Distance judgments under different size-information conditions*

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Seventy-two Ss judged the absolute distance of a target presented without distance cues other than retinal size and assumed size. The method by which E communicated information about the size of a 3-in. target had a significant effect on the magnitude of the discrepancy between judged distance and the perceived distance required by the size-distance invariance hypothesis. In order of increasing effectiveness in producing distance judgments meeting invariance requirements were: size information in the form of verbally communicated metric units, size information communicated by labeling the target with the name of a familiar object, and size information in the form of a visual representation.

According to the size-distance invariance hypothesis, judgments of the absolute distance of a target under completely reduced conditions can be made on the basis of information about the size of the target (Epstein, Park, & Casey, 1961). Coltheart (1970) has summarized evidence that distance judgments are affected by size information, regardless of the manner in which this information is communicated to S—whether by means of a visual representation (Gogel & Mertens, 1967), by means of a verbal statement of size in metric units, e.g., “1½ in. in height” (Coltheart, 1970), by giving the target the name of a familiar object, e.g., “foot ruler” (Baird, 1963), or by means of a haptically presented comparison object (Coltheart, 1969). Distance judgments based on size information of whatever kind are typically highly variable and conform only roughly to the requirements of the size-distance invariance hypothesis (Coltheart, 1970; Epstein, Park, & Casey, 1961). Variation in amount of deviation from invariance-hypothesis requirements may reflect variation in the specificity of the information about target size communicated to the S in different ways.

One purpose of the present experiment was to compare the amount of deviation from invariance-hypothesis requirements produced by each of several methods of communicating size information when these methods are all employed in the same experimental situation. A second purpose was to explore the extent to which the high variability of distance judgments might be attributed to the use of verbal estimates as the response indicators of perceived distance. Ss may be expected to differ from one another in their concepts of the sizes of feet and inches. In the present experiment, each S was asked to respond to the target under reduced conditions by making a magnitude estimation in feet and inches; later, in a full-cue situation, each S was given the magnitude estimation he had previously made and asked to mark off a distance

which appeared equal to the previously estimated distance. For purposes of data analysis, it was assumed that marked-off distance represented what each S meant when he said that the target was at a particular distance.

METHOD

Subjects

Thirty-six men and 36 women volunteered to participate in the experiment in order to fulfill a class requirement for introductory general psychology. All Ss were naive with regard to the purpose of the experiment.

Apparatus

A blank electroluminescent disk with a diameter of 3.81 cm was presented in a light-tight tunnel, 182.88 cm from a monocular viewing port. The disk was the only object visible against a completely dark background. The apparatus eliminated all cues to the distance of the disk except image size and accommodation. Accommodation was assumed to be ineffective as a distance cue for two reasons: (a) In spite of the availability of accommodation as a distance cue, judged distance did not vary as a function of physical distance in a similar experimental situation with visual angle constant for seven target distances ranging from 25 to 395 cm (Künnapas, 1968; Epstein & Landauer, 1969). (b) Lenses placing the targets at optical infinity had no significant effect on size or distance judgments in a replication of the Epstein-Landauer experiment done under the direction of the first author and employing the experimental apparatus used in the present experiment.

For the purpose of conveying size information by visual representation, each of a pair of photographic transparencies, 3.81 cm in diam, could be placed immediately in front of the electroluminescent disk.

Procedure

To prevent Ss from forming an impression of the size of the experimental room and hence of the possible range of distances of the target, each S was led blindfolded by a roundabout route from a student lounge to the experimental room and was not permitted to remove his blindfold until seated in front of the apparatus in the darkened experimental room.

