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10

THE JUDGMENT OF VERY WEAK SENSORY STIMULI

WITH SPECIAL REFERENCE TO THE ABSOLUTE THRESHOLD OF SENSATION FOR COMMON SALT

BY
WARNER BROWN

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THE JUDGMENT OF VERY WEAK SENSORY STIMULI

I

Introduction

The term *absolute threshold of sensation* occurs very frequently in the writings of psychologists, and it is generally treated as if it were a technical term of precision. But it has appeared to the present writer that the concrete experiences upon which the notion of the absolute threshold of sensation is founded have received very little consideration, and remain, for the most part, unanalyzed. The experiences in question are those in which a stimulus is presented which is so weak in intensity, or so little different in quality from the general background upon which it is presented, that there is some question whether or not it can be perceived.

The attempt to produce such an experience under experimental conditions is beset with serious difficulties. No one is ever free from all sensation, nor is it possible to impress a weak stimulus upon a person in the absence of other sensations which resemble the one produced by the stimulus. Hypothetical exceptions may be found in infancy or in the return of consciousness after a period of unconsciousness, but in normal life none of the sense-organs is ever so perfectly adapted that it fails to yield some sensation. The minimum visible light comes as a change in a field of vision always abounding in sensation. No one ever heard a faint sound beginning out of utter stillness; to listen for such a sound is to become aware of countless sounds produced both within and without the body. The cutaneous senses, as well as smell and taste, present the same difficulties only a little less obtrusively; these senses do reach states of almost perfect adaptation so long as we do not attend too closely in their direction; but once we begin to experiment upon them, we are overwhelmed

with sensations which refuse to be eliminated. The least perceptible pressure or pain, or temperature, or smell or taste is only a modification of a complex of sensations already present.

Such being the case, it might be presumed that an examination of the conditions determining the threshold of difference would cover the case for the absolute threshold as well. There is, however, a simple and fundamental distinction between the two cases. The threshold of difference is found between two stimuli of almost the same quality, but differing slightly in intensity. The absolute threshold marks a difference of quality within a field which does not change appreciably in intensity. The difference-threshold is observed only by comparison with a standard sensation of some kind; the absolute threshold must be observed without the help of such a standard. Moreover, every one who has ever investigated the matter knows that the attitude of the observer is radically different in determining the two thresholds. When examining an apparently tasteless substance to discover whether or not it contains salt (search for the absolute threshold), one ignores the relative intensities of such sensations as are clearly present, seeking to detect the quality of those which are dimly suspected. When concerned with the threshold of difference, the observer withdraws his attention from everything else in order to apprehend as clearly as he can the relatively conspicuous sensations with which he is directly concerned, and about whose existence there is not the slightest doubt.

A fair determination of an absolute threshold depends upon the fulfilment of two chief conditions. First, before stimulation the sense-organ must be in a state of adaptation to its surroundings, and for purposes of practical experimentation it must be possible to produce this state of adaptation quickly. Second, it must be possible to introduce a relatively simple, familiar, and distinct stimulus which can be easily graded quantitatively. Under these conditions the expected sensation can be observed with a minimum of comparison with other sensations, and with a maximum of difference in quality between itself and such other sensations as are present.

Without entering into details, it may be said that the sense of taste satisfies these conditions as well as any of the other senses. It is well known that the organs of taste are almost completely adapted when not stimulated by foreign substances taken into the mouth. Only in morbid states of the organism are there tastes, sweet, bitter, or sour (not, however, salt), due either to some disturbance of the sense-organs or to the presence of unusual products in the saliva. None of the other senses is so free from subjective sensations and so perfectly passive. The organs of taste are sheltered from outside disturbances by the strong surrounding walls of the mouth. They are stimulated from within by a fluid of a very uniform consistency and savor.[1] The amount of salt constantly present in the saliva is considerable compared with the small additional amounts which can be detected by taste. None of the other senses has the benefit of constant stimulation by a uniform irritant. In a word, adaptation is secured by freedom from occasional stimulation and by a weak, uninterrupted stimulation. In practice it is not possible, however, to avoid comparison with a standard; and this is as true of taste as of any of the other senses. A single sample stimulus can be judged after a period of comparative passivity of the organ; but if further judgments are to be made within a reasonable period of time, they are subject to disturbance from the traces of the preceding stimulus or from the mechanical means employed to remove such traces. Traces of any substance taken into the mouth remain until removed by the slow flow from the salivary glands or by the help of a rinse. It is customary to use pure water as a mouth-wash to remove traces of previous stimuli, and water is thought of as being itself tasteless. But all water when closely examined yields a taste.[2] It appears that the only way to insure perfect quiescence in the taste-organs is to allow them to remain

[1] See W. Nagel, *Handbuch der Physiologie des Menschen* (Braunschweig, F. Vieweg u. Sohn, 1907), vol. 2, p. 521; C. Oppenheimer, *Handbuch der Biochemie des Menschen und der Tiere* (Jena, G. Fischer, 1910), vol. 3, pt. 1, p. 27.

[2] On the taste of water, see Appendix I.

for a considerable time unexcited by any substance other than the normal saliva.[3]

The second requisite of a good threshold-stimulus—that its quality be familiar and at the same time clear and distinct and easily regulated in intensity—is satisfactorily fulfilled by any of the four chief taste qualities; but salt possesses certain advantages over the other three. Salt sensations are not produced accidentally by stimulation with water.[4] Weak salt solutions have no disagreeable effects, and even after repeated tasting produce none of the strong feelings which attend bitter, sweet and sour. Salt solutions are easily prepared and keep well.[5] A large number of previous determinations of the threshold are available in the case of salt, while for the other taste qualities such old determinations are fewer and rest upon stimulation by such a variety of substances that very few direct comparisons can be made.[6] The previous determinations seem to be more consistent with each other for salt than for the other taste qualities, and this fact would seem to indicate that fewer difficulties or errors are encountered in administering this stimulus. The reaction time for salt is shorter than for the other qualities, and the discrepancy between the simple reaction time and the time for discriminating salt is less, and this would seem to indicate that

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[3] Moreover perfect strictness of method would require that time be allowed in which the saliva itself may return to a normal state after the disturbances of its constitution caused by the introduction of foreign substances into the mouth. See Pavlov, I. P., *The Work of the Digestive Glands*, tr. by W. H. Thompson (2nd Eng. ed., London, Charles Griffin and Co., 1910), p. 71.

[4] Kiesow, F., *Philosophische Studien*, vol. 10 (1894), p. 528; Titchener, E. B., *Textbook of Exp. Psychol.*, vol. 1, pt. 2, p. 100; and see Appendix I, On the Taste of Distilled Water.

[5] There are various technical difficulties in the way of standardizing sugar for such work, and the curious differences between sugar and saccharine discovered by Lemberger, *Arch. f. d. ges. Physiol.*, vol. 123 (1908), p. 293, are sufficient warrant for rejecting sweet tastes for the present work, in which simplicity in the stimulus is the first requisite.

Acid stimuli require such extraordinary dilutions for the threshold that they are inconvenient. Richards, *Amer. Chem. Jour.*, vol. 20 (1898), p. 121, finds that hydrochloric acid tastes sour as long as there is any free HCl present, and that the sense of taste gives finer discriminations than some so-called quantitative methods.

[6] On the determinations of the threshold of intensity for salt, see Appendix II.

the salt quality, when perceived, is more clear or unambiguous than the others.[7]

As a further point in favor of using salt as a stimulus it may be noted that the tongue is about equally sensitive all around to salt, while for the other qualities some portions are more sensitive than others.[8] On this account it makes less difference with salt if the stimulus does not always strike first on the same part of the tongue.

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[7] Kiesow, *Ztsch. f. Psychol.*, vol. 33, (1903), p. 456, gives the following reaction times:

Salt,	0.308 sec.
Sugar,	0.446 sec.
HCl,	0.536 sec.
Quinine,	1.082 sec.

See also von Vintschgau and Hönigschmied, Pflüger's *Arch. f. d. ges. Physiol.*, vol. 10 (1875), p. 42, and the article by von Vintschgau in Hermann's *Handb. d. Physiol.*, vol. 3, pt. 2 (1880), p. 205.

Notwithstanding the fact that the salt solutions used were less intense than the other tastes, von Vintschgau, *Arch. f. d. ges. Physiol.*, vol. 14 (1877), p. 550, found that the time required to discriminate salt from water was less than the time required to discriminate the other tastes from water, as follows:

Salt,	0.276 sec.
Acid,	0.332 sec.
Sugar,	0.384 sec.
Bitter,	0.413 sec.

Salt shows the least difference between the maximum and minimum reaction times (*ibid.*, p. 551). The time for discriminating between two tastes is shortest when one of these tastes is salt (*ibid.*, p. 554).

[8] Wundt, *Physiol. Psychol.*, vol. 2 (1910), p. 62; Haenig, *Philos. Studien*, vol. 17 (1901), pp. 606–608.

II

STATEMENT OF THE WORK DONE

Two sets of solutions of common salt[9] in water[10] were prepared in quantity once for all. One set, called the "strong" solutions, contained the following sixteen members, the figures denoting the per cent of salt to water by weight, i.e., the number of grams NaCl per 100 cubic centimeters H_2O.

Name of solution	Strength, per cent
0	0.0%
1	0.1%
2	0.2%
3	0.3%
4	0.4%
and so on, by steps of 0.1%, to	
15	1.5%

The "weak" series contained the following fifteen members:

Name of solution	Strength, per cent
0	0.0%
¼	0.025%
⅔	0.05%
¾	0.075%
1	0.1%
5/4	0.125%
and so on, by steps of 0.025%, to	
1¼	0.35%

For each observer a set of small bottles was provided, one for each solution in the series, and for each bottle a common medicine-dropper, or pipette, the tube of which slipped snugly into the bottle,

[9] The salt used was that prepared by the J. T. Baker Chemical Company of Philipsburg, New Jersey, under the label "Sodium Chloride, C.P., M.W. 58.5." It is said to contain, besides NaCl, 0.0002 per cent iron, and 0.005 per cent sulfate.

[10] The water used was taken from the still of the Department of Chemistry in this University. It is distilled once from copper and contains some traces of copper salts, but is sufficiently pure for use in ordinary quantitative analysis.

and of which the rubber bulb closed the neck of the bottle and prevented evaporation. Before a sitting, these small bottles were filled from the stock and brought into the operating room in time to allow their contents to come to the temperature of the room.[11]

After work had once begun the observers reported regularly once or twice a week, or daily, as the case might be, at the same time of day. They did not work if they felt out of sorts or had colds. All judgments were recorded. The observer was seated so that he could not see the bottles.[12] The stimuli were administered in chance order, but in several series a record was kept of this order so that it was possible to tell what stimulus and what judgment preceded any particular stimulus, and in these latter cases care was taken to see that each solution should come first in a series as often as did any other solution. Otherwise a chance order was followed.

When the observer had seated himself and rinsed his mouth (using as much or as little water for this purpose as he chose),[13] the experimenter took one of the small bottles, pumped with the pipette to stir up the solution, filled the pipette till it contained one cubic centimeter, and handed it to the observer, who opened his mouth and emptied the pipette on to the center of his tongue,

[11] Authorities differ as to the effect of the temperature of the solution upon the sensitivity of the observer. I am not prepared to say that the threshold would be affected by using blood heat instead of the temperature of the room, but I am ready to admit, in the light of occasional introspections from my observers, that it would be worth while, for the sake of precision, to take the pains to keep all of the fluids used at a fixed temperature of about 30° C and also to regulate the room temperature carefully. On the other hand, I wish to state that my own *a priori* objections to using a fixed temperature were, that it would appear warmer on a cold day and cooler on a warm day, and that if it were as high as blood temperature it would make the stronger salt solutions somewhat nauseating. I kept all the fluids at the temperature of the room, which was never hot or cold, and so they bore a constant relation to the physiological zero point of the observer's skin. See Kiesow, *Philos. Studien*, vol. 12 (1896), p. 464.

[12] The bottles were not labeled in order, but according to an arbitrary system of which even the experimenter did not, then and there, have the key.

[13] The amount of rinse water is a minor factor, and yet it may assume some importance when an effort is being made to keep the conditions perfectly uniform from one stimulation to the next. I rather thoughtlessly followed precedent in allowing each observer to use his own discretion in this matter.

then closed his mouth, moved the solution about with his tongue and spit it out.[14] The observer then expressed his judgment by "yes" or "no," meaning "salt" or "not salt."[15] Some observers expressed judgment by a shake of the head and omitted spitting out the solution, taking the rinse water while the solution was still in the mouth. All but the most conscientious observers occasionally swallowed the rinse water, almost involuntarily (and with it the one dose of salt) as the result of thirst, induced partly by

[14] See Appendix II.

[15] No doubt objection will still be made to the exclusion of doubtful answers. In reporting my experiments on "The Judgment of Difference" (page 28 of this volume of the present series), I tried to justify the exclusion, in general, of doubtful answers when these answers represent, not a distinct type of judgment, but rather the absence of any explicit judgment at all. It would be useless to repeat those arguments here; but there is one peculiarity of the present problem that makes the case more than usually obvious. Our whole interest in the present situation lies in determining whether the observer does or does not have a particular sensation. A doubtful answer from him has no significance at all. Nominally it signifies a sort of intermediate state between sensation and absence of sensation. The answer "I don't know" to the question "Do you taste salt?" means either that no salt was tasted or that the observer was incapable at the time of making a rational judgment. Under no circumstances can it mean that he had a half taste of salt or that what he tasted was half salt and half water. Psychophysics must run wild in its attempt to measure sensations before it can undertake to count up fractions of sensations.

A good example of the absurdity arising from the admission of doubtful answers can be seen in the work of Lemberger, *Arch. f. d. ges. Physiol.*, vol. 123 (1908), p. 304, in comparing sugar with saccharine. In only eight out of a total of 40 cases in one series was the sensation reported, and yet this 20 per cent of positive judgments mounts to 60 per cent by the inclusion of the doubtful cases, of which there were 32. In other words, 16 positive cases are derived from the doubtful column, when there were only 8 truly positive cases. Two-thirds of the positive judgments reported for this solution arose from situations in which the observer was really unable to make any judgment at all. This is merely a horrible example, taken from what is in many ways an admirable piece of work, of the dangers of allowing states of uncertainty to figure in a statistical array of explicit judgments. It seems to me that there is no way of getting judgments upon a concrete situation except to ask for them. Surely it is not requiring too much to ask a person to report whether he tastes or does not taste salt. If he does not taste salt, all he has to do is to say so. As a matter of fact, none of my observers, many of whom were entirely new to work of this sort, had the slightest difficulty in meeting these requirements. They were told beforehand that there were some of the solutions that tasted salt and others that did not, and that they were to decide which were which, and that they must decide in every case. They decided every time, and there was seldom any hesitation. The tables show that some of them, at any rate, were exceedingly consistent in these decisions.

Some light may be obtained on the true nature of the "doubtful"

the sight and taste of the water itself and partly by the continual loss of saliva and consequent dryness of the throat.

