctuation in intensity, even entailing complete disappearance of the image is reported at four seconds interval, and is characteristic of all longer intervals, though the image-less gaps are not common till the intervals of 15 seconds and longer. (2) The fluctuations may be regular, coincident with breathing, or quite irregular. (3) The support of the image by various muscular strains begins at the two-seconds interval, and is a feature of all the other periods. (But see below, 6).

"Held breath throughout interval" (two seconds). "Contraction in my throat, as if getting the pitch by singing, seem to steady the image." "Great strain around eyes to retain image." "Shook my head to keep out distracting thoughts." "Image disappears when I exhale. I sometimes 'catch' it by inhaling quickly and holding my breath."

(4) The auditory image may fluctuate independently of its visual and other concomitants, or they may vary together.

"Image spatial and auditory. Took a definite position and stayed there, though the auditory image often faded away completely." "The spatial setting of the image grew larger and smaller each time the auditory element varied."

(c). Variation in clearness is rarely noted, with the exception of obscurations of pitch, when a tendency to flat is suspected.

6. Relation of the image to V.

(a) The sounding of V (1) usually recalls the image; rarely it (2) exercises an unfavorable effect upon it.

(1) "Nearly lost image, but it came back all right after V ceased." A rather peculiar recovery, in which the reliability of the image thus gained may be doubted, is the following: "Lost image entirely after about three seconds, and did not recover it again till after V had come. All through the interval I sat relaxed, but confident that the image would come back." (30 seconds, D = -8, judgment 'higher'). (2) "Retained image, but was unable to decide between 'plus' or 'equal' because I lost the image too soon after V sounded to be able to compare."

Observer F.

1. The standard never arouses associative phenomena; there is only an occasional unpleasantness at 'reedy' clangs.

2. No mention is made of an interval after N free from an image, but the image is said to be weak just after N, then "budding out."

3. The timbre of the image is indifferently that of the tonometer or vocal. F says he can think tones vocally beyond the range of his voice.

4. The localization is usually in the left ear, less often within the head, occasionally over the tonometer or directly in front; it may shift during the interval.

"Vaguely somewhere on the wall." "Location in head through the interval, then, expecting V, it changed to my left ear."

5. Variation in the image.

(a) Qualitative variation is very common, and always in the form of a tendency to flat.

"Tendency to flat resisted by effort. Tendency caused by the presence of a number of lower tonal images in my mind." "Image flatted at least half an octave; it was a vocal image varying with the position of my mouth, throat, etc." "Attempted to replace the lost image by 'sliding the scale'; thought I recognized it when I came to it." "The tendency of the pitch to flat was marked by a feeling that the muscles of the head were being relaxed."

(b) A curious but frequent report was that of the presence of an "unconscious tone." This may be interpreted as an 'organic set' of some sort.¹

We shall see later that *F*'s judgments abound in 'motor' elements. The "unconscious tone" is the persistence in consciousness of the 'feel' of the place of the tone when all auditory features are lacking. "Image good for half the interval (40 secs.); then while the image seemed to last, no tone was to be found." "Image seemed to lapse before V, yet the sense of strain in my left ear continued, being increased at V." (Judgment *plus*, correct.)

(b) *F*'s images were for the most part of but "fair" strength. They tended to fluctuate irregularly, and in intervals beyond 10 seconds to lapse entirely for considerable lengths of time. They were replaced by "will power" generally, though sometimes this is analyzed into "strains in the throat," especially if the image be of vocal timbre.

(c) The image was very often vague even when of fair intensity. Clean-cut images were the exception at all intervals.

6. Relation of the image to V.

A lost image may return at the sound of the bellows before V. More often the sounding of V causes the image to disappear.

"Image crowded out of consciousness by turning the attention to V." In one series *F* contracted the habit of letting the image go into "passive attention," in order to have his "active attention" ready for the coming stimulus.

Observer L.

1. N causes strain and pressure sensations about the head, affective reactions or associations.

Low tones are uniformly pleasant, and are further described as big, round, filling the ear passages; high tones are uniformly unpleasant, thin, penetrating. There are two instances of visualization: "After N was given, a picture of the tonometer and of a musical reed came up, and I saw the sound come from a reed in the box." "N aroused a visual-auditory ideas of a long, lanky 'co-ed' with a voice like this stimulus, thin and 'smudgy.'" Verbal associations are: "Like the sound of the letter *L*." "Like the sound *il* made in the upper and back part of the mouth by a female voice." The strain and pressure sensations (probably contraction of scalp and ear-adjusting muscles and perhaps changes in blood supply) are illustrated thus: "N produced an expansive effect within the head as if something were inside

¹ Cf. the 'organic set' of *W*, the introspection of *S*, 5 (b) 4, and the tone-less image of *Wh*.

trying to force out the forehead." "N produced a quiver of sensation around and above each ear."

2. No mention is made of an imageless gap directly after N.

3. The timbre of the image is either that of the tonometer or of *L*'s own voice, natural or falsetto.

(Standard *a* is said several times to be so low as to be imaged in terms of his natural voice, but this is obviously impossible since its frequency is 612 vib/s.) Images beginning in the reed timbre usually become vocal if a strong effort is made to hold them in consciousness.

4. The image is variously localized, in the head, in both ears, just outside the ear, at the tonometer, or nowhere.

The localizations at the tonometer have some significance because the standards are placed there in strata, *a* being invariably near the floor, *e* being invariably near the ceiling, the other clangs disposed with less exactness between these two. As will be seen, this spacing plays a subsidiary part in the judgment consciousness. *L* occasionally converts intensity into distance, *i. e.*, a "waning" image seems "to wander off, far away."

5. Variation in the image.

(a) Qualitative variation is but three times mentioned, always taking the form of a tendency to flat.

(b) *L*'s images are reported to be exceptionally good.¹ Fluctuation is not reported until the 20 second interval. At 30 seconds the waning of the image is quite noticeable, but it rarely goes entirely, and can be recovered by imagining it as hummed by the voice. Even at 40 seconds the image may persist through the interval without active effort to retain it.

(c) Obscuration was not differentiated from lessened intensity.

Observer Wh.

1. At N the breath is held; associations, always auditory-verbal, are often aroused, and, with certain high notes, aural sensations, described as a sort of reflex pull, are prominent. At the sounding of the bellows for V there is a "peculiar feeling of excitement and expectation all over," and a tendency to call up the image as vividly as possible.

Examples are: standard *e*: "Verbal association, 'peep,' clear, piping, pleasant, easy to keep as an image."² Standard *a*, "A nasal, 'blowy,' clang: thought of my nose."² "Verbal, 'that's a.'"

2. The image "wells up" or forms itself at from ½ to 2 seconds after the cessation of N.

3. The prevailing timbre is that of the tonometer, but it may be vocal, or part vocal and part tonometer, and it may shift during an interval.

"Kept image clear and steady by making it vocal timbre, not actually

¹ Obviously these estimates are based upon a subjective standard of excellence. It seems likely, for instance, that *L* overestimates, while *F* underestimates, the worth of his images.

² It is of interest to note that this preference for *e* and distaste for *a* are exactly opposite to the attitude of *L*.

vocalizing, but hearing a purely centrally-excited humming or falsetto tone." "Image usually tonometer timbre now, but it has a number of vocal associations tacked on to it, *e. g.*, contractions of the pharynx, alterations of expiration, localization in the throat, though all these are frequently only imaged, not carried out peripherally." "Started vocal; changed it arbitrarily to tonometer." "Images of a clear, penetrating timbre are easily held."

4. The image is usually localized at the tonometer; it may also be in the head, throat, ear or nowhere. By attention it may be placed almost anywhere. Often its location suddenly shifts when V sounds.

"Image was at the tonometer, held there by purposed visualization of the instrument.¹ At V, or at the sound of the bellows for V, it shifted to my throat, and V placed itself outside my head higher up. V seems to belong outside because it is peripherally excited, and higher because it is higher tonally.