The S was asked to look into the light-tight tunnel with his preferred eye and was asked to estimate the distance from himself to the target in feet and inches. Prior to making his estimate, he was given information about the size of the target. Information about target size was communicated by one of three different methods. Under the metric size (MS) condition, the S

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Table 1
Means and Standard Deviations of Untransformed Values of
Verbal Estimates and Magnitude Productions

Condi- tion	Verbal Estimate (Feet)		Magnitude Production (Feet)		Expected Value (Feet)
	Mean	SD	Mean	SD	
MS,S	8.00	13.64	9.91	17.81	6
MS,L	6.67	5.16	9.23	7.16	12
FO,S	5.75	4.83	6.58	4.67	6
FO,L	36.58	46.56	36.02	40.63	12
PT,S	6.50	4.17	7.07	4.53	6
PT,L	14.17	6.01	13.69	7.12	12

was told that the electroluminescent disk had a certain diameter. Half of the Ss in the MS condition were told that the diameter was 1½ in.; the other half were told that the diameter was 3 in. Under the familiar object (FO) condition, each S was told that the target was the same size as a familiar object. Half of the Ss were told that it was the same size as a golf ball; the other half were told that it was the same size as a baseball. Under the photographic transparency (PT) condition, the S was exposed to a transparency fixed over the electroluminescent panel. For half of the Ss, the transparency was of a golf ball, and created the effect of a golf ball suspended in space. For the other half of the Ss, the transparency was of a baseball, and created the effect of a baseball suspended in space. Since golf balls are normally 1½ in. in diam and baseballs are normally 3 in. in diam, each method of communicating information about target size had two subconditions—one of which was intended to create the assumption that the target was 1½ in. in diam (Size Condition S), and the other of which was intended to create the assumption that the target was 3 in. in diam (Size Condition L).

The assignment of Ss to method of communicating size information was in the order of Ss' arrival, following an ABCBA sequence of conditions. The Ss were alternately assigned to the "large" or "small" size condition within each instructional condition. In order to equate the number of men and women assigned to each of the treatment conditions, a separate sequence of conditions was maintained for each sex, and each S was assigned to the appropriate sequence upon arrival.

After making a verbal estimate of distance, S was asked to put his blindfold back on and was led from the experimental room to a fully lighted hallway located at the opposite end of the building, where he was allowed to remove the blindfold. The S was reminded of the distance estimate he had made in the experimental room and was asked to mark off along the floor of the hallway a distance which appeared to him to be equal to the distance he had estimated. A piece of masking tape was placed on the floor of the hallway to indicate one limit of this distance, and E stood next to the tape. The S was instructed to walk away from the tape until he reached a point at which the distance from himself to the tape appeared equal to the estimated distance. At that point, S placed a second piece of tape. Then S was encouraged to move about at will until he was completely satisfied with the distance he had marked off. The distance between the tapes, as measured by E, gave the value of S's magnitude production.

RESULTS

In Table 1 are entered mean verbal estimates, mean magnitude productions, and the distance judgments required by the size-distance invariance hypothesis for the size information given to S. The Pearson coefficient of correlation between verbal estimates and magnitude productions was +.95 ($p < .005$, $df = 70$). (For

Condition MS, the correlation was +.95; for Condition FO, it was +.93; and for Condition PT, it was +.96.)

For targets subtending a constant visual angle, the size-distance invariance hypothesis requires that increases in assumed size be accompanied by corresponding increases in judged distance. An examination of Table 1 reveals that magnitude productions were generally larger under the "large" than under the "small" assumed size condition. To determine the significance of the observed effect of assumed size, magnitude productions were subjected to an analysis of variance. It was found that assumed size had a significant effect on judged distance [$F(1,66) = 7.11$, $p < .01$]. Method of communicating size information did not have a significant effect. Because the interaction was significant [$F(2,66) = 2.93$, $p < .05$], a test for simple main effects was made and revealed that assumed size had a significant effect under Conditions FO and PT but not under Condition MS.

