ON THE 'AFTER-SENSATION' OF PRESSURE¹

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In 1916 F. L. Dimmick published, from the Cornell Laboratory, an experimental study of cutaneous after-images.² The stimulus, a hair of the tension-value of 4.5 gr./mm., was applied to pressure spots localized on the volar surface of the forearm.³ While the experiments were performed with all due care, it has for various reasons seemed desirable to repeat and extend them. In the first place, Dimmick had but two observers; and, as it happened, the results furnished by these observers differed very considerably. On the whole, the times obtained from the one are eight times as large as those obtained from the other. It is true that the ratios of the times of after-sensation, interval and after-image are approximately constant in both cases, so that the difference is uniform and not casual or variable. Still, it seemed worth while to repeat the experiments with other observers, if only to decide whether or not the extreme types are connected by intermediates. In the second place, there is something paradoxical about a sensory response, to a weak stimulus of 1 sec. duration, which lasts (with the after-image) from 40 to 90 sec. The result contradicts the experiences of everyday life, and suggests the operation of some source of error which the experimental technique failed to control. In the third place, both of Dimmick's observers, though in unequal measure, reported experiences of tickle as accompanying the pressures; and it is not easy to see why that quality should have intervened.⁴ We felt, then, that there is sufficient

¹ From the Psychological Laboratory of Cornell University.

² *Amer. Jour. Psych.*, XXVII., 1916, 556-569.

³ The stimulus was so chosen as to affect only the cutaneous and not the subcutaneous organs, a precaution which was apparently neglected by M. H. S. Hayes in her "Study of Cutaneous After-Sensations," *Psych. Rev. Mon. Suppl.*, 60, 1912.

⁴ These results are, of course, not peculiar to Dimmick's investigation: see Hayes, *op. cit.* On the other hand, M. von Frey, in his review of the sense of pressure (L. Asher and K. Spiro, 'Ergebnisse der Physiologie,' XIII., 1913, 96 ff.), makes no reference to tickle, even in his discussion of the phenomenon of *Entlastung*.

ground for reopening the problem of the time-relations of the sensation of pressure, and accordingly undertook the experiments now to be described.

It was our intention to work with stimuli of different durations, and also with stimuli of different intensities, some adequate to the cutaneous organs alone, and some involving also the subcutaneous tissues. Circumstances have made it impossible for us to carry out this programme; and the present study is concerned accordingly with the results obtained from a single stimulus applied for a uniform period of time.

APPARATUS AND PROCEDURE

The stimulus employed was a horse-hair, set in a von Frey hair-æsthesiometer. We wished to use a hair which should affect only the cutaneous organs, should give a definitely supraliminal pressure for all spots and all observers, and should have as nearly as possible the same tension-value as the hair employed by Dimmick. We found such a hair, with the following constants: length from handle, 30.5 mm.; diameter (the hair was sensibly circular in cross-section), 0.2 mm.; force, 0.48 gr.; tension-value, 4.8 gr./mm.¹ Repeated trials with light etherization of the skin showed that this stimulus affected the cutaneous organs only. The stimulus was also positively supraliminal: out of 1,511 applications there were but 27 failures, 19 of which occurred early in the course of the experiment, before the introduction of the reading glass (see below). Since *E*'s uncertainty of manipulation was the reason for recourse to the reading glass, we have little doubt that most at any rate of these 19 blanks are attributable to maladjustment of the stimulus; the remainder of the 27 we can account for only conjecturally, as due to some minimal displacement of *O*'s arm.

The stimulus was applied to the skin by means of the mechanical applicator described by Dimmick. The time of application, 1 sec., was taken by *E* from the swings of a noiseless seconds' pendulum. By way of further control, *E* closed a lip-key at the moment the hair touched the skin, and opened it again as the stimulus was removed. The records of ten series, each one of ten applications, taken at random from the whole number, show the following times:

(1) 0.99 ± 0.04,	(2) 1.09 ± 0.05,	(3) 0.99 ± 0.01,
(4) 1.01 ± 0.06,	(5) 0.96 ± 0.06,	(6) 1.03 ± 0.07,
(7) 1.02 ± 0.07,	(8) 1.06 ± 0.08,	(9) 1.05 ± 0.04,
(10) 1.03 ± 0.05.		

The second was therefore approached with a fairly high degree of accuracy. The procedure is, indeed, less complicated than it might appear; and *E*, after practice, was able to time his applications almost automatically.

The exact localization of the pressure spots was secured partly by clipping the surrounding hairs, and partly by entry on a map of transparent celluloid which could

¹ The account of von Frey's stimulus-hairs given by W. H. Howell ('A Text-Book of Physiology,' 1915, 281) is misleading. The pressure-value of the hair is rightly calculated; von Frey, however, calculates, not this pressure-value, but the tension value. See E. B. Titchener, *Exper. Psychol.*, II., ii., 1905, 49.

be fitted to the arm-cast in the manner to be described below. Accuracy of stimulation on *E*'s part was furthered by ink-dots placed just peripherally to the spots and by the use of a large reading glass (magnifying 1.5 diam.). Ten well-marked spots were localized on the dorsal, and ten on the volar surface of the left forearms of our five *O*'s. The rectangular areas within which these spots were included (beginning at a line about 65 mm. from the carpal folds) were of the following approximate dimensions: for *D*, 30 x 80 mm. (dorsal), 10 x 60 mm. (volar); for *H*, 25 x 75, 10 x 50; for *M*, 15 x 50, 10 x 50; for *Ta*, 20 x 65, 15 x 30; for *Tu*, 15 x 45, 15 x 45. The smallest distance between spots was 3 mm. (*D*, *M*, *Tu*), the largest was 26 mm. (*D*); the average distance was 7.5 mm.