5. Variation of the image.

(a). Qualitative. *Wh* exhibits two peculiar phenomena of a qualitative nature, the feeling of a "tone-less" image, and the presence of two or more rival tonal images during the interval. The latter occurrence is extremely frequent, almost the rule in the long intervals. The general tendency of the image is to sharp rather than flat.²

"Several times during the interval, I thought I had the image, but there was only an 'organic tone,' a throat contraction and an altered breathing, etc., without any auditory elements. I kept thinking something which swelled up and gradually died out at regular intervals but it was not tonal." "At about six seconds a lower tone, separated from my image by quite an interval, appeared and bothered me." "Several other pitches presented themselves as candidates. I got disgusted, dropped them all, and made the decision without any image." "During interval, I heard repeated several times a little melody of three notes. Two came with each inspiration, and one, longest and strongest, the image proper, with each expiration. The last was coincident with V, so judged 'equal' easily." "Lost my image, so ran up and down the scale: a certain quality seemed most familiar, so I imaged that, and made judgment easily" (and correctly).³ "Two images after about the 4th second, the new one was higher and seemed to be suggested by an apparent rise in N as it was shut off."⁴

(b) Intensive. As reported, *Wh*'s images rank in intensity between those of *F* and *L*. At two seconds the image is faint,⁵ not having had

¹Reference to the tonometer is a very frequent device with *Wh* to artificially "force" the image, *e. g.*, "Got twice a very strong, hallucinatory image by thinking of blowing the tonometer very forcibly."

²This tendency is found in such introspective verdicts, as, "V way below my image." It is further amply borne out by the numerical tables which indicate that in the intervals of 30, 40, and 60 seconds, *Wh* has a strong tendency to err in the direction which presupposes a sharpening of the image, provided the image is used in the judgment. In conjunction with *F*'s tendency to flat the image, as shown both by his introspection and his numerical results, this individual difference shows the futility of such generalizations as that of Wolfe when he takes it for granted that the image, because of its weakness, will be constantly underestimated in pitch. We do not wish to imply, however, that the qualitative status of the image necessarily influences the decision at all. *Wh*, for example, often gave such reports as, "V was way below my image, yet I felt compelled to judge 'equal' on account of some feeling of familiarity." (Correct.)

³The usefulness of an image thus secured in making a discrimination of 8 vibrations after an interval of 40 seconds is clearly questionable.

⁴Compare a similar effect with the bottle tones later mentioned. The rise, at least here, is subjective, as subsequent tests demonstrated.

⁵*Wh* suggests that the seeming faintness, which amounts sometimes to absence of the image, may be due to the fact that since, in this interval, it is so near N and V, the image suffers from contrast.

time to fully "mature." At four seconds it is steady after it has matured, and does not need to be actively forced. At six seconds general attention strains appear, composed of sensations set up by contraction of the pharynx, of the arms, and by alterations in breathing which is irregular and shallow. There may be a gap without image.

"Heard image sound, stop, start, etc., twice, an exact repetition of the sounding of N."

No image persists through 10 seconds without fluctuation. Usually there are either two or three waves or periods of intensity, the image being strengthened at each expiration.¹ Keen attention to N is a prerequisite for a good image for this period. At 30 seconds, the image is precarious, it suffers from the slightest distraction, central or peripheral, demands urgent attention, is subject to lapses and to qualitative obscuration by the appearance of other pitches. At 40 seconds, it is always unreliable at the end, and usually gone entirely. To hold it in fair intensity for 60 seconds is almost impossible; any relaxation kills it.

(b). Clearness. Variations in clearness are indicated closely parallel to those in intensity. The qualitative uncertainty occasioned by the presence of secondary pitches may also be regarded as a loss in clearness. Clearness may be recovered when lost, as well as intensity; *e. g.*:

"Slight uncertainty of pitch for a while, then it cleared up" (15 secs.). "Got clearer toward the end of the interval" (6 secs.).

Several times artificial devices are used to enhance the clearness, *e. g.*: "At about the tenth second, I tried to see if I had the image clearly by imaging a lower tone as if on the tonometer, and seeing if I could tell the difference. I wanted to make sure that the image had some determinateness."

6. Relation of the image to N. A good image depends on keen attention to N. If for any reason, N is somewhat faint, the image may yet be steady and clear, though faint.

B. THE PROCESS OF JUDGMENT.

The analysis of the judgment consciousness is a matter of some difficulty. The reason is to be found in (1) its complexity, (2) its rapidity, and (3) in the close combination of the essential with the many unessential features of the process.

Observer M.

The following statements indicate the nature of *M*'s judgments.

1. Terms: The judgments may, for convenience sake, be grouped under a number of headings, although it is to be remembered that no hard and fast lines can be drawn and that exact rubrication is not always possible.

¹This is very commonly reported, *e. g.*, "Pharyngeal contractions at each expiration seem to be the natural sort of innervation by which to attend to tones." Later, however, *Wh* says "it is perhaps partly accidental because, by taking thought I can make the intensity increase at each inspiration, and furthermore, the image often fluctuates independently of breathing." Cf. the "innere Singen," mentioned by Stumpf, *op cit.*, I, 176-7.

(a). Exclusively tonal. This type is very rare, and found in 'equal' judgments only.

(b). Auditory-visual, more frequent.

"V seemed to fill the place occupied by N and to be a repetition 'out loud' of my image." This type is closely allied to

(c). Auditory-visual-motor, in which the 'placing' is more emphatic.

"Image just appearing when V came and perfected it, for they 'melded' perfectly." "Seems to be an auditory placing together of the tones as one would place two sticks side by side." "V higher in auditory scale; feeling of actually placing it there."

(d). Visual-motor, in which the auditory element is practically negligible. "I placed the notes visually in a ladder scale."²

"V fell in place visually just below N." "I could see the comparison. Judgment based on this visual feeling, coupled with strain in the forehead." "N was high up in my visual scale (ladder). V took its place below N at once. Judgment was visual and immediate. Later came the auditory verbal formulation, 'lower.'"

(e). Purely visual, rare.

"N caused a peculiar feeling as if something dark were pressing on my eyes; at the sounding of V, it was lifted, and a slightly blue, bright gray appeared. Knew at once that it was 'plus.'" "Very light blue color with N. Judgment made by comparing this color with what might be the color of V."

(f). Auditory-motor, rare.

"Judgment made by direct comparison of tones, aided by muscular strain in throat."

(g). Purely motor (strain sensations, usually of eye or scalp muscles).

"Although I saw nothing, I was comparing visually." "Eyes dropped on N, raised on V. Made an easy and certain judgment of 'plus.'" "Immediate judgment, for at V there was a slight movement of the eyes as though placing one object below another."

(h). Affective (always with other elements).

"Feeling of 'melding' of tones. Pleasant feeling as though something were satisfied."

(2). Dependence of judgment upon the image.

a) The presence of a satisfactory image usually favors the decision, but (b) with the longer intervals, 'certain' judgments are made when no image is present, and, on the other hand, (c) the presence of a good image does not guarantee a satisfactory judgment.

Illustrations are: "Judgment not immediate, but almost so. Image entirely gone [60 secs.], yet V seemed certainly lower" (correct). "Best image I have had yet (20 secs. interval), but V weakened and destroyed it. Judgment immediate, but uncertain [and wrong]; reconsideration did not make it certain."

3. Speed of judgment.

(a). The majority of *M*'s judgments are immediate, *i. e.*, made with-

¹ A word coined by *M* to express the feeling of 'equal' judgments. It is, she says, not exactly either 'welded' or 'melted,' but between the two.

² This is an early and a very prevalent type. It is found, excepting in a few cases, with judgments of 'higher' or 'lower' only.

out conscious comparison (decided always before V has ceased sounding, one second). The image may be present or not. The greater part or 73% of the immediate judgments are correct. This type prevails when $D=0$, 68% of the judgments then being immediate.¹

(b). (1) Conscious comparison, *i. e.*, the voluntary relating of the image of N to the image of V after V ceases, is less frequent on the whole, but it is more frequent when $D=\pm 8$, 57% of these tests being judged by comparison. (2) Judgments involving comparison are oftener wrong than right. (3) Comparison is a clumsy device, used in cases of doubt.

"V different from N, but could n't tell the direction, so I finally decided by trying to recall both tones."

(c). Judgments in which the decision is reversed or debated are not uncommon. There is an immediate judgment, then indecision followed by laborious comparison, and usually by a change of judgment. It is especially interesting to note that in three-fourths of these cases the first 'immediate' reaction is correct.

4. Certainty of judgment.² In 269 cases *M* reports 195 'certain' judgments. Of these the majority (127) are correct. On the other hand, of the 74 'uncertain' judgments, the majority (46) are wrong. The certain judgments are distributed thus: when $D=0$, 72; when $D=+8$, 59; when $D=-8$, 64.

5. Judgments of difference without knowledge of the direction of the difference are quite common.³ They are, for the most part, recorded only when V really differed from N. The judgment 'different' seems to be more easily and more quickly aroused than the judgment 'higher' or that of 'lower.'

"My judgment of difference was immediate, but that of the direction was later and quite slow."

Observer W.

1. Terms.

(a). Exclusively tonal. (1) Qualitative. This is the typical form of judgment for *W*. It is usually characterized by deliberate comparison of memory images of both tones.

