

## THE PERCEPTION OF TWO POINTS NOT THE SPACE-THRESHOLD.

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In the older psycho-physical conception of Weber and Fechner, the space-threshold of a locality on the skin is that distance of two stimulating points from each other at which they are at first perceived as two. The classical works of Weber, 'De Pulsu, Resorptione, Auditu, et Tactu,' and 'Tastsinn und Gemeingefühl,' first excited physiologists and psychologists to seek an exact knowledge of this distance for different localities on the skin and to form some physiological explanation of its regularities and variations. Fechner, using the terminology of Herbart, first named this distance the *Raumschwelle*, and the term has come to be used to a greater or less extent in psychological literature. The conception is mathematical in so far as it is based on the geometrical fact that two points are necessary to the simplest form of space-extension. It is physiological in so far as based upon Weber's theory of sensory circles, according to which two or more 'sensory circles' must lie unstimulated between two 'touched circles' in order that space, in its simplest form, be tactually perceived. The conception presupposes that there is a space-threshold; that it is the point of transition from the sensation of one point to that of two; and that it is to be found either by the so-called 'method of least perceptible changes' or by that 'of right and wrong cases,' provided the answers collected be passed through one or another of the formulas of Fechner, Müller and Camerer, all of which are based upon the Gaussian formula<sup>1</sup> of the theory of Probability.

These three formulas arose in connection with the method of right and wrong cases which Vierodt first formulated and

<sup>1</sup> This formula contains but two variables.

applied.<sup>1</sup> It was found from the first that between the sensation of one point and that of two, a variety of sensations which can neither be classed as those of one point nor of two appear. Of the pupils of Vierordt in the physiological institute at Tübingen, Kottenkamp and Ulrich<sup>2</sup> divided the sensations which appear in such experiments into the following classes—I. Double sensations, including *a*) those with a correct and *b*) those with an incorrect judgment of the affected spots of skin; II. simple sensations, *c*) pointed or *d*) as if the skin were touched with a long-shaped instrument, *a*) correctly so felt and *β*) incorrectly. Out of these cases they included only I *a*) under the category of 'right judgments,' leaving all the others to the class of 'wrong' ones. Paulus<sup>3</sup> and Riecker<sup>4</sup>, as also Schimpf<sup>5</sup> and Hartmann<sup>6</sup> adopted the same classification, adding only the answer 'undecided' to the list of 'wrong cases.' In his first series of experiments,<sup>7</sup> Dr. Camerer subsumed 'all sensations which cannot be nearer described than that they seem to be produced, not by one pin-point, but by something more extensive,' among the cases of 'right judgments.' But in his later series<sup>8</sup> he accepted the four answers, 'two points,' 'more than one point,' 'undetermined,' and 'one simple point.'

To dispose of these troublesome groups of intermediate sensations, the three mathematical formulas of Fechner, Müller, and Camerer, each claiming superiority to the other two, were constructed. Their purpose is to reduce, by a simple calculation in the Theory of Probability, this numerous group of intermediate answers to the two variables, *r* and *f*, or *r* and *z*, which the formulas contain. In Camerer's first experiments in which the answers were 'one point,' 'two points,' and 'undecided,' that latter group were evenly di-

<sup>1</sup> Unterschieds empfindlichkeit im Schallgebeite—Vierordt's Archiv, 1856, Heft 2, p. 185.

<sup>2</sup> Versuche über den Raumsinn der Haut der oberen Extremitäten, p. 42.

<sup>3</sup> Versuche über den Raumsinn der Haut der oberen Extremitäten, p. 3.

<sup>4</sup> Versuche über den Raumsinn der Kopfhaut, Tabelle II, p. 14.

<sup>5</sup> Raumsinn der unteren Extremität bei Anchylose des Kniegelenks I, p. 11 and ff.

<sup>6</sup> Raumsinn der Haut des Rumpfes und des Halses. Tabelle I, p. 7.

<sup>7</sup> Versuche über den Raumsinn der Haut nach der Methode der r. u. f. Fälle, I.

