Difference threshold for stimulus length under simultaneous and nonsimultaneous viewing conditions¹

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The present study was concerned with Weber's Law as it is related to the discriminability of the lengths of lines. Experiments were conducted to investigate three questions: (1) Is Weber's Law equally applicable to simultaneous and nonsimultaneous viewing conditions? (2) Is the relationship between the stimulus sizes and the values of DLs described more adequately by the function proposed by Weber or a generalized Weber's Law stated by Miller? and (3) Is Weber's Law better approximated by proximal or distal size? It was demonstrated that the discriminability of the lengths of lines follows Weber's Law under the nonsimultaneous viewing condition, but not under the simultaneous viewing condition. Under the nonsimultaneous viewing condition, it was noted that the generalized Weber's Law as stated by Miller described the relationship between the DL and stimulus size significantly better than the function proposed by Weber. From the results pertaining to the third question, it was not possible to determine whether the proximal or the distal size follows Weber's Law more closely.

Investigations dealing with the difference thresholds (DL) for different stimulus lengths played a role in the inception of psychophysics. Following Weber's report (1849) on the applicability of "Weber's Law" (not then so labeled) to lengths of lines, Fechner (1860) conducted an experiment dealing with the discriminability of distances between two points and cited several similar experiments by Volkmann and Appel and one by Hegelmayer. Since that time there has been mild but continued interest in this topic (Henmon, 1906; Bühler, 1913; Kiesow, 1926; Veniar, 1948; Pheiffer, 1949). Notwithstanding the early beginnings and continued interest, there is room to explore further the problem of discriminability as a function of different sized objects, and that is the purpose of the present study.

A fact that emerges from the existing literature is that there is confusion concerning the conditions under which Weber's Law holds. Hence, the first question asked in this study attempted to clarify this confusion: Does Weber's Law apply equally to the discriminability of the lengths of lines under two different experimental conditions, the two experimental conditions being simultaneous viewing and successive viewing?

The difference between the simultaneous and successive viewing conditions was noted by Weber in his original paper, although not stated in these terms. Indeed, one needs to consult the original Weberian

account of his experiment, rather than the more remote descriptions of it, to find out what he actually did. The discrepancy arises from an unfortunate mistranslation (or printing error) in Benjamin Rand's *Classical Psychologists* (1912), doubtless the most commonly consulted English version of Weber. Freely, but carefully (!) translated, Weber says, "It makes no difference whether one compares lines that are about two inches or one inch long, if one examines first one, then the other, and cannot see both at once in juxtaposition. . . ." (the italics are mine). Rand left out the "nicht" that goes with "sehen" and thus seems to say that Weber investigated the simultaneous as well as the successive condition, which he did not. The error, not unnaturally, has been perpetuated in various secondary sources.³ What Weber found was that the range of Weber's fraction was 2% or less to 4% only under successive viewing conditions. Weber explicitly excluded the viewing conditions in which standard and comparison stimuli were presented parallel and close to each other as a condition in which Weber's Law holds.

In the present study, the two separate experimental conditions were set up in the following manner: In one of the conditions, the nonsimultaneous, the comparison and standard stimuli were presented in the same visual field at the same time, but the distance between them was sufficiently large so that the observer would not attend to both of them at the same time. In the other experimental condition, the simultaneous, the standard and comparison stimuli were presented in the same visual field but in close proximity so that the observer would attend to both stimuli at the same time.

The second question asked in this study was subsidiary to the first, and was concerned with the function which describes the relationship between the stimulus sizes and the values of the DLs. The function originally stated by Weber is of the form:

$$DL = ks \quad (1)$$

where the constant k is called Weber's fraction. There are, however, both empirical and rational reasons to doubt Weber's Law as thus stated. Fechner (1860) proposed, and Miller (1947) stated, a generalized Weber's Law as follows:

$$DL = ks + c \quad (2)$$

where k and c are constants. Miller has shown that

the above equation described the intensity discrimination of random noise much more accurately than does Equation (1). Also, a preliminary experiment conducted for this study indicated that discriminability of the altitude of a triangle also follows Equation (2). On rational grounds, Galanter (1962) pointed out that Equation (2) is more reasonable because it takes into account the existence of the absolute threshold. The second question asked, then, is: Does Equation (1) or Equation (2) better describe the relationship between the stimulus sizes and the values of the DLs?