"When V came I listened to it, then heard the first (N) again, and then judged the second lower by comparing the two images." "Seemed to identify V with N auditorily." "Judged in tones and then translated into words." This form occurs also when D differs from N, in contrast with the case of *M*. "V seemed to run in on image, and there was a change."

(2). Auditory judgments are occasionally based upon the intensity instead of the quality of V.

For example: at 60 seconds standard *e* was given both as N and V. *W*'s judgment was 'lower.' "No image left, but when V came it

¹ These facts correlate well with the further fact that for *M* there are more right cases when $D=0$ than when $D=\pm 8$.

² For further discussion see pp. 445-6.

³ Reported also by Wolfe and by Angell and Harwood and by Preyer (Stumpf, *op. cit.*, I, 313).

just appeared to me that it was lower than the first by feeling more intense."¹

(3). *W*'s unmusicalness is well exemplified by the fact that he is often unable to differentiate quality from timbre, and that, accordingly, large numbers of decisions are based upon what he terms a difference in timbre.

We have already mentioned that the reeds used were carefully selected to avoid any such differences, but convincing proof of the subjective nature of this alleged distinction is afforded by the fact that in the cases when $D=0$, *W* frequently reports "2nd more reedy," and again in the repetition of the same standard and variable (*e. g.*, *a* and *a-8*), the report is once, "first clearer," and again, "first more reedy." It is likewise impossible to see any uniform connection between *W*'s estimate of the timbre and his decision. To be sure, he says once "2nd had that reedy quality more and, hence, is *lower*," but on the same day he makes several judgments of '*higher*' when the "second is more reedy."

(b). Auditory-visual, but (unlike *M*'s) with the visual features subordinate and inessential.

"Almost always (?) when I judge I visualize the tonometer and bellows." "Deliberately compared, and saw keys of a piano."

(c). *W* has no visual-motor or purely visual judgments.

(d). Auditory-motor, rare.

"I know how the sounds sound exactly (?), but just can't say whether it should be '*plus*' or '*minus*.' I tried to determine by articulating."

(e). Motor.

Both *N* and *V* often occasioned a "twitch in the ear." *W* thinks these sometimes influence his judgment; if the second twitch were stronger he would certainly say '*higher*.'

A sort of organic basis of judgment is once or twice found.

"At *N* felt a nervous feeling go through my whole body. When *V* came I said it did not feel at all like the first. I think I compared the feelings."

(f). Affective.

A single doubtful use of the affective reaction as a basis for judgment is this. "*N* caused a twitch in my ear. *V* sounded better and softer to the ear, so I at once judged '*lower*.'" This instance may be, perhaps, reduced largely to intensity. Like *M*, *W* is most pleased by 'certain' judgments, but, since most of his certain judgments are based upon a process of comparison, he does not report that pleasure in quick, flash-like judgments which we have noted in the case of *M*.

2. Dependence of the judgment upon the image.

The doubtfulness of *W*'s estimate of his images makes this point difficult, but it is safe to say that (a) judgments may be formed after the image-less two second interval, though possibly the image does get formulated in the judgment, and that (b) judgments made by sudden impression, without the presence of any image, are quite rare.

We have already seen that the auditory excellence of the image

¹It is probable that this error of mistaking the intensity of *V*, as compared with the remembered intensity of *N*, as an index of '*lower*,' accounts for the peculiar prevalence of this judgment in the longer intervals, *e. g.*, 10 out of 15 cases at one sitting. Here again is evidence against Wolfe's appeal to the lessened intensity of the image as a source of the error =+. (Note our previous discussion, p. —.)

reported is probably questionable. The following is an instance: "Fell to noticing a twitch in my throat, and thus lost the image, and then the image got lost in a song, but at the judgment I had both tones (*N* and *V*) in my head to compare." (60 secs.)

3. Speed of judgment. It is difficult to classify *W*'s judgments on the basis of speed.

(a). When $D=\pm 8$, it is usual to have a quick judgment of difference, and a slow one of direction.

(b). Really immediate, flash-like judgments are very rare.

Even in his so-called 'quick' judgments *W* compares the two images. Thus *W* differs from *M* in every point under this rubric.

(c) Outside of the hesitancy in assigning the direction of a difference, just mentioned, the chief debated judgments waver between '*equal*' and '*lower*.'

An example of a less frequent class is the following: "I said quickly 'this is *plus* or *equal*,' and then reasoned that saying *equal* was only because they seemed almost *equal*, but that *V* was really a little *higher*. This all quick. Had images of both to compare."

4. Certainty of judgment. *W* has less 'assurance'¹ than *M*, yet the majority of his judgments are 'certain.' Contrary to *M*, his assurance is greater when $D=\pm 8$ than when $D=0$. The majority (59%) of the certain judgments are correct; the majority (58%) of the uncertain are wrong. Uncertainty increased markedly after the 15 seconds interval.

5. Judgments of difference without knowledge of its direction are extremely common when *D* is 8, even with the short intervals.

Instances have already been noted. *W* suggests that this may be due in part to a confusion of the two images while they are being compared. "Compared the tones, knew they were different, but had trouble in deciding *which* was high and which low."

Observer S.

1. Terms.

(a). Tonal, very frequent, especially in long intervals, with all forms of *D*.

"Convinced myself of the '*plusness*' of *V* because it did not seem to harmonize with *N*." "Thought of scales as I had heard them sung, and this seemed like the interval c-b as one sings down the scale, and so I judged *V lower*" ($D=0$). "*Equal* judgments usually seem to chord or harmonize tonally."

(b). Auditory-visual, infrequent.

(c). Visual, not common.

"*N* caused pale bluish-green, and *V* was the same. Recognized equality by color." "Heliotrope patches all through image and interval. These were reinforced by *V*, so said '*equal*.'" By the addition of the place relations this type merges into (d).

(d). Visual-motor.

"*N* had a certain definite length, breadth and thickness, and *V* seemed to fit over it." "Image seemed like a horizontal line, and *V*

¹Assurance is measured by the number of times '*certain*' is recorded, without heed to the correctness of the decisions.

was placed in the same position. Made the judgment in these terms, though uncertain because the auditory relations did not seem to correspond with these." (Judgment correct.)

(e). Auditory-motor.

"V placed itself on N, and I made the judgment in these terms, though the auditory elements also entered in."

(f). Motor.

"I had a certain position for N, and I seemed to put it there, and felt it would stay there all through the interval. When V came it took a higher position without any effort on my part."

(g). Affective elements appear often in the judgment process, but they do not constitute an essential part. S has pleasure in 'certain' and generally in 'equal' judgments.

2. Dependence of judgment upon the image.

(a). The large majority of S's judgments make use of the image either in its auditory form, or, less often, in its visual setting (place, lines, color, etc.). Conversely, the lack of the tonal image works the most damage.¹

"Held spatial position of the image, but lost its auditory portion. When V came I could make no judgment because it was auditory, while my image was only spatial."

(b). Only a single instance of a sudden imageless judgment is reported, and that felt uncertain.

"Judgment an impression, not a decision." On the other hand,

(c). Occasionally a good image may be present without insuring a decision.

"Good attention, and good image, but I simply could not make up my mind between 'equal' or 'different.'"

3. Speed of judgment.

It is almost useless to speak here of the speed of S's judgments, for unfortunately only 109 out of 270 tests contain the introspective indications required. Of those reported, however, it may be said that (a) slightly more judgments are compared than immediate, and (b) the majority of the immediate judgments are correct while the majority of the slower, compared, are incorrect. (c) A sort of comparison coupled with the method of exclusion is a curious feature of S's judgments. With $D = -8$ it is so frequent as to be the rule rather than the exception. Almost always the result is correct.

"Compared the images several times. Decided they were not equal, and V was not higher, hence it must be lower." "Always have trouble with the 'minus' judgments, and have to argue them out."

(d). Another very common and peculiar feature with S is the comparison of the feeling of the present relation of N and V with that of some just previous test or tests. This is a part of the many schemes (singing descending scale, visualizing piano keys and scale, etc.) used to keep the categories 'equal,' 'higher,' 'lower' distinct, for owing to her unmusical nature S has apparently no deeply ingrained 'feel' for these relations.

¹ S's quantitative results, which are extremely poor, are to be laid to poor sensible discrimination rather than to a poor tonal memory. Cf. Stumpf, *op. cit.*, I, 289.

Examples are: "After recognizing a difference, I said 'minus,' influenced by my two previous judgments of *minus*." "Judgment slow; thought first that the two were *equal*. Then thought of test 2 (third before this), and compared the two impressions (of 2 and 5). Then decided that V was *higher*." "This combination felt different from the preceding test ('*equal*'), and felt high rather than low, hence '*plus*'" (correct).