While the mouth was being rinsed the experimenter was preparing the next pipette and entering the judgment. As soon as the rinse water had been spit out, the next pipette was handed to the observer. This routine was continued until the series of fifteen or sixteen solutions had been gone through once; then a two-minute rest was taken, and then the routine was resumed.[16]

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answer by an inspection of one of the tables published by Camerer, *Ztsch. f. Biol.*, vol. 21 (1885), p. 601.

The distribution of answers found by Camerer when there were 3 bitter, 3 salt, and 2 water cases in each series. The judgments are given in per cent out of 160 for each solution for each of two observers. The upper number refers to Observer I, the lower to Observer II. The method of work was "unwissentliches, gemischt" as in our own experiments.

	Salt Solutions			Quinine Solutions				
Judgment	No. 2	No. 3	No. 8	No. 1	No. 1.5	No. 3	Water	Water
"Salt"	27.5	66.9	98.7	.....	.....	.....	.....	0.6
	52.5	71.9	98.7	.....	.....	.....	.....	....
"Bitter"	1.9	.....	.....	41.2	55.6	81.9	10.0	1.9
	0.6	.....	.....	64.4	83.1	90.6	1.2	0.6
"Water"	23.1	9.4	.....	28.7	20.6	6.2	81.1	85.0
	15.6	3.7	.....	6.9	1.9	0.6	92.5	97.5
	41.9	21.2	1.2	1.2	1.2	.....	0.6	3.7
	22.5	19.4	.....	0.6	.....	.....	.....	....
"Uncertain, perhaps bitter"	2.5	1.2	.....	26.2	21.9	10.0	7.5	5.6
	0.6	0.6	.....	22.5	10.0	7.5	5.0	1.2
"Not water, and and not surely salt or bitter"	3.1	0.6	.....	2.5	0.6	1.9	0.6	3.1
	8.1	4.4	1.2	5.6	4.4	1.2	0.6	....
No judgment	.....	0.6	.....	.....	.....	.....	.....	....
	.....	.....	.....	.....	0.6	.....	0.6	0.6

Here three salt, three bitter, and two water stimuli occurred in the series. In this case the judgments "uncertain, perhaps salt" or "uncertain, perhaps bitter" should really be listed as correct judgments. They are as apt to be right as the "surely salt" or "surely bitter." The judgment "not water and not surely salt or bitter," is correct in so far as it stands for a sensation which is positive but not clear as to quality. "No judgment" gives practically no returns at all; there was always a judgment. Under these circumstances it becomes evident that the doubtful answers, instead of being half right and half wrong, are nearly all right.

Under ordinary circumstances, when the alternative of "salt" or "not salt" is offered, the judgment "uncertain" means "uncertain, perhaps salt" as in this table of Camerer's. It is absurd to decide *a priori* that half or any part of these judgments are wrong. The rational thing to do is to exclude such judgments from the start.

[16] The interval between successive stimulations was much less than is customary in such experiments. Careful preliminary experiments indi-

The experimenters fall into two groups. The observers in the first group were students in the University of California Summer Session of 1910 who were doing their first work in experimental psychology. There were eight of them, of whom five were mature and experienced persons; the others were college students. They received no preliminary training and were allowed only a few trials before they began the actual work of the experiment. Their observations were made under my eye and with my help by fellow-students. They each passed forty judgments on each of the sixteen "strong" solutions (see p. 206). The data from these observations are given in the curves of Plates 1 and 2, and in Table XVIII. In the same group with them are the data from observer Libbin, a graduate student without previous laboratory training. In the case of this observer, however, an extended period of tentative experiment with other intensities of salt and other modes of judgment preceded the forty judgments for which the curve is drawn.

The experiments of the second group were all performed by the writer himself during the year 1910–11. In these cases the order of succession of the judgments was recorded. Observer Noteware, who had already made forty rounds of judgments in the summer on the "strong" series, now made forty more the

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cated that judgments could be made in rapid succession without any more difficulty than when they were made at longer intervals. The rate used was that at which the work of tasting and rinsing on the part of the observer and recording on the part of the experimenter could be carried on without interruption, for a series of fifteen or sixteen judgments. At the end of such a series a rest of two minutes was taken. Some eight series of fifteen judgments were usually made in a fifty-minute sitting, or about three judgments per minute. This rate seems fast compared with the leisurely methods of some of the early investigators (Camerer's observers studied vocabularies during intervals of two and a half minutes) but I feel confident that it is wise to work on such experiments continuously with sustained attention instead of allowing the observer's mind to wander off into other paths from which it must again soon be recalled to work. Continuously sustained attention demands far less energy than continuously renewed attention to such monotonous tasks; the number of judgments made at a sitting is greater, and there is no evidence that they are in any respect inferior.

While we ought, tentatively, to adopt the most efficient programme for such work, refusing to use more time than is demonstrably necessary, direct experiments are required to discover the limits within which it is desirable to "speed up" in psychological laboratories.

following spring on the "weak" series (see Plate 3, fig. 3.) Observer Kohlberg, a senior student working for the second year in the laboratory, made eighty rounds of judgments on the "strong" series without preliminary practice (see Plate 1). Observer von der Nienburg, of like training, after preliminary practice made 120 rounds of judgments (1800 in all) on the "weak" series, of which only the last hundred rounds are regarded in some of the tables (see Plate 3, fig. 1.) She later made forty-five rounds on the "strong" series, of which only the last forty have been counted (see Plate 2.) Observer Levy, a graduate student with several years' experience in the laboratory, made eighty rounds on the "weak" series after a good deal of practice on somewhat stronger and weaker stimuli, devoted to determining the best intensities with which to work (see Plate 3, fig. 2.)

III

DIFFICULTIES TO BE CONSIDERED IN THE EXPERIMENT

A. Practice, Adaptation, and Fatigue

Tables I–V show for four observers the number of series of fifteen or sixteen judgments made at each sitting and, at the bottom, the average number of positive judgments given in the course of each of these successive series. These averages are all shown together in Table VI. If the very rapid rate of presentation exercised a bad influence on the observer, we might expect it to appear in these tables as a fatigue effect. That is, the number of positive judgments might steadily increase (or decrease)

Tables Showing the Number of Positive Judgments in Each of 16 (or 15) Stimuli on Each Day of Work

Table I

Observer Miss Kohlberg

16 Strong Stimuli

Round	1	2	3	4	5	6	7	8	Average
Sept. 21	10	12	10	14	....	....	....	....	11.5
26	9	10	10	9	9	....	....	....	9.4
Oct. 3	10	10	11	11	11	10	10	6	9.9
10	10	5	8	7	7	10	....	....	7.8
17	11	7	8	7	7	9	....	....	8.2
31	10	7	8	8	7	10	8	....	8.3
Nov. 7	9	9	7	9	10	9	9	....	8.9
14	8	5	9	9	8	9	8	....	8.0
21	8	9	9	9	6	7	7	....	7.9
28	8	8	8	8	7	6	7	6	7.3
30	11	9	9	8	9	10	8	11	9.4
Dec. 5	10	8	8	6	6	6	9	....	7.8
Av. per round	9.5	8.3	8.8	8.8	8.0	8.6	8.3	7.7	8.6

TABLE II

OBSERVER MISS VON DER NIENBURG

16 Strong Solutions

Round	1	2	3	4	5	6	7	8	9	10	Average
Nov. 24	10*	10*	10*	11*	11*	11	12	10	....	....	10.6
28	12	14	15	15	15	14	15	15	15	....	14.4
30	14	15	14	13	13	13	15	12	14	....	13.7
Dec. 5	15	15	14	16	15	14	14	15	14	....	14.9
7	15	15	15	16	13	13	14	15	14	16	14.6
Average per round	13.2	13.8	13.6	14.2	13.4	13.0	14.0	13.4	14.2	16.0	13.7

* Not included in other tables.

TABLE III

OBSERVER MISS VON DER NIENBURG

15 Weak Solutions

Round	1	2	3	4	5	6	7	8	9	Average
Sept. 26*	14	13	12	11	14	....	....	....	....	12.8
28*	10	11	8	8	5	6	6	8	....	7.8
Oct. 3*	10	7	5	9	8	9	7	....	....	7.9
5	5	3	5	2	4	3	3	5	3	3.66
10	4	5	4	6	6	6	4	4	....	4.88
12	3	5	5	4	4	4	3	....	....	4.00
17	4	3	4	2	2	4	4	....	....	3.27
24	3	3	2	3	3	2	2	....	....	2.59
26	1	1	2	1	0	3	2	2	....	1.50
31	3	2	2	2	2	2	3	....	....	2.28
Nov. 2	3	2	3	2	2	1	1	....	....	2.00
7	2	2	3	3	2	1	2	3	....	2.25
9	4	6	2	3	1	3	4	4	....	3.38
14	5	3	4	3	4	5	2	1	....	3.38
16	6	4	4	4	4	3	5	4	....	4.00
21	6	4	1	5	4	2	3	4	....	3.63
Average per round	3.77	3.31	3.15	3.08	2.92	3.00	2.92	3.38	3.00	3.18

* The observations made on these days are not included in other tables, nor in the averages at the foot of this table.

Table IV

Observer Mr. Levy

15 Weak Solutions

	Round	1	2	3	4	5	6	7	Average
Sept.	30	4	8	7	5	7	7	..	6.3
Oct.	8	5	6	5	4	5	7	5	5.3
	12	8	6	9	5	8	7	9	7.4
	24	6	10	7	6	5	6	..	6.7
	29	8	9	5	10	7	10	..	8.2
Nov.	3	9	4	6	6	8	..	..	6.6
	18	8	7	6	..	..	..	..	7.0
	25	7	8	6	6	7	7	..	6.8
Dec.	2	8	6	6	6	7	5	..	6.3
	9	6	8	8	6	6	..	..	6.8
Feb.	3	8	6	7	8	8	..	..	7.4
	10	7	7	6	8	5	7	..	6.7
	17	6	5	10	7	6	9	7	7.1
	24	5	5	7	7	6	..	..	6.0
Average per round		6.8	6.8	6.8	6.5	6.5	7.2	7.0	6.75

Table V

Observer Miss Noteware

15 Weak Solutions

	Round	1	2	3	4	5	6	7	8	Average
Feb.	24	6	7	4	7	7	9	5	6	6.4
Mar.	3	7	7	6	9	7	8	13	6	8.0
	10	6	8	10	5	7	7	6	7	7.0
	17	9	10	7	9	10	10	10	11	9.5
	24	9	11	8	9	8	7	8	7	8.4
Av. per round		7.4	8.6	7.0	7.8	7.8	8.2	8.4	7.6	7.85

with the advance of the hour. One observer only, Miss von der Nienburg, and in only one of her two series (Table III), gave less and less positive judgments from round to round. Observer Kohlberg (Table I) gave more positive judgments on the first round, but showed no decrease after the second round. The other two observers showed no regular change at all during the sitting.

Reference will be made later (p. 218) to certain purely "central" or subjective factors which influence the attitude of the observer and determine roughly the proportion of positive and negative judgments in a series. For observer von der Nienburg these factors tend to reduce the number of positive judgments in the "weak" series and to increase them in the "strong" series. These factors account for a progressive change in the proportion of positive judgments during the course of the sitting; and such an account holds for both of the series with this observer, whereas the effect can be ascribed to fatigue in only one of the series.

TABLE VI

SHOWING THE AVERAGE NUMBER OF POSITIVE JUDGMENTS OUT OF 15 OR 16 GIVEN ON EACH SUCCESSIVE ROUND DURING AN HOUR'S SITTING

Round		1	2	3	4	5	6	7	8	9
Miss K.	out of 16 strong solutions	9.5	8.3	8.8	8.8	8.0	8.6	8.3[1]	7.7[2]	.....
Miss v. d. N.	out of 16 strong solutions	13.2	13.8	13.6	14.2	13.4	13.0	14.0	13.4	14.2[3]
Miss v. d. N.	out of 15 weak solutions	3.77	3.31	3.15	3.08	2.92	3.00	2.92	3.38[4]	....
Mr. L.	out of 15 weak solutions	6.8	6.8	6.8	6.5	6.5	7.2[5]	7.0[6]	....	.....
Miss N[7]	out of 15 weak solutions	7.4	8.6	7.0	7.8	7.8	8.2	8.4	7.6	.....

[1] Results obtained on only 8 of 12 sittings.
[2] Results obtained on only 3 of 12 sittings.
[3] Results obtained on only 4 of 5 sittings.
[4] Results obtained on only 8 of 13 sittings.
[5] Results obtained on only 9 of 14 sittings.
[6] Results obtained on only 3 of 14 sittings.
[7] Five sittings.

On the whole, there seems to be no reason for supposing that the rapid succession of stimuli tended to dull the sensory acuity of any of the observers.

The further question remains whether an after-effect persisted from one stimulus to the next, so that the successive stimulations interfered with one another.

B. CONTRAST

It might be supposed that if the stimuli were applied in too rapid succession there would be disturbing positive after-effects, i.e., that the effects of strong positive stimuli would persist after

Table VII. CONTRAST

Influence of the Strength of the Preceding Stimulus upon the Judgment

The last column of percentages shows the proportion of positive judgments from all cases, without regard to the preceding stimuli or judgments. The next to the last column shows the proportion of positive judgments when contrast conditions are present and when they are not.

Miss K., 80 rounds of 16 strong solutions	496	positive judgments	follow	586	weaker*	stimuli,	or 84.6%	against 54.4% normally
	157	"	"	614	stronger	"	or 25.6%	
Miss v. d. N., 40 rounds of 16 strong solutions	289	"	"	293	weaker	"	or 98.6%	against 87.5% normally
	236	"	"	307	stronger	"	or 76.9%	
Miss v. d. N., 40 rounds the first 6 of the above 16	24	"	"	28	weaker	"	or 85.8%	against 67.0% normally
	126	"	"	196	stronger	"	or 64.2%	
Miss v. d. N., 100 rounds of 15 weak solutions	240	"	"	698	weaker	"	or 34.5%	against 22.4% normally
	73	"	"	702	stronger	"	or 10.4%	
Miss L., 80 rounds of 15 weak solutions	274	"	"	553	weaker	"	or 49.5%	against 45.8% normally
	239	"	"	567	stronger	"	or 42.2%	
Miss N., 40 rounds of 15 weak solutions	166	"	"	285	weaker	"	or 58.2%	against 52.3% normally
	127	"	"	275	stronger	"	or 46.2%	

*"Weaker" means a stimulus weaker than the one being judged.

their removal and be carried over to the next stimulus. Table VII shows that in every instance in which a record was kept of the order of the successive judgments a negative after-effect, or what is ordinarily called contrast, appeared. If the solution which is being tasted is stronger than the one preceding, there is a tendency to call it salt; but if it is weaker than the preceding there is an equally strong tendency to call it water.[17] It should be observed that three of the four observers were judging of very weak stimuli, and that for two of them (the last two in the table) none of the stimuli were clearly salt, although both of the observers often *said* that salt was clearly present.

Since observer von der Nienburg gave a very large proportion of positive answers in the "strong" series, a separate presentation is made of the results after excluding the ten strongest of these solutions. Only one negative judgment occurred on any of these ten solutions. For the remaining six solutions the proportion of positive answers is normally 67 per cent, but when the preceding stimulus has been weaker the proportion of positive answers rises to 85.8 per cent.