Table 1 indicates that invariance requirements were met more closely under some instructional conditions than under others. Under Condition PT, magnitude productions conformed closely to the required values, while under Condition FO, magnitude productions greatly exceeded invariance requirements for the "large" size condition. To determine whether method of communicating size information had a significant effect on amount of deviation from invariance requirements, an analysis of variance was performed on signed discrepancy scores. Each discrepancy score was the algebraic value of the difference: S's magnitude production minus the distance required by the invariance hypothesis for the size condition to which S had been assigned. An analysis of variance of algebraic discrepancy scores revealed that only the interaction was significant [$F(2,66) = 4.23$, $p < .05$]. A test for simple main effects revealed that only under Condition FO did assumed size have a significant effect on the magnitude of the deviation from invariance requirements. The effect of instructional condition was significant only under the "large" size condition (see Fig. 1). For the "large" size condition, individual comparisons among mean algebraic discrepancy scores revealed that Condition FO produced significantly larger deviations from invariance requirements than did Conditions MS and PT. The mean discrepancy score for Condition MS was not significantly different from the mean discrepancy score for Condition PT.

Because error may be expected to be proportional to the virtual distance being judged (the distance required by the invariance hypothesis for a particular assumed size), an analysis was made of proportional algebraic discrepancy scores. Each score was the decimal value of a fraction, the numerator of which was the algebraic value of S's magnitude production minus the invariance requirement, and the denominator of which was the invariance requirement.

An analysis of variance of proportional algebraic

discrepancy scores produced virtually the same results as the analysis of raw discrepancy scores, indicating that the obtained effects exceeded those which could be attributed to proportionality. As with raw discrepancy scores, only the interaction was significant [$F(2,66) = 3.32, p < .05$]. Assumed size had a significant effect only under Condition FO, while instructions had a significant effect only under the "large" size condition. Under the "large" size condition, the mean for Condition FO was significantly different from the means for Conditions MS and PT, but the mean for Condition MS was not significantly different from the mean for Condition PT.

To determine whether method of communicating size information had a significant effect on absolute error, an analysis of variance was performed on absolute discrepancy scores, which were obtained by taking the absolute value of the difference between each magnitude production and the score predicted by the invariance hypothesis. Each discrepancy score, X , was subjected to a logarithmic transformation to yield a transformed score, X' , such that $X' = \log_{10}(X + 1)$. The analysis of variance of the transformed discrepancy scores showed that the effect of method of conveying size information was significant [$F(2,66) = 3.29, p < .05$], as was the effect of assumed size [$F(1,66) = 10.23, p < .01$]. Because the interaction was also significant ($F = 7.48, p < .01$), a test for simple main effects was made and revealed that the assumed stimulus size had a significant effect only for Condition FO. The effect of method of conveying size information was significant only when the assumed size of the target was large ($F = 9.58, p < .01$). For the "large" size condition, the mean for Condition FO was significantly different from the means for Conditions MS and PT, but the mean for Condition MS was not significantly different from the mean for Condition PT.

DISCUSSION

The results of the analyses of variance suggest that certain kinds of size information can be used more effectively than others when judgments of distance are required. Assumed size did not have a significant effect on magnitude productions under Condition MS, while it did have a significant effect under the other two instructional conditions. From the observed means for Condition MS, it appears that Ss may not utilize metric size information at all in making distance judgments; there was no noticeable difference between distance judgments made by Ss told that the target was 1½ in. in diam and distance judgments made by Ss told that the target was 3 in. in diam. (Metric size information might be more effective for larger ratios of assumed size to virtual distance; the metric size values employed in the present experiment were close to the values employed by Coltheart, 1970.)

Mean judged distances under Condition MS were very

Fig. 1. Logarithms of the means of untransformed magnitude productions for three sources of information about target size, with one mean for large assumed size and one mean for small assumed size for each source of size information.

close to the actual physical distance (1.83 m) of the target. Since there is no evidence of the operation of residual distance cues under either Condition FO or Condition PT, it appears likely that the results under Condition MS may be attributed to the "specific distance tendency" (Gogel, 1969), which is a tendency to perceive an object as being at a specific distance, generally ranging from .5 to 2 m, with this specific distance being independent, in general, of retinal size.