The ten spots of the area under experimentation were stimulated once each and once only during an experimental hour. The spots were numbered arbitrarily 1 to 10. The order of stimulation was determined by chance: ten tickets, bearing the serial numbers of the spots, were shaken together, and drawn one by one. This procedure was repeated 10 times, so that *E* obtained a random sequence of 100 stimulations. The sole departure from chance occurred when the numbers of adjacent spots were drawn in immediate succession; in this event the second number was thrown back among the rest, and a new drawing was made. Since there was an average interval of 4 min. between stimulations, there was an interval of at least 8 min. between the stimulations of adjacent pressure-spots.

O's left forearm was held in a carefully molded plaster cast, which included both elbow and hand. The fingers lay in an easy and natural position; and the cast, placed on a low table, allowed the whole arm to rest as comfortably as possible. The edges of the cast were built up to take the celluloid map referred to above; marks were also made upon the plaster, to ensure the precise fitting of the map to the area of stimulation.

O's free (right) hand controlled a key whose pressure and release recorded the appearance and disappearance of sensation or 'after-image.' The two records (*E*'s record of the time of application of stimulus, and *O*'s record of sensation) were made side by side upon ticker tape drawn over a spool by a noiseless motor of practically constant speed and wound upon a kymograph drum; the time-line was given by a Kronecker interrupter marking tenths of a second. The three magnets of the recording apparatus carried eosin writing-points of the type used for recording barometers. *E* threw the motor and interrupter into action by means of a foot-lever. A curtain hanging across the experimental table prevented *O* from seeing arm or instruments.

Five *O*'s served throughout the experiment: Dr. K. M. Dallenbach (*D*) and Dr. L. B. Hoisington (*H*), instructors in psychology; Miss M. F. Martin (*M*), scholar in psychology; and Messrs. S. Takaki (*Ta*) and S. Tung (*Tu*), graduate students in the department. Practice was continued for some three weeks before the regular series were begun.

The instructions given to the *O*'s were as follows: "After the usual Ready-Now signals, I shall apply a pressure-stimulus to your forearm. When sensation begins, close the key; when it ends, release the key. Be ready for a recurrence: and if a sensation recurs, close the key again at the moment of its appearance, and release it at the moment of disappearance. Continue until there is no recurrence. Afterwards, give a brief description, in attributive terms, of the pressure or pressures set up by the stimulus." These instructions remained unchanged throughout the experiments, save for a modification introduced in the course of Series II., to which we refer presently.

EXPERIMENTAL

Series I.: Forearm Prone

It is rare that an *O*, in experiments upon the volar surface of the forearm, does not sooner or later complain of the discomfort of his bodily posture. Since we planned a long series of experiments, it occurred to us that it might be better to lay the forearm prone, and to work on its dorsal surface. The suggestion was tried out in a few preliminary series, and was approved by the *O*'s.

As the regular series progressed, it became apparent that the *O*'s fell into two distinct groups. The one, which we shall call the 'regular' group, consisted of D, Ta and Tu. These *O*'s reported times of primary sensation which were of the same order of magnitude as the duration of the stimulus, and noted relatively few and brief recurrences or 'after-images.' The following tables set forth, for these three *O*'s,

TABLE I
OBSERVER Tu

Spot	Sensation	No.	Int.	A.-S.
1	0.56 ± 0.20	(1)	1.5	2.5
2	0.57 ± 0.24	(1)	0.3	0.3
3	0.80 ± 0.40	(2)	0.5 ± 0.1	0.4 ± 0.2
4	0.85 ± 0.39	(1)	1.1	0.2
5	0.81 ± 0.28			
6	0.84 ± 0.50	(2)	2.3 ± 1.0	0.5 ± 0.3
7	0.89 ± 0.36	(2)	1.0 ± 0.3	0.2
8	0.85 ± 0.35	(1)	1.3	0.2
9	0.86 ± 0.33			
10	1.22 ± 0.46			

TABLE II
OBSERVER D

Spot	Sensation	No.	Int.	A.-S.
1	1.3 ± 0.19			
2	1.6 ± 0.43	(1)	1.1	2.5
3	1.8 ± 0.38	(1)	1.9	2.5
4	1.6 ± 0.33	(1)	0.5	1.0
5	1.6 ± 0.21			
6	1.8 ± 0.49			
7	1.2 ± 0.22			
8	1.4 ± 0.37	(1)	4.6	0.9
9	1.4 ± 0.34			
10	1.7 ± 0.33			

the duration in sec. of the primary sensation (average of 10 applications); then, in parenthesis, the number of times that a given spot showed a recurrence; and then the duration of the blank interval and of the first 'after image.' One table (Ta) is continued to a further stage: it sets forth, again in parenthesis, the number of times that a given spot showed a second recurrence; and then the durations of the second interval and of the second 'after-image.'