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[17] See p. 219 for a further statement of the method of securing these facts.

IV

THE DEPENDENCE OF SENSORY JUDGMENTS ON CENTRAL CONDITIONS

The chief aim in undertaking the present group of experiments was to show that every judgment we make, no matter how simple the subject-matter, is conditioned to a very large extent by inward or "subjective" factors. Such factors are more properly designated "central" in contradistinction to the peripheral factors which, in one way or another, compel the individual to make a reaction. The central factors may be thought of as the condition of the organism itself modifying its reaction. Obviously different organisms react differently to the same stimulus, and one reason is to be found in the different capacities which different individuals have. So, too, the same organism does not always react in the same way to stimuli which are apparently identical, and in this case the difference in reaction may be thought of as due to the different condition of the organism. Such a difference in condition constitutes a "central" factor in the reaction.

In the case of the judgment of difference[18] it was found that small differences in the task assigned, or small differences in the mode of reaction demanded, had the effect of altering considerably the observer's judgment in situations which were otherwise precisely equivalent. Moreover, a change in the arrangement of the subject-matter so that a particular case appeared in different company so altered the general attitude of the observer that his judgment would be affected. When, for instance, all the differences between the weights which he was judging were small, he could judge very small ones competently; but let the same task be given when coarser differences were being

[18] See "The Judgment of Difference," p. 52 of this volume.

judged, then the central conditions were no longer favorable for such accurate judgment.

The judgment of difference is a comparatively complicated undertaking. The judgment of sensory stimuli is generally supposed to be much simpler. Is it still true in the simpler case that central conditions play an active part in the formation of judgments? There is no question here of the distinction between sensation and perception or of the association processes necessarily involved in the recognition of a stimulus. The point is whether there are changes in the attitude of the observer which affect his capacity to perform his part in sensation, no matter what that part is.

A. The Influence of Successive Judgments on One Another as a Disturbing Central Factor

In the second group of experiments, embracing one hundred rounds of weak stimuli and forty rounds of strong stimuli with observer von der Nienburg, eighty rounds of strong stimuli with observer Kohlberg, forty rounds of weak stimuli with observer Noteware, and eighty rounds of weak stimuli with observer Levy, a record was kept of the order of presentation of the stimuli. A sample record sheet for one of these 340 series is shown on page 220. From these original record sheets, tally sheets were made up, of which a sample appears on page 221, showing the complete distribution of all the judgments passed on each stimulus. Taking all the positive judgments for that solution, the tally sheet shows how many were preceded by solutions stronger than the one in question and how many were preceded by a solution weaker than the one in question. Then, further, the tally sheet shows the number of preceding cases which were judged salt and the number which were judged not salt. And so for the various

combinations, so that the footing up of the tally sheets for an individual observer gives all the judgments in the following categories:

A. Positive judgments, "salt."
B. Negative judgments, "not salt."
A1. Positive judgments preceded by a *positive judgment* on a *solution stronger* than the one in question.
A2. Positive judgments preceded by a *negative judgment* on a *solution stronger* than the one in question.
A3. Positive judgments preceded by a *positive judgment* on a *solution weaker* than the one in question.
A4. Positive judgments preceded by a *negative judgment* on a *solution weaker* than the one in question.
A5. Positive judgments preceded by *nothing*, that is, the stimulus was given after a rest.
B1, 2, 3, 4, 5. The same as above, except that negative judgments are considered instead of positive ones.

Sample Record Sheet

Observer Miss Noteware. March 24. Round 40, K3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A											—				
B												+			
C						+									
D														—	
E		⊹													
F									—						
G				+											
H			—												
I								+							
J															—
K	—														
L					—										
M													+		
N										+					
O							—								

"+" means "salt"; "—" means "not salt."

The letters at the left are the arbitrary names of the solutions. This was the 40th series, or round, for this observer and the prearranged programme required it to begin with solution K; this was the third time that K had come around to the head of the series, each solution coming first in turn. The numbers at the head of the table give the sequence of the judgments. The record sheet shows what solution and what judgment preceded any given case.

SAMPLE TALLY SHEET

Observer Mr. Levy. Weak Solutions. Solution D = 0.25%

Positive judgments on D preceded by:										Negative judgments on D preceded by:
		—	—	Q	+	+				
		—	+	O	+	—	—	—	—	—
—	—	—	—	F	—	—				
	—	+	—	K	—	—	—			
		+	—	A	—	—	—			
			+	N	+					
			—	G	—					
+	+	+	—	C	+	—	—	+	+	—
		—	—	J	—	+	+	+		
				B	—	+	+			
				(D)						
+	+	—	—	L	—	+	+			
		+	—	M	+	+				
	+	—	+	H	+	+	+			
	—	—	—	E	+	+				
		0	0	Nothing	0	0	0	0		

A positive (+) judgment on solution D was preceded by:

Positive judgments on solutions weaker than D	7 times
Positive judgments on solutions stronger than D	5 times
Negative judgments on solutions weaker than D	14 times
Negative judgments on solutions stronger than D	7 times
Nothing, i.e., this solution was the first in the series	2 times

A negative (—) judgment on solution D was preceded by:

Positive judgments on solutions weaker than D	12 times
Positive judgments on solutions stronger than D	9 times
Negative judgments on solutions weaker than D	19 times
Negative judgments on solutions stronger than D	1 time
Notning, i.e., this solution was the first in the series	4 times

The solutions are arranged in order of intensity from the top down to the strongest. On the left the table shows what happened each time just before solution D was called *salt*. On the right, what happened just before solution D was called *not salt*. Thus solution L was given 4 times before solution D was called *salt;* in 2 of these cases L was called *salt itself*, an in 2 *not*. L was given 3 times just before D was called *not salt;* on 2 of these 3 occasions L was itself *called salt*, the other time *not*. Six times D came nrst, so that nothing came before it; on 2 of these occasions it was called *salt*, the other 4 times *not*. Like all the other solutions in this series D was judged 80 times; 35 times it was called *salt* and 45 times *not*. See Table XI, solution 0.25 per cent, for the final tabulation of the data from this tally sheet.

Tables VIII to XII show the results obtained from each person for each solution. In Table XIII there is a statement of the final results with regard to the positive judgments for each person. The results for negative judgments are merely complementary to these.

The general method here employed is to find the total number of positive judgments in any one of the above categories and then to find the proportion of them which had one kind of antecedent and the proportion of them which had another kind. The result is expressed in per cent, and it thus becomes possible to measure the effect of the antecedents upon the judgment. This method has already been employed in ascertaining the fact mentioned on page 217—that all of the observers, but some more distinctly than others, show a tendency to call a solution salt more

TABLE VIII

OBSERVER KOHLBERG. 80 ROUNDS OF STRONG SOLUTIONS

"strong" = stronger than the one in question
"+" = positive judgment of salt

	+ jdmt. preceded by:					— jdmt. preceded by:				
Sol. in % NaCl	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.
0.0%	0	2	0	0	0	0	38	0	35	5
0.1	0	0	0	1	0	0	39	0	32	5
0.2	0	4	0	0	0	0	49	3	19	5
0.3	0	3	3	1	1	0	43	6	19	4
0.4	0	6	2	4	2	1	32	12	18	3
0.5	1	7	6	3	0	2	40	9	7	5
0.6	1	21	11	1	2	0	26	9	5	4
0.7	4	10	27	2	0	2	17	9	4	5
0.8	5	13	28	0	0	1	15	11	3	4
0.9	7	17	36	1	4	0	6	8	0	1
1.0	11	17	35	2	3	1	6	3	0	2
1.1	19	14	33	1	5	2	3	3	0	0
1.2	20	15	38	0	4	0	0	2	0	1
1.3	30	7	35	0	4	1	1	1	0	1
1.4	36	5	33	0	3	1	0	0	0	2
1.5	43	0	32	0	4	0	0	0	0	1
Total	177	141	319	16	32	11	315	79	142	48

TABLE IX

OBSERVER VON DER NIENBURG. 40 ROUNDS OF STRONG SOLUTIONS

"strong" = stronger than the one in question
"+" = positive judgment of salt

Sol. in % NaCl	+ jdmt. preceded by: + weak	+ strong	— weak	— strong	0 jdmt. 0 sol.	— jdmt. preceded by: + weak	+ strong	— weak	— strong	0 jdmt. 0 sol.
0.0%	0	14	0	0	3	0	23	0	0	0
0.1	0	14	0	1	2	0	21	0	1	1
0.2	1	17	1	0	2	0	17	0	1	1
0.3	2	24	3	0	3	0	5	3	0	0
0.4	7	26	3	0	2	0	2	0	0	0
0.5	4	30	3	0	2	0	0	1	0	0
0.6	10	25	3	0	2	0	0	0	0	0
0.7	15	17	5	0	2	0	1	0	0	0
0.8	13	19	5	0	3	0	0	0	0	0
0.9	18	13	6	0	3	0	0	0	0	0
1.0	19	12	6	0	3	0	0	0	0	0
1.1	22	11	4	0	3	0	0	0	0	0
1.2	23	10	4	0	3	0	0	0	0	0
1.3	31	3	4	0	2	0	0	0	0	0
1.4	27	0	12	0	1	0	0	0	0	0
1.5	31	0	7	0	2	0	0	0	0	0
Total*	14	125	10	1	14	0	68	4	2	2
Total†	223	235	66	1	38	0	69	4	2	2

* First 6. † All 16.

often if it has been preceded by a weaker than if it has been preceded by a stronger one.[19] In the same way one can tell whether a particular stimulus is more apt to be judged salt if the one before it has been judged salt. That is to say, we may expect to see a positive or a negative after-effect from one stimulus affecting the judgment of the next; and along with such a physiological after-effect there may be a psychological tendency to reverse the preceding judgment or to repeat the preceding judgment. Table XIV presents some of the data upon this point which are included in Table XIII. Table XIV is directly comparable to Table VII on contrast.

[19] The data which were presented in Table VII are included in Table XIII.

Table X

Observer von der Nienburg. 100 Rounds of Weak Solutions

"strong" = stronger than the one in question
"+" = positive judgment of salt

Sol. in % NaCl	+ jdmt. preceded by: + weak	+ strong	— weak	— strong	0 jdmt. 0 sol.	— jdmt. preceded by: + weak	+ strong	— weak	— strong	0 jdmt. 0 sol.
0.0%	0	2	0	7	0	0	15	0	69	7
0.025	0	1	0	5	0	0	15	7	65	7
0.05	0	2	1	2	1	0	21	4	63	6
0.075	1	0	0	0	0	1	22	23	46	7
0.1	0	3	0	2	0	2	13	27	47	6
0.125	0	1	5	2	0	4	18	21	42	7
0.15	0	1	3	6	0	1	15	34	33	7
0.175	3	2	6	7	0	3	10	42	22	5
0.2	0	1	12	2	0	2	10	41	25	7
0.225	1	1	19	5	0	4	11	40	13	6
0.25	5	5	19	5	0	3	11	33	13	6
0.275	6	3	21	2	2	7	11	32	11	5
0.3	5	2	29	0	1	7	4	44	2	6
0.325	7	2	38	2	1	5	0	36	2	7
0.35	15	0	44	0	0	10	0	25	0	6
Total	43	26	197	47	5	49	176	409	453	95

In the cases of observers Levy and Noteware we see a tendency to reverse the judgments from one time to the next (Table XIV). Any particular judgment is influenced by the strength of the preceding stimulus, and also it is influenced by the *expression* of the preceding judgment. If the last solution was called salt the present one is not so likely to be called salt, regardless of the actual intensities of the stimuli. Without fully realizing it themselves, both of these observers were doing a good deal of rather blind guessing and each of them was calling any particular solution salt almost as often as not (see Plate 3, figs. 2 and 3.) They seem to have been laboring under the impression (for which no justification could be offered) that about half of the solutions ought to taste salt. Such being their attitude, it is reflected in this tendency to keep things even by alternating positive and negative judgments.

TABLE XI

OBSERVER LEVY. 80 ROUNDS OF WEAK SOLUTIONS

"strong" = stronger than the one in question

"+" = positive judgment of salt

	+ jdmt. preceded by:					— jdmt. preceded by:				
Sol. in % NaCl	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.
0.0%	0	15	0	20	0	0	19	0	21	5
0.025	2	9	0	9	3	3	31	2	19	2
0.05	1	5	5	11	2	1	24	6	22	3
0.075	3	5	1	19	3	6	19	8	14	2
0.1	4	4	3	6	1	5	17	15	20	5
0.125	3	14	14	12	2	4	15	6	7	3
0.15	6	9	7	12	2	5	15	11	10	3
0.175	6	10	9	18	4	4	9	10	8	2
0.2	6	6	17	6	1	13	10	9	8	4
0.225	13	7	10	9	2	10	3	12	10	4
0.25	7	5	14	7	2	12	9	19	1	4
0.275	10	5	13	3	1	14	5	19	6	4
0.3	15	5	24	2	1	9	3	15	2	4
0.325	17	3	22	3	2	8	1	21	0	3
0.35	10	0	32	0	1	14	0	18	0	5
Total	103	102	171	137	27	108	180	171	148	53

Observer Kohlberg (Table XIII) shows a contrast effect between the stimuli, like that of the others; that is, the probability of a positive judgment is increased if the stimulus just preceding was weaker than the one in question. But there is also another tendency at work, for the contrast effect is not equally marked in all cases. When there is contrast between two solutions, A and B, the observer is apt to attest the contrast by calling B salt if it is really salter than A, or *vice versa*, and this tendency exists without regard to the judgment passed upon A; but the striking fact appears that this tendency is stronger if the judgment of A was mistaken. Normally 54 per cent of the judgments in this series are positive, but after weaker solutions 85 per cent of them are positive; after weaker solutions which have been called "salt" 94 per cent of the judgments are positive ("salt"), while if the weaker preceding solution was

Table XII

Observer Noteware. 40 Rounds of Weak Solutions

"strong" = stronger than the one in question
"+" = positive judgment of salt

	+ jdmt. preceded by:					— jdmt. preceded by:				
Sol. in % NaCl	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.	+ weak	+ strong	— weak	— strong	0 jdmt. 0 sol.
0.0%	0	11	0	11	1	0	12	0	4	1
0.025	0	3	0	6	1	2	14	1	12	1
0.05	0	8	4	4	1	3	11	2	5	2
0.075	1	6	3	6	2	0	12	3	6	1
0.1	0	9	4	1	3	4	9	2	8	0
0.125	4	7	7	6	1	3	5	2	4	1
0.15	2	3	7	7	1	5	7	5	1	2
0.175	8	4	4	7	1	2	4	7	2	1
0.2	7	1	9	5	2	1	5	6	3	1
0.225	9	1	6	4	1	5	6	3	3	2
0.25	7	1	7	1	2	5	3	10	2	2
0.275	9	3	10	5	0	5	2	3	1	2
0.3	11	3	5	2	2	7	4	5	1	0
0.325	8	1	14	1	1	6	2	5	0	2
0.35	9	0	11	0	2	10	0	7	0	1
Total	75	61	91	66	21	58	96	61	52	19

called "not salt" only 78 per cent of the following judgments were positive. In other words, the effect of contrast between two stimuli is complicated by a tendency to repeat a judgment just made. This may be called a tendency to "iteration." It should be observed, however, that the combined figures of Table XIV show a general tendency on the part of this observer in the opposite direction, i.e., to give more positive judgments following negative than following positive judgments.