4. Certainty of judgment. (a) The amount of certainty was recorded in but 232 of the 270 tests. Slightly more than half (128) are 'certain.' The majority of these (76) are correct. The objective accuracy of the 'uncertain' judgments differs from the results of the other observers in that more, though but very slightly more, are correct than incorrect (53 correct out of 104 uncertain).

If we ask the reason for this, it is easily found in the method of making '*minus*' judgments just mentioned. The figures show that when $D = -8$, the majority of the 'certain' judgments are wrong, and the majority of the uncertain judgments are right. S makes many of her '*minus*' judgments by the method of argument and exclusion; they are troublesome, hence uncertain, but they are oftener right than wrong. Omitting these peculiarly constructed '*minus*' decisions, the conclusions found for the other observers hold good for S.

(b) An interesting feature with this subject is the fact that writing down the judgment, or repeating the tonal interval several times, often brings on a feeling of certainty which was not present when the judgment was made.

"Thought this interval (tonal) did not seem exactly like the previous one ($D = +8$, judgment '*minus*'). Reflected that this might, however, be right, my previous judgment wrong, so gave the judgment '*minus*.' (D was 0.) After writing it down, I felt very positive that I was right."

5. As with the other observers, judgments of difference are more quickly and more easily made than judgments of higher or lower. This occurs only when D is really ± 8 vibs. With S it may even be said that judgments of higher or lower are, as a rule, made only after a preliminary assertion of difference.

6. An isolated instance which illustrates the automatic nature of the judgment consciousness as it is created by the conditions of experimentation is afforded by S who, while attending to the image during a long interval, mechanically passed a judgment of '*higher*' when a street car bell rang outside the building, very much to her surprise and amusement.

Observer F.

1. Terms. F's judgments are of two types, an auditory and a motor, with or without an auditory fringe.

(a). Auditory. This type is always found with judgments of equality. V is felt to be simply a re-enforcement of the auditory image. Auditory-verbal phrases such as "That's higher" may be present in judgments of difference, but they are secondary.

(b). A single instance of a visual component in the judgment consciousness is the following:

"Saw image as a line in the space before me, and then V as another line shooting just below it whereupon the old one faded from view. At the same time a sense of relieved muscular strain was noted." We are inclined to class this under the motor type and consider the visual element as the result of some suggestion from the other subjects of visual proclivities.

(c). The auditory-motor or motor type is meant to embrace judgments which are characterized by pressure, strain, and organic sensations of any sort which combine to place the tones spatially in a vague manner. This type is always found with judgments of higher or lower.

Examples are: "Judgment conditioned by a loosening of the muscles (scalp?) on the left side of the head." "Based upon a further tightening of the muscles of the ear already 'set' for the pitch of N." "Recognition a moving of the head up and forward." "My 'set of the ear' means not only strain sensations, but also, apparently, an expectation of a certain sort of pressure. A low note gives a broad dull pressure, a high one a stronger pressure. In a 'plus' judgment I feel this change." "Judgment accompanied by a pressure upward in the head."

2. Dependence of the judgment upon the image. *F* exhibits an irregularity difficult to explain, for

(a) many judgments are passed easily without the presence of an auditory image, but

(b) often the absence of an image precludes any attempt at a decision. It may be that in the latter case whatever serves to represent the image in (a) is also gone.

3. Speed of judgment.

(a). Of the cases reported the majority are immediate, *i. e.*, passed within one second and without comparison. There are 202 such instances and 164, 82%, are correct. This type is most common when $D = +8$.

(b). Deliberative judgments are most frequent when $D = 0$. Only 23 out of 40, or 57%, are correct. *F* contributes one peculiar case of a very slow decision in which there were nevertheless, no image and no comparison.

(c). There is but one instance of a debated judgment.

"At first it seemed *equal*, and then suddenly recognized it as *lower*, and was certain."

4. Certainty of judgment. In 266 cases *F* reports 171 'certain.' Of these 145 were correct. 55 of the 95 uncertain cases were wrong. Certainty was greatest when $D = +8$, least when $D = -8$. Usually *F* had three or four uncertain tests in a group, perhaps indicative of a temporary lapse of attention or of a temporary loss of confidence.

In one test "V was higher, hence judgment instantaneous, but it was so much higher that I knew image must have flatted, so I was uncertain."

5. *F* never confuses the direction of a difference.

Observer L.

1. Terms. *L*'s judgments seem, perhaps as a consequence of his ex-

cellent images, to be substantially all of the auditory type. When other elements are present they are subsidiary.

(a). Auditory. These judgments may be quick, but they involve the presence of the image and a rapid observation of the relation of V to this image as tonal sensations. In the few cases reported in which the image was lacking just before V, *L* thinks that it must have "popped back" and thus entered the judgment process. Whether this is not the result of the logical bias in favor of comparison which we have already noted in *L* is very doubtful.

(b). Auditory-visual type, but once reported.

"Process of judgment involved a visualization of a piano keyboard. Tones were seen to be apart, V above N."

(c). Auditory-cutaneous (?). *L* often mentions that the sensation around the ears, which is external and quite pronounced, starts at N and gradually fades during the interval. If $V = N$, this sensation is picked up or re-enforced in a noticeable manner; if $V = N \pm 8$ vibs. this sensation is not intensified. At any rate it is a secondary phenomenon.

(d). Auditory-motor.

"There was a distinct representation of V being vertically above N." "Image localized just outside the ear. Thought, if V is the same, it must come right to the same locality, and it did."

(e). Affective elements appear only as a pleasantness at judgments of equality, especially if the tones were also low.

This pleasantness may account for the fact that *L* makes the error 'equal' for 'plus' 17 times as against the error 'minus' for 'plus' 4 times, and the error 'equal' for 'minus' 49 times as against the error 'plus' for 'minus' 10 times.

2. Dependence of the judgment upon the image. As already hinted, *L*'s judgments are unique in the constant use of the auditory image.

An interesting feature in this connection is afforded by his description of the relation of the judgment and the image in fairly long intervals. Following N the image of the clang itself ensues, first "wide" (strong), then "narrowing to a point." "When the point is almost reached I renew the image, so that it is wide again, by executing some imaginary humming for a brief time. If N comes when the image is 'wide,' judgment is easy, otherwise more difficult."¹

3. Speed of judgment. Data sufficient for numerical results are lacking. At first *L* insisted upon deliberate comparison. Later he reported many rapid judgments, always auditory and with the presence of the image; the deliberative judgments² being exhibited only

¹ If we add to this description the further fact that such a process of renewal takes place according to *L* about three times in a 40 or 60 second interval, we have some facts not unlike Wolfe's phenomenon of periodicity. The likeness is enhanced by the fact that *L*'s curve for right cases shows peaks at 15 and, more noticeably, at 40 seconds. It seems plausible, then, that *L* represents a type of observer similar to those of Wolfe, using in the judgment an image which, either voluntarily or involuntarily, is renewed at intervals of time approximately constant for the same individual.

² The distinction is this: in the rapid judgment the image is present. As soon as V sounds it is known to be *equal*, *higher* or *lower* than the image. In the slow, deliberative judgments, exhibiting true comparison, no decision can be reached until, after V has ceased, the attention is turned alternately to the image of N and to the image of V. The first type is the more common with *L*, and, save when $D = -8$, the more accurate. It is never uncertain.

in difficult tests, whether because V and N seemed only very slightly different, or because some distraction had weakened the image.

(b). Debated judgments are not met with.

4. No quantitative statement of *L*'s certainty is possible owing to the lack of introspective evidence. One can merely say that his assurance was far greater than his correctness.

5. *L* never confused the direction of a difference.

Observer *Wh*.

1. Type of judgment. *Wh*'s judgments are nearly identical in type with those of *F*, being almost uniformly auditory, not in the sense that the variable tone is compared with the image of the standard, but in the sense that it is this *tone* V which is judged to be 'equal,' 'higher' or 'lower,' and not a color, or pressure or other sensation. But, it must be added that the position of V as an auditory sensation is for the most part determined by other than auditory elements, viz.: by those sensations which we have, for convenience sake, grouped under the term 'motor.'

(a). Purely auditory. Notably in cases of equality, V simply reinforces the auditory image. Rarely the auditory judgment is verbal.

"Judgment took one second, not to compare, only did n't feel sure till I had put the decision into words and said 'lower.'"

(b). Auditory-motor. Judgments of either 'higher' or 'lower' almost invariably are based upon some more or less distinct spatial relation between the image and V, or upon an alteration of strain at V without any reference to either the pitch or 'place' of the image.