Somewhat related to the second question is a third, namely: Is the DL a function of proximal size or of distal size? That is, does Weber's Law apply to the retinal image size or the visual angle which represents the measurement of stimulus at a receptor level or does it apply to the physical size which represents the measurement at the location of the stimulus? Given two ways of specifying size, it was asked which way is more adequate for predicting the value of the DL. This problem was investigated by presenting the same stimulus at different distances from the observer. This permitted different proximal sizes while using the same distal size of line and vice versa.

In order for the third question to have any meaningfulness, there has to be a different relationship between the "sizes" and the values of DLs when we specify the stimulus in terms of proximal and distal sizes. However, if Weber's Law, as originally stated by Weber, were correct, the DLs based on distal and proximal size would be approximately of the same magnitude. If the stimulus were placed at a greater distance from the observer, the visual angle subtended by the stimulus would decrease and, according to Weber's Law, so should the value of the DL in terms of visual angle.

However, if we assume that Equation (2) describes the values of the DLs for the lengths of lines, the prediction based on the proximal and distal sizes becomes quite different. That is, if the distal size predicts the values of the DLs, the DLs in terms of proximal size are not predictable unless we know the distances from which the judgments were made. Likewise, if the DL is a function of proximal size, the DLs in terms of distal size are not predictable unless we know the distance.

To recapitulate, three questions concerning the discriminability of lengths of lines were asked in this study. They were: (1) Is Weber's Law equally applicable to simultaneous and nonsimultaneous viewing conditions? (2) Is the relationship between the stimulus sizes and the values of the DLs more adequately described by the function proposed by Weber or a generalized Weber's Law stated by Miller? and (3) Is Weber's Law a function of proximal or distal size? These three questions constitute the core of this study.

METHOD

For the sake of easier description of the method, the nonsimultaneous and simultaneous viewing conditions will be described separately.

Nonsimultaneous Viewing Conditions

Stimulus material and apparatus. The standard stimulus was a black line on a 15 cm x 25 cm piece of white cardboard. The stimulus was made by pasting a strip of black engineering tape, 3 mm wide, on the piece of cardboard. The standard stimuli were of three different lengths: 5 cm, 10 cm, and 15 cm. The center of each line was always at the center of the piece of cardboard.

There were three sets of comparison stimuli. All the comparison stimuli were made in the same manner as the standard stimuli described above. One set of comparison stimuli consisted of 17 stimuli which varied in length from 3.4 cm to 6.6 cm; the second set of stimuli varied in length from 8.4 cm to 11.6 cm; and the third set varied in length from 13.4 cm to 16.6 cm. In all three sets the lengths differed in equal steps of 2 mm.

The apparatus consisted of a 65 cm x 75 cm rectangular display panel made of plywood. The panel was constructed so that an experimenter could place the centers of the standard and comparison stimuli at the approximate eye level of the observer when he placed his chin in the chin rest.

The stimulus was placed at three different distances from the observer, depending on the experimental condition. The three different distances were 1.5 m, 3.0 m, and 4.5 m. A chin rest was provided to control for exact distance between the stimuli and the observer. The distance between the standard and comparison stimuli was 20 cm, 40 cm, or 60 cm, also depending on the experimental condition.

The sizes of the standard stimuli in terms of visual angles subtended by the lengths of the lines at each of the distances were as follows for 5 cm, 10 cm, and 15 cm stimuli, respectively: at 1.5 m, $1^{\circ}54'36''$, $3^{\circ}49'6''$, and $5^{\circ}43'32''$; at 3.0 m, $57'14''$, $1^{\circ}54'36''$, and $2^{\circ}51'52''$; and at 4.5 m, $38'12''$, $1^{\circ}16'24''$, and $1^{\circ}54'36''$. The standard and comparison stimuli were presented without restriction of normal distance cues in all the experimental conditions.

Experimental design. The experiment consisted of 3 by 3 by 2 by 6 by 2 factorial system with the factors being:

(a) sizes (5 cm, 10 cm, and 15 cm). Each observer made judgments on three different sizes at one of three different distances. Thus, the data from different sizes at a given distance were correlated observations.

(b) distances of stimuli from the observer (1.5 m, 3.0 m, and 4.5 m).