Two separate records are available for observer von der Nienburg in this connection, one for the weak series and one for the strong series of stimuli. She was able to distinguish the salter from the less salt solutions very clearly in both series. In both series she shows the influence of contrast; more markedly in the strong series, where more than half of the solutions were clearly salt. At the same time the tendency to iteration is seen to be

TABLE XIII. DEDUCED FROM TABLES VIII–XII

Showing what proportion of the judgments are positive when the stimuli have been preceded by stronger or by weaker stimuli which have been called either "salt" or "not salt." The numerator indicates the number of positive judgments; the denominator the whole number of judgments, both positive and negative, which were preceded by stimuli and judgments as indicated.

	Miss K., 80 rounds of 16 strong solutions		Miss v. d. N. 40 rounds of 16 strong solutions		Miss v. d. N. 40 rounds (1st 6 of the above 16)		Miss v. d. N. 100 rounds of 15 weak solutions		Mr. L., 80 rounds of 15 weak solutions		Miss N., 40 rounds of 15 weak solutions	
	Ratio	%	Ratio	%	Ratio	%	Ratio	%	Ratio	%	Ratio	%
Preceding solution *stronger* and called "salt."	$\frac{141}{456}$	=30.9	$\frac{235}{304}$	=77.4	$\frac{125}{193}$	=64.7	$\frac{26}{202}$	=12.9	$\frac{102}{282}$	=36.2	$\frac{61}{157}$	=39.5
Preceding solution *stronger* and called "not salt."	$\frac{16}{158}$	=10.1	$\frac{1}{3}$	=33.3	$\frac{1}{3}$	=33.3	$\frac{47}{500}$	= 9.4	$\frac{137}{285}$	=48.1	$\frac{66}{118}$	=55.9
Preceding solution *stronger* disregarding the judgment.	$\frac{157}{614}$	=25.6	$\frac{236}{307}$	=76.9	$\frac{126}{196}$	=64.2	$\frac{73}{702}$	=10.4	$\frac{239}{567}$	=42.2	$\frac{127}{275}$	=46.2
Preceding solution *weaker* and called "salt."	$\frac{177}{188}$	=94.2	$\frac{223}{223}$	=100.0	$\frac{14}{14}$	=100.0	$\frac{43}{92}$	=46.7	$\frac{103}{211}$	=48.8	$\frac{75}{133}$	=56.4
Preceding solution *weaker* and called "not salt."	$\frac{319}{398}$	=78.2	$\frac{66}{70}$	=94.3	$\frac{10}{14}$	=71.4	$\frac{197}{606}$	=32.5	$\frac{171}{342}$	=50.0	$\frac{91}{152}$	=59.9
Preceding solution *weaker* disregarding the judgment.	$\frac{496}{586}$	=84.6	$\frac{289}{293}$	=98.6	$\frac{24}{28}$	=85.8	$\frac{240}{698}$	=34.5	$\frac{274}{553}$	=49.5	$\frac{166}{285}$	=58.2
Preceding solution called "salt" disregarding the strength.	$\frac{318}{644}$	=49.4	$\frac{458}{527}$	=87.0	$\frac{139}{207}$	=67.1	$\frac{69}{294}$	=23.5	$\frac{205}{493}$	=43.4	$\frac{136}{290}$	=47.0
Preceding solution called "not salt," disregarding the strength.	$\frac{335}{556}$	=58.6	$\frac{67}{73}$	=91.7	$\frac{11}{17}$	=64.7	$\frac{244}{1106}$	=22.1	$\frac{308}{627}$	=49.1	$\frac{157}{270}$	=58.2
Preceding solution: All, *strong* and *weak*, "salt" and "not salt."	$\frac{653}{1200}$	=54.4	$\frac{525}{600}$	=87.5	$\frac{150}{224}$	=67.0	$\frac{313}{1400}$	=22.4	$\frac{513}{1120}$	=45.8	$\frac{293}{560}$	=52.3

TABLE XIV

ITERATION AND REVERSAL OF JUDGMENT. INFLUENCE OF FORM OF THE PRECEDING JUDGMENT UPON THE NEXT JUDGMENT

The last column of percentages shows the proportion of positive judgments from all the cases, without regard to the preceding stimuli or judgments. The next to the last column shows the proportion of positive judgments when the stimulus in question has been preceded by a positive or by a negative judgment.

Miss K., 80 rounds of 16 strong solutions	318	pos. jdmts. follow	644	pos. jdmts.,	or, 49.4%	as against a normal of 54.4% positive judgments
	335	" "	556	neg. "	or, 58.6%	
Miss v. d. N., 40 rounds of 16 strong solutions	458	" "	527	pos. "	or, 87.0%	as against a normal of 87.5% positive judgments
	67	" "	73	neg. "	or, 91.7%	
Miss v. d. N., 40 rounds the 1st 6 of the above 16	139	" "	207	pos. "	or, 67.1%	as against a normal of 67.0% positive judgments
	11	" "	17	neg. "	or, 64.7%	
Miss v. d. N., 100 rounds of 15 weak solutions	69	" "	294	pos. "	or, 23.5%	as against a normal of 22.4% positive judgments
	244	" "	1106	neg. "	or, 22.1%	
Mr. L., 80 rounds of 15 weak solutions	205	" "	493	pos. "	or, 43.4%	as against a normal of 45.8% positive judgments
	308	" "	627	neg. "	or, 49.1%	
Miss N., 40 rounds of 15 weak solutions	136	" "	290	pos. "	or, 47.0%	as against a normal of 52.3% positive judgments
	157	" "	270	neg. "	or, 58.2%	

very strong. The number of positive judgments after a weak solution, or of negative judgments after a strong solution, already relatively large as the result of contrast, is greatly increased if the judgment to be made is a repetition of the one just made. In this observer the tendency to iteration is at work when the solutions are so strong that most of them taste distinctly salt, and it is no less evident when the solutions are so weak that very few of them appear salt.

Thus it appears that for the two persons who were capable of fairly reliable observations a combination of circumstances in which a negative after-effect is reinforced by the fact that a positive judgment has just been made is peculiarly likely to elicit a positive judgment upon the next stimulus. In any event it is clear that the comparatively simple judgment involved in perceiving a weak stimulus is influenced by factors which lie wholly within the individual who is making the judgment. Whether or not a sensation will appear as the result of any particular stimulation depends upon the intensity of the stimulus and the state of attention; but it also depends upon other factors of a very different order. One of these factors, and an important one, is the tendency to repeat the experience which has just been had. Even if the experience itself was illusory, it paves the way for another experience of the same kind. Not even the most elementary sense-experience appears in isolation. Its appearance is governed to some extent by the mental attitudes which precede and usher it into consciousness.

B. The Influence of Surrounding Stimuli; A Central Factor which Dislocates the Threshold of Sensation

The determination of the threshold is subject to another disturbing central factor. Compare the records for observers Levy and von der Nienburg on the weak series (Plate 3.) Both of them give more than 50 per cent of positive judgments on the two strongest solutions, but this fact does not have the same

significance in the two cases. Mr. Levy is habitually free with his positive judgments, so that there are 45 per cent positive even in the case of pure water. In his case, therefor, the 50 per cent point is at the very beginning of things. On the other hand, Miss von der Nienburg is always chary, in this series, of positive judgments, and when she gives as many as fifty out of a hundred we may be sure that she has a large number of clear sensations, for she does not often report salt unless there is some there. But if we turn to the subsequent record of this same observer (v.d.N.) with the stronger stimuli, we find that she also can be prodigal of positive judgments under the influence of a relatively large number of positive sensations (Plate 2.) In the weak series, when the stimulus was water, she gave only nine positive judgments of salt out of one hundred; and for the solution of 0.1 per cent she gave only five; in the strong series she gave seventeen out of a possible forty positive answers for both water and the solution of 0.1 per cent. In the weak series the 50 per cent threshold would fall on a solution of 0.325 per cent and in the strong series it would fall on slightly under 0.2 per cent. Or, stating the same relations somewhat differently, the 50 per cent threshold stimulus of the weak series gives almost 80 per cent positive judgments in the strong series. It is, of course, out of the question to suppose that the sensitivity of the observer is appreciably different in the two series. On the contrary the greater number of positive judgments on weak stimuli in the strong series must be ascribed to the inertia of judgment by which this observer is led to give an undue proportion of judgments of the kind that are already predominant in the series.[20]

Let us see how the matter stands for observer Noteware, who was the only other one taking part in both strong and weak

[20] That this phenomenon does not depend upon special conditions of time and place may be seen from an inspection of some of the data long since reported by Camerer (*Ztsch. f. Biol.*, vol. 6, 1870, p. 443). In one of his endeavors to reach a threshold, using a 7-millimeter glass tube to apply the solution, he tried weaker and weaker solutions on successive days with the peculiar result that the weaker solutions of one day gave as many positive answers as the stronger ones of the day before. By

series. In the strong series she gave, out of forty cases:

for water	0.0%	3 positive "salt" answers
for solution	0.1%	8
	0.2%	1
	0.3%	1

But in the weak series she gave, again out of forty cases:

for water	0.0%	23 positive answers
for solution	0.1%	17
	0.2%	23
	0.3%	23

In the strong series, which came first with her, the 50 per cent threshold stimulus is stronger than a solution of 0.6 per cent. This is considerably stronger than the strongest solution to be

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condensing his table we get the following:

1st day		2nd day		3d day		4th day	
% salt	% pos. jdmt.	% salt	% pos jdmt.	% salt	% pos. jdmt.	% salt	% pos. jdmt.
0.39	69						
0.31	61						
0.25	31	0.25	71				
0.00	23	0.22	66				
		0.19	32				
		0.00	27	0.14	64		
				0.12	49		
				0.11	28	0.11	32
				0.00	15	0.10	25
						0.09	8
						0.00	11

From this it appears that the solution of 0.25 per cent, which was the strongest on the second day, gave as many positive judgments as were given by the solution of 0.39 per cent which was the strongest of the preceding day, and gave more than twice as many positive judgments as it had itself given on the preceding day when it was the weakest in the series. The phenomenon continues very strong for three days, disappearing on the fourth; but on a later occasion a solution as weak as the weakest in the series of the fourth day gave 79 per cent of right answers for the same two observers, or more than even the strongest solution of the previous days. It should be noted that the ability to detect water remains about the same from day to day, so that the increasing number of positive judgments on the weaker solutions really means a keener power of discrimination between water and salt. Camerer himself attributes this phenomenon in part to practice, but in part to "unconscious comparison" between the various solutions tasted on any one day.

For these two observers the "absolute threshold" depends very largely upon the strength of the solutions entering into the series upon which the tests are made. The threshold is lower in a group of weak solutions than it is in a group of stronger solutions.

found in the weak series, and yet when she comes to the weak series she gives 50 per cent or more of positive judgments on ten out of the fifteen solutions. It will be observed that these data are not in agreement with those from observer von der Nienburg. The latter gave more positive judgments and had a lower nominal threshold in the strong series. But observer Noteware gives more positive judgments and has a lower nominal threshold in the weak series. In this case we know that all the solutions in the weak series are well below what seems, by a fair determination, the threshold in the strong series. The subject herself felt that she was doing little more than guessing in the weak series, and a mere glance at the graphic representation of the data (Plate 3, fig. 3) shows that her feeling was justified. She was actually working with intensities which were, in one sense, below the threshold. Yet she could give more than fifty positive judgments to the hundred. It should be noted also in this connection that she gave more positive judgments on the seven strongest solutions than she did on the seven weakest, so that there is still a threshold of difference represented within the series. But as a consequence of the disconcerting nature of the situation she fell back upon guessing, and as a guide in her guessing she seems to have been inclined to make the supposition that about half of the solutions contained salt and the other half not. There are 314 positive judgments out of the possible 600.

It is apparent in a case like this that the mere fact that some stimulus is called salt more often than not salt is in itself no proof that the stimulus in question is above the threshold of sensation. Other factors may be responsible for the preponderance of positive judgments. Judgments must be accounted for psychologically as well as psychophysically, and one of the most important of the psychological conditions which must be considered is the magnitude of the other stimuli which are subject to judgment in the same series. The discovery of the importance of this particular factor was one of the most conspicuous results of the writer's investigation of the judgment of difference (page 51 of this volume).

It appears from what has just been said that the observers who worked with both strong and weak solutions maintained different attitudes in the two series, showing that their judgments were affected by the total group of stimuli so as to be disturbed with regard to any member of one group that might be transferred to the other group. This is best seen in the case of observer von der Nienburg, who increased the number of positive judgments upon weak stimuli when she was making a good many positive judgments in the series.[21]

Observer Noteware seems to have been seriously influenced by the general proportion of the judgments. She gave always about as many positive as negative judgments; so that, when she came to judge very weak stimuli, she gave several times as many positive judgments upon certain ones as she had given upon the same stimuli when found among stronger solutions. Some place had to be found for what she felt to be the proper proportion of positive judgments, and they fell by chance all along the scale, piling up where otherwise there would have been very few of them.

During the course of the experiment, all of the observers were, from day to day and more or less steadily, inclined to change their opinion as to the number of salt solutions in a series. What the grounds of this change were does not appear. Perhaps there was merely a shift from a comparatively unfounded prejudice to an opinion better in accord with the actual sensations.

Table XV shows the percentage of positive judgments made by each of four observers at each successive sitting during the course of the experiment. Observer Levy shows a good deal of irregular fluctuation; on some days there were more positive judgments, on others less. Such results might be due to fluctuations in the condition of the observer, to more local conditions in the mouth, or to the weather. Observer Noteware gives about

[21] This tendency is associated with the tendency to repeat a preceding judgment, which has been discussed already in a previous paragraph. When once it is found that one type of judgment is more frequent than the other type in a series, the tendency to iteration will result in a still further increase in the number of judgments of the predominant type.

Table XV

Change of Attitude from Sitting to Sitting

Showing the average number of positive judgments per round of 15 or 16 stimuli given at each sitting.

Sitting	Miss Kohlberg 16 strong stimuli	Miss von der Nienburg 16 strong stimuli	Miss von der Nienburg 15 weak stimuli	Mr. Levy 15 weak solutions	Miss Noteware 15 weak solutions
1	11.5	10.6	12.8*	6.3	6.4
2	9.4	14.4	7.8*	5.3	8.0
3	9.9	13.7	7.9*	7.4	7.0
4	7.8	14.9	3.66	6.7	9.5
5	8.2	14.6	4.88	8.2	8.0
6	8.3	.....	4.00	6.6	....
7	8.9	.....	3.27	7.0	....
8	8.0	.....	2.59	6.8	....
9	7.9	.....	1.50	6.3	....
10	7.3	.....	2.28	6.8	....
11	9.4	.....	2.00	7.4	....
12	7.8	.....	2.25	6.7	....
13	....	.....	3.38	7.1	....
14	....	.....	3.38	6.0	....
15	....	.....	4.00	....	....
16	....	.....	3.63	....	....
Average	8.6	13.7	3.18	6.75	7.85

* Not included in the average.

the same number of positive judgments each day. The result proved that neither of these two observers could really discriminate between the solutions. The number of positive judgments represents merely the attitude assumed by the observer as the basis for guessing. Each of them assumed that about half of the solutions were salt and gave about fifty per cent of positive judgments each day.