<sup>8</sup> Versuche über den Raumsinn der Haut nach der Methode der r. u. f. Fälle, No. II, p. 285 ff.

vided between the two classes of 'right' and 'wrong judgments.' That all these methods leave much room for gross inaccuracies in results seems admitted by all. Nor do the elaborate formulas settle the question. The discussion of their relative values seems to have died with their champions, and the applicability of the methods of right and wrong cases to the determination of the so-called *Raumschwelle* is still an open question in the school of Psycho-physics, as the late discussions of Merkel amply demonstrate.

A more recent view has offered a somewhat different conception of space according to which it is based upon a quality of sensation as such. According to Külpe this quality, viz., extensity (*Ausgedehntheit*) belongs to sensations of sight and touch<sup>1</sup>: according to James<sup>2</sup> and Ward,<sup>3</sup> to all sensations. In connection with a series of experiments to determine the effect of exercise on the perception of two points, it was thought that a new side of the facts in regard to the tactual perception of space might be gained by asking the observer to describe his sensations, as fully as possible, giving their spatial characteristics and, in connection with the perception of two points, their apparent distances apart. A large number of the descriptions received are difficult to classify and cannot be conveniently given in the form of tables; but enough can be thrown into the following groups to convince one that every sensation of touch has a space-quality which at once becomes apparent through the comparison of two or more different sensations with each other.

The observers in these experiments were Herr Max Arrer (Ar.), M. Victor Henri (H.), Rev. S. Gringe Hefelbower (Hef.), and Messrs. G. M. Stratton (St.), A. Müller (A. M.); and G. Tawney (T.). We wish here to express our thanks to these five gentlemen for their indispensable assistance. Table I. gives the cases in which one sensation only was felt. In the first vertical column are the observers; in the following four the applied stimuli, viz., one point, two points whose distance apart is below the threshold for the

<sup>1</sup> Grundriss der Psychologie, p. 347, § 3.

<sup>2</sup> Principles of Psychology, Vol. II, Chap. XX, p. 135.

<sup>3</sup> Encyclopædia Britannica, Article 'Psychology,' pp. 49, 53.

perception of two points, two points near the threshold, two points over the threshold; in the following four columns are given the answers received, thrown into the following groups: 'small,' 'sharp' or 'pointed;' 'medium,' 'round' or 'good;' 'large,' 'blunt' or 'extended,' and 'a line' or 'lengthy sensation.' The adjective 'good' was used by nearly all, and when asked what they meant, they answered 'medium-sized,' 'round,' 'solid,' 'not to be mistaken,' 'easy to recognize,' etc. The instrument used in all the experiments was a simple pair of compasses, into which fine, carefully-prepared bone points had been inserted.

TABLE I.—Descriptions of 667 single sensations in terms of space, the stimuli being 1 point, 2 points below the threshold, 2 about the threshold, and 2 over the threshold.

OBSERVER.	STIMULUS.				ANSWER.			
	One point.	Two points under the threshold.	Two points about threshold.	Two points over threshold.	'Small,' 'sharp' 'pointed.'	'Medium,' 'good' 'spherical.'	'Large,' 'blunt' 'extended.'	'A line' or 'lengthy sensation.'
Ar.	12	84	58	13	2 11	7 30 20 1	1 3 11 3	2 40 27 9
H.	45	27	3		23 6	5 6 1	12 11 2	5 4
St.	26	22	3		7 3	6 3	2 6	11 10 3
A. M.	3	39	30		3 10	2 11	27 19	
Hef.	30	84	77	21	20 7 4	10 17 6 1	8 10 9 2	2 50 58 18
T.	56	22	4	8	15 12	15 2 2 4	17 4 1 3	9 4 4 1

In this table the sensations shift gradually from the first column, 'small and pointed,' toward the last two, as the stimulus passes from one point to two points over the threshold. In the cases of H., A. M., and St., the absence from the table of experiments with two points over the threshold is due to the fact that these observers seldom or never mistook two points over the threshold for one point as the others so often did. The table shows that the space-quality of the sensations of different persons varies widely. Only a very general regularity exists between them. A. M. seemed not to experience single long sensations at all, while St. and Hef. seemed to have more lengthy ones than any other kind. I touched the arm of A. M. with the edge of a visiting-card and asked whether he ever had similar sensations from the compass-points. His answer was an unqualified no.<sup>1</sup>