TABLE III

OBSERVER Ta

Spot	Sensation	No.	Int.	A.-S. 1	No	Int.	A.-S. 2.
1	1.6 ± 0.15	(7)	2.0 ± 0.32	1.4 ± 0.55	(1)	3.5	6.5
2	1.9 ± 0.40	(4)	1.5 ± 0.72	2.1 ± 0.23			
3	2.1 ± 0.35	(6)	2.1 ± 0.71	1.6 ± 0.40			
4	1.7 ± 0.19	(10)	2.5 ± 0.45	1.9 ± 0.97			
5	2.2 ± 0.44	(7)	2.0 ± 0.58	2.2 ± 0.79	(2)	5.6 ± 3.8	0.9 ± 0.6
6	1.5 ± 0.23	(6)	2.9 ± 0.65	1.6 ± 0.84			
7	2.2 ± 0.64	(4)	2.2 ± 0.90	1.8 ± 0.94			
8	2.0 ± 0.24	(5)	2.4 ± 0.47	1.4 ± 0.57	(1)	3.8	1.0
9	1.9 ± 0.49	(4)	1.7 ± 0.29	2.3 ± 1.35			
10	1.7 ± 0.49	(5)	2.3 ± 0.77	1.4 ± 0.34			

The averages from these results are as follows:

TABLE IV

O	No.	Sensations	No	Int.	A.-S. 1	No	Int.	A.-S. 2
Tu.....	(100)	0.82 ± 0.38	(10)	1.18 ± 0.58	0.55 ± 0.45			
D.....	(100)	1.56 ± 0.34	(4)	1.02 ± 1.28	1.72 ± 0.82			
Ta.....	(100)	1.89 ± 0.39	(58)	2.21 ± 0.37	1.74 ± 0.44	(4)	4.62 ± 2.38	2.35 ± 2.08

The results themselves are, it seems, what we might have expected. As regards the primary sensation, the *O*'s differ gradually and within narrow limits; the average times of sensation vary from nearly one second to nearly two seconds. The responses of the spots also differ gradually; the extreme ranges give the ratios 1:2 for Tu, 2:3 for D, and 3:4.4 for Ta. The *O* who shows the longest average time for the primary sensation shows the greatest liability to recurrence; but the recurrence rarely (only in 4 cases) goes beyond a single return, and its average value is slightly less than that of the primary sensation. All in all, the tables wear an appearance of uniformity.

Reports.—D's regular¹ report is of a quality of contact or bright, sharp, clear but weak pressure. This quality is sometimes obscured by, or passes into, a thin wiry prick (10 cases) or a more diffuse tickle or itch (4). Usually the intensity decreases steadily throughout the observation; occasionally it remains steady or decreases until the removal of the stimulus, when it suddenly increases (5). Of the 4 recurrent experiences, 2 are of the original quality (one of these may have been erroneously reported, owing to shift of attention), 2 are diffusely ticklish or itchy.

Tu, a less practised observer, was somewhat disturbed by visual images. His regular report is of a bright, ticklish contact. This quality is sometimes obscured by, or passes into, 'a sort of prick, a little painful' (9). Of the 10 recurrences (2 of which are reported as doubtful), 7 are of the original quality (one of these is localized aside from the spot), and 3 are of a heavier, stinging nature.

Ta, who is also a relatively unpractised O, reports regularly for the primary sensation a weak but clear pressure, which gradually fades out, and only rarely brightens or becomes ticklish when the stimulus is removed. Of the 58 first-recurrences, 46 are described as faint, vague, diffuse, tickish; 12 are at first clear, 'concentrated,' fairly intensive, but quickly pass into the other stage. All 4 of the second-recurrences have the quality of vague, unsteady tickle.

TABLE V

OBSERVER H

Spot	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.-S. 3
1	2.4±0.48	(9)	1.5±0.73	3.5±1.14	(1)	3.5	2.0			
2	3.1±1.10	(8)	1.8±0.95	3.8±1.10	(5)	2.5±1.37	4.7±1.83			
3	3.1±0.89	(7)	1.5±0.27	4.5±1.96	(4)	1.7±1.27	4.4±0.76			
4	3.0±0.80	(7)	1.7±0.29	4.0±1.86	(3)	3.1±1.13	2.7±0.55			
5	2.4±0.55	(7)	2.0±1.45	5.6±3.66	(4)	2.4±0.60	6.0±1.71			
6	2.8±0.53	(8)	1.3±0.65	4.1±1.50	(6)	2.1±0.56	4.5±1.34			
7	2.6±0.54	(5)	1.2±0.14	7.4±4.68	(1)	2.7	1.1			
8	2.9±0.82	(7)	2.0±0.82	4.8±1.89	(1)	3.2	2.2			
9	2.1±0.29	(5)	1.5±0.74	3.2±2.04	(1)	2.5	3.5			
10	4.1±0.58	(8)	1.4±0.55	3.8±1.25	(5)	3.8±0.96	4.4±2.00	(1)	0.4	0.8

Our other O's, H and M, belong to what we may call the 'irregular' group.² It is, to be sure, possible to make out for these O's tables which show, for the primary sensation, time-values lying on the average under 3 sec. (see Tables V., VI., VII.). But, in the first place, the recurrences are

¹ The reports that we term 'regular' are, of course, summaries of a large number of individual descriptions. All O's, and especially the trained O's, D and H, indicate differences (as between spot and spot) of compactness or sharpness and bluntness or dullness. Since, however, the differences are not pronounced, and since they are normal to groups of pressure spots, we have not thought it worth while to go into further detail.

² The group also includes Dr. C. W. Perky, who made 89 observations in this first series of experiments. P's selected average time of primary sensation was (82) 2.38 ± 0.90 sec. The remaining 7 times (nearly 8 per cent.) were long.

