Offprinted from THE AMERICAN JOURNAL OF PSYCHOLOGY
September 1958, Vol. 71, No. 3, pp. 557-562

SENSITIVITY IN THE JUDGMENT OF SIZE BY FINGER-SPAN

By HENRY F. GAYDOS, Quartermaster Research and Engineering Center

The object of this experiment was to study tactual-kinesthetic sensitivity to differences in size of stimulus-objects as measured by finger-span, using the method of adjustment. Although few studies have dealt with tactual-kinesthetic perception of size, some pertinent work has been reported by Bartley, Kelvin, Raffel, and Langfeld.[1] Of these, only Langfeld studied size-discrimination by finger-span, and obtained a measurement of relative sensitivity of approximately 1/100, using the method of constant stimuli. Unfortunately, he worked with only one standard (50 mm.), and employed only six *Ss* in his study.

The present study, which is actually made up of three consecutive experiments, was designed to measure differential size-discrimination for a number of standard lengths falling within the limits of normal finger-span. In addition, the use of a graded series of standards made it possible to test for a systematic relationship between absolute length of stimulus-object and sensitivity to differences in size.

Subjects. The *Ss* employed in this study were men, unselected paid volunteers drawn from a college population. Their numbers were 50 in Experiment I, 50 in Experiment II, and 20 in Experiment III. None of the *Ss* in Experiment II had participated in the Experiment I, but 14 of those serving in Experiment III had served in one or the other of the earlier experiments.

Apparatus. Standard stimulus-objects were made up of aluminum cylinders 20 mm. in diameter. In Experiment I, standard lengths of 25 mm., 50 mm., and 100 mm. were employed. To these were added lengths of 35.4 mm. and 70.8 mm. for Experiment II, and 17.7 mm. for Experiment III.[2] The variable stimulus-object consisted of two 20-mm. diameter disks mounted in such a way that the distance between their outer parallel faces could be adjusted with a rack-and-pinion mechanism. In effect, this simulated a cylinder of variable length. A vernier scale enabled *E* to read the effective length to within 0.1 mm. When mounted, the standard and the variable cylinders had the same axis and the distance between their proximal faces was fixed at 10 cm. The apparatus was set on a table in such a position that the axis of the cylinders was horizontal and in the sagittal plane of *S*.

* Received for publication April 28, 1957.

[1] S. H. Bartley, The perception of size or distance based on tactile and kinesthetic data, *J. Psychol.*, 36, 1953, 401-408; R. P. Kelvin, Discrimination of size by sight and by touch, *Quart. J. exp. Psychol.*, 6, 1954, 23-34; Gertrude Raffel, Visual and kinaesthetic judgments of length, this JOURNAL, 48, 1936, 331-334; H. S. Langfeld, The differential spatial limen for finger-span, *J. exp. Psychol.*, 2, 1917, 416-430.

[2] The seemingly odd values of the added standards were chosen to give equal log-unit intervals which, however, were not pertinent to this experiment.

Procedure. The cylinders were hidden from *S*'s view, and judgments of relative length were made by spanning them between the tips of the thumb and the forefinger. To control any constant errors that might arise because the variable and standard were at relatively different distances from the body, half the *S*s made their judgments with the standard nearer to *S* and the other half with the variable nearer.[3] *S* matched the variable to the standard by employing the psychophysical method of adjustment.

Four trials were given with each of the standard lengths, two trials with the variable set initially smaller than the standard, and two trials with the variable set