(c) distances between the standard and comparison

stimuli [distal distance constant (DDC) condition, and visual angle constant (VAC) condition]. In the DDC condition the distance between the standard and the comparison stimuli was 40 cm at the three different distances. In the VAC condition, the visual angle separating the standard and the comparison stimuli was $7^{\circ}37'44''$ at three different distances. In terms of distal distance, 20 cm was used at 1.5 m, 40 cm at 3.0 m, and 60 cm at 4.5 m. It should be noted that when the stimuli were 3.0 m from the observer, the DDC and VAC conditions were actually the same condition.

(d) the side (left or right of the standard stimulus) to which the comparison stimulus was presented.

(e) order of presentation (six permutations of three different sizes).

Factors (d) and (e) are connected with experimental technique, and, thus, are not of direct interest. Only the analysis of other factors ((a) to (c)) are reported in the following result section.

Procedure. When the observer was seated in front of the chin rest, the following instructions were read:

"You will be shown two black lines. You are asked to judge the length of the left line (or right line) in terms of the length of the right line (or left line). That is, your task is to tell me whether the left line (or right line) is *equal* to or *shorter* or *longer* than the right line (or left line). When you are uncertain about your judgment, or when you cannot tell whether it is equal to, longer, or shorter, give 'equal' as your answer. Make your judgment as soon as you can after you see the lines."

As soon as the instructions were given, every aspect of the instructions was elaborated on, and any questions related to the procedure asked by the observer were answered. He was then asked to use the chin rest while making his judgments. Following this, eight serial explorations on one of the three standard lengths were given. The standard stimulus was on the display panel during the total time the eight serial explorations were presented.

Between the first and second and between the second and third sets of serial explorations the observer was given a rest period of 5-10 min. to break the monotony. When the third set was finished, the observer was asked how he had made his judgments and, after his answer, the purpose of the experiment was explained to him.

The method of limits procedure employed in this experiment differed from the conventional one in one respect. In this study, the experimenter maintained an ascending series until three "larger" responses were given in sequence (and a descending series until three "smaller" responses were given in sequence) before going on to the next serial exploration.

The rule for defining a threshold in this study was as follows: In a descending series, the first shift from "larger" to "equal" or "smaller" was defined as an upper threshold, and the last shift from "equal"

or "larger" to "smaller" was defined as a lower threshold. Similarly, in an ascending series, the first shift from "smaller" to "equal" or "larger" was defined as a lower threshold and the last shift from "equal" or "smaller" to "larger" was defined as an upper threshold. The exact numerical value assigned as the threshold was the midpoint values of two comparison stimuli where the shift took place.

The reason for deviating from the conventional method of limits was that the method described above yielded an interval of uncertainty which was felt to be a reasonable one. The argument here was that when an observer's responses fluctuated from "equal" to "smaller" or "larger," it was more appropriate to think of these initial changed responses as being in the interval of uncertainty. Except for this change, all the other procedures of the conventional method of limits were followed.

Observers. Sixty Stanford undergraduates, 40 males and 20 females, participated in the experiment to partially fulfill a requirement of the introductory psychology course. When the observers signed for the experiment they were informed only that the task involved size estimation. Otherwise all the observers were naive concerning the purpose of the experiment.

Simultaneous Viewing Conditions

Stimulus material and apparatus. The standard and comparison stimuli were like the black lines used in the nonsimultaneous viewing condition. There were three standard lengths, 5 cm, 10 cm, and 15 cm. The differences between the stimulus material in the two viewing conditions were in the lengths of comparison stimuli employed and the way in which the lines were placed on the 15 cm x 25 cm piece of white cardboard.

In this viewing condition both the standard stimulus and one of the comparison stimuli were placed on the same piece of cardboard. One set of stimuli consisted of 17 pieces of cardboard, and on each piece of cardboard were two lines, of which one was the 5 cm standard stimulus and the other was one of the 17 comparison stimuli. The lengths of comparison stimuli varied from 4.9 cm to 5.1 cm. In the second set of 17 stimulus cards each piece of cardboard had the 10 cm stimulus and one of the 17 comparison stimuli. The lengths of the comparison stimuli varied from 9.9 cm to 10.1 cm. In the third set of 17 stimulus cards each piece of cardboard had the 15 cm standard stimulus and one of the 17 comparison stimuli. The length of the comparison stimuli varied from 14.9 cm to 15.1 cm. In all three sets, the lengths of the comparison stimuli varied in equal steps of 0.125 mm. The center of each line was always equidistant from the bottom and the top of the cardboard.