"'Minus' because of a distinct feeling of depression about my arms and chest." "Some sort of drop in my throat as well as a different external spacing for image and V. This spatial difference is certainly in consciousness before the fiat of judgment itself, whether it be its essential basis or not." "I hold the image steady at a certain point in my throat or externally, and in judgments of 'minus' or 'plus,' V comes in above or below this point." "V came into same space in my head, so judged 'equal.' This is unusual; there is not apt to be any spatial reference in the equal cases." "V considerably separated from image, further from me and perhaps to the right; a sort of 'here versus there' feeling."

(c). Auditory-visual-motor. There are two rather hazy instances of visual components.

"V lower vertically, in a different place visually." "V farther to right, perhaps with a vague association of a piano keyboard."

(d). Unanalyzable. Certain judgments, especially at the end of long intervals are made, as *Wh* puts it, "by catching at straws;" such decisions are difficult of analysis.

"Judgment slow. Thought it was 'equal,' but at the last moment I had an irresistible impulse to put down 'minus,' though I don't see why this impulse came." (Correct judgment.) "The feel of familiarity which touches off the judgment of equality seems to resist further analysis."

2. Dependence upon the image. *Wh*'s introspection is uniform in

showing that keen attention to N is of importance to the decision, but that the condition of the image when V sounds is of secondary significance.

"Good image, but judgment took about 4 seconds, and was uncertain" (and wrong). "No image at all at end, but judgment very rapid and certain." "V was far below my image, yet I felt impelled to judge 'equal' on account of some feeling of sameness not further analyzable." "Image split up into two, and I gave up trying to hold either one. V had feeling of *belowness*, no shadow of a comparison."

3. Speed of judgment. *Wh* found it very easy to subdivide the speed of judgment into several categories,—instantaneous, very quick, slow, deliberate comparison. The rate termed "slow" belongs in classification to the 'immediate' group, for it implies a time of about one second, and, what is of importance, does not imply any trace of comparison of images.

(a). Thus grouped, *Wh* has 220 immediate judgments, of which 194, 88%, are correct. Immediate decisions are slightly more common when $D = -8$.

(b). The 'compared' judgments number but 35, of which but 24, or 65%, are correct.¹

(c). Judgments in which the decision is reversed or debated are occasionally found. These are almost always cases in which there is an instantaneous judgment for 'minus' or 'plus,' followed by a doubt and a fear that it might be 'equal' because the difference is so small.²

4. Certainty of judgment. *Wh* had 200 certain, 70 uncertain judgments. The correlation of assurance and correctness is shown clearly, since 182 of the certain but only 45 of the uncertain cases are correct. There is greatest certainty when $D = +8$.

5. Judgments of difference without knowledge of its direction are infrequently reported, perhaps a half dozen in all.

In three of these cases the difference was finally judged correctly, e. g. "Knew difference at once, but had to compare tones to get its direction." "Judgment certain and quick, but it seems as if I noted the difference before its direction. Very vague spatial *belowness*."

C. SUMMARY OF THE INTROSPECTION.

In the light of the fairly bewildering individual variations just recorded, one can but hesitate to generalize. The following statements are put forth, therefore, only tentatively, not even in the hope of covering all the main points of importance, but in the endeavor to present a sketchy outline of the course of the image and of the nature of the judgment process.

¹ We should hardly expect *Wh* with his extensive practice to show a predominance of wrong cases with deliberated judgment as do some of the observers.

² This seems an exceedingly apt illustration of the use of the image in the judgment. The decision for 'minus' or 'plus' is based upon a 'feel,' a sudden relaxation of some muscles or a 'motor' spacing. There is in that moment no thought of the tonal relations of the variable to the standard pitch; only in the next pulse of consciousness does the auditory relation come into the focus of attention, if it comes at all, and only then does the doubt of the decision appear. The first decision is the one commonly recorded, and nine times in ten it is correct.

(1) The tonometer clang arouses a wide-spread reaction, adjustments of the organs of hearing, pleasantness or unpleasantness, visual, verbal and other associations, often of considerable vividness and detail, and organic 'sets' of various kinds. These supplementing processes help to give the auditory image an individuality; their nature, prevalence and distinctness depend upon the constitutional tendencies of the observer.

(2) Not until a noticeable interval after the stimulus does the auditory image appear. It then swells suddenly out into its maximal clearness and intensity, in the timbre of the stimulus, localized at the instrument, and usually devoid at first of all those adjuncts just mentioned.

(3) Left by itself it then decreases in intensity and clearness. To offset this, the observer has recourse to various memorial aids; he visualizes the instrument, contracts his throat with incipient humming (changing the timbre and localization of the image), and exhibits all those muscular phenomena which characterize active attention, with emphasis also upon certain similar phenomena (notably in connection with respiration) which are felt to be especially effective for attention to an auditory image. Despite these efforts, attention must wane, and with attention, the image. It suffers most noticeably in intensity, less in clearness, and least in quality (here by tending to flat or by getting mixed with other auditory images). Some observers exhibit a long inaccurate retention, others a shorter but more accurate retention.¹

(4) As a rule the image, under the conditions of our tests, is of little avail for discrimination at the expiration of 30 seconds, while it is very often entirely gone at 60 seconds.² This decline and loss of the auditory image does not necessarily imply a corresponding decline and loss of the various supplementary features which played a part in the identification of N

¹C. Stumpf: *op. cit.*, I, 77.

²This is quite contrary to the conclusion of W. v. Tschisch, who says (*Dritter Intern. Cong. f. Psych.*, Munich, 1897, p. 108): "Ebenso ist es eine allgemein bekannte Thatsache, dass wir die Qualität von Gehörswahrnehmungen einige Minuten hindurch mit aller Schärfe behalten, während gute Musiker in dieser Beziehung über ein erstaunliches Gedächtniss verfügen." Stumpf's violin test (*op. cit.*, 230-1) is entirely off the point so far as it pretends to indicate the reliability of the tonal memory image. The tuning of a stringed instrument, according to our experience, may be effected with some accuracy, after any amount of elapsed time, by the aid of certain secondary criteria,—tension of the string, sympathetic resonance of the other strings, etc. Compare Bentley's results already cited, to the effect that brightness images could be recalled better at the end of five minutes than at the end of one minute.

and which may have persisted in the background, now to become themselves the objects of attention.

(5) When the comparison stimulus sounds, it is, under favorable conditions, immediately known to be 'equal,' 'high' or 'low;' this whether or not there is at the moment any trace of the auditory image in consciousness.

(6) If the image is present and V is identical, the experience appeals to the observer as distinctly auditory, V re-enforces, or flows into, the image; if the image is not present, the experience may still feel largely auditory; V is the same *tone*, a familiar *tone*.

(7) If V differs from N, the process is not, as a rule, felt to be so largely auditory; the attention is entirely taken by a complex 'something' which stands for 'high' or 'low.' (We use these terms advisedly in place of 'higher' or 'lower.') What the 'something' is, depends upon the individual; its core is usually a complex of strain sensations, its remoter elements visual or organic.

(8) Sometimes there is a feeling of difference not standing specifically for either 'up' or 'down.'

(9) If V fails to engender either the reaction of familiarity or of specific difference, the observer resorts to auditory comparison, *i. e.*, he hears the image of V alternate with the image of N. The resulting decision is usually uncertain and very apt to be incorrect.

(10) Pleasantness is the correlate of 'certain' judgments, not of any one of the categories 'equal,' 'higher' or 'lower.'

(11) The verbal formulation arises only after the decision has been made otherwise.

(12) The relation of speed of judgment to certainty of judgment is summarized conspicuously in Table III; that of certainty to correctness in Table IV; that of speed and immediacy to correctness in Table V.

TABLE III.

Correlation of Speed and Certainty.

Observer	IMMEDIATE		COMPARED	
	Certain	Uncertain	Certain	Uncertain
<i>M</i>	119	9	54	52
<i>W</i>	22	4	69	71
<i>S</i>	42	2	17	48
<i>F</i>	161	39	1	40
<i>Wh</i>	194	24	2	33
Total	538	78	143	244

It must be explained that in Table III the compared cases for *W* include the type which he characterizes as "quick comparison," and that the 17 cases for *S* include many instances in which the judgment is deliberated for the sake only of identifying its "feel" with that of some previous test, but without any comparison of images. *L*'s results are omitted because the data are insufficient. It should be further stated that in the case of *Wh*, the correlation is somewhat more detailed than the Table implies; thus, as a rule, instantaneous judgments are absolutely certain; quick are certain; slow, less certain; and deliberated uncertain. The 24 immediate but uncertain cases of *Wh* are nearly all from the longer intervals. There is an immediate judgment of 'plus' or 'minus,' but the difference is so very wide that there is uncertainty. So these few cases cannot be said to make against the generalization that immediate judgments are correct and certain.¹

TABLE IV.
Correlation of Certainty and Correctness.