Observers Kohlberg and von der Nienburg were not guessing to any great extent. Miss Kohlberg changed her attitude some-

what irregularly from day to day, but in general she gave fewer positive answers as the work progressed from week to week. Miss von der Nienburg gave many more positive judgments in the preliminary experiments with the weak series of solutions than she did later on. The table shows, in the column for weak stimuli, that, after the third day, there was no further regular shift in the attitude of this observer. The attitude finally assumed required about one positive judgment to four negative judgments. There was a larger proportion of positive judgments on some days and a smaller proportion on others, but there was no further systematic change during the course of the experiment.

When observer von der Nienburg came to take up the series of stronger solutions, her attitude underwent a change in this, as in other respects. In this series she gave, on the average, more than four positive judgments to one negative judgment, and there was a tendency to increase the proportion of positive judgments after the first day. From the data it is clear that this observer required two or three sittings before becoming adjusted to the conditions of the experiment, or before becoming adjusted to changed conditions, but that when once she had assumed an attitude toward either series she showed no disposition to disturb the normal ratio between the numbers of positive and negative judgments.

These shifts in the general proportion of positive and negative judgments are significant because they involve a corresponding shift in the apparent position of the threshold. When there is a larger total number of positive judgments in the series, there will be more of them on each member of the series, and the result will be that a solution will appear to be above the threshold, whereas the same solution would appear to be below the threshold if the total number of positive judgments in the series, and consequently on that solution, were reduced.

V

THE INTERPRETATION OF THE THRESHOLD OF SENSATION IN VIEW OF THE DISTURBING CENTRAL FACTORS

There are at least two ways of defining intelligibly the threshold of sensation. The first, which may be called the physiological, regards it as an intensity of stimulus so weak that any weaker stimulus of the same kind would produce no sensation or reaction at all.[22]

Obviously there are stimuli so weak that they are never apprehended by the sense-organs, but it does not follow that there is any discoverable and measurable stimulus which is just strong enough to be apprehended. Certainly an inspection of typical curves of the distribution of judgments such as we have in the accompanying plates gives no warrant for asserting that we can ever find a definite stimulus just strong enough to provoke a positive judgment. The first impression produced by these curves is that every stimulus, no matter how weak, is capable of producing a sensation, but that the stronger ones are more apt to do so than the weak ones. But there are numerous details to be considered before finally adapting this interpretation of the curves.

One of the peculiar things about the curves (see Plates 1 and 2) is that some of them start from a comparatively elevated plateau instead of starting off low when the stimulus was pure water and thence increasing steadily the number of positive judgments. It will be seen that most of the curves which are otherwise regular do proceed in a regular staircase fashion from the very beginning. But the exceptions are worthy of consideration. The record of

[22] A direct statement of this point of view may be found in Titchener, *Experimental Psychology*: Student's Manual, Quantitative, Introduction, p. xxxvii. The general assumption that "a stimulus must attain a certain magnitude in order to arouse a sensation at all" is so universally made that other authorities need not be cited.

observer Bates (Plate 1) is typical in this regard. While they are regular enough so far as the stronger solutions are concerned, there is a plateau representing the judgments on the five weakest solutions. Each of these solutions, including water and the strongest of them being 0.4 per cent, is called salt in 25 per cent or more of the cases. In the case of observer Whisman (Plate 2) the plateau is not elevated; instead there is no rise whatever in the curve until a solution of 0.4 per cent is reached.

In the first of these cases it may be that the taste of the water is strong and that it is confused with the taste of salt. As the dose of salt is increased it does not increase the taste of the water but does gradually submerge it. So, according to this strictly hypothetical explanation, the first few solutions would all have a taste, interpreted as salt, but really a mixture of salt and the water taste, and all these solutions would have about the same taste until the salt became strong enough to be tasted alone, over and above the taste of the water. Unfortunately no record was preserved of this observer's separate estimate of the taste of the water. It may be presumed that the whole record of observers Levy and Noteware with the weak solutions (Plate 3) is nothing more than the nearer view of such a plateau at the beginning of the curve before any true positive cases begin to appear. Observer Noteware shows a tendency to form such a plateau even in the stronger series (i.e., in Plate 2) and shows also, as many others do—the clearest example is seen in the weak series for observer von der Nienburg (Plate 3)—a slight tendency to confuse the taste of water with salt, and to find a very weak salt solution more tasteless than water.[23]

A somewhat similar hypothesis may be advanced with more certainty to account for the plateau at the base line in the case of observer Whisman. This observer was familiar with the disagreeable taste of the water and frequently said "that's water" with an emphasis that denoted more than the mere absence of salt. Now since the water is clearly recognized for itself, it obscures the salt taste until that becomes strong enough to be

[23] For a discussion of the taste of water see Appendix I.

detected over the water. In other words, we seem here to be dealing with a case of discrimination between nearly complementary tastes; and in the four weak solutions the taste of water is recognizable each time, then it is not recognized so often, next there is a sudden leap to cases where salt is recognized in a majority of the cases, and finally there are three solutions in which the salt is recognized every time. It is conceivable that similar results might have been obtained from other observers if they had been equally familiar with the water taste and had differentiated it from, instead of confusing it with, the salt taste.

On the whole, the records which are the most consistent within themselves, and which seem to have been taken under the most favorable circumstances so that there are few stimuli which are unnecessarily strong and yet enough strong ones to give a fairly large number of clear positive judgments, show regular increases in the number of positive judgments, beginning with water or the most tasteless mixture of water and salt. Thus the record of observer von der Nienburg for one hundred rounds of the weak series (Plate 3) shows only one positive judgment for a solution of 0.075 per cent (the weaker solutions had a stronger taste arising from the water, or at any rate, were more often called salt), but from that point on each increase of one quarter of one per cent in the strength of the solution increases the number of positive judgments with almost perfect regularity. In this case it seems certain that every intensity of stimulus employed has produced at times a salt sensation with the exception of the 0.075 per cent solution which is nearly neutral, and the weaker ones, which, while they seemed to taste salt, probably produced a somewhat different sensation. Data of the same type are given by observers Robinson and Noteware for the stronger stimuli. Other examples of what appears to me to be the normal situation are found in the records of observers Kohlberg, Jackson, and Libbin. All of them show a quite regular stepping-up from the weakest solution to the strongest. Several other instances show the same regular stepping-up but involve a considerable number of positive judgments on even the weakest solutions;

for example, observers von der Nienburg (strong series), Detter and Ham. Whatever the reason for the excess of positive judgments on the weakest solutions, it can not be adduced to prove that it is possible to measure the weakest solution which can be tasted. The easiest explanation of the positive judgments on water and weak solutions would be that the water tasted salt, but this hypothesis is inconsistent with all the direct observations, and it would not hold for observer von der Nienburg. A more psychological explanation has already been advanced in her case, namely, that the large preponderance of distinctly salt solutions created a tendency to call a large proportion of all of the solutions salt.

All of the data obtained have now been reviewed. Of the thirteen records, two cases (Bates, Whisman) seem to indicate the existence of intensities less than the weakest which can be perceived, but there is evidence that this interpretation is not the only one open; two cases (Levy, Noteware, weak stimuli), are badly confused by the absence of clear salt sensations in the series, and are capable of explanation either as cases of unperceived stimuli or in another way; six (Libbin, Jackson, Kohlberg; von der Nienburg, strong; Detter, Ham), show no trace of an unperceived intensity; three (von der Nienburg, weak; Noteware, strong; and Robinson), show a saline solution or two which is not perceived as salt, but do not indicate that there is a class of solutions too weak to be perceived.

The distributions of judgments reported by Camerer[24]—the only ones hitherto made which are at all comparable with the present work in respect of the number and intensity of the stimuli employed—do not show any imperceptible intensities. The data from three of Camerer's four observers are presented in Plate 4 in as good a graphic form as I can devise for them. The fourth observer shows no characteristics not found in one of these three. Only the results of the method "without knowledge" are considered. Each observer made fifty rounds of judgments on the set of nine solutions. The unit solution was only 0.0159 per cent

[24] *Ztschr. f. Biologie*, vol. 21 (1885), p. 578.

and the weakest was only one-eighth as strong as the unit. It will be seen that although these intensities are much less than those employed by me (but the quantities administered are ten times as great), the curves both for number of right judgments and for right judgments plus half the number of uncertain judgments, begin to rise from the weakest solutions and rise gradually as the solutions become stronger. Even the weakest solutions (0.002 per cent and 0.004 per cent) are not exactly equivalent to each other or to water. With regard to the absolute intensities here, allowance should be made for the fact that Camerer worked with "Brunnenwasser," which contained an unspecified but appreciable quantity of lime. The fact remains, however, that very minute increments of salt did influence the number of positive judgments on this water.

A second view of the nature of the threshold seeks to place it at some point on a scale midway between the intensity which is just barely strong enough to produce a sensation and the intensity which always produces a sensation. From the nature of the disturbances of judgment by the central factors discussed in the last few pages, it should be clear that the threshold can not be located by arbitrarily deciding *a priori* that a stimulus above the threshold ought to be perceived in more than half or more than three quarters of the cases. Whether a given stimulus is perceived in half or in three quarters of the cases depends too much upon irrelevant accidents like the presence of too few or too many strong stimuli in the series in question. It should be noted particularly that the 50 per cent and 75 per cent thresholds here have a different meaning from that which they have in the case of the difference threshold; for when one is comparing two intensities his judgment is as apt, by mere chance, to fall one way as the other, but there is no such easy law when one is looking out for a sensation. One might, indeed, suppose that the series had been so prepared that half of the solutions would taste salt and half not, and in that case the chances would be even that any particular solution would or would not taste salt. But our observers were cautioned that no such arrangement was

contemplated, and that the differences between individuals would make such an arrangement impossible.

In the case of the difference-threshold 50 per cent of right judgments represents the minimum of discrimination, but in the case of the absolute threshold 50 per cent means pure hit-and-miss for one person (the one who merely guesses, upon the supposition that about half will taste salt), while for another person 50 per cent means a high degree of assurance compared with the 10 per cent or 20 per cent of positive judgments accorded to weaker stimuli.

VI

A MEASURE OF SENSITIVITY PROPOSED AS A SUBSTITUTE FOR THE CONVENTIONAL THRESHOLD

Is there then any less arbitrary method of establishing a threshold of sensation anywhere between the stimulus which is always perceived and the one which is never perceived? The way to answer this question in the affirmative is much simpler than I, for one, had any expectation of finding it. It appears from the observations in this case, as generally, that when the intensities in a series advance by arithmetical (equal) steps, the number of positive judgments advances at first slowly, with very weak stimuli, then more rapidly, and finally, with strong stimuli, more slowly again until it stops entirely. In the conventional way, used in this paper, of representing the steps graphically, the steps are all of one width, but they are highest in the middle and become shorter at both top and bottom of the stairs. This is all in accord with Weber's Law, and may indeed be in accord with Fechner if it can be shown that the magnitudes of the steps follow a logarithmic series.

In such a graphic representation one step in the middle of the curve is higher than any of the others and marks the point where the curve turns from concave to convex. Without precluding in the least a more exact determination of this critical point by the application of the calculus we may approximate it graphically. Once it has been discovered, it proves to be an admirable substitute for the conventional threshold.

This point can be defined precisely and has exactly the same significance for every person and for every kind of stimulus. It corresponds to the intensity of stimulus from which a change of a given amount will be most frequently or easily recognized.

This point can be determined in a comparatively small number of trials, provided the series contains enough different intensities, embracing both extremes of the scale and arranged in an arithmetical progression.

The peculiar advantage of this measure of sensitivity is that it is independent of the constant proportion between the positive and negative answers, and also independent of the errors which accumulate near the extremes of the scale as the result of imperfect attention. Thus, an observer may double the total number of positive judgments all along the scale as the result of some of the disturbing factors which we have found in actual operation, without affecting in the least this crucial point. So, too, one may give very inconsistent judgments upon very weak or very strong stimuli, and still it will remain possible to determine accurately the threshold according to this method.

Mere inspection of the graphic representation of the data will often suffice to determine such a crucial point; for example, the curve for observer Whisman (Plate 2) gives an undoubted threshold between 0.7 per cent and 0.8 per cent, the steps above and below this step are much smaller, and this single step reaches from 25 per cent of correct judgments to 77 per cent; the 0.7 per cent solution and all the weaker ones are very weak or subliminal (only rarely recognized); the 0.8 per cent solution and all the stronger ones are very strong (almost always recognized). For observer von der Nienburg (strong solutions, Plate 3) the crucial point lies between the 0.2 per cent and 0.3 per cent, while for the same observer when using the weak stimuli (Plate 2) it may be placed between 0.3 per cent and the next stronger solution, but here the data are not adequate. For observer Jackson (Plate 2) it may be placed between 0.7 per cent and 0.8 per cent. For observer Detter (Plate 1) between 0.3 per cent and 0.4 per cent, and for observer Noteware (strong series, Plate 2) between 0.5 per cent and 0.6 per cent. In these latter cases the crucial point can safely be placed at the apparent center of the group of largest steps, even though the particular step at the center happens to be comparatively small. It may be

seen at once, however, that these determinations are only approximate. No great accuracy can be expected from work of this sort carried out by novices and continued only for a few sittings (the forty-round series usually required only five sittings). All that is claimed for this crucial point is that, with due regard for the validity of the data from which it is obtained, it has psychological significance as a substitute for the conventional threshold.

Table XVI

Array of Steps for Different Observers

Showing the increase in the number of positive judgments resulting from an increase of 0.1 per cent in stimulus intensity.

Steps	Observer: Bates	Detter	Ham	Jackson	Kohlberg	Libbin	Noteware	Robinson	von der Nienburg	Whisman
0.0–0.1%	0	2	–2	–1	–1	5	5	–5	0	0
0.1–0.2	–1	3	5	1	2	–1	–7	0	4	0
0.2–0.3	–1	7	7	2	3	3	0	18[4]	11[4]	0
0.3–0.4	0	6[2]	6[2]	2	4	2	3	4	6	1
0.4–0.5	9[1]	7	7	1	5	7	11	5	1	4
0.5–0.6	–3	5	2	6	8	2	4[2]	2	1	5
0.6–0.7	4	0	–2	11	4	4[3]	14	6	–1	0[5]
0.7–0.8	5[1]	–2	3	–1[2]	–1	–1	5	–1	1	21
0.8–0.9	4	2	0	13	7	11	0	4	0	5
0.9–1.0	3	2	–1	3	1	2	1	0	0	3
1.0–1.1	–1	–1	2	2	5	3	1	0	0	–2
1.1–1.2	0	1	–1	0	0	0	–3	0	0	2
1.2–1.3	4	0	1	0	1	0	3	0	0	1
1.3–1.4	3	0	0	0	–2	2	0	0	0	0
1.4–1.5	1	0	0	0	2	0	0	0	0	0

[1] It is assumed that the large step from 0.4 to 0.5 is due to errors. Judging by the number of positive judgments on 0.4 and 0.6 there should not be so many on 0.5.

