

Acta Medica Okayama

Volume 5, Issue 1

1936

Article 13

SEPTEMBER 1936

An Experimental Investigation on the Measurability of Sensation.

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Received on the 25. May 1936.

Introduction.

Though the intensity of sensation can not be estimated directly, it has been commonly supposed that the intensity of sensation kept pace with the strength of the stimulus so that in general, it has been assigned quantitative values on a scale. This assumption however has been questioned by *Myers* (1931), *Gage* (1934) and other students. *Gage's* experimental results indicates that the intensity of sensation does not keep pace with the strength of stimulus, so that, a scale of sensation can not be built up.

The present work concerns the foregoing question in regard to the sense of muscle and vision, whether the intensity of sensation is variable or keeps pace with the intensity of the corresponding stimuli which produce those sensations.

Method and Experimental Results.

The experimental procedure on the whole was the same as the method which was used by *Gage*. This method is as follows; sensations corresponding to the intensities X_1 and X_5 are bisected by the sensation corresponding to the adjustable intensity X_3 . These X_1 , X_5 and X_3 show the weight in the muscular sense or the brightness in the visual sense. Similarly X_2 bisecting X_1 and X_3 is found, and X_4 bisecting X_5 and X_3 . Then X'_3 bisecting X_2 and X_4 is determined. This final bisection X'_3 should give the X_3 sensation, if there is to be a possibility of correlating sensations with measurements of stimuli.

1. *Measurement of the Muscular Sense.*

The muscular sense was measured as follows:

Six bottles each weighing 45 g were taken and made the one of them weigh 50 g and the other one 150 g, by putting slugs in each bottle. These two bottles correspond to X_1 and X_5 , while the other four bottles also carry a certain weight of slugs put in them. In comparing the weight of these two bottles X_1 and X_5 with the third bottle X_3 by having a suitable weight of slugs put in the third one, X_3 was determined by bisecting the interval between X_1 and X_5 , lifting these bottles alternately by the tips of fingers. Similarly, X_2 , X_4 and X'_3 were found and the weight those four bottles are determined on a balance. Thus an experiment was performed while one's eyes being closed. After every experiment a rest was taken to prevent fatigue.

The experimental results are presented in Table 1.

Table 1.
 $X_1 = 50$ g, $X_5 = 150$ g

Date	Hand	X_2 (g)	X_3 (g)	X_4 (g)	X'_3 (g)	X'_3/X_3
3/12	left	86	111	133	111	1.00
"	"	86	116	134	115	0.99
"	"	75	106	129	105	0.99
5/12	"	83	109	134	115	1.06
"	"	88	114	134	117	1.03
"	"	88	110	129	115	1.05
6/12	"	84	112	126	110	0.98
"	"	83	100	123	102	1.02
"	"	86	117	134	115	0.98
7/12	right	87	105	124	112	1.07
8/12	"	80	109	122	104	0.95
"	"	89	117	135	114	0.97
"	left & right	86	108	132	110	1.02
"	"	86	106	120	100	0.94
10/12	"	89	117	132	115	0.98
"	"	80	105	128	108	1.03

The results in the case of $X_1 = 10$ g, $X_5 = 30$ g and $X_1 = 2$ g, $X_5 = 10$ g is expressed in Table 2 and Table 3. As shown in Table 1 and 2, X_3 and X'_3 are almost equal but as noted in Table 3, X'_3 differs from X_3 to some extent.

Table 2.
 $X_1 = 10$ g, $X_5 = 30$ g

X_2 (g)	X_3 (g)	X_4 (g)	X'_3 (g)	X_3/X'_3
13.0	18.5	23.0	19.5	1/1.05
13.3	19.0	23.2	20.0	1/1.05
14.0	21.0	25.3	20.0	1/0.95
14.1	21.2	25.5	21.5	1/1.01
17.1	21.7	27.0	22.5	1/1.04

Table 3.
 $X_1 = 2$ g, $X_5 = 10$ g

X_2 (g)	X_3 (g)	X_4 (g)	X'_3 (g)	X_3/X'_3
4.8	7.3	9.2	6.2	1/0.85
3.8	8.1	8.3	7.5	1/0.94
5.1	7.3	7.8	6.8	1/0.93
5.8	6.7	7.8	7.6	1/1.13
3.7	5.5	8.3	5.4	1/0.98
7.1	7.5	9.5	8.5	1/1.13
5.8	7.2	8.3	6.5	1/0.90

Next, three bottles were used in the said experiment and made to weigh 50 g, 100 g and 300 g respectively, by putting slugs in them. These three bottles are designated as the standard bottles. In comparing a standard bottle with one of those which are shown in Table 4, one judges which bottle weighs more than the other by the muscular sensation. Of course, the eyes are closed during the experiment.