The way the stimulus material was constructed was quite different from the nonsimultaneous viewing condition. Because the differences in length between

the adjacent sides were so minute, it was not possible to make them manually. The pair of lines was constructed eight times larger than the desired size, then reduced photographically to the desired size. When the photograph was reduced the width of each line was 3 mm.

The distance separating the standard and comparison stimuli were 1 mm, 2 mm, or 3 mm depending on the experimental condition.

The other details of the stimulus material and the apparatus were identical to the nonsimultaneous viewing condition.

Experimental design. The experimental design for this viewing condition was almost identical to that of the nonsimultaneous viewing condition. The experiment consisted of a 3 by 3 by 2 by 6 by 2 factorial system with the factors being: (a) size, (b) distance of the stimuli from the observer, (c) distance between the standard and comparison stimuli, (d) the side on which the comparison stimulus was presented, and (e) order of presentation. For factor (c) there are slight variations from the nonsimultaneous viewing condition. In the DDC condition the distance between the standard and comparison stimuli was 2 mm at the three different distances. In the VAC condition the visual angle separating the standard and comparison stimuli was 2'18" at three different distances. In terms of distal distance, 1 mm was used at 1.5 m, 2 mm at 3.0 m, and 3 mm at 4.5 m.

Procedure. The procedure followed was identical to that of the nonsimultaneous viewing condition, except for the way in which the stimulus material was presented. In this condition both the standard and comparison stimuli were changed for each presentation.

Replication. When the results were obtained and the preliminary computations on the mean values of DLs were done, it was found that the difference between the VAC and DDC conditions at 1.5 m was not readily obvious. Although not statistically significant, the DL values were slightly smaller for the DDC condition, despite the fact that the distances between the stimuli were larger. Therefore, the two experimental conditions were repeated.

However, upon examination of the results of the replications, it appeared that the results originally obtained were fairly reliable. Thus, in the following results section the data from the original and replication experiment are combined, making the sample size of the two conditions both 24.

Observers. Eighty-four Stanford undergraduates, 62 males and 22 females, were selected from 109 who volunteered for the experiment to partially fulfill a requirement in the introductory psychology course. When the volunteers signed up for the experiment, they had the same information concerning the experiment as had those in the nonsimultaneous viewing condition. When a volunteer arrived for the experiment, he or she was first tested on his acuity by three pieces of cardboard with 5 cm and 5.1 cm

stimuli; 10 cm and 10.1 cm stimuli; and 15 cm and 15.1 cm stimuli, respectively. These pieces of cardboard were presented individually at 4.5 m from the volunteer. The experimenter asked the volunteer to identify the longer line. If the volunteer was able to identify the longer ones correctly for the three stimulus cards, he was used as an observer in the experiment.

RESULTS AND DISCUSSION

From the foregoing description of method it is clear that the values of DLs obtained under simultaneous viewing conditions do not represent the average values of the general population (not even the average values for the college population). Fortunately, however, the experiment gave a clear answer to the first question asked in this study: "Is Weber's Law equally applicable to simultaneous and nonsimultaneous viewing conditions?"

The mean DL values for each stimulus size in terms of both distal size and proximal size (visual angle) are presented in Tables 1 and 2. Table 1 presents the results from the nonsimultaneous viewing conditions and Table 2 the simultaneous viewing conditions. Also included in Tables 1 and 2 are the percentages of observers for whom Weber's Law applied. The criterion used was: If an observer gave the largest DL value for the 15 cm stimulus and the smallest DL value for the 5 cm stimulus, then Weber's Law was applicable to that observer.