Assumed size had a significant effect on judged distance under Conditions FO and PT. For the "large" assumed size, Condition PT produced significantly less deviation from invariance requirements than did Condition FO. That is, showing S a photographic transparency of a baseball produced significantly less deviation from invariance requirements than telling S that the target was the same size as a baseball. On the other hand, there was no significant difference between Conditions PT and FO for the "small" assumed size, the golf-ball size. Distance judgments of the golf ball were relatively close to invariance requirements under both instructional conditions. Under Condition FO (but not under Condition PT), distance judgments of the baseball deviated significantly more from invariance requirements than did distance judgments of the golf ball. These findings may be attributed to the ambiguity of the verbal label "baseball." Baseballs commonly come in hardball and softball sizes, while golf balls have a standard size. Hence, the verbal label "baseball" is more ambiguous than the verbal label "golf ball," and may well be more ambiguous than a photograph of a baseball, which may contain cues to the size of the ball, such as the ratio of the size of the stitches to the size of the ball.

The ambiguity of the term "baseball" may be responsible for the direction of the error obtained for the large assumed size under Condition FO. If a sufficient number of Ss assumed that the target was the same size as a softball, mean distance judgments would have been larger than those predicted for the 3-in. hardball. To evaluate this possibility, 23 students in a general psychology class (different from the one from which Ss were drawn for the original experiment) were asked to give verbal estimates in inches of the diameters of a baseball and a golf ball, without being shown either ball. The mean estimated diameter of a baseball was 4.14 in. ($SD = 1.38$ in.), which would require a perceived distance of 16.59 ft for the visual angle subtended by the target in the light-tight viewing tunnel. This required perceived distance still falls short of the mean judged distance of 36.02 ft obtained under Condition FO "large." (The mean estimated diameter of a golf ball was 1.90 in. ($SD = .67$), which would require a perceived distance of 7.61 ft.)

There is insufficient evidence to draw a conclusion about the role of overestimation of baseball size in producing deviations from invariance requirements. One problem is that judgments of size and distance were not obtained from the same Ss. What is required is a replication of the present experiment, in which Condition FO Ss would themselves make size judgments in response to the verbal labels "golf ball" and "baseball." In addition to verbal estimates, size judgments by the method of magnitude production should be obtained, since the results for Condition MS of the present experiment suggest that a S's possession of metric size information about golf-ball- or baseball-sized objects does not provide a good basis for predicting the S's distance judgments.

According to Coltheart (1970), the high variability of distance judgments made in response to verbal size information may be attributed to individual differences in the way in which Ss use verbal estimates to describe apparent distance. However, the present experiment produced high correlations between verbal estimates and magnitude productions, indicating that Ss can make a precise use of verbal estimates to describe apparent distance. (The Ss' ability to use metric distance information effectively is puzzling in view of their inability to use metric size information effectively; possibly involved is the fact that distance magnitudes in the present experiment were relatively large and the ratios of assumed size to virtual distance relatively small.) A further objection to Coltheart's hypothesis is that the standard deviation of verbal distance estimates obtained in the present experiment varied from 4.17 for

Condition PT "small" to 46.56 in. for Condition FO "large." This suggests that a large portion of the variability of verbal estimates must be attributed to something other than the method of making distance judgments. Even though Ss employed the same method of making distance judgments under all instructional conditions, the mean absolute discrepancy score (which reflects variable error in magnitude productions) increased significantly from 4.13 in. under Condition PT "large" to 29.62 in. under Condition FO "large," suggesting that the factor significantly affecting variability of distance judgments is the usefulness of the size information provided under the different instructional conditions.

The results of the present experiment require a qualification of Coltheart's (1970) contention that size information, however obtained, can be used in making judgments of distance. At least in certain experimental situations, Ss are not able to utilize size information in the form of verbally communicated metric units. Size information in the form of the names of familiar objects is more effectively utilized, but yields highly variable distance judgments. Size information in the form of visual representations yields distance judgments which are the least variable and which conform most closely to invariance-hypothesis requirements.

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