TABLE VI
OBSERVER M

Spot	Sensation	No.	Int.	A-S. 1	No.	Int.	A-S. 2	No.	Int.	A-S. 3	No.	Int.	A-S. 4	No.	Int.	A-S. 5
1	3.4 ± 1.33	(5)	6.5 ± 2.44	1.1 ± 0.56	(3)	7.2 ± 4.83	3.7 ± 0.37	(2)	3.2 ± 0.60	3.9 ± 0.6	(1)	13.4	2.8			
2	2.8 ± 1.04	(10)	4.2 ± 2.60	1.4 ± 1.11	(4)	5.3 ± 1.37	6.6 ± 9.34	(2)	4.6 ± 0.30	11.7 ± 11.5	(1)	8.5	0.7			
3	3.4 ± 1.15	(6)	4.2 ± 1.80	22.9 ± 33.0	(1)	16.6	2.3	(1)	5.5	0.4	(1)	27.3	3.0			
4	3.1 ± 0.94	(6)	6.0 ± 3.55	5.2 ± 4.42	(3)	3.3 ± 1.77	2.0 ± 2.00	(1)	3.7	0.4	(4)	10.1 ± 2.48	3.0 ± 1.58	(1)	0.15	3.7
5	2.2 ± 1.18	(7)	6.1 ± 1.61	5.5 ± 3.45	(3)	22.8 ± 18.37	16.1 ± 17.30	(3)	9.0 ± 6.83	16.0 ± 7.9						
6	3.1 ± 1.41	(9)	5.2 ± 4.42	21.3 ± 25.70	(7)	6.5 ± 4.01	2.8 ± 1.46	(4)	3.8 ± 1.94	3.3 ± 1.0						
7	2.5 ± 0.96	(4)	4.0 ± 1.35	4.1 ± 3.11	(2)	2.5 ± 0.67	1.6 ± 0.15	(2)	3.3 ± 7.20	1.92 ± 0.3						
8	2.2 ± 0.49	(8)	6.7 ± 1.29	3.9 ± 4.92	(4)	4.2 ± 1.70	4.2 ± 1.97	(3)	2.4 ± 1.40	27.0 ± 18.9	(1)	3.2	0.6	(1)	1.50	3.6
9	2.3 ± 1.10	(9)	2.6 ± 2.14	13.5 ± 17.00	(4)	14.7 ± 11.31	3.9 ± 2.15	(1)	1.0	5.8	(1)	2.2	5.8			
10	2.0 ± 0.79	(8)	7.0 ± 5.47	9.4 ± 8.45	(4)	6.6 ± 5.55	12.1 ± 6.26	(1)	3.8	3.6	(1)	5.3	3.8			

TABLE VII

O	No.	Sensation	No.	Int.	A-S. 1	No.	Int.	A-S. 2	No.	Int.	A-S. 3	No.	Int.	A-S. 4	No.	Int.	A-S. 5
H	(100)	2.88 ± 0.78	(71)	1.59 ± 0.66	4.37 ± 2.01	(31)	2.63 ± 1.04	4.26 ± 1.64	(1)	0.4	0.8						
M	(100)	2.71 ± 1.16	(72)	4.99 ± 3.16	0.21 ± 11.16	(35)	8.30 ± 0.64	5.73 ± 4.80	(20)	2.0 ± 2.8	3.4 ± 7.4	(10)	7.0 ± 4.9	2.0 ± 2.7	(2)	0.8 ± 0.7	3.6

more marked: H gives 71 of the first and 31 of the second order; M gives 72 of the first, 35 of the second, and 20 of the third order. And secondly, the tables do not record (as the earlier tables have done) the results of 100 consecutive experiments; the values are selected. It is characteristic of the members of this group that the ordinary or regular times for the primary sensation are replaced at irregular intervals by times of much greater length, times ranging for H between 10.1 and 55.9, and for M between 10.5 and 204.2 sec. H gives 8 per cent. of these long times, indifferently from the 10 spots, and M gives 27 per cent., principally from 6.¹

Since H, in particular, is a practised *O*, we thought, on the recurrent appearance of the long times, that something must be at fault with apparatus or procedure. Fatigue could hardly come into play; there were but 10 observations in the hour; and in point of fact the long times, from first to last, were as likely to occur at the beginning as in the middle or at the end of an experimental sitting. H's reports gave us no cue. M, however, sometimes reported with the long times: 'tingling as when the arm is asleep,' 'twitching of muscles under skin like gooseflesh,' 'tickle with pulse,' 'pulse in wrist,' 'pulse in fingers.'² Although these remarks were by no means frequent, we nevertheless imagined that they might point to an interference with circulation due to the prone position of the arm. We therefore again worked carefully over the surfaces of the casts, to make them if possible still more comfortable for the *O*'s; and we divided the experiments of an hour into groups of 4, 3, 3 (or 4, 4, 2), between which the arm was taken from the cast and the *O* was free to move. These changes were of no avail; the long times persisted. We therefore determined to continue the observations until series of 100 'regular' times had been completed (Tables V., VI.) and then to repeat the work with the arm supine. It was possible that with this position of the arm the long times would disappear; it was possible also that the reports of the *O*'s would give, by comparison, a clue to their conditioning.

¹ Yet M's spot 8, which responded irregularly to but 2 out of 12 stimulations, jumped in these two instances from its average of 2.2 ± 0.49 sec. to 17.3 and 109.5 sec. respectively!

² P also spoke occasionally of 'throbbing' and 'pulse' in the arm.

Reports.—H's regular report is of a weak or moderately intensive neutral pressure, punctiform or of very limited area. The quality sometimes passes into, or is interrupted by, pain (8 cases) or tickle (8). Usually the intensity either decreases steadily throughout the observation or shows a rise followed by a continuous decrease; occasionally it remains steady or decreases until the removal of the stimulus, when it 'flares up' (6). Of the 71 first-recurrences, 41 repeat the original quality, but weaker, and of diffused and indefinite area; 32 (there is a slight overlap) possess a brighter, ticklish quality; and 2 are painful. Almost invariably these experiences fade out gradually. The second-recurrences are still weaker, show a greater tendency to become ticklish, and occasionally are 'very like imagery.' Their disappearance, when recorded, is always gradual.