An examination of Tables 1 and 2 indicates that the results of the simultaneous viewing conditions are quite different from the results obtained in the nonsimultaneous viewing conditions. Table 1 shows that, under the nonsimultaneous viewing conditions, Weber's Law applied not only to the group of observers, but also to each single observer. The mean DL values increased with an increase of the stimulus size as predicted from Weber's Law, and the percentages of observers for whom Weber's Law applied

Table 1. Mean DL in mm and min. and sec. of angle and percentage of observers for whom Weber's Law applied under the nonsimultaneous viewing condition

		Distances and Viewing Condition			
		1.5 m		3.0 m	
Stimulus size		VAC		VAC	
		DDC		DDC	
5 cm		1.86 mm	2.35 mm	2.39 mm	2.51 mm
		(4'20")	(5'22")	(2'46")	(1'56")
10 cm		2.83 mm	3.68 mm	3.82 mm	3.73 mm
		(6'26")	(8'24")	(4'24")	(2'53")
15 cm		3.24 mm	5.10 mm	5.55 mm	5.03 mm
		(7'22")	(11'40")	(6'20")	(3'52")
Mean		2.64 mm	3.71 mm	3.92 mm	3.76 mm
		(6'3")	(9'3")	(4'30")	(2'54")
% of observers		58%	100%	100%	92%

Table 2. Mean DL in mm and sec. of angle and percentage of observers for whom Weber's Law applied under the simultaneous viewing condition

	Distances and Viewing Condition				
	1.5 m		3.0 m		4.5 M
	VAC	DDC	VAC DDC	VAC	DDC
Stimulus size					
5 cm	.168 mm (23.2'')	.154 mm (19.8'')	.228 mm (15.8'')	.413 mm (18.6'')	.301 mm (14.0'')
10 cm	.189 mm (26.2'')	.179 mm (24.8'')	.214 mm (14.8'')	.427 mm (19.9'')	.340 mm (15.8'')
15 cm	.168 mm (23.2'')	.172 mm (23.6'')	.225 mm (15.8'')	.423 mm (19.5'')	.355 mm (16.6'')
Mean	.175 mm (24.2'')	.168 mm (22.7'')	.222 mm (15.4'')	.421 mm (19.3'')	.332 mm (15.5'')
% of observers	13%	21%	17%	33%	25%

were unquestionably higher than the chance level of 17%.

However, under the simultaneous viewing conditions, not only are the DL values obtained much smaller, but also Weber's Law does not hold for any of the five conditions. The mean DL values did not increase with an increase of the stimulus size as predicted from Weber's Law, and the percentages of observers for whom Weber's Law applied were near the chance level of 17%. Thus it is quite clear that Weber's Law does not apply under the simultaneous viewing condition.

It should be emphasized that the term "simultaneous" is defined from the observer's point of view. Although the label of "nonsimultaneous" was given to one of the viewing conditions, by general experimental convention the first condition could be called simultaneous. In the nonsimultaneous viewing condition the standard and comparison stimuli were presented together in front of the observer. Furthermore, both stimuli were in the same visual field. Because the observer selectively attended to one stimulus at a time, however, the label of nonsimultaneous was given.

The other viewing condition was simultaneous in that the observer attended to both lines at the same time. However, the statement that the observer attends to both lines can be misleading. The post experimental interview revealed that the observers directed their attention to the ends of the stimuli in order to make their judgments. That is, although attention was given to both lines simultaneously, attention was not given to the entire length of the stimuli. In this situation the length of the lines was irrelevant information for discrimination.

The results suggest that entirely different perceptual processes are involved in the two experimental situations. In the nonsimultaneous viewing condition the observer had to code the length of one of the stimuli and compare the coded information with the per-

ception of the other stimulus. That is, the length of the line was the critical information for discrimination. In the simultaneous viewing conditions, the critical information for discrimination was the angular displacement subtended by the difference in lengths of two lines at both ends of the stimuli. Consequently, the task became very similar to that used in measuring acuity.

Viewing the results as those of an acuity task, one point should be mentioned. The values of the DLs in terms of visual angle obtained under the VAC and DDC conditions at 1.5 m are larger than the DL values obtained in the other three conditions ($t=3.85$, $df=82$, $p<.001$). But it is very likely that the results obtained are an artifact of the experimental procedure. The gradation of the comparison stimuli was not fine enough, at the 1.5 m distance, to obtain an accurate estimate of the DLs. If the observer was correct in all his responses, the DL values would be .125 mm because the comparison stimulus next to the "equal" comparison stimulus had a difference of .125 mm. In effect, the procedure placed a limit on the possible values of the DLs which were within the range of discriminability for some observers at the distance of 1.5 m. That is, even if an observer could discriminate better than .125 mm at a 1.5 m distance, the procedure did not allow this to be reflected in the results.