[2] Intermediate between two large steps.

[3] This case is highly doubtful. There is no safe ground for choosing between the maxima at 0.4–0.5 and at 0.8–0.9. The critical point is assigned to the position half way between the two maxima only because some position is desired as a basis for averaging later.

[4] The steps are too coarse for an accurate determination.

[5] Errors at this stage make the next step extraordinarily large.

In practice we have no need of exceedingly delicate determinations of sensitivity. If such need does arise, however, it can be satisfied only by the accumulation of statistically valid data, not by over-refining on inadequate data; and even in that case it will be found, I am sure, that the simple method here suggested gives a threshold the precision of which is commensurate with the adequacy of the data. For any given number of experimental observations this method has the advantage over the usual methods of determining the threshold, that it is not subject to errors from the inclusion of the observations on the strongest and weakest stimuli. As a result of disturbances of attention, the observations on these strong and weak stimuli are not as reliable as are observations upon stimuli of moderate intensities.

In some cases the superficial inspection of the curve is helped out by a perusal of an array of the arithmetical magnitudes of the steps. Such an array is shown in Table XVI for the ten records from the stronger series of salts. It may be seen again that it is much simpler to find the largest step, or the center of the group of largest steps, than it is to find the true zero at either the top or the bottom of one of the columns of figures. It is of some interest further to find how the threshold discovered by

TABLE XVII

Showing the per cent of positive judgments corresponding to the threshold as determined by the largest step in the curve.

Observer	Largest step lies		Per cent positive jdmts.	
Bates	between 0.7%	and 0.8%	between 50%	and 63%
Detter	0.3	0.4	50	65
Ham	0.3	0.4	57	73
Jackson	0.7	0.8	57	56
Kohlberg	0.5	0.6	35	55
Libbin	0.6	0.7	47	57
Noteware	0.5	0.6	37	48
Robinson	0.2	0.3	5	50
von der Nienburg	0.2	0.3	52	80
Whisman	0.7	0.8	25	77
Average	0.47	0.57	41.5	62.4

this method is related to the one obtained by the conventional 50 per cent method, which assumes that a stimulus is above the threshold if it is detected in more than half of the cases in which it is presented.

Table XVIII

Showing the average size of the step at the critical point and for intensities above and below the critical point. Compare Plate 3, fig. 4.

	Average position of step		Average number of positive judgments forming step
Third step below the critical one	0.2%	−0.3%	2.4 out of 40
Second " " "	0.3	−0.4	2.5 " 40
First " " "	0.4	−0.5	4.1 " 40
The critical step itself	0.5	−0.6	8.2 " 40
First step above the critical one	0.6	−0.7	5.8 " 40
Second " " "	0.7	−0.8	3.7 " 40
Third " " "	0.8	−0.9	0.9 " 40
Fourth " " "	0.9	−1.0	1.3 " 40
Fifth " " "	1.0	−1.1	1.3 " 40
Sixth " " "	1.1	−1.2	0.5 " 40
Seventh " " "	1.2	−1.3	0.7 " 40

Note.—Since two of the critical points lie at the second and third members of the series, they give no values for the third step below the threshold. Two others would give no values for a fourth step below, and three would give no values for an eighth step above the critical one.

Table XIX

Average number of positive judgments out of 40 given by 10 observers on 16 strong solutions. Compare Plate 2.

	Solution														
Observer	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Bates	12	12	11	10	10	19	16	20	25	29	32	31	31	35	38
Detter	8	10	13	20	26	33	38	38	36	38	40	39	40	40	40
Ham	13	11	16	23	29	36	38	36	39	39	38	40	39	40	40
Jackson	1	0	1	3	5	6	12	23	22	35	38	40	40	40	40
Kohlberg	1	0	2	5	9	14	22	26	25	32	33	38	38	39	37
Libbin	1	6	5	8	10	17	19	23	22	33	35	38	38	38	40
Noteware	3	8	1	1	4	15	19	33	38	38	39	40	37	40	40
Robinson	7	2	2	20	24	29	31	37	36	40	40	40	40	40	40
von der Nienburg	17	17	21	32	38	39	40	39	40	40	40	40	40	40	40
Whisman	0	0	0	0	1	5	10	10	31	36	39	37	39	40	40
Total for ten	63	66	72	122	156	213	245	285	314	360	374	383	382	392	395

Table XVII shows that the conditions under which the observers worked with the strong stimuli were such that the crucial point, as determined by an inspection of the curves, generally lies in the neighborhood of the intensity which yields fifty positive judgments per hundred. Making a crude average of the ten determinations, the threshold is found, for the group, between a solution of 0.47 per cent and one of 0.57 per cent. The former yields on the average 41.5 positive judgments per hundred and the latter 62.4. If the crucial point is placed half way between them it will yield 52 positive judgments per hundred. The agreement between the two modes of determination holds roughly for each individual case in the sense that the step constituting the crucial point either bridges the stimulus which would yield 50 per cent of positive judgments, or else has as one of its limits an intensity which yields very nearly that proportion. The worst departure from the rule is found in the case of observer Ham, for whom the point is found clear above the 57 per cent level. Inspection of the record will show (Plate 1) that there is justification for thinking that the crucial point has been placed too high in this case.

Experiments with weaker stimuli lead to the conclusion that the correspondence just spoken of is the result of the particular arrangement of conditions and is not inherent in the nature of the threshold itself. The determination for observer von der Nienburg with the weaker solutions gives a much lower number of positive judgments in spite of the fact that the solutions selected as marking the crucial step are stronger in this case.

Weak series, crucial step between 0.3% and 0.325% yields between 36% and 50% of positive judgments.

Strong series, crucial step between 0.2% and 0.3% yields between 52% and 80% of positive judgments.

So, too, the data from observers Levy and Noteware indicate that more than half of the judgments may be positive without reaching a threshold.

Before leaving the subject of the threshold it may be worth while to call attention to the results obtained when a whole group of persons is examined in the mass. Combining the separate determinations for the individuals, we obtain from the average a measure of the sensitivity of the group. The crucial point for the group lies between an intensity of 0.47 per cent and one of 0.57 per cent. It is therefore about twice as high as the threshold intensity usually given as determined by the "physiological" method, i.e., the weakest solution which can be tasted at all.[25]

We may also measure the average size of the step determined upon as the crucial one as in Table XVIII. This is found to be 8.2. That is to say, on the average, out of forty possible judgments, the solution just above the crucial point receives eight more positive judgments than the one just below. And further, if we obtain, by averaging, the size of the steps on each side of the crucial point, we see more clearly than in any individual case that the steps decrease in size as the solutions become stronger or weaker than the threshold intensity. This is shown graphically in Plate 3, fig. 4. No particular mathematical validity can be attached to this average, however, because, of course, the steps are of very different values for the different observers and so should not be equally weighted, as they here are; but it seems to support the theory upon which the present method of approximating a threshold is based.

From Table XIX, giving in full the number of positive judgments made by each observer on each solution, it is possible to obtain an average of the number given by all the observers for each solution. A graph representing this average and constructed like the graphs representing the individual records is shown at the bottom of Plate 2. As might be expected, most of the significant features of the individual records are hidden under this average. One can see, however, that each increase in the strength of the salt solution increases the frequency with which the salt is observed. There is only a trace of a crucial

[25] See Appendix II.

point left between 0.4 per cent and 0.5 per cent (the average of the different determinations falls between 0.47 per cent and 0.57 per cent), in the neighborhood of the stimulus which is perceived in half of the cases (the 0.5 per cent solution). The various determinations of the crucial point for different individuals are scattered over the entire middle range of intensities, giving to the average curve the appearance of a series of almost equal steps in this region. Only when we come to the strongest and weakest solutions, which are never liminal for anyone, does it become evident that the size of the steps decreases as we depart from the threshold-intensity in either direction.

VII

CONCLUSION

A systematic attempt to analyze the conditions under which judgments are made in a typical instance in determining an absolute threshold of sensation leads to the conclusion that such a determination is fruitless if conducted along the customary lines. Not only are successive judgments upon weak stimuli subject to contrast-effects in a marked degree, but they are also disturbed by a tendency to repeat or contradict a previous judgment.

Moreover, the judgments are so affected by the general trend of the earlier stimuli and judgments in the series, that by judiciously arranging two sets of stimuli the same person can be made to appear to have a high threshold in one set and a low one in the other set.

In view of these difficulties some plan must be devised for measuring the delicacy of sense-perception in a more reliable way. The graphic representations of the distribution of the judgments of individual persons invites our attention to the fact, long established, that equal increments of stimulus intensity do not carry with them equal increases in the number of positive judgments representing sensation. At some point in the scale of stimulus-intensities a given increase in intensity has the effect of producing a maximum increase in positive judgments. This critical intensity can be discovered with comparative ease, and its determination is not affected by the errors which vitiate the determination of the least perceptible stimulus.

It is suggested that this critical point in the stimulus series be taken as an index of the delicacy of sense perception. It would be idle to talk of abolishing the least perceptible stimulus as a standard index, but we should recognize its inadequacy and should be ready to adopt a more rational and consistent index, not perhaps as a substitute but as an auxiliary, when we are seriously endeavoring to measure accurately the endowment or condition of individuals with regard to the mechanisms of sense-perception.

APPENDIX I

The Taste of Distilled Water, Including an Account of a Direct Experiment upon the Subject

The water used in this experiment, although "pure" according to ordinary standards, was by no means tasteless. All of the observers noted that the water had an undefinable, slightly disagreeable, taste; but none of them would admit that it tasted either salt, sweet, sour, or bitter. Some of them described the water as "flat," others as "musty." An inspection of the curves in the plates reveals the fact that several persons had a tendency to call the water "salt" (unknowingly) more often than some of the weakest salt solutions. In other words, the taste of the water is mistaken for salt but can be compensated for by salt—a rather contradictory state of affairs. Titchener, in his *Experimental Psychology*, vol. 1, pt. 2, p. 101, speaks of neutralizing the water by the addition of a little salt in case it tastes sweet or sour. But he does not think that salt will neutralize a bitter taste in the water, and he does not consider the possibility just broached of neutralizing a salt taste by the addition of salt. At any rate he does not think distilled water ever tastes salt, and in this he is undoubtedly correct, notwithstanding the fact that its taste is sometimes confused with that of salt.

A direct investigation of the taste of the water used in this experiment was instituted, and it reveals the fact that most persons call it bitter rather than anything else. In this investigation a single set of judgments was secured from each of one hundred persons. These observers tasted from a porcelain spoon one cubic centimeter of each of nine solutions in the following order:

1. 2.0% salt
2. 1.0% salt
3. 0.5% salt
4. 0.25% salt
5. 0.125% salt
6. 0.0625% salt
7. 0.0% salt
8. 0.0% salt
9. 0.0% salt

They were told that they would first taste salt and that the successive solutions would be weaker and weaker, and that they were to report in every case just what they tasted, whether salt or anything else. The experiment purported to discover the least perceptible intensity of salt solution. Aggregating the results for the three doses of water which contained no salt we have the following distribution of judgments:

No taste—"water"	49.3 per cent
Bitter	25.4 per cent
Sweet	8.3 per cent
Unknown taste	7.0 per cent
Other taste (known)	4.0 per cent
Salt	3.0 per cent
Sour	2.7 per cent

It seems certain that this particular water does not taste salt. Making allowance for the large number of university students who are familiar with the water and immediately put it down as "no taste," simply because they have been taught that that is the proper thing to say about distilled water, there can be little question that the water is slightly bitter for most persons.

The experiences of other experimenters help, by their diversity, to explain the difficulties which confronted our observers when they were asked to pass judgment on the taste of the water or of extremely weak solutions of salt in the water. Richards speaks of a double-distilled water as being "unusually tasteless," but so far as I know there is no evidence that additional purity involves a loss of taste; in fact we should expect that if the taste depends either on the chemical constitution of the water or on the absence of oxygen (the two principal lines of explanation) an increase of purity would increase the taste. On the other hand Nagel suggests that the (for him) bitter taste of water may be due to the floating of particles of matter which are already present in the mouth on to new locations where they are tasted. In that case the purity of the water would have nothing to do with its taste, and it is a little difficult to see how stimulation of single papillae by water can produce a taste. But Kiesow as well as

Camerer found that water tasted bitter at points all over the tongue when applied in a punctiform manner.

Kahlenberg is the only authority that I can find willing to assert that "pure water is tasteless." His reasons for thinking it ought to be are good, but I question the accuracy of his observation. Keppler could detect no taste in distilled water, but he discovered a smell, which is worse. Kiesow does not attribute the taste to the water itself but to the mouth. The permanent mouth-taste is generally bitter, he thinks, but there may be a sweet after-effect from salt or sour. Under no circumstances does he discover salt in this mouth-taste.

Richet shares the opinion of many when he remarks that distilled water has "a very disagreeable taste" which it is hard to disregard. On the other hand Largier des Bancels thinks that it is sweetish, although he will admit that it may be *fade*. The latter quality is generally unpleasant, I believe.

Camerer, who devoted his youth and his middle age, if not more of his life, to this subject, has made some very acute observations. Clean snow-water he found to be ideal, but it is not easy to obtain. The apothecary's distilled water smelled of the still. Water from the Danube, even in its mountain reaches, also smelled. Well-water containing lime, tastes a little bitter. The admixture of a little salt to this water makes it taste "soft," while a weak quinine solution resembles the well-water in tasting "hard."

Titchener suggests that the bitter sometimes noted as a contrast effect from sugar or salt may be due to an agreement between water and bitter, in that both taste "smooth." Considering this with Camerer's observation just quoted, we may infer perhaps that the "taste" of water is not, after all, a taste-quality but is due rather to the presence or absence of some accompanying tactual characteristic; the absence, perhaps, of the "bite" which is associated with sweet, salt, and sour alike.

The upshot of all of these observations seems to be that water is not tasteless (in the broader sense of the word), that it tastes more like bitter than anything else, and that its taste can be

neutralized by salt. In any event it does not taste like salt, so that we can be sure that a series of salt solutions can be started from a true zero point with regard to that quality. Furthermore there is evidence that some of the weakest solutions of salt in water give a substance which is as nearly tasteless as any which can be produced.

APPENDIX II

Concerning Various Modes of Applying the Taste Stimulus, and Various Determinations of the Threshold for Salt, with an Experimental Contribution

A large number of independent determinations of the threshold for salt are available, but they have been secured by such divers methods, both with regard to the mode of applying the stimulus and with regard to interpretation of the threshold, that comparisons between them are of doubtful value. In the sense of taste the threshold determinations depend primarily upon the mode of administering the stimulus. The least perceptible stimulus may be stated in term of the concentration or "strength" of the solution employed. But this can be significant only if we know also the amount of the solution taken into the mouth, for only then do we know the absolute amount of the sapid substance brought into contact with the taste organs. Numerous devices have been employed in the endeavor to measure the actual intensity of the stimulus, either in terms of "strength" or of gross amount.