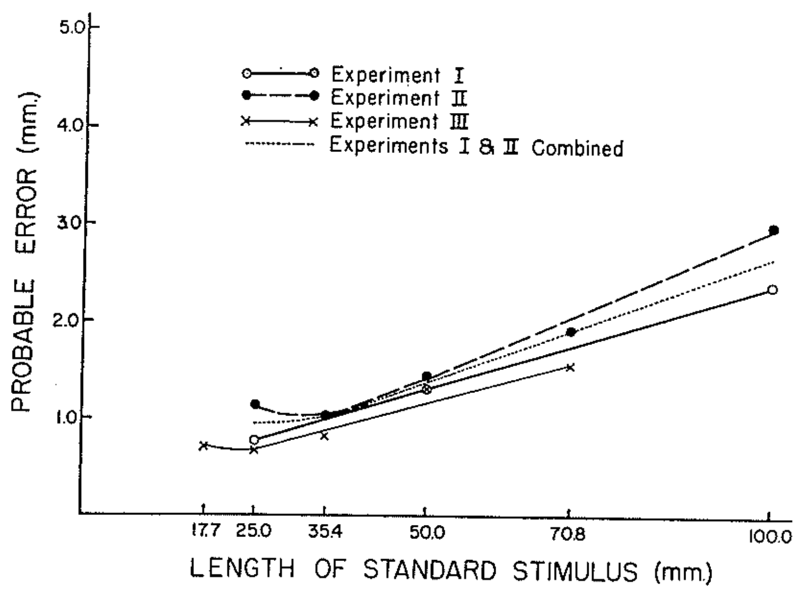

FIG. 1. RELATIONSHIP BETWEEN VARIABLE ERROR OF SIZE-DISCRIMINATION BY FINGER-SPAN AND ABSOLUTE LENGTH OF THE STANDARD

initially larger. *S* was permitted to make as many corrective adjustments as necessary to achieve the best possible match. The order in which the different standards were presented was varied from *S* to *S* according to a Latin square. At the conclusion of each trial the setting of the vernier scale was recorded by *E*. *S* was not given any information about the accuracy of their judgments during the course of the experiment.

Results. The relationship between variability of the settings, in terms of the probable error of the distribution about the mean, and the absolute length of the standard is shown for all three experiments in Fig. 1. An analysis of variance indi-

[3] Bartley, *loc. cit.*, found that the apparent size of objects as perceived by touch, decreased as their distance from *S* increased.

cated that the increase in variability of settings is indeed attributable to the increase in the absolute length of the standard and not to random variations ($F = 15.95$ for Experiment II). The results of Experiment I show a perfectly linear relationship in Fig. 1, but the addition of interpolated standards in Experiment II produced a curve that turns upward at its lower extremity although the major portion remains roughly linear. When the data of both experiments are combined, the relationship between probable error and length of standard appears to be quite linear between 35.4 mm. and 100 mm.

To obtain a more complete picture of the errors characteristic of the lower end of the stimulus-scale, the third experiment was performed with a 17.7 mm. standard added to the series, but omitting the 100 mm. standard. The general shape of the curve is similar to what was obtained in the previous experiments, although the magnitude of errors is somewhat less. The reduction of error was thought at first to be caused by a practice effect since 14 of the *Ss* had participated in a previous experiment, but a comparison of their performances in both experiments did not bear this out. The difference might be accounted for by the small size of the sample.

In any event, the trend to be noted is the flattening out of the curve at the lower end of the continuum. Between the 17.7 mm. and the 25 mm. points on the abscissa, the curve may be regarded as horizontal for all practical purposes, and this flattening could be interpreted as an indication that these points fall near the absolute threshold of discriminability.

Fig. 2 indicates how the experimental results conform to Weber's Law ($\Delta I/I = k$). The $\Delta I/I$ ratio remains fairly constant in each experiment between $I = 35.4$ mm. and $I = 100$ mm. This constancy seems, however, to break down for values of I below 35 mm. This is not surprising since Weber's Law rarely, if ever, holds at the extremes of a given stimulus-continuum. Exact numerical values of the points plotted in Figs 1 and 2 are presented in Table I.

Attention must also be directed to the constant errors which are presented in Table II. First to be noted is the increase in magnitude of the constant error as the size of the standard is increased. Although there is a rather wide disparity among the three experiments for errors when the 50-mm. standard was used, a plot of the average of the errors for each standard results in a negatively accelerated curve (not shown). This function becomes a reasonably straight line if the errors are plotted as a function of the logarithm of the length of the standard. The second noteworthy result concerns the direction of the constant error: the variable stimulus was consistently set larger than the standard. These values were all tested for statistical significance, and levels of confidence are shown in Table II.