Let us now examine the results obtained under the nonsimultaneous viewing conditions. An examination of Table 1 reveals that the DL values obtained for the VAC condition at 1.5 m were at variance with the four other conditions. Looking at the percentages of observers for whom Weber's Law applied, we see that the VAC condition at 1.5 m gave the smallest percentage. The percentage for this group was 58%, but the percentage computed for the other four groups was 98%. Also, the mean value of the three DLs from the VAC condition at 1.5 m is different from the mean value of the DLs for the four other groups combined. The mean for the VAC condition at 1.5 m is 2.64 mm, and for the four other conditions combined the mean is 3.89 mm. The difference of 1.25 mm yielded a t value of 2.43 ($df=58$) which is significant at the .02 level.

From the above finding it appears that the VAC condition at 1.5 m is different from the four other conditions. The reason for the difference may be due to the manner in which the observers made their judgments. No record of the post experimental interview was taken, but the experimenter recalls that almost half of the observers reported that in this 1.5 m condition they tried to fixate between the standard and comparison stimuli and then make their judgment. This fact indicates that at least some of the observers in the VAC condition at 1.5 m did not meet the experimental requirement that they view the stimuli nonsimultaneously.

If this ad hoc interpretation of the lack of appli-

cability of Weber's Law for the VAC condition at 1.5 m is correct, the question can be raised as to why the same kinds of results were not obtained under the DDC condition at 4.5 m and under the VAC condition at 3.0 m and 4.5 m. The visual angles subtended by the distance between the two stimuli in the VAC condition at 3.0 m and at 4.5 m are the same as the visual angle subtended in the VAC condition at 1.5 m. Furthermore, the visual angle subtended by the distance between the two stimuli in the DDC condition at 4.5 m is smaller. Given these facts, one might expect the observer under these conditions to view the two stimuli simultaneously. The reason this did not occur can be attributed to the Aubert-Förster phenomenon which states: "Smaller near objects can be distinguished over a larger portion of the retina than larger more distant objects that subtend the same visual angle" (English & English, 1958).

In this present experiment, it is argued that attention can be given to a greater visual angle for objects at a close distance than for objects at a great distance. Owing to the closeness of the stimuli to the observer in the VAC condition at 1.5 m, the two stimuli were viewed simultaneously. Accordingly, this argument was used as a premise in an attempt to answer the two subsidiary questions in this study. Thus, the VAC condition at 1.5 m was not included in the subsequent analysis.

The exact functions computed from the mean DLs were as follows: In terms of distal size, the function was

$$DL \text{ (mm)} = .293X + .927 \quad (3)$$

where the unit of X is in cm. In terms of proximal size, the function was

$$DL \text{ (sec.)} = 1.919X + .858 \quad (4)$$

where the unit of X is in degrees.

The above functions were computed from nine data points (three sizes at three different distances) which are represented in Table 3 and Fig. 1. The nine data points were obtained in the following way: At a distance of 1.5 m the VAC condition is eliminated for the reason discussed above. Therefore, the data points used for the 1.5 m distance are those of the DDC

Table 3. Mean DL in mm and min. and sec. of angle for three different distal sizes at three different distances under the nonsimultaneous viewing condition

	Distances		
	1.5 m	3.0 m	4.5 m
5 cm	2.35 mm (5'22")	2.39 mm (2'46")	2.54 mm (1'58")
10 cm	3.68 mm (8'24")	3.82 mm (4'24")	3.89 mm (2'58")
15 cm	5.10 mm (11'40")	5.55 mm (6'20")	5.44 mm (4'11")

Fig. 1. Mean DL in mm as a function of distal size and mean DL in min. as a function of proximal size.

condition at 1.5 m. For the 4.5 m distance, the data obtained from the DDC and VAC conditions were combined. Thus, the data points for 4.5 m were computed from the 24 observers.

In relation to the second question asked in this study, it should be noted that Equation (3) and Equation (4) are both of the form of a generalized Weber's Law rather than the function proposed by Weber. This can be considered as further support to the generalized Weber's Law stated by Miller (1947). The statistical support for this notion was attained by first assuming linearity of the DL values associated with the stimulus sizes. A best-fit line describing the relationship between the values of DLs and the stimulus sizes was computed for each observer. Then, the mean y intercept for 48 observers was computed and was tested as to whether the observed mean deviated significantly from zero. In terms of distal size, the mean y intercept was .939 which yielded a t value of 5.73 (df=47, $p < .001$), which is highly significant. In terms of proximal size, the mean y intercept was 1.172 which yielded a t value of 5.59 (df=47, $p < .001$), which is also highly significant.