	D = 0		D = + 8		D = - 8		ALL D'S.	
	r	w	r	w	r	w	r	w
Certain	230	60	217	92	202	83	649	235
Uncertain	72	91	68	67	96	68	236	226

TABLE V.
Correlation of Immediacy and Correctness.

	Observer*	D = 0		D = + 8		D = - 8		ALL D'S.	
		r	w	r	w	r	w	r	w
Immediate	<i>M</i>	38	8	26	7	15	14	79	29
	<i>S</i>	12	3	8	8	5	11	25	22
	<i>F</i>	44	19	67	7	53	12	164	38
	<i>Wh</i>	62	11	62	9	70	6	194	26
	Total	156	41	163	31	143	43	462	115
Compared	<i>M</i>	11	15	12	24	27	17	50	56
	<i>S</i>	2	8	7	9	12	7	21	24
	<i>F</i>	8	10	4	2	11	5	23	17
	<i>Wh</i>	8	4	7	6	9	1	24	11
	Total	29	37	30	41	59	30	118	108

*Observers *W* and *L* omitted for want of accurate data.

¹*Cf.* the results of Martin and Müller, *op. cit.*, 197 ff.

PART II.

The experimental work comprised under Part II is subdivided into four more or less distinct series.

Series 1.

The first series embraces six groups of 36 tests each with introspection recorded after every four tests instead of after each test as before. The qualitative results gained by this arrangement are not detailed enough to warrant its recommendation throughout a whole investigation. They demand a more substantial backing, such as is afforded by the method of Part I, in which introspection is taken after each test. A single time-interval (10 seconds)¹ and a single D (8 vibrations) are employed throughout. The image is actively held. The tonometer is replaced by the Stern blown bottle apparatus.² There are used four standard tones, *a*, *b*, *c*, *d*, corresponding to the settings 2, 10, 18, and 26 of the recording device upon the instrument, and to the pitches 233.6, 256, 276.4 and 300.8 vibs. respectively, and also eight variable tones (*a*, *b*, *c*, *d*, ± 8 vibs.).

The objects of Series 1 are to get a fairly large number of tests with a single time-interval, to see whether long practice changes the method of judgment, to compare the results of blown bottle tones with tonometer clangs, and to prepare the observers for tests with the bottle tones by the method of continuous change.

The observers are *M*, *S*, *Wh*, *B* (Miss A. M. Baldwin), and *O* (Mr. R. Ogden).³

¹Ten seconds was chosen because it affords a suitable time in which to operate the apparatus carefully and noiselessly, and because it is a favorable period for introspection.

²For a general description, see *Zeits. f. Psych. u. Physiol.*, XI, 1896, 4-12 and XXI, 1899, 361-4. In all the experiments of Part II the bottle is blown by compressed air from a tank in which the pressure is between 1 and 2 kg. per sq. cm., the pressure at the stop-cock being regulated, by manometer gauges and a patent valve, at slightly less than ½ kg. per sq. cm. The slight hissing sound of the current of air may be lessened by a 'reducer,' a glass tube of small bore introduced within the large rubber feed tube where the latter attaches to the projecting glass tube of the bottle. Thanks to this device, the hiss was inaudible at the distance of the subjects. It is essential that the cog-wheels be heavily smeared with graphite to stop the rattle of the gearing, which otherwise not only distracts the attention, but, owing to the difference in the sound between going up and going down, indicates the direction of the coming V. As it was, we found it advisable to 'blind' the observers by simulating movements in both directions whether the actual V was to be 'same,' 'higher' or 'lower.'

³The quantitative results obtained from *O* are omitted from the Tables because illness prevented his participation in the work beyond this series, but full advantage has been taken of his introspective reports.

Observer *B* is to be classed as distinctly musical; has taken lessons upon piano and guitar; has done much playing both as soloist and accompanist, especially with the guitar; sings mezzo-soprano; whistles. *B* is very fond of the orchestra; often has centrally excited music, but finds it somewhat difficult to memorize.

Quantitative Results.

(1) The total number of right cases remains practically constant from day to day.

(2) There are very slightly more right cases when $D = \pm 8$ than when $D = 0$, a result quite different from that of the tonometer tests. This difference is, however, due to the difference in the individuals concerned.

(3) Subjects *M*, *S* and *Wh* (who had taken both series) make fewer errors with the bottle than with the tonometer, 413 to 354 on a scale of 540 tests. The manner of distribution of the right cases is the same in both series for *S* and *Wh* (*S* having more when $D = 0$, *Wh* least when $D = -8$), but for *M* the majority of right cases shifts from the column of $D = 0$ to those of $D = \pm 8$, largely on account of the predominance in the bottle series of the error $= -$.

(4) As in Part I, the most frequent error is $= -$.

Qualitative Results.

All the general conclusions of Part I are confirmed, especially the correlation of immediacy, certainty and accuracy of judgment. On the other hand, this series shows even greater individual differences in the methods of judgment and in the types of error than did the series of Part I. Subjects *O* and *B*, especially the former, being entirely new to the work, exhibit at first a sharp contrast to the better trained observers, but the inequality is soon remedied, and their introspection has the merit of revealing how the methods and standards of judgment of a given individual are liable to alter in a long series conducted under constant objective conditions.

Observer *O*.

O shows the effect of practice upon both retentiveness and discrimination. At first his images are fluctuating and especially uncertain in quality. Later they are held steadily throughout the interval. Moreover *O* exhibits here what is still better brought out in Part III,—the transition from the slow, image-dependent, deliberate type of judgment to the flash-like, immediate, very certain and imageless type. It is an interesting example of the short-cut tendency in mental operations. In this final stage, *O*'s introspection most resembles that of *F* or *Wh*. The image, which emerges in from one to two seconds after *N*, is in the bottle timbre, steady in quality, varying slightly in intensity with the breathing and often supported by "bodily

feelings," *e. g.*, "Felt image in mouth." "Unconsciously represented the feeling of *N* by moving my pencil-point the way it felt." In his judgments of 'higher' and 'lower,' *O* develops a new type, as they are based upon rather widespread strain and organic sensations. "If *V* differs from *N*, it affects my body differently. I have a rising feeling for higher tones, a lowering feeling for lower." There is one good illustration of the effect of fatigue upon the judgment process. "Got inattentive. Had to repeat the images of *N* and *V* alternately two or three times, yet I had good images and the difference was marked and certain, once I had rendered the decision."

Observer *B*.

During the second day's experimentation *B* reports that often *N*, less often *V*, rises in pitch just as the air is shut off.¹ This rise often causes the image to be obscure,— "Didn't know which part of the tone to remember,"—and, it is asserted, is the main cause of whatever hesitancy the judgments exhibit. The image appears after an imageless gap, is in the bottle timbre, located doubtfully in the head, with the usual fluctuations in intensity. *B* thinks that there may be a slight tendency for the higher images to flat, and a slight effort, chiefly facial, to keep them up. *B* has few slow decisions, even from the outset. Unfortunately she is unable to analyze the rapid-certain type, so that the introspective account of her judgments must be confined to a record of their certainty, speed and dependence upon the image. There is little light on the last point. The certain, immediate judgments are made with good, bad and

¹ This phenomenon is also reported a very few times by *O*, and *Wh*, while *M* and *S* merely say that at times the notes seem like a curved line, swelling in the middle, *S* adding that it is a change of intensity. The explanation of this seeming rise is difficult. Very careful trials show that at a certain position of the air-cock, when the air is nearly shut off, the second partial of the bottle tone can be heard with some distinctness. Now since the movement of turning the valve through a quarter-turn occupies but a brief fraction of a second, and since this partial appears only when the valve is passing through a single very limited position in the arc, it is clear that there can be only an extremely brief variation in the color of the tone as it is shut off. This variation may be perceived, subjectively exaggerated in duration, and misinterpreted as a qualitative change. Besides this, there is the possibility that the simple fall in the intensity of the tone, occupying, say, $\frac{1}{4}$ second, is in itself sufficient to engender the illusion. (Compare the subjective rise in a dying tuning fork tone. Stumpf, *Tonpsychologie*, I, 242 f., 254 ff., II, 237; also incidental reference to rise in tonometer clang, p. 432). If there is any purely qualitative objective error in the blown bottle, it must be a tendency to flat, for if the mercury be replaced by water, or even glycerine, one finds that the thrusts of the air-blast force the liquid, after the first moment of inertia, down the bottle and up into the variator, thus flattening the pitch. We never, however, observed any movement of this sort with mercury, nor was there any observable lowering of pitch. It seems, then, impossible to say whether the rise effect is entirely subjective or an illusion based upon a brief shift in the intensity or color at the end of the tone.