Michelson[26] mixed a little gum-arabic with the solution to keep it from running, and then applied a single drop. The same method was employed by Kiesow and Hahn.[27] This method is designed for local exploration rather than for quantitative measurement.

Zwaardemaker[28] used a solution thickened with gelatin and applied with a glass rod for exploration. For quantitative work he prepared pellets of Hollundermark saturated in a ten per cent solution of salt, and found how many of these must be laid on the tongue in order to produce a taste. A somewhat similar

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[26] Virchow's *Arch. f. pathol. Anat. u. Physiol.* vol. 123 (1891), p. 396.
[27] *Ztsch. f. Psychol.*, vol. 26 (1901), p. 383.
[28] *Ergebn. d. Physiol.*, vol. 2, pt. 2 (1903), p. 716.

device was tried by Haemelinck.[29] He used punch discs of blotting paper, but soon abandoned them for a brush. With a single drop of liquid on a dry brush applied to the extended tongue he found that a strength of from 0.2 per cent to 0.3 per cent is needed to produce a sensation.

A brush pencil narrow enough to reach single papillae was employed by Oehrwahl.[30] A brush, a sponge, and a dropper were all used by Schreiber, according to a review by V. Henri in *Année psychol.*, vol. 3 (1897), p. 445. As a result of some 6300 experiments he is reported as giving the following values for the threshold with the solution at 30° C: Tip of tongue, 0.1 per cent; borders, the same; caliciform papillae, 0.08 per cent; whole mouth, 0.5 per cent.

Keppler[31] also used the brush for part of his work, which had to do chiefly with the threshold for difference, but he preferred to take a dose of thirty-five cubic centimeters from a glass. The brush was used by Kiesow[32] for purposes of exploration. He reports average thresholds for six observers as follows: Tip and borders of tongue, 0.25 per cent; base of tongue, 0.28 per cent; but some of the individual threshold determinations run as low as 0.18 per cent. He also used a dose of half a cubic centimeter of liquid.

Hänig,[33] whose work establishes the doctrine of isochymes or zones of equal sensitivity, used first a single drop from a dropper, but later adopted the brush. He found, for five subjects in whom he examined fourteen areas of the tongue, that the threshold ranged from 0.3 per cent to 0.48 per cent, but that most of them were found between 0.35 per cent and 0.4 per cent.

A single drop on the protruded tongue is recommended by Toulouse and Vaschide.[34] Their lowest threshold is 0.9 per cent.

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[29] *Année psychol.*, vol. 11 (1905), p. 116.

[30] *Skandinav. Arch. f. Physiol.*, vol. 2 (1891), p. 1.

[31] Pfluger's *Arch. f. d. ges. Physiol.*, vol. 2 (1869), p. 453.

[32] *Philos. Studien*, vol. 10 (1894), p. 362.

[33] *Philos. Studien*, vol. 17 (1901), p. 607.

[34] *C.-R. Acad. Sci.*, Paris, vol. 130 (1900), pp. 803 and 1216.

Vaschide, using the same method, reports the following thresholds for 28 men and 30 women in his article "Gout" in Richet's *Dictionaire de Physiologie,* vol. 7 (1907), p. 666:

For sensation, men, 0.2%; women, 1.0%
For discrimination, men, 1.0%; women, 4.0%

Fontana[35] dropped three drops on the outstretched tongue and found that a solution of 0.2 per cent was the weakest salt solution which could be perceived clearly and without doubt.

At one time Camerer[36] applied the solutions to single papillae by one or by two capillary tubes. He found that a single papilla stimulated in this way by one part of saturated salt solution in 410 parts of water would give a positive response in half of the cases. This method was also employed by Oerwahl,[37] and it suggests the method extensively used by Sternberg[38] for local exploration, of projecting a fine jet of chloroform or ether vapor against the papilla. Camerer also employed tubes about seven millimeters wide, but it was with this device that he encountered the apparent shift in threshold, due to the effect of the strength of the other stimuli in the series, which effectually prevented his discovering any definite threshold. By dropping one drop containing 0.03 cubic centimeter of solution upon the tongue, he discovered that so little as 0.0024 milligram of salt could be tasted; that is, a solution of 0.8 per cent.

A large number of experimenters have used liquid solutions in larger or smaller quantity. Valentin is quoted as having advised regulating the quantity rather than the concentration of the solution and as reporting that one part of salt in 213 parts of water is perceptible in a dose of 1.5 cubic centimeters, or one part in 426 perceptible in 12 cubic centimeters.[39]

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[35] *Ztsch. f. Psychol.,* vol. 28 (1902), p. 255.

[36] *Ztsch. f. Biol.,* vol. 6 (1870), p. 440.

[37] *Skandinav. Arch. f. Physiol.,* vol. 2 (1891), p. 43.

[38] *Geschmack und Geruch,* Berlin, 1906; also numerous contributions in periodicals.

[39] This is according to the quotation by von Vintschgau in Hermann's *Handbuch,* vol. 3, pt. 2, p. 210, and by Nagel in his *Handbuch,* 1905, vol. 3, p.

Venables[40] found that the most sensitive of two observers could barely detect the presence of salt in one cubic centimeter of a solution of 0.1 per cent. The same amount of solution was used by Kastle[41] in his work on acids. Lombroso and Ottolenghi[42] used only half a cubic centimeter in their tests of criminals and others. Höber and Kiesow[43] found that a molecular concentration of 0.026 was perceptibly salt, not only in the case of NaCl but also for all the other univalent salts tested. Their dose was two cubic centimeters. Kahlenberg[44] used twice as large a dose. Richards[45] gave a small mouthful, perhaps a little more than Kahlenberg. In general the chemists do not seem to share in Valentin's opinion that the quantity of the solution affects the threshold fundamentally.

Camerer at one time used a dose as large as thirty cubic centimeters.[46] An even larger dose was used by Keppler, whose work was published in the same volume as was that of Camerer. In the thirty cubic centimeters Camerer could detect 4.8 milligrams of salt, or 1.6 per cent. In his most elaborate work,[47] Camerer administered a dose of ten cubic centimeters. With this dose the weakest concentration, 0.016 per cent, yielded in each of several extended experiments more positive judgments than did water. A typical set of these observations has already been presented in the text of the present article.[48] The very abundance of the data in this extraordinary thorough investigation of Camerer's precludes the adoption of any particular figure for a threshold. An elaborate explanation and justification would be required

635. The quotation by Vaschide in Richet's *Dictionaire*, vol. 7, p. 664, seems to be erroneous. The original work of Valentin is not accessible to me; a later edition (1855) gives the threshold for salt at 0.75 per cent without specifying the conditions or the amount of the dose.

40 *Chem. News*, vol. 56 (1887), p. 221.

41 *Amer. Chem. Jour.*, vol. 20 (1898), p. 466.

42 *Ztsch. f. Psychol.*, vol. 2 (1891), p. 346.

43 *Ztsch. f. Physikal. Chem.*, vol. 27 (1898), p. 604.

44 *Bull. Univ. Wisc.*, vol. 2, no. 25 (1898), p. 5.

45 *Amer. Chem. Jour.*, vol. 20 (1898), p. 121.

46 Pflüger's *Arch. f. d. ges Physiol.*, vol. 2 (1869), p. 323.

47 *Ztsch. f. Biol.*, vol. 21 (1885), p. 571.

48 See p. 239 and Plate 4.

for the selection of one intensity rather than a weaker or stronger one.

Heymans[49] also used ten cubic centimeters as a dose. He places the normal threshold at 0.25 per cent.

Bailey and Nichols[50] used a liquid solution which was apparently tasted from a common drinking cup or glass; how much was taken is not stated. They state as the result of observations by 82 men and 46 women that a solution of 0.05 per cent is the weakest that can be tasted.

	Judgments						
Strength of solution, %	"0" or "Water"	"Unknown taste"	"Salt"	"Sour"	"Sweet"	"Bitter"	Other (known) taste
2%	0	0	100	0	0	0	0
1	0	0	99	0	0	0	1
0.5	8	0	86	1	0	3	2
0.25	11	0	76	1	4	3	5
0.125	30	6	47	1	7	5	2
0.0625	52	5	16	2	8	13	4
0	51	6	7	2	9	21	4
0	51	5	1	2	9	27	4
0	46	10	1	4	7	28	4

The observations of 100 students, 32 men and 68 women, already mentioned in Appendix I, are presented here in tabular form for what they are worth. The solutions were presented in an order of descending intensity only, and we should be suspicious that any threshold determined from such a series will be too low. It seems clear that the solution of 0.125 per cent tasted salt to a considerable proportion of the observers, but there is a good deal of doubt about the solution of half that strength for it tasted bitter almost as often as it tasted salt, and it tasted like water to fully half the observers.

This review does not pretend to be complete. It leads to the conclusion that taste-stimuli should be administered in fluid form and in as nearly a normal manner as possible. If the stimulus is so administered, the least perceptible concentration is found

[49] *Ztsch. f. Pschol.*, vol. 21 (1899), p. 341.

[50] *Nature*, vol. 37 (1887–8), p. 557.

to contain from two to three parts of salt in a thousand parts of water.

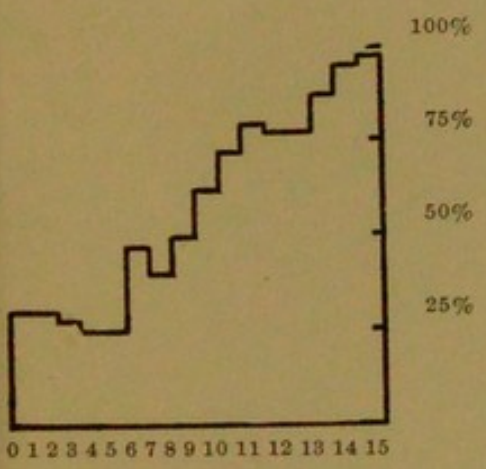
Stimulation by brushes or otherwise, of single papillae, while indispensable in discovering the points and zones of sensitivity for different qualities of taste, is not suitable for quantitative work. In the first place, one never knows how closely the substance is brought into contact with the papilla; if the application is made a little to one side or with a little less force than usual, the substance will not so easily reach the taste organs within. A similar objection holds against the use of pellets or the broad brushing of the tongue, and even against merely dropping the substance upon the protruded tongue. Still more objectionable in quantitative work is the application of the substance in dry form so that it must be dissolved by the more or less abundant fluids already in the mouth.

With regard to the quantity of liquid to be taken into the mouth, it seems to me that there should be enough so that a slight movement of the tongue will bring it into equal contact with all the sensitive parts at once. But the quantity should not be sufficient to disconcert the observer or to give rise to the swallowing reflex.

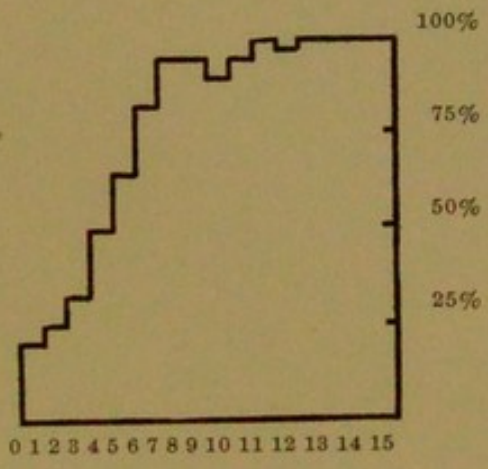
The way of taking the liquid into the mouth is of no great consequence and was determined in the present instance by the greater convenience of pipettes in handling. A small quantity of the fluid in a drinking glass or spoon would first have to be measured out and then the glass rinsed. The pipette combines the two processes in one, and delivers the fluid to the mouth a little more conveniently besides. The slight "taste" due to the odor of the rubber bulb is, on the other hand, a real disadvantage which is not wholly obviated by remarking that all observers quickly learn to disregard it or to treat it as a constant factor.

PLATE 1

Each figure represents the results of 40 judgments on each of 16 solutions. The strength of solution is laid off along the base line and the unit of strength is one gram of salt per liter of water, or 0.1 per cent. Thus "9" means 0.9 per cent. The number of positive judgments rises to a possible 40 for 100 per cent. The last figure for Obs. Kohlberg represents 80 judgments, including the 40 of the figure next to it.



Mr. Bates



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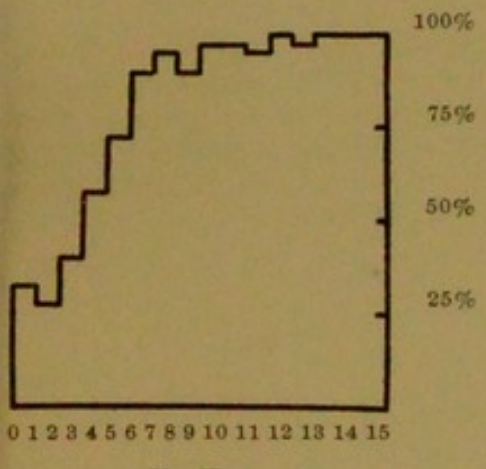
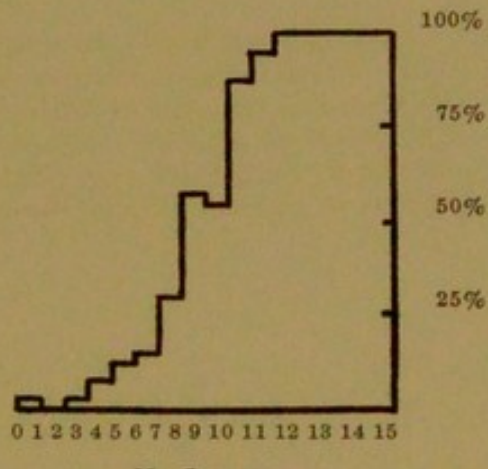


Mr. Ham



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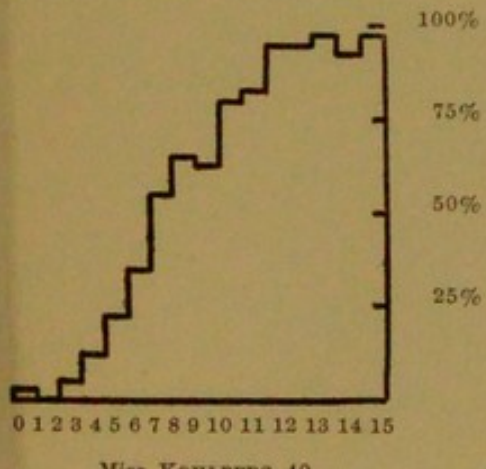
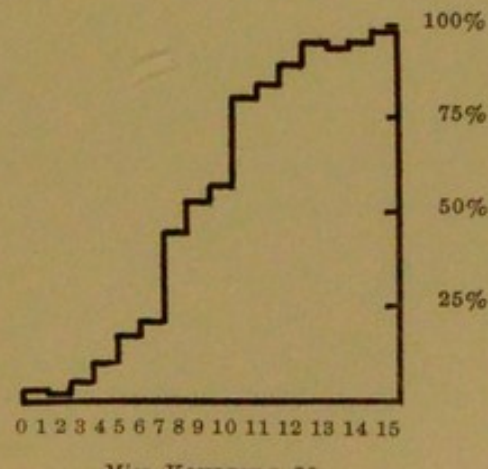