Table 4.

Standard Bottle (Weight in g)	Comparing Bottle (Weight in g)
50	48.5
50	51.5
100	97
100	103
300	291
300	309

The difference between the standard and comparison bottles was adopted as the liminal difference respectively. About the liminal difference, various values are known. For instance, *Weber* measuring the just noticeable difference between weights successively lifted by the same arm, found that difference to be one-fortieth part of the lesser of the two weights compared. In *Jacobi's* observations, the liminal difference remained pretty constantly $1/20$ throughout a long range of weights. In *Fechner's* observations, it was $1/51.1$ (standard weight 300 g). In the author's own experiments and those of his fellows at this institute of physiology, it showed $1/30 - 1/50$, over a range of from 50 to 300 g, so that, in this experiment, the liminal difference was estimated at $1/30$.

The results of this experiment are given in Table 5.

Table 5.

S. B.	C. B.	C. J.	I. J.	TOTAL
50	48.5	16	4	20
50	51.5	17	3	20
100	97	17	3	20
100	103	18	2	20
300	291	17	3	20
300	309	17	3	20

S. B. Standard bottle (Weight in g)

C. B. Comparing bottle (Weight in g)

C. J. Correct judgements (Number)

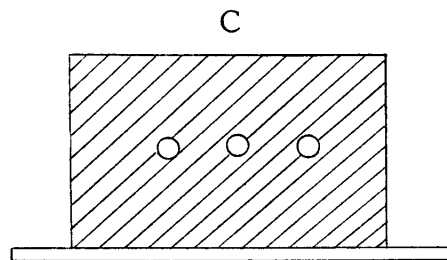
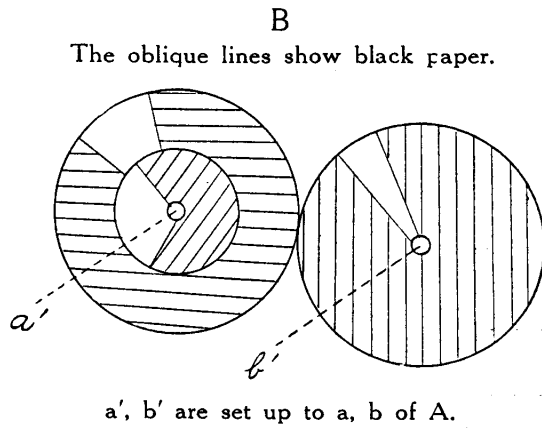
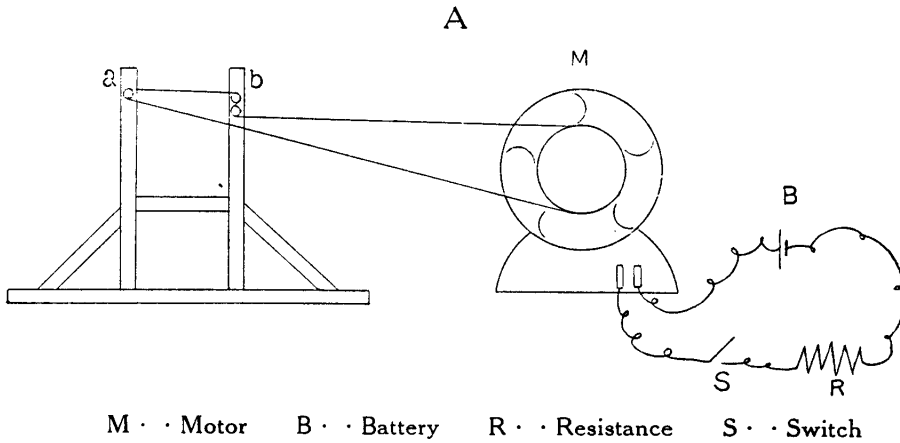
I. J. Incorrect judgements (Number)