Tested for significance were also the differences between the means of the settings with the variable in the near and far positions relative to *S*. In this case, the differences were not found to be significant. Apparently the judgments were not appreciably affected by the relative distance of the variable and standard from the body.

Discussion. Certain points require more elaboration. For one thing, the author recognizes that measures of differential sensitivity as obtained with the method of adjustment may not be the same as difference-limens found by other phychophysical methods. According to Guilford, however, the measures of dispersion obtained with the method of adjustment can legitimately be used to verify Weber's law, and the probable error of the distribution is usually taken as being at least proportional, if not equivalent, to the *DL*.[4] Since it was more important to test the relationship of the *DL* to the size of the standard, rather than defining the *DL* more exactly by more cumbersome methods, the author chose the method of adjustment.

There is little to be gained by comparing Langfeld's results with the present results. Both experiments had in common one standard, but even if we were to assume no differences attributable to the different psychophysical methods involved, there is the added difference that his *Ss* were highly trained. In fact, the Weber

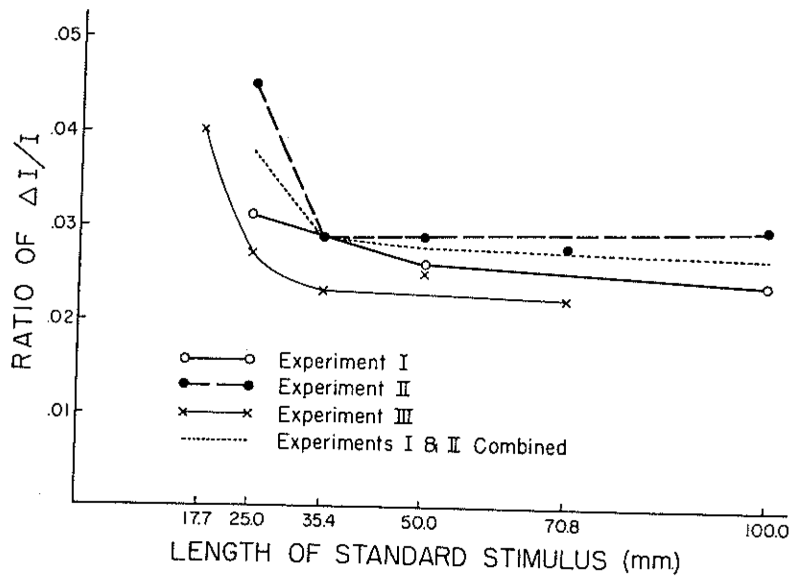

FIG. 2. THE WEBER FUNCTION IN DIFFERENTIAL SIZE-DISCRIMINATION BY FINGER-SPAN

ratio of 1/100 represents the performances of the best two of his six *Ss*. The Weber ratios reported here were derived from the mean performance of a relatively large group of naïve *Ss* among whom considerable variability occurred.

The discriminative ability of the *Ss* certainly determines the value of k descriptive of the horizontal portions of the curves in Fig. 2. It also seems plausible that the point at which constancy of k breaks down would also be a consequence of the same underlying factor. In other words, the turning points at the lower ends of the curves could be interpreted as being points at which the absolute threshold had been reached. Below such a point Weber's law would no longer hold since the ΔI term would remain relatively constant while I would continue to decrease. Consequently, the range over which the Weber ratio remains constant would be

[4] J. P. Guilford, *Psychometric Methods*, 2nd ed., 1954, 97 f.

greater for a more sensitive *S* and smaller for a less sensitive *S*. On this assumption, the absolute threshold in size-discrimination by finger-span would fall in the region of 1 mm. for the group that was tested. Actually, more experimentation in the range of stimuli below 35 mm. is needed before these conjectures are carried any further.