The reports for the long times are naturally incomplete. There is fluctuation of quality, of intensity, and of area. What is more to the point is that, on several occasions, H refers to these experiences as 'perceptual'; they are 'patterned'; there may be a 'granular core' with 'a fine and fuzzy edge, extended longwise,' and the pattern may shift instably, with change of localization.

M is an observer somewhat more practised than Ta and Tu, but far less practised than D and H. She reports a light, clear contact (68), a tickle (17), a delicate prick (4), or a dual combination of contact with tickle or prick. The quality either fades out gradually, or shows an increase of intensity followed by a steady decline. There is no report of terminal increase of intensity, though in a few cases the disappearance of the primary sensation is said to be sudden or abrupt. The recurrences are almost always described as diffuse tickle, 'spread on the arm,' 'not localized at spot'; the tickle is occasionally blended with contact, and very rarely contact is reported alone.

Primary sensations and recurrences are, one and all, accompanied by visual images, —so M remarks in a summary report; but these images are seldom recorded, and seem not to have distracted attention from the skin. M also reports a strong reflex tendency, when tickle is aroused, to take her right hand from the key and move it to the left arm. The tendency seems to be regarded at least as a secondary criterion of the presence of tickle.

In her reports for the long times, M mentions, as a rule, a temporal fluctuation of qualities, in which two or all three of the familiar members of the group (contact, tickle, prick) appear; sometimes there is a 'third' or a 'fourth' quality which is left unnamed; every now and then warmth or cold flashes in. The attributive report is cut across by references to pulse, arm asleep, tingling, gooseflesh. There are a few cases in which the perceptual nature of the experiences is clearly brought out: M speaks of a wide spread of tickle in which 'points come and go associated with bright spots in [visual] image'; of contact and diffuse tickle accompanied by 'visual image of belt of tickle on arm'; of tickle coming in 'as ring round the original spot touched, as I imagine'; of a blend of tickle and contact 'spreading right and left in visual image, with prick-sensation separate.' Here the visual imagery plays a more active part.

Second and later recurrences, with both regular and long times of primary sensation, are frequently given with a question-mark: 'may have been imaginative,' 'not sure whether real or imaginal.'

Series II.: Forearm Supine

The following Tables VIII.–XI. show the results obtained from the three O's of the previous regular group.

TABLE VIII

OBSERVER Tu

Spot	Sensation	No.	Int.	A.-S.
1	0.90 ± 0.24	(1)	1.7	0.2
2	0.96 ± 0.20	(1)	1.6	1.1
3	0.93 ± 0.23			
4	0.93 ± 0.14			
5	0.94 ± 0.15			
6	0.98 ± 0.22			
7	0.96 ± 0.20			
8	0.99 ± 0.26			
9	0.97 ± 0.22	(1)	0.7	0.2
10	0.91 ± 0.13			

TABLE IX

OBSERVER D

Spot	Sensation	No.	Int.	A.-S.
1	$1.33 \pm .016$	(1)	3.1	1.0
2	1.50 ± 0.27			
3	1.35 ± 0.23			
4	1.60 ± 0.27			
5	1.50 ± 0.23			
6	1.53 ± 0.26			
7	1.50 ± 0.20			
8	1.80 ± 0.50			
9	1.42 ± 0.18	(2)	1.5 ± 0.17	0.7 ± 0.5
10	1.62 ± 0.18			

TABLE X

OBSERVER Ta

Spot	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.S.-3
1	2.57 ± 0.70	(7)	6.2 ± 1.8	10.2 ± 7.5	(2)	7.2 ± 2.5	10.2 ± 9.4	(1)	0.4	0.5
2	2.90 ± 0.69	(9)	4.8 ± 2.2	9.9 ± 4.3	(1)	7.5	19.6			
3	3.00 ± 0.90	(8)	6.1 ± 2.4	8.7 ± 8.6	(2)	6.0 ± 1.4	10.0 ± 9.6	(1)	3.1	0.7
4	3.00 ± 1.20	(8)	3.1 ± 1.4	7.2 ± 4.6	(2)	7.1 ± 2.6	1.8 ± 1.8	(1)	3.0	0.5
5	3.00 ± 0.86	(7)	4.6 ± 1.0	13.5 ± 7.2						
6	3.50 ± 0.88	(9)	6.8 ± 2.8	11.7 ± 5.2	(2)	5.9 ± 0.6	1.9 ± 0.5			
7	2.80 ± 0.55	(10)	5.4 ± 1.9	11.0 ± 9.5	(3)	8.8 ± 8.5	2.9 ± 1.3	(1)	2.4	0.5
8	3.40 ± 1.00	(8)	5.8 ± 3.6	12.9 ± 1.0	(1)	3.0	4.6			
9	2.50 ± 0.35	(7)	6.9 ± 2.9	8.2 ± 4.5	(1)	5.2	6.8			
10	3.00 ± 1.00	(2)	5.6 ± 0.6	5.2 ± 3.2						

TABLE XI

OBSERVER Ta

O	No.	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.-S. 3
Tu	(100)	0.95 ± 0.19	(3)	1.30 ± 0.4	0.5 ± 0.4						
D	(100)	1.51 ± 0.23	(6)	2.10 ± 0.7	0.6 ± 0.36						
Ta	(100)	3.00 ± 0.85	(75)	6.20 ± 2.5	10.6 ± 6.0	(4)	6.8 ± 3.2	6.3 ± 5.8	(4)	2.2 ± 0.9	0.5 ± 0.6

The tables are very similar to Tables I.-IV. The three *O*'s stand in the same order of rank. *Tu* has decreased his range to 10:11; *D* and *Ta* have hardly changed in this regard (11:15, 5:7). *Ta* has increased his average time of total sensation from nearly two to three seconds, and his record of recurrences is fuller, with longer times. On the whole we may say that *Tu* and *D* have behaved as they behaved in Series I., and that *Ta*, while he does not fall obviously out of line with his former record, may perhaps show the influence of some condition tending progressively to lengthen his periods of response.