indifferent images; while, on the other hand, poor images sometimes entail uncertain judgments. The solution of this incongruity appears in the fact that the latter condition holds true only when there is general weariness of body, and hence less strenuous attention to N. If this be granted, it confirms the principle previously set forth, viz.: that good attention to N, not a good image, is the prerequisite of a good judgment. With B, the doubtful or hesitating judgments are most frequent when $D=0$, almost nil, 2 out of 60, when $D=+8$, and quite frequent when $D=-8$. It is an obvious corollary that judgments of 'plus' are very certain, rapid and accurate (only one error in 60 tests); and, what is more, the difference is then much exaggerated, e. g., V is judged to be a third, a fifth, or even an octave higher than N.¹ The introspection does not explain this excellence in 'plus' judgments. We may assume that it is due to some tendency, not further explicable, to pass this decision. 'Equal' was actually pronounced 47 times, 'plus' 72 times, 'minus' 61 times. All certain judgments are made "as soon as V begins to sound." A wait of even two seconds would mean a doubtful decision. Fatigue may bring it about that both sorts of judgment take place; there is an instantaneous decision, "founded on impulse," followed by a comparison of the two images. It appears that not only tonal intervals, but also time-intervals are subject to overestimation, for some of B's deliberated judgments are registered as occupying the preposterous time of 10, 20 and even 30 seconds.

Turning to those observers who participated in Part I, we have to inquire what new introspection is afforded by the conditions of the present series.

Observer M.

N causes visualizations less often, blue being especially predominant. Associations are quite frequent, as before: e. g., "Like a cork bursting from a bottle of fermenting cider." "Like cobwebs and dust." "Buzzed in my head like a bee in a paper bag." The judgments are at first varied in nature, but, as practice with the bottle tones proceeds, they settle down into practically two types, the purely auditory for cases of equality and the auditory-visual-motor type for cases of difference. There seems to be much less visual aid than in the tonometer series, and much more muscular aid.

¹Tonal intervals on the blown bottle are overestimated by all the observers. This fact is, perhaps, foreshadowed in the 'rise' phenomenon just discussed; it is further brought out by the distinctions made by the observers between the "high" "middle" and "low" standards used, although the interval from *a* to *d* is but 66.2 vibs., equivalent in this region to about a major third.

Illustrations are: "With equal tones, judgment does not seem to be spatial, but seems to be a flowing together, like a mixture of two glasses of water. It is thoroughly auditory and not at all visual." "Before V sounds, my eyes, which are shut, are fixed on a level; at V they move, or tend to move, up or down, as V dictates, thus denoting higher or lower." "I can say positively that it is not the image, but the first position taken by V that determines the relation of the two." "I feel or see a raising or lowering when V is higher or lower." There is one curious case of disparity between the 'expressed' and the 'felt' judgment, "Verbal judgment was 'equal,' but mental judgment was 'minus.'" With the bottle, difference and direction are both cognized at once, with the exception of one instance. Quantitatively the peculiarity of M's results in this series is the frequency of the error— which occurs 15 times in 60 tests. It seems impossible to explain this frequency whether by appeal to the introspection or to the distribution of the errors when D is ± 8 .

Observer S.

The introspection is very similar to that of Part I. The tones arouse fewer colors than the reed clangs, but perhaps more general associations of objects, most frequent being steamboats and trains, from the whistle-like sound of the bottle. "Had a vivid picture of something moving very swiftly, like a train. Saw it begin and stop. This recurred through the interval and V was like it." The apparatus is often strongly visualized to hold the image.¹ In the judgments the qualitative change is several times misinterpreted as an intensive difference only. There are a very large number of doubtful cases,—cases in which, had the impulse toward a decision been followed, the majority would have been correct. S is able now to distinguish three speeds of judgment; a very quick, completed before V is half over; a quick, made directly after V ceases; a slow, necessitating two or three comparisons of images. Direction is still cognized after, and less easily than, difference, and in one case light is thrown upon the mechanism of judgment as it is conditioned by what might be called ease of reproduction. "I knew the difference easily, but not the direction. Said 'lower' because it is easier to say."

Observer Wh.

In general, Wh has similar reports to those of Part I. Like M and S he has more associations with the bottle tones, e. g., "N tight and strained, like a quarrel or some distressing situa-

¹Cf. Wh in Part I.

tion." "The 'choppy' start of the tones is pleasant, like the plunge into water in diving." "Verbal association—'clownish,' a laughable tone as if it tried to be mock-serious, or to be somebody big in vain." The image is in the bottle timbre, localized at the instrument, and held strongly by visualization of the machine. Toward the end of the series the incipient singing mentioned in Part I becomes less prominent. "No tendency to sing or contract the throat now. The idea occurred to me during one interval, but seemed odd and foreign to my present method, though these tones are within the region of my voice." There is none of the double image effect so frequent before, but instead such effects as these,—"Had an idea that there are really two sorts of images, of the same pitch however. One I try to hold; it is weak and bothers me; the other, clear and intense, asserts itself like an after-image, without volition." In the first few days also there is "an alternation between the bottle image and another one in my own voice." On the first trial of the bottle *Wh* has very poor judgments indeed, but it is impossible to say whether because of the newness of the tones or because of the loss of practice during the summer vacation. The judgments take place much as in Part I. The following introspections are inserted, as they make the nature of the process somewhat clearer than before. "Some 'equal' judgments have nothing about them but simple familiarity; there is no tonal reference at all." "In this 'equal' judgment, I had an effect of repetition and coincidence, and an association of touching a place on the skin twice, as in experiments on cutaneous localization, in which, if you happen to hit the point stimulated, you know it because it is more sensitive. Just so my auditory apparatus seems more sensitive to a repeated tone." "The muscular strains which give a spatial setting to judgments of difference are certain enough, but very difficult to analyze farther; they seem simply to stand as symbols of auditory rise or fall and are hence very elusive when attended to for their own sake." "When the D is subjectively very wide, the judgment consciousness is apt to be very spatial. The image is (almost) visualized as a thing here, and V as a thing there, about five inches away, to the right and higher, or to the left and lower." "The verbal contents of the judgment, *e. g.*, the words '*plus*' '*same*,' are not as usual present until some moments after the decision is made." "Fatigue interferes with the images, but seldom with the judgment." "If the image is good and steady, it is a part of the judgment consciousness, not as a standard of comparison, for it is to V only that I attend; moreover, often the images are poor or lacking, but the judgment goes on just the same."

Series 2.

This section includes two groups of 36 tests with each subject, 10 seconds interval, but made with the tonometer. For the sake of distribution of practice they are interpolated in Series 1, but may be conveniently regarded as a distinct series. The object is to gain additional data for the comparison of the tonometer and the bottle as sources of sound. The image is, as before, actively held; the observers are those of Series 1, with the exception of *O*.

The most obvious quantitative result is that the shift of instrument diminished the number of right cases in the first trial. In the second, every observer improves; the total number of right cases increases 15%. This increase is most striking for *B*, who had never heard the tonometer before. Her introspection shows that the, to her unusual, 'reedy' color of the instrument obscured¹ at first the purely qualitative variations given; quantitatively this influence shows in the fact that in the 24 tests in which V differs from N, there are nine errors caused by judging 'equal' instead of 'higher' or 'lower.' But these effects are not limited to *B*; even observers *M*, *S* and *Wh*, who have had one year's practice upon the tonometer, find it very difficult to adjust themselves at once to the change in the stimuli; images are at first poor and uncertain,² while the judgments are slowly made, with little assurance or accuracy. As in Part I, the clangs arouse brilliant photisms in the case of *M*, while *Wh* falls back into the habit of contracting the pharynx to hold the image, a tendency which is strong in Part I, but gradually lost in Series 1 of Part II. This tendency seems engendered by the higher pitch, not by the altered color of the clangs. There is also an indication of a shift in the subjective standard of excellence for *Wh*. "I think that what I am calling a good image now is not as a rule up to those termed 'good' last year; perhaps because I don't need the images so much now."

Series 3.

This series comprises two groups of 12 tests with each subject, bottle tones, with 40 seconds interval. The object is to get introspections and data for bottle tones for a longer interval than 10 seconds. The observers are those of Series 2; the image is actively held; introspection is written at the end of each test. A ready signal is given just before V. The most

¹ Stumpf, *op. cit.*, I, 235. "Aber selbst die Frage, welcher Ton höher, wird bei ungewohnter Klangfarbe schwieriger."