Table II. gives experiments in which two sensations were felt and described. In the first two vertical columns are the observers and the stimuli for each; in the following seven are the judgments, divided into two classes, where the sensations were alike, and where they were unlike or different. In the first class the two points are alike and either 'small' and 'sharp,' 'medium-sized' and 'spherical,' 'large' and 'blunt,' or 'two points with a line connecting them;' in the second class the points are different: 'the one large and the other small,' 'the one lengthy and the other round,' 'different in space-quality, but connected by a line or long sensation.'

<sup>1</sup> It may be significant that the muscles of H. and A. M., those of A. M. especially, were hard and round at the investigated places, filling out the skin so as to prevent its movement; while those of St. are comparatively soft, and those of Hef. rather fleshy, permitting the compass-points of their own weight to sink into them and thus causing comparatively extensive movements of the skin. This may explain the fact of their frequency with St. and Hef. and their infrequency with H. and A. M. In any case the cause of these variations seems to be chiefly peripheral, as distinct from imagination, expectation, etc.

TABLE II.—Descriptions of 1063 double sensations, 765 alike and 298 unlike, the stimuli being 1 point, 2 points below the threshold, 2 points near the threshold, and 2 points above it.

OBSERVER.	STIMULUS.	TWO POINTS FELT ALIKE.				TWO POINTS FELT UNLIKE.		
		'Small, 'pointed.'	'Medium, 'spherical, 'good.'	'Large, 'blunt, 'diffuse.'	'A line, 'or 'lengthy sensation between.'	'One large, the other small.'	'One lengthy, the other round.'	'Two unlike points connected.'
Ar.	One point.	10	5	2	1	1	5	
	2 p'ts under threshold.	15	12	5	6	20	10	
	2 p'ts about thres.	25	20	15	1	2	3	
St.	One point.	28	25	6	23	8	2	
	2 p'ts under thres.	31	20	13	30	11	4	
	2 p'ts about thres.	5	5	6	5	1	1	
A. M.	One point.	5	1			2		
	2 p'ts under thres.	3				7		
	2 p'ts about thres.	6	7	4	1	3	4	
H.	One point.	22	22	10	8	1		
	2 p'ts under thres.	7	5	1	2	20	5	
	2 p'ts about thres.	4	3	1	5	25	3	
Ta.	One point.	50	21	1	27	38	6	
	2 p'ts under thres.	7	2		6	1		
	2 p'ts about thres.	4	1		2	2		
	2 p'ts over thres.	61	32	4	15	15	5	

Table II. gives ample illustration of the fact which we have in hand, viz., that all sensations of touch have a space-quality. It will be noticed that the larger proportion of the cases where the two points are different are stimulated by one point or by two points under the threshold. For example, Ar. felt two points alike 10 times and unlike 20 times when the stimulating points were below the threshold, 15 times alike and 26 times unlike when the points were near the threshold, but 25 times alike and only 2 times unlike when the points were over the threshold. This fact accords

with the self-observation of Ar. that there is always a difference between the two sensations of a so-called *Vexirfehler*, where two points are felt where only one is touched, such that he can in most cases recognize the illusory and the genuine points. But this was not the observation of St. or A. M., but rather the opposite. In the case of Hef. the two sensations from two points over the threshold were always felt as separate, round, solid, and perfectly alike. But what the cause of these differences in different observers may be we are not able to surmise owing to the lack of a large number of observers. The false perception of two points where only one point was touched was most frequent with St. and T.; and least frequent with Hef. who seems to possess in general a very highly developed and very healthy sensory nervous system.

Variations in the 'threshold' were frequent with the same individuals, not only from day to day, but also within the same hour. One observer was found in Wundt's institute who has taken part in numerous skin-experiments, on the volar side of whose lower arm a 'threshold' could not be found which remained constant for a half hour; a similar experience was that with St. and T. Moreover, we made the attempt to repeat the same experiment several times in succession under exactly the same conditions. An example of the results obtained is the following. The place is the volar side of St.'s right lower arm, as it lay unmoved throughout the experiments on the table. The distance apart of the points was 20 mm. The spots on the skin were the same in each experiment, the time interval being always about two minutes. The pressure in each trial was the same, viz., the weight of the compasses. His answers were as follows:

First experiment—two points, 15 mm. apart, clear, equally strong, simultaneously and immediately perceived.