TOTAL Total number of experiments

2. Experiment on the Visual Sense.

For the visual sense experiment, three discs were driven by an electromotor (see Fig. 1, A and B). In using this, three pairs of white and black paper were applied at one time, two pairs on the left side and one pair on the right side. The diameters of the discs were nineteen cm (large disc) or eleven cm (small disc). The observer was placed one metre in front of the discs and there placed between the observer and the discs at the distance of five cm from the discs a black board (see Fig. 1, C) through which three apertures of two cm in diameter were bored. By varying the resistance in the electrical current, the speed of the electromotor was made to vary, and one can determine precisely the point at which flickering just ceases.

Fig. 1.



The diameter of each aperture is 2 cm.

Then through the said three apertures which stood side by side, three gray discs were seen and the intensity of brightness of each disc was changed by varying the degree of the sector of white paper. Always the brightest disc, namely the one whose degree of black sector is smallest, was set to the right. The discs were lighted up

with the sunshine indirectly. The intensity of $X_1, X_2 \dots$ was shown with the degree of angle of white sector. The brightness of a gray disc was varied with the change of only 1 or 2 degrees of angle of white paper.

The author took the disc of white paper as X_5 , black paper as X_1 , and these are set both edgeways. The middle disc X_3 (that of intermediate brightness) was determined by adjusting until it appeared to be equal in brightness between the brightnesses of these discs, by increasing or decreasing the angle of white paper, rotating the motor adequately. Similarly, X_2, X_4 and X'_3 were found. The results of this experiment are noted in Table 6, and they showed X_3 and X'_3 are almost equal in every case.

Table 6.
 $X_1 = 0$ degree of angle (blank paper)
 $X_5 = 360$ degree of angle (black paper)

Names of subjects	Date	X_2 (degree)	X_3 (degree)	X_4 (degree)	X_3 (degree)	X'_3 (degree)
K. T.	22/12	9	20	35	20	18
"	26/12	7	20	33	20	19
M. T.	24/12	15	31	61	31	31
"	26/12	16	30	57	30	32
"	22/1	16	29	49	29	28
S. T.	11/1	16	33	60	33	33
"	18/1	17	33	63	33	34
"	21/1	17	32	57	32	32
H. H.	8/1	14	29	56	29	29
K. S.	12/1	22	37	51	37	35
K. K.	12/1	18	44.5	80	44.5	44
N. K.	16/1	16	41	93	41	39
H. Y.	21/1	23	56	90	56	56
M. M.	29/1	17	32	57	32	31

Discussion of Results.

These experiments were performed to test the possibility of establishing a scale of sensation in the case of vision and of muscle.

In the sense of muscle and vision, the corresponding two different values of weight or brightness, X_1 and X_5 , were bisected by the sensation corresponding to the adjustable intensity X_3 . Similarly, X_2

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bisecting X_1 and X_3 was found and X_4 bisecting X_5 and X_3 , X'_3 bisecting X_2 & X_4 . In the muscular sense, six bottles which having a certain amount of slugs in each was used. In the visual sense, three discs of various brightness were presented to the eye side by side and the intensity of the middle disc was adjusted until it appears to lie equally in brightness between the brightness of the outer discs. In every case, X'_3 was nearly equal to X_3 in the middle of the range of stimuli.

On the other hand, comparing the weight of two bottles, one of which was $1/30$ as heavy (light) as the other, by lifting them with fingers of the right hand alternately, the ratio of the total number of experiments to those of incorrect judgement was 10 to 1 or 10 to 2 each time, with weights ranging from 50 to 300 g. From these results, the author judges that the intensity of sensation keeps pace with the strength of stimulus and does not change in a short time. Therefore, it may be stated that a scale of sensation is possible to be constructed.

Conclusion.

The intensity of sensation keeps pace with the strength of stimulus so that it can be represented with the intensity of stimulus.

The author wishes to express his thanks to Prof. Dr. S. Oinuma for his helpful suggestions and advice.

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