Miss Kohlberg 40



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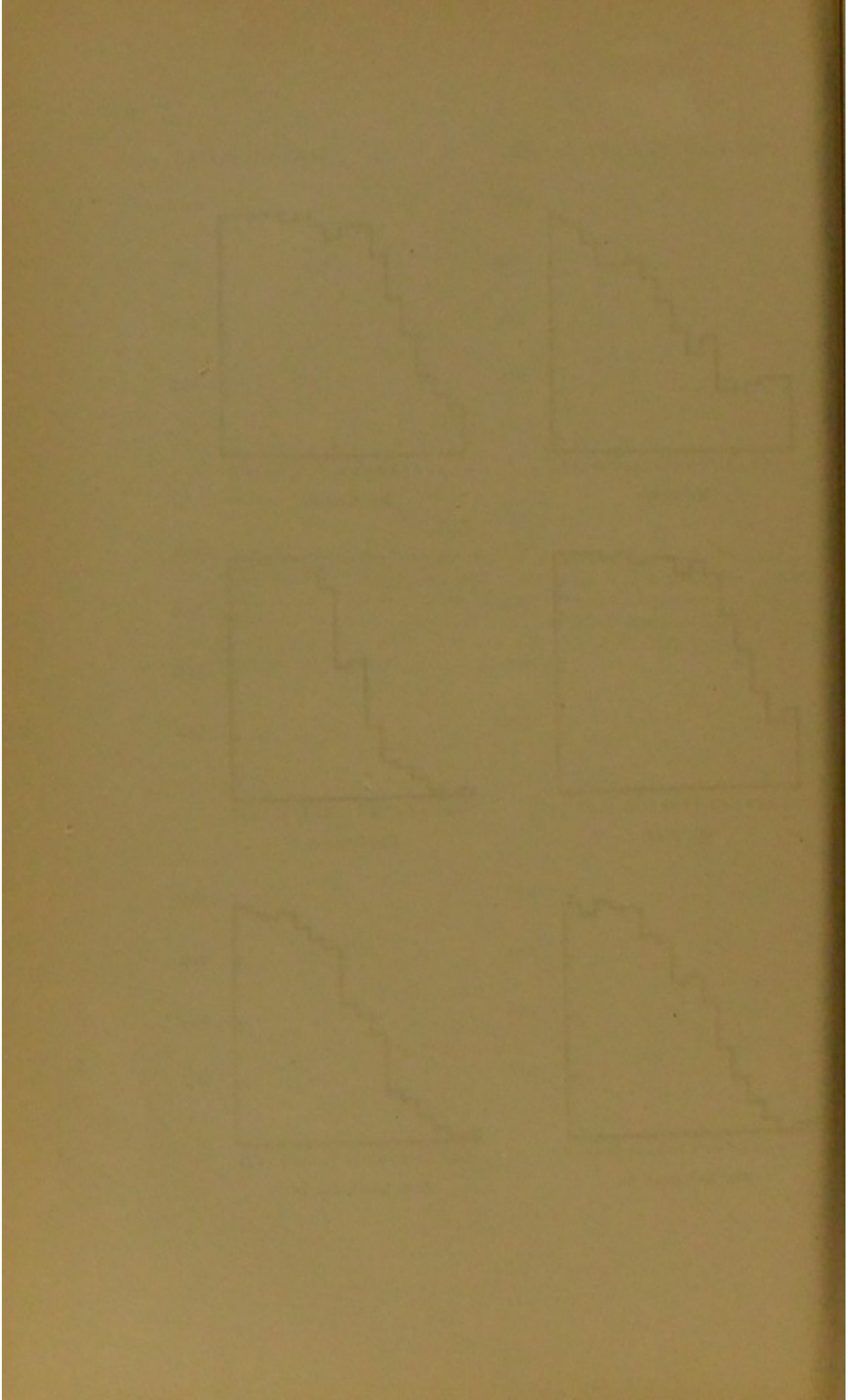


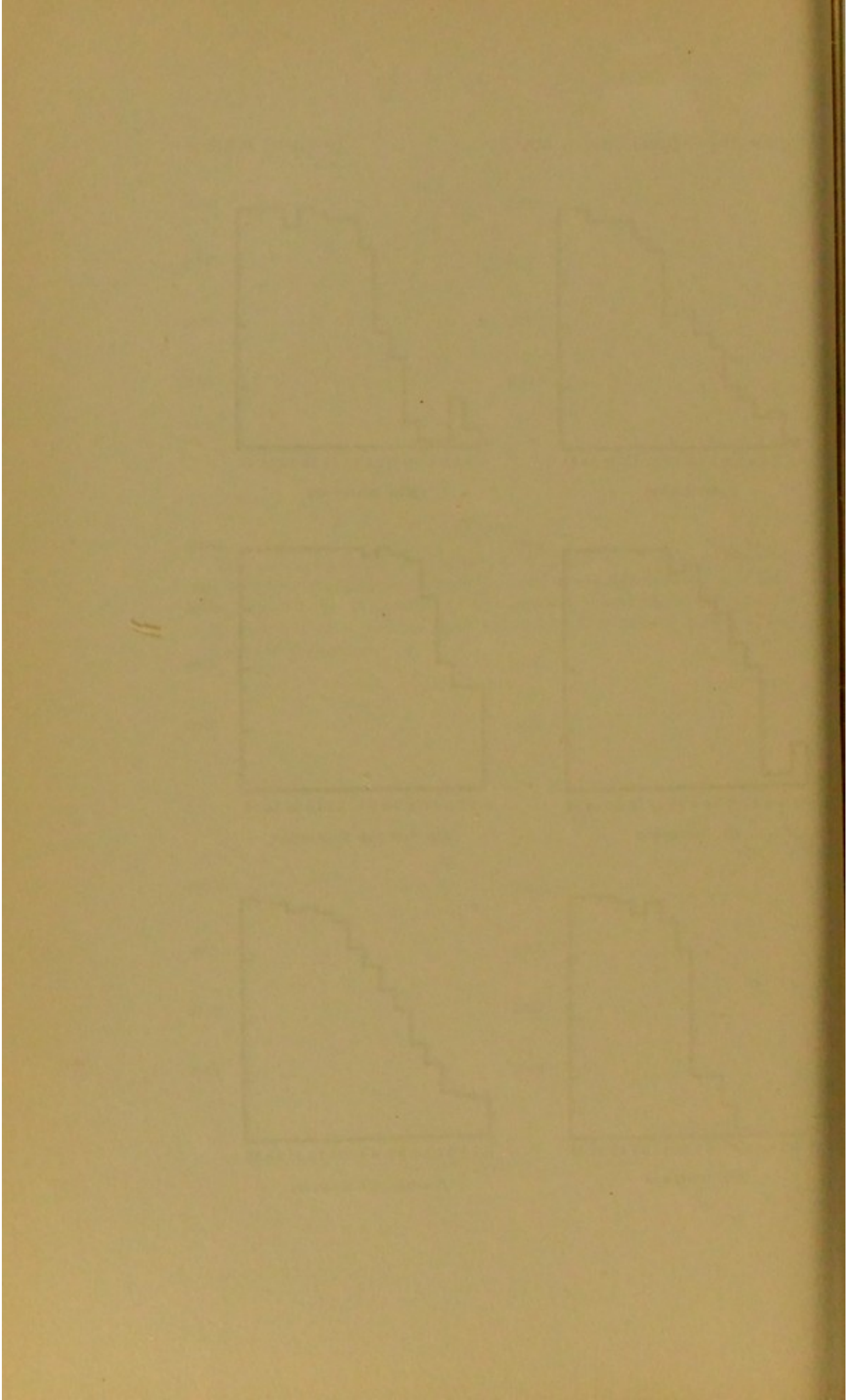


PLATE 3

Figures 1, 2, and 3 are constructed on the same principle as those of Plates 1 and 2. In this case the unit of intensity along the base line is one-quarter of a gram of salt per liter of water, or 0.025 per cent. Thus "9" represents 9 times 0.025 per cent, or 0.0225 per cent.

Figure 4 corresponds to Table XVIII. For each person the step from some one solution (M) to the next (N) produces a maximum increase in the number of positive judgments. For all the persons the average of this maximum increase (without regard to the strength of M or N) is 8.2 judgments. The average from N to O is 5.8, and from L to M 4.1. This figure bears no direct relation to the "average" figure in Plate 2.

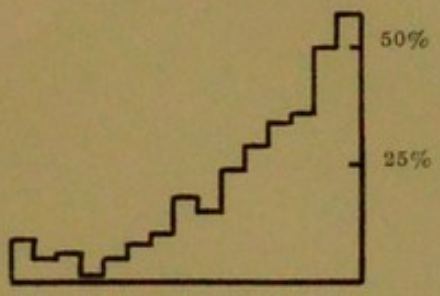


Fig. 1

Miss VON DER NIENBURG

100 judgments on each weak solution

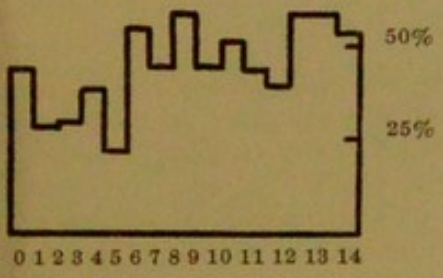


Fig. 2

Mr. LEVY

[illegible]0 judgments on each weak solution

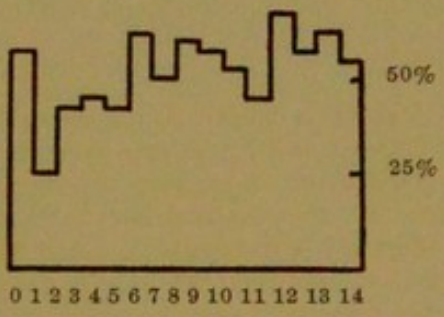


Fig. 3

Miss NOTEWARE

40 judgments on each weak solution

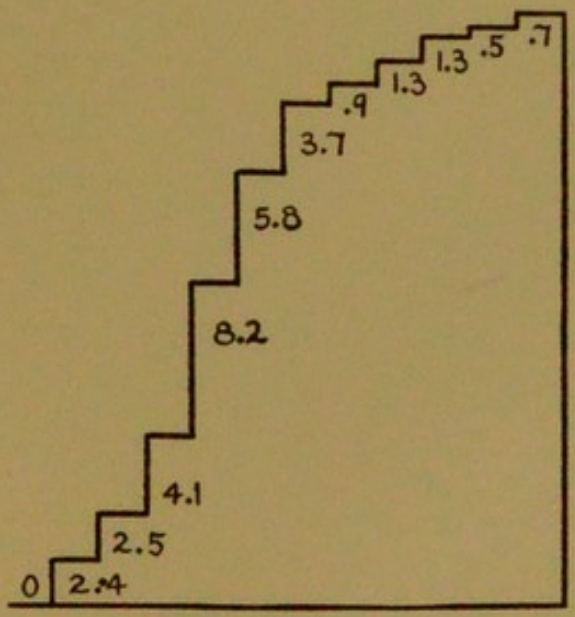
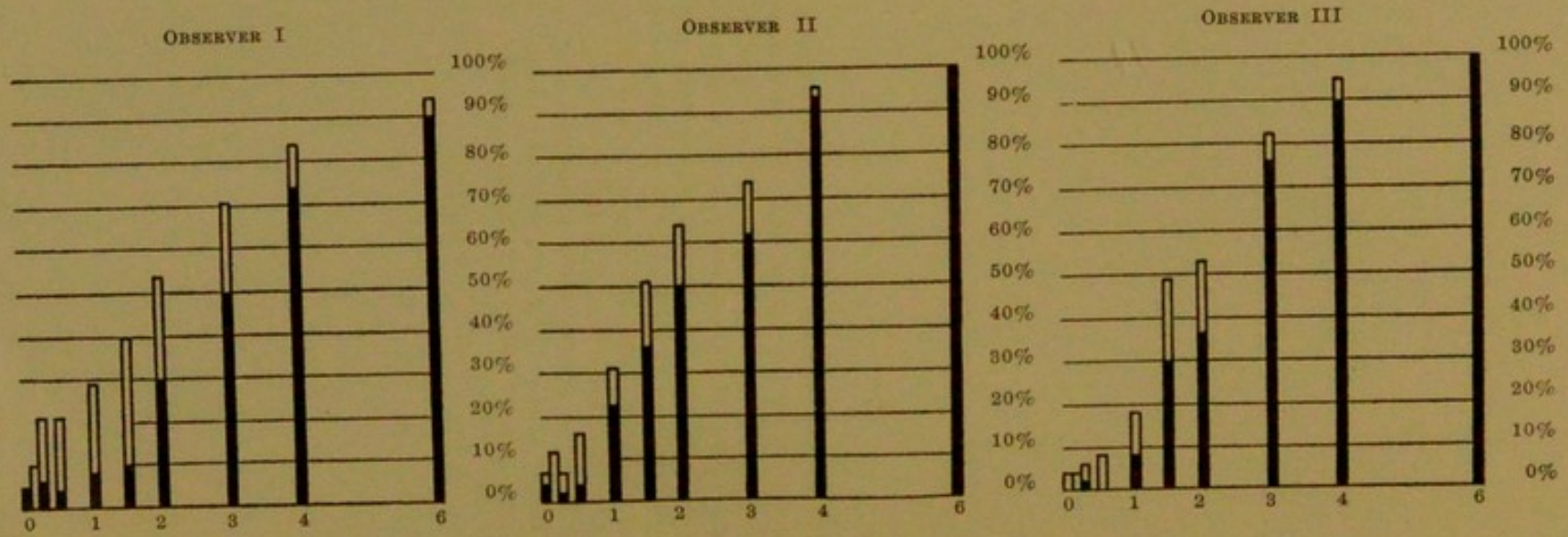


Fig. 4

Average Height of the Threshold or Critical Step and of the other Steps

PLATE 4

The three figures represent the work of three of the four observers in one of Camerer's experiments (Ztsch. f. Biol., vol. 21 (1885), p. 578). The intensity of the salt solution is measured off to scale along the horizontal base line. The unit solution is 0.0159 per cent, so that "6" means 6 times 0.0159 per cent, or 0.0954 per cent. The first stimulus is water (0), then comes a solution of one-eighth of the unit, then one of one-quarter of the unit, then one of one-half the unit; then of one, one-and-a-half, two, three, four, and six times the unit strength. The height of the solid line represents the percentage of positive judgments out of a possible 50 for each solution. The height of the outlined portion represents one-half of the number of doubtful cases, also reduced to per cent.


OBSERVER I
OBSERVER II
OBSERVER III
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
6