Second experiment—at first a line; then two distinct ends which became perfect points about 30 mm. apart but connected by a line.

Third experiment—one point, sharp, deep, somewhat painful.

Fourth experiment—two points separated about 20 mm., but lying at right angles to the above two points.

Fifth experiment—one point, somewhat large.

Sixth experiment—at first several points: then three became clearer than the remainder: at last one seemed a real point surrounded by a group of fainter ones.

Seventh experiment—at first two points bound together by a line: then a large lengthy sensation about 15 mm. in length.

Eighth experiment—two points about 12 mm. apart, clear, equally strong and simultaneous.

Ninth experiment—one point, small, simple, and definite.

Tenth experiment—two points, 10 mm. apart, simultaneous, equally strong, becoming painful.

Experiments similar to these were made on H. and, later, by H. on T. with the same general results. Such variations are well known to every observer of skin-sensations. The genius of Fechner did not succeed in reducing their manifoldness to simple regularity. Such experiments seem to show clearly that the perception of two points takes place under conditions too varying and too different to be regarded as the first tactual space-perception. Our tactual sense of space seems to be far more exact and far more regular than the perception of two points.

From these and similar experiments it seems that there is no such thing as a 'space-threshold' in the entire field of skin-sensations, because there is no sensation of touch, not even that of a fine needle-point, which does not already possess a spatial quality. The latter does not enter into sensations of touch at the perception of two points. The mathematical point, a point without extension, does not exist either to sight or touch. Geometrical extension in one direction begins with two points, but tactual extensity-perception clearly begins with the comparison of simple tactual sensations. The difference between a point and a line like the edge of a visiting-card is sooner perceived on the lower arm at least, than the difference between two points, thus showing that the perception of extensity through touch does not depend upon the experience of more than one simple sensation. We are fully convinced that the sensation of one point, however fine, has in it the data for abstracting three dimensions by comparison with other points, *i. e.*, by the usual



process of assimilation and discrimination which underlie all perception. The space-threshold should be a certain moment in sensations where extensity, *i. e.*, spatiality, first enters consciousness; but the *Raumschwelle* of Weber and Fechner is the moment where two simultaneous touches enter consciousness which we have seen comes much later and under much more varying conditions—it is in short not a *Raumschwelle* at all. If we wish to speak of a space-threshold at all, we should designate by the term a fact of assimilation rather than any measurements on the surface of the skin. ‘The fineness of the locality sense’ (*Feinheit des Ortsinnes*) is, properly speaking, the object of all such measurements, but never the ‘space-threshold.’ We have shown that single sensations and double sensations are both indefinitely various, but the variations are not without some regularity corresponding to the outer stimulus. The single point, the line, the surface, and even the solid, are all perceptions of touch which have their origin in the subjective and objective conditions of the sensations. In short, we have here a large field of sensations which has never been exhaustively investigated. Sensations belonging to this field have, until very lately, been regarded as mere hindrances to the ascertainment of the *Raumschwelle*, and have been either ignored, as in the first experiments of Camerer and those of Vierordt’s pupils, or dealt with as food for psychic threshing-machines, such as the formulas of Fechner, Camerer and Müller.

Finally, the conception of a *Raumschwelle* is nothing more than a remnant of the old way, ‘von oben nach unten,’ of ‘Scholastic deduction,’ which Fechner strove so faithfully to eradicate from psychology. It is the carrying downward, ‘von oben nach unten,’ of a physiological and mathematical conception—a reading into sensations of the forms of a highly abstract intellect; whereas the mathematical conception is in fact an abstract of the spatial quality of sensations themselves. It may be that when psychologists have studied sensations humbly and exhaustively they will find among them, and in all of them, the germs of every flower that blows—of both the form and substance of thought, feeling, and will.