² Apparently indicative of a loss of practice in ideating a specific sort of image, rather than a loss of practice in attention. Cf. Stumpf, *op. cit.*, I, 75 ff.

striking fact evinced by the quantitative results is one, confirmative of Wolfe and of Angell and Harwood, which we have already mentioned in Part I, viz.: with a long time-interval the number of right cases for either $D=+8$ or $D=-8$ is greater than that for $D=0$; in the present case it is more than twice as great. In other words, with long time-intervals, difference and its direction are much more readily noted than sameness; or, put in obverse form, the two most frequent errors are $=-$ and $=+$. *B* never gives the judgment 'equal' during the entire series; *M* has but one right case in 8 when $D=0$, while, with the other observers, positive judgments of equality are relatively very infrequent. Immediate judgments of 'higher' or 'lower' are, on the other hand, in the predominance, and are made without any trace of the auditory image. The image has, for most observers, become exceedingly obscure and faint by about 30 seconds, and is often entirely absent by the 40th second. Assurance is lessened more rapidly than objective accuracy. The following bits of introspection culled from this series throw additional light upon the course of the image and of the judgment process. "Held image by thinking how it would sound if a man were to sing it" (*S*).¹ "It seems impossible to hold image at all well with my head held erect or backwards. I have to lean forward, and if very anxious, to rest my head on my hands with my elbows on my knees. This attitude seems necessary to attention to the image" (*Wh*). "Image mixed up with another higher image, and they recurred interchangeably. Very annoying. *V* seemed to settle the difficulty, as the lower of the two was at once felt to be the right image" (*M*). (*Cf. Wh* in Part I.) "Muscular strains in throat and chest to keep the image in its proper 'plane,' *i. e.*, I held the muscles of my body up to the 'level' of the tone, and then relaxed to the level of *V* when it came." "I believe I never think the tones are equal because at 40 seconds the image has a sort of 'silent softness,' while *V* sounds terribly loud and material, so utterly different that it is hard to see any sameness of pitch, but real difference I can tell easily" (*M*). "Auditory image absolutely lost. *V* immediately noted as 'away below.' *N* must be held physiologically better than it is consciously, but how, it is impossible to say. These judgments are too quick and surprising to analyze. It is a very odd feeling to have no idea where *N* is, and yet feel that *V* is below." "Good strong image, but it sharpened slightly. Knew it because *V* was below it, and yet *V* was so strongly familiar that I unhesitatingly judged 'equal' to the neglect of the testimony of the auditory image." "This long interval affects my general assurance, so

¹ *Cf.* the predilection for low tones and male voices, p. 420.

that while I make very rapid judgments (usually correct also), I don't like to put down 'certain' till perhaps one second after the first impulse comes" (*Wh*).

Series 4.

The four observers of Series 2 and 3 are given 36 tests each, bottle tones, 10 seconds interval, but now, for the first time, with instructions to forget *N* as soon as possible after it is given. To aid in this attempt, smells are employed as distractors. Some 30 odors,¹ both pleasant and unpleasant, consisting of essential oils, perfumes and powders, are enclosed in similar vials with the names concealed. The observers pick up a vial at random (avoiding repetition) and attend vigorously to the odor at the cessation of *N*. Distraction is maintained, if possible, until *V* sounds.

We were led to employ odors as distractors, first, by the successful results obtained from them in this laboratory by a previous investigator,² and secondly, because our preliminary tests had showed the futility for this purpose of such processes as adding and reading. We hardly expected to attain complete distraction for so long a time as 10 seconds, since the earlier experiments had merely indicated a possibility of distraction for five seconds, but, as Table VI shows, we were happily disappointed. When supplemented by the introspection, this Table gives a comprehensive idea of the effect of distraction. From both sources, the following conclusions may be drawn:

(1) *Distraction slightly lessens the total number of right cases for all observers*, though, it may be added, this effect is not due so much to the loss or impairment of the image as to the time consumed by the shift of 'venue' at the moment *V* sounds; *V* fails to 'sink in' at first if the distraction be complete.

(2) *We must distinguish four different degrees of distraction:* (a) no auditory image throughout the interval or in the judgment, (b) a momentary, very faint reappearance of the image once, twice (or very rarely three times) during the interval, but entire absence of it thereafter, (c) an appearance of the image near the end of the interval, persisting into the judgment consciousness, (d) no appearance of the image until *V* sounds, usually not until *V* has ceased. The Table shows 84 instances of (a), 33 of (b), 13 of (c), 14 of (d), while the sum of (a) and (b) gives 117 out of 144 cases in which the image is effectually eliminated from consciousness during the period of the decision.

¹ A set prepared by Fritzsche Bros., New York. For the qualities included, see E. B. Titchener, *Experimental Psychology*, New York, 1901, Part II, 125 f.

² L. G. Burch, this *Journal*, IX, Oct., 1897, 45.

TABLE VI.
The effect of Distraction. (36 cases.)

Image	None		Momentarily in interval		In interval and at V		At or after V only		Not at V	Total right cases	
	r	w	r	w	r	w	r	w		Ser. 4	Ser. I
M	14	5	8	0	3	0	2	4	27	27	28.2
B	15	9	5	1	4	3	0	0	30	24	31.0
S	10	14	2	0	1	2	4	2	26	17	21.0
Wh	13	4	15	2	0	0	2	0	34	30	33.2
Total	52	32	30	3	8	5	8	6	117	98	113.4

(3) *The degree of distraction attained varies with the observer.* Thus *Wh* has (a) and (b) equally often, never (c) and rarely (d); *B* never has (d); *S* is most easily distracted to the (a) degree. Under the second heading *B* has the image only at the very beginning, *M* and *Wh* later, at about the 6th second.

(4) If one can trust the small number of cases involved, complete distraction is much more damaging to accuracy of judgment than is distraction of the second type. This conclusion is justified by the introspection. The recall of the image at V is of little avail for the purposes of comparison.

(5) *Distraction in short time-intervals produces in an exaggerated manner certain phenomena of judgment previously mentioned as a feature of long intervals, viz.: lessened assurance, a prominence of spatial elements in judgments of difference, and a greater number of immediate, certain and right cases for both $D=+8$ and $D=-8$ than for $D=0$.*

(6) *The best distractors are those smells that arouse interest, either by calling up vivid and detailed associations, or by being particularly elusive, yet puzzlingly familiar; they may be pleasant or unpleasant.*

Typical introspections are the following: "Image gone entirely, due to the fact that I thought of candied orange slices. Amusing and interesting" (*M*). "Had unpleasant vision of camphor balls, my trunk and a dark closet at Sage. It was curious; I was so interested in the smell that when V came, I forgot that I had to make a judgment, at least verbally. However, when I came to write the judgment, I found that I naturally wrote 'equal, certain.' No possibility of comparison" (*M*). "At the very beginning there was a slight image, but it was lost and did not reappear. The odor seemed familiar, but I could not tell its name, and this kept me busy during the interval" (*B*). "Made a conscious effort to think of the smell, its name, nature, probable origin, etc." (*Wh*). "Succeeded perfectly in keeping the image away by vigorous and constant sniffing and by compar-

ing the intensity of the odor with each nostril" (*Wh*). The remaining introspections concerning the judgment are all from *Wh*. "The 'wave back' of the auditory image seems to come when my first wave of attention to the odor dies low. It is not hard to reinstate the smell consciousness. I have a hazy feeling that this recurrence, brief and vague as it is, may somehow make the judgment easier; that it leaves some effect which would not otherwise be there." "At about the 6th second the image was back for a moment. I thought, 'that's not it.' Judgment was made without image, a wide D, spatial-motor setting, and at once came the thought 'that image was all right,' *i. e.*, instead of the comparison process, I really checked the image by the imageless judgment." "Good distraction. Judgment immediate, but not quite so fast as in experiments without distraction. There is no hesitation or comparison, but the feeling does not 'flash out' as it does sometimes. Moreover, after many of the quick judgments I have doubts. Often I almost forget what to write; the judgment consciousness is more fleeting. In the previous test the judgment was certain when made, but uncertain at the time I wrote it." "Judgment just a quick impulse to 'plus.' As I wrote it down a sudden uncertainty arose. This uncertainty was clearly due to the presence in the fringe of consciousness of some other judgment. If but one judgment arises I am very certain; if two arise with one distinctly predominant, I am fairly certain; if balanced in strength, I am in a state of doubt and considerable unpleasantness."

This concludes our attempt at the qualitative analysis of tonal memory as it is investigated with the use of discrete stimuli and the modified method of right and wrong cases. In a subsequent article we propose still further to examine the judgment-consciousness by the aid of the continuous change method, and to give a general résumé of the results of both methods.