Reports.—*D*'s regular report is of a contact, or bright, clear pressure, more intensive than in Series I. This quality is sometimes obscured by, or passes into, a prick or wiry pain (13 cases) or a more diffuse tickle (8) or itch (15). Usually the intensity decreases steadily throughout the observation; sometimes it decreases and then increases (11); occasionally it decreases or remains fairly steady until the removal of the stimulus, when it suddenly increases (3). Of the 6 recurrences, one (of which *O* reports that it was probably imaginal) is of the original quality; 4 are diffusely itchy; one has a tingling character.

Tu's regular report is of a light, delicate, ticklish contact. This quality is sometimes obscured by, or passes into, a bright pain (8). *Tu* now reports comparatively few visual images; we get, in exchange, reports of intensity. The contact usually disappears gradually; sometimes (9) its intensity decreases and then increases. All three of the recurrences are of the original quality, a ticklish contact.

Ta regularly reports a weak but clear (or very moderately intensive and clear) pressure, which either gradually fades out or (in 22 cases) passes, for the most part abruptly, into something bright and ticklish. Of the 75 first-recurrences, 57 are described as faint, vague, diffuse, unsteady, ticklish; 9 begin in this way, quickly become clearer and more intensive, and relapse into the first stage; 7 begin as dull, heavy and diffuse, and pass into the familiar vague tickle; and 2 only begin as 'concentrated.' Once a sensation of cold is remarked. All of the later recurrences are termed, comparatively, fainter, more obscure, more diffuse, fluctuating; all are of a ticklish quality.

We had hoped that, with change of the position of the arm from prone to supine, the two members of our 'irregular' group would give results comparable with those obtained from *D*, *Ta* and *Tu*. This hope was not fulfilled. In the first series taken under the new conditions with *H* and *M*, typical 'long' times (56 and 83 sec. respectively) occurred among the normal short times. Fortunately, one of *M*'s reports in an early series gave us the cue to the situation: it appeared that *M* was making a voluntary effort to hold the

TABLE XII

OBSERVER H

Spot	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.-S. 3	No.	Int.	A.-S. 4
1	4.4±1.3	(9)	1.7±0.6	5.8±1.0	(4)	2.5±0.4	4.8±0.7						
2	3.3±0.9	(9)	1.9±0.9	5.3±2.4	(3)	1.9±0.5	14.9±16.5	(1)	1.0				
3	3.3±1.3	(10)	1.4±0.4	7.4±3.0	(5)	2.9±0.9	6.1±2.4	(1)	0.5	3.5			
4	4.0±1.4	(8)	2.1±0.8	5.4±1.7	(2)	2.7±0.0	4.0±1.5						
5	4.5±1.5	(9)	2.2±0.9	7.5±1.7	(5)	4.0±1.6	4.8±1.3						
6	3.9±0.9	(9)	1.8±0.7	4.9±1.9	(1)	3.8	3.1						
7	4.0±1.2	(8)	1.3±0.4	7.3±3.5	(4)	6.9±6.3	6.0±2.0	(2)	2.7±2.7	14.9±9.6	(1)	6.5	11.4
8	3.4±1.5	(8)	1.6±0.4	6.2±1.3	(2)	3.6±1.0	4.3±1.7						
9	4.1±1.2	(7)	3.1±2.0	12.2±8.2	(2)	1.3	5.1±1.4						
10	3.9±1.4	(8)	1.6±5.8	7.3±2.3	(4)	3.1±0.6	5.0±1.4						

TABLE XIII

OBSERVER M

Spot	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.-S. 3	No.	Int.	A.-S. 4
1	2.0±0.29	(8)	4.3±3.2	7.0±9.1	(2)	13.3±1.6	0.7±0.5	(1)	16.0	0.9			
2	1.8±0.34	(8)	3.6±2.1	5.3±6.4	(3)	3.6±1.3	2.1±2.4	(3)	9.3±7.4	1.8±0.9	(2)	7.3±4.1	0.2±0.03
3	1.7±0.38	(8)	2.9±1.8	1.4±1.3	(6)	3.2±0.4	0.4±0.2	(3)	27.3±2.3	6.6±6.1	(1)	5.1	0.2
4	1.8±0.54	(8)	3.7±3.0	8.9±10.4	(4)	5.1±5.2	3.6±4.5	(2)	12.2±9.4	1.2±1.7	(2)	2.6±1.2	1.5±0.07
5	2.3±0.77	(9)	5.8±4.5	2.8±2.5	(4)	3.6±1.1	1.6±0.7	(2)	1.8±3.6	0.7±0.6	(2)	3.8±1.2	0.7±0.05
6	2.4±1.00	(9)	6.4±4.7	2.5±2.6	(5)	4.6±3.7	4.2±4.6	(2)	6.4±5.2	2.2±2.0			
7	2.1±0.65	(7)	3.4±2.0	1.5±1.9	(4)	2.4±4.3	0.3±0.1	(2)	8.3±6.4	3.5±0.1	(2)	5.2±2.2	0.3±0.10
8	1.8±0.36	(8)	4.2±1.2	6.6±10.1	(5)	6.9±2.3	2.6±1.8	(2)	2.8±0.8	1.3±1.2			
9	1.9±0.23	(9)	4.8±3.0	2.1±2.2	(6)	3.8±1.1	0.9±1.0	(4)	5.2±1.2	1.7±1.5	(1)	5.4	0.5
10	2.0±0.40	(9)	4.2±3.7	13.2±16.0	(5)	4.5±1.4	4.4±5.1	(2)	11.1±7.1	7.3±7.1			