The extent to which one should generalize Weber's Law for discriminability of the lengths of lines even under the nonsimultaneous viewing conditions must be noted. It should be remembered that the lengths of lines employed in the experiment were relatively limited, and for shorter or longer lines the above conclusion may not hold. There are numerous studies that show Weber's Law does not hold at low intensity stimuli, and often does not hold at high intensity stimuli. As a result of these findings, it has been customary to say that Weber's Law is correct, but only in the middle ranges of intensity (Boring, 1942). The same sort of results has been obtained for the lengths of lines (Kiesow, 1926). However, it is possible that Weber's Law would apply for all ranges in a rough sense. It might be the case that there is always a diminishing DL value with a decrease in the length

of line, since this is true of other types of stimuli.

Two schemes of statistical analysis were used in an attempt to answer the third question asked in this study: "Is Weber's Law a function of distal or of proximal size?" One scheme was to compare the degree of association between the stimulus sizes and the values of the DLs. That is, the correlation coefficient between the distal sizes and their DLs was compared with the correlation coefficient between the proximal sizes and their DLs. The notion was that if one of the correlations was significantly higher, it could be concluded that the corresponding method of specifying the size, i.e., the distal or the proximal, is the better method to use in predicting the values of DLs.

The second scheme was to examine the values of the DLs where the sizes of the stimuli were the same but at different distances from the observer. In terms of distal size, the 5 cm, 10 cm, and 15 cm stimuli were presented at three different distances. In terms of proximal size, the stimuli that subtended the visual angle of $1^{\circ}54'36''$ were the same sizes under the three different distances; i.e., the 5 cm stimulus at 1.5 m, the 10 cm stimulus at 3.0 m, and 15 cm stimulus at 4.5 m. If the values of the DLs in terms of the proximal sizes at three different distances were statistically different, and if the values of the DLs for the three distal sizes at three different distances were not, then it would imply that generalized Weber's Law is a function of distal size. Conversely, if the values of the DLs in terms of distal sizes were statistically different, and if the values of the DLs for the $1^{\circ}54'36''$ stimuli at three different distances were not, it would imply that generalized Weber's Law is a function of proximal size.

The two schemes of analysis did not allow any conclusion to be made. The correlation coefficient between the distal sizes and their DLs was .994, and the correlation coefficient between the proximal sizes and their DLs was .993 (see Fig. 1). Needless to say, these two correlations are not statistically different.

To analyze the data according to the second scheme, a one-way analysis of variance was performed on the values of the DLs for each of four different "same" sizes. The F values for the 5 cm, 10 cm, and 15 cm stimuli were .13, .05, and .11 ($df=2/45$), respectively, which are not statistically significant. The F value for the stimulus size of $1^{\circ}54'36''$ was 1.26 ($df=2/45$) which is also not significant.

The analysis indicates that a conclusion cannot be made as to which method of specifying the sizes of the stimuli would better predict the values of DLs. Or, looking at the results in a more positive fashion, it might be said that, because of the high correlations obtained, both the distal size and the proximal size predict the value of DL equally well, and that observers are responding not in terms of distal or proximal sizes, but somewhere between the two.

Examination of Table 3 reveals that, on the one hand, in terms of distal size, the DLs for each stimulus size systematically increased with increasing distance (except for the 15 cm stimulus). This would be expected if generalized Weber's Law is a function of proximal size. On the other hand, in terms of proximal size, the DLs for the $1^{\circ}54'36''$ stimuli decreased with the increase in distance, which would be expected if generalized Weber's Law is a function of distal size. Thus, it is possible that the observers' responses are analogous to the compromise of the distal and proximal sizes noted in the early size constancy research (Thouless, 1931; Brunswick, 1933).

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Notes

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2. Now in the Department of Psychology, University of Hawaii.
3. Indeed, it was when the author of one of these, *The Human Senses*, was questioned concerning the discrepancy, that the source of confusion came to light. I am indebted to Professor Geldard for having searched it out. He also notes that histories of psychology have been similarly influenced; a case in point is Murphy's *Historical Introductions* (1930, p. 83).

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