The occurrence of a constant error connected with the use of the method of adjustment has long been recognized, but no conclusive explanation of its cause has been advanced. Guilford refers to the phenomenon as a "constant time-error"

TABLE I

VARIABLE ERROR AND WEBER RATIOS FOR EXPERIMENTS I, II, AND III

Length of standard (*I*)	Experiment I (*N*=50)		Experiment II (*N*=50)		Experiment III (*N*=20)		Expt. I & II combined (*N*=100)	
	PE	*PE/I*	*PE*	*PE/I*	*PE*	*PE/I*	*PE*	*PE/I*
17.7	—	—	—	—	.70	.040	—	—
25.0	.76	.031	1.13	.045	.66	.027	.96	.038
35.4	—	—	1.02	.029	.80	.023	1.02	.029
50.0	1.31	.026	1.47	.029	1.26	.025	1.39	.028
70.8	—	—	1.95	.028	1.53	.022	1.95	.028
100.0	2.38	.024	3.01	.030	—	—	2.71	.027

TABLE II

CONSTANT ERRORS BY WHICH THE VARIABLE WAS SET LARGER THAN THE STANDARD

Length of standard (mm.)	Experiment I (*N*=50)		Experiment II (*N*=50)		Experiment III (*N*=20)	
	Constant error (mm.)	Level of signif.	Constant error (mm.)	Level of signif.	Constant error (mm.)	Level of signif.
17.7	—	—	—	—	.4	5%
25.0	.5	1%	.6	5%	.7	1%
35.4	—	—	1.0	1%	.8	5%
50.0	.8	1%	1.4	1%	.8	—*
70.8	—	—	1.5	1%	1.4	5%
100.0	1.5	1%	1.6	5%	—	—

* Not significant at 5% level.

and states that such errors are inherently unavoidable in the method of adjustment.[5] On the other hand, Postman varied the time-interval between the presentations of standard and variable stimuli in judgments of loudness, and found that the size of the constant error increased with increasing time-interval with the method of constant stimuli but remained unaffected with the method of adjustment.[6] This finding casts some doubt on the validity of referring to constant errors found with the method of adjustment as 'time'-errors. Stevens observes that constant errors typically occur in quantitative but not qualitative judgments.[7] He proposes a 'cate-

[5] *Ibid.*

[6] Leo Postman, Time-error as a function of the method of experimentation, this JOURNAL, 60, 1947, 101-108.

[7] S. S. Stevens, On the psychophysical law, *Psychol. Rev.*, 64, 1957, 153-181.

gory effect,' based on *S*'s inability to discriminate equally well over the entire stimulus-continuum, to account for at least one source of systematic error in psychophysical judgements. Stevens, however, discusses this effect mainly in regard to category scaling-methods, and its relationship to the method of adjustment is not made clear.

Lacking an adequate ready-made explanation of the constant errors occurring in the present experiment, no attempt will be made here to construct one. The purpose of this paper is to present data on tactual-kinesthetic size-discrimination and not to analyze the peculiarities of the psychophysical method involved. It must, therefore, suffice to note that the constant errors in this instance lie in the direction of the variable stimulus being set consistently larger than the standard, and that the magnitude of the error increases with increasing size of the standard. The exact nature of this latter relationship must await further study. As was mentioned in the previous section, there is no evidence here to indicate that the constant error can be attributed to the differences between variable and standard stimuli with respect to relative distance from the body of *S*. This result is not interpreted as contradicting Bartley's findings, since the distances involved here were probably inconsequential.

Summary. A series of three experiments was performed in which *S*s were required to match a cylinder of variable length to a series of standards by spanning the stimulus-objects with the thumb and forefinger. The probable error of the distribution of settings about the mean was taken as the measure of differential discrimination. Conclusions drawn on the basis of the experimental results are as follows.

(1) The ratio of the magnitude of the variable error of judgment to the absolute length of the standard remains constant and thus verifies Weber's law in the 35-mm. to 100-mm. range of stimulus-length. Below 35 mm. the constancy of the ratio breaks down as the variable error approaches a lower limit and does not decrease further. This limit is interpreted as being the mean absolute threshold for the group that was studied.

(2) The variable stimulus was consistantly set larger than the standard, and the magnitude of this constant error increased with increasing length of the standard stimulus.