TABLE XIV

O	No.	Sensation	No.	Int.	A.-S. 1	No.	Int.	A.-S. 2	No.	Int.	A.-S. 3	No.	Int.	A.-S. 4
H...	(100)	3.9±1.3	(85)	1.8±7.6	6.8±3.2	(32)	3.4±1.5	6.0±2.7	(4)	1.7±1.3	16.6±8.9	(1)	6.5	11.4
M...	(100)	1.9±0.5	(83)	4.5±3.0	4.4±6.1	(44)	4.9±0.6	2.4±2.9	(23)	10.0±8.9	1.9±1.9	(10)	4.3±2.6	0.5±0.6

sensation and 'after-image' as long as possible, was seeking by 'effort of attention' to prolong her experiences. We accordingly modified the instruction given to H and M, to the effect that they were to take the stimulus passively, receptively; to be on the alert to signal what should 'come,' by way of sensation and after-experience, but not to try to 'hold' or to 'bring' these experiences. *From the time that this instruction was introduced, not a single 'long' time appeared in the records of the primary sensations.* Tables XII-XIV. show, in the usual form, the results of 100 observations.

M's times of primary sensation have fallen to an average of 1.9 sec., *i.e.*, to a value of the same order as the times of D in both sets of experiments and of Ta in Series I. H's average is higher, nearly 4 sec. Both O's show many recurrences.

Before we discuss the effect of the new instruction, and the light which the consequent regularization of the times throws on the experiment as a whole, we present in summary the reports of H and M in this Series II.

Reports.—H's regular report is of a neutral pressure, of very limited area. The quality often passes into, or is obscured by, tickle (25); sometimes (10) a pain appears, 'quality baffling,' 'quality hard to tell.' Usually the intensity decreases steadily throughout the observation; in 14 cases H notes an increase followed by a decrease. There is in this Series no report of an increased intensity at the moment of removal of stimulus. Most of the 85 first-recurrences appear as a weak, lively, diffuse, indefinite contact, fluctuating in intensity; 15 are reported as actual tickle. There is one instance of 'pain.' The later recurrences are recorded as very weak, light contact; diffuse, fuzzy, fringy, indefinite in area. They seem to be weaker even than weak tickle (which is reported 4 times only), and to be little more than experiences of a 'something light and lively.' Occasionally O remarks: 'might have imagined it'; 'may have been illusion.' In three cases he says that the experience is not localized on the skin; it is 'perceptual.'

M regularly reports a light, bright, clear pressure or contact, of punctiform area; there are 19 cases in which a delicate prick, and 9 cases in which a tickle overlaps or replaces the contact. The quality either fades out gradually, or shows an increase of intensity followed by a steady decline. There is no terminal increase, though in a few cases the primary sensation drops out abruptly.

The reports of the recurrences are brief and very often doubtful. Three times only there is a blend of very weak pressure with tickle; once only a blend of very weak pressure with prick. Usually we have the adjectives fainter, weaker, indistinct, not localized, not cognitively clear, diffused, indefinite; not certain, not sure, doubtful; and such phrases as 'perhaps imagined,' 'not sure whether in sensation or imagination,' 'may have been pulse wave,' 'might not have been there.' Occasionally recourse is

had to visual imagery, with a perceptual consequence: 'visual image gives meaning of localization'; 'contact, not clear; visual image comes in with eye-movement, to localize'; 'weaker; gradually diffuses; visual image of *R* going down and moving off.'

If in the light of these results we now look back over the course of the entire experiment, we see (1) that *D* and *Tu* preserved stably the attitude which we had hoped to induce by instruction. (2) *Ta*, on the other hand, was impressed by the injunction to 'be ready for a recurrence'; his faith in *E* led him (as he told us later) to believe that if recurrences were mentioned, recurrences would come; he began to observe with an expectant set for recurring after-sensations. Hence in Table IV. we have a normal primary sensation, but an undue number of recurrences. Table XI. is then simply an exaggeration of Table IV.; it appears probable (though we cannot be certain of the point) that *Ta*'s expectancy has extended to the primary sensation, and that the recorded average time (3 sec.) is somewhat too large. (3) *H* and *M*, finally, interpreted the instructions to mean that they were to take up an active attitude to their experiences, to secure and to maintain all the cutaneous sensations possible.¹ They give, accordingly, (a) highly irregular times for the primary sensation, times which jump from the normal to three or four times the normal's value, and thence to times which are extremely large. They report (b), even with their normal times, a high percentage of recurrences. They insist (c) on the difficulty of distinguishing between after-experience and imagination. And they have recourse (d) to perceptual construction, in order (by the aid of visual images) to anchor the fleeting and doubtful after-experiences. When the instructions are changed, they give (e) no more 'long' times for the primary sensation. *M*'s average of 1.9 sec. suggests that her average in Table VII. (like *Ta*'s in Table XI.) is affected by her general attitude. We may guess, though we cannot be sure, that both of *H*'s averages, 2.88 and 3.96 sec., are for the same reason too long. The *O*'s (f) also show the continued influence of their original set in the high percentage of recurrences; but their reports have changed. *H*'s recur-

¹ The same thing holds of *P*, so far as her results go.

rences, after the first, are too weak and faint even to be called ticklish; and M's recurrences are all so indefinite that she hardly ventures to give them a qualitative characterization.

We see, therefore, that the question of attitude or *Einstellung* is here of primary importance. Quantitatively we have a fairly satisfactory accordance of results with conditions. Qualitatively, to be sure, the problem is less simple. We know too little of cutaneous imagery to be able to say definitely wherein the recurrent experiences consist. Some of them, we may suppose, are true after-sensations of pressure. Others may rest upon some faint, ordinarily subliminal sensation, now raised to maximal clearness by O's attentional attitude, and supplemented or embroidered by imagery. Others again may gather about an intercurrent sensation of tingling or warmth or cold. And yet others may be wholly imaginal, the result of autosuggestion. Our experiments do not permit us to decide, or to assign percentages; specially directed observations are required.¹

We return to Dimmick's experiments. Dimmick's first observer C gives as average time of primary sensation 1.44 sec., interval 0.78, after-image 6.15. We are not told the precise frequency of the after-images, but they seem to have been rather the rule than the exception. This difference between C and our own D and Tu may have been (like that of Ta) due to C's reading of his instructions; apart from it, there is close agreement.

Dimmick's second observer R gives an average primary sensation of 11.41 sec., interval 6.7, after-image 44.39. It will be recalled that the lowest of H's and M's 'long' times were about 10 sec.; there was a jump from the normal to this abnormal value. We may suppose, perhaps, that R observed more or less consistently (his *MP* was 10.45) at this first level of prolongation, and that he was prevented by some auto-suggestion or suggestion of instruction from proceeding to longer times. It is possible also that his after-image, recorded as a whole, was oftentimes a fluctuating and interrupted experience.² These interpretations are, of course, guesswork, but they are guesswork based upon results gained with longer series and from a larger number of O's.

We have little doubt that the tickle into which the primary sensation may merge is a phenomenon of adaptation; the initial contact brightens and lightens, and the

¹ A. S. Edwards ('An Experimental Study of Sensory Suggestion,' *Amer. Jour. Psych.*, XXVI., 1915, 124 f.) finds anticipatory images of touch which simulate sensation. J. R. Angell (*Psych. Mon.*, 53, 1910, 79, 94 f.) notes individual differences and proposes some simple tests. Hayes (*op. cit.*, 33 f.) makes brief preliminary reference to attention, but in her own work appears not to have regarded 'subjective' conditions.

² Our observer M reported only five continuous after-sensations of the 'long' type; they ranged from 40 to 170 sec.

quality becomes ticklish. We may thus account for the frequent appearance of tickle in the reports of Dimmick's short-time observer C. For the rest, there is always the question of practice. Tu's pricks, *e.g.*, may have been true pressure-spot responses; an O has to learn by experience the nuances of the pressure-sensation; but the pricks of the more practised O's probably derived from concomitant stimulation of pain-spots.

Series III.: Forearm Supine, Blank Experiments

The care which our O's took to report imaginal characters and resemblances puts it practically beyond doubt that the primary sensations were in fact sensational. We thought, nevertheless, that it would be worth while to add a few series which included blank experiments, in order to determine whether an anticipatory image might arise, clear and strong enough to create illusion. Since the introduction of a single blank in the series of 10 might possibly sharpen O's attention, and thus lead to results not comparable with those of the preceding series, we introduced three or four blanks, placed at haphazard. Three to five series of the regular type (30 to 50 observations; all 10 pressure-spots) were secured from the 5 O's.

D, H, M and Tu reported 'Nothing' every time that the R was omitted. Three of these O's made no comment; the fourth remarked—what the others very probably thought—that something must have gone wrong with the apparatus. Ta went successfully through a first series. It happened that the first 'observation' of his second series was a blank; on this occasion Ta pressed his key about a second after the R, had there been one, would have been removed, and reported: "Nothing at first; then something very weak and faint." Some 3 sec. later he released the key, with the comment: "Don't know when it went away." Three further series passed without error. Ta's positive report (due, as it seems, to the suggestion of the first observation in a series; we may recall Ta's suggested rendering of the formula of instruction) is valuable; it shows how an after-experience may arise under the influence of expectant attention.¹

¹ We may remind the reader that there were 8 cases, scattered through the total experiment after the introduction of the reading glass, in which spots failed to respond to stimulation. As it happened, the scattering included every one of the 5 O's.

We conclude, then, that the primary sensations were, as we had supposed, genuinely sensational, and that their somewhat undue length in certain of our tables indicates simply their maximal prolongation by attention.

CONCLUSIONS

A. If *O* is in a passive, receptive attitude toward the experiment:

1. A stimulus-hair of 4.8 gr./mm. tension-value, applied to pressure-spots on dorsal or volar forearm, arouses a sensation of contact or light neutral pressure, which under adaptation brightens to a tickle. Sometimes (by stimulation of a near-by pain-spot ?) a wiry pricking pain is also aroused.

2. The normal duration of the primary sensation is from 0.75 to 2.00 sec. The sensation either decreases steadily in intensity throughout its course, or shows an initial increase followed by a decrease. Sometimes there is a sudden intensive increase at the moment of removal of the stimulus.

3. After-experiences are few and brief.

B. If *O* assumes an active attitude, making a voluntary effort to secure as much cutaneous experience and to maintain it as long as possible:

4. The normal primary sensation may last on the average 4 sec.

5. After-experiences are numerous and often of considerable duration.

6. Abnormal primary sensations, lasting as long as 200 sec., appear mixed irregularly with the normal.

7. There is a tendency to resort to perceptual construction.

C. The discrepant results obtained by previous experimenters under similar objective conditions are therefore, in all probability, due to variation in the attitude of their *O*'s.

D. While there is no doubt that true after-sensations ('after-images of pressure') occur, there seems also to be no doubt that free or tied pressure-imagery plays a part in the formation of cutaneous after-experiences. A systematic study of cutaneous imagery is needed.