TABLE 4

Analysis of Variance of Trials to Criterion for Groups Making Within-Dimension Shifts

| Source | $df$ | $MS$ | $F$ |
|---|---|---|---|
| Type of within-dimension shift (S) | 1 | 1.049 | 6.213* |
| Color-shape task (C) | 1 | 0.265 | 1.571 |
| S × C | 1 | 0.122 | |
| Within groups | 44 | 0.169 | |
| Total | 47 | | |

Note.—Transformed scores [log $(1 + X)$] used.
* $p < .05$.

carried out. This was accomplished in a separate 2 × 2 analysis of variance, using the transformed scores (log $1 + X$). The two variables present (see Table 4) were: (*a*) type of WDS, and (*b*) color-shape task. The essential comparison was that for the type of WDS. This comparison was significant, indicating (Tables 2 and 4) that Groups 2 and 6, which only made WDSs, learned quicker than Groups 1 and 5, which made both WDSs and RRs.

The data suggest that what appears to be the facilitating effects of RRs results from their always involving WDSs. There are further indications that RRs actually retard learning as compared to WDSs.

The results from the present experiment also permit us to answer a question basic to the nature of WDSs and of importance in concept formation. That is, if WDS lead to facilitative effects in learning, is this because *S*s have been trained to respond to the specific stimuli they have learned are important? The alternative hypothesis is that the advantages of a WDS occur because *S*s have learned to pay selective attention to a *general* dimension of the stimuli (such as color) while learning a first task, and that they continue to pay selective attention to that aspect of the stimuli, even when the *specific* colors formerly present are no longer there. In the current transfer-of-training situation, facilitation occurred for the groups making WDSs when the dimension of the stimuli on which discrimination wa[s] based was kept constant, but the specifi[c] stimuli important for correct discrimina[-]tion were changed. This supports th[e] hypothesis that the facilitative effects o[f] a reversal shift occur because it involve[s] using a dimension of the stimuli which was previously relevant.

## REFERENCES


Buss, A. H. Reversal and nonreversal shif[ts] in concept formation with partial reinforc[e]ment eliminated. *J. exp. Psychol.*, 195[8], **52**, 162–166.

Edwards, A. L. *Experimental design* [*in*] *psychological research.* New York: Rine[-]hart, 1950.

Gormezano, I., & Grant, D. A. Progressi[ve] ambiguity in the attainment of concep[ts] on the Wisconsin Card Sorting Tes[t]. *J. exp. Psychol.*, 1958, **55**, 621–627.

Harrow, M., & Buchwald, A. M. Revers[al] and nonreversal shifts in concept formati[on] using consistent and inconsistent response[s]. *J. exp. Psychol.*, 1962, **64**, 476–481.

Kendler, H. H., & D'Amato, M. J. A com[-]parison of reversal and nonreversal shifts i[n] human concept formation behavior. *J. ex[p.] Psychol.*, 1955, **49**, 165–174.

Kendler, H. H., & Mayzner, M. S. Re[-]versal and nonreversal shifts in card-sortin[g] tests with two or four sorting categorie[s]. *J. exp. Psychol.*, 1956, **51**, 244–248.

Kendler, T. S., & Kendler, H. H. Re[-]versal and nonreversal shifts in kinder[-]garten children. *J. exp. Psychol.*, 1959, **5**[8], 56–60.

Osgood, C. E. *Method and theory in expe[ri]mental psychology*. New York: Oxfor[d] Univer. Press, 1953.

Reese, H. W. Verbal mediation as a functi[on] of age level. *Psychol. Bull.*, 1962, **59**, 50[2]–509.



(Received May 23, 1963)


# AN INVESTIGATION OF VARIABLES IN JUDGMENTS OF RELATIVE AREA [1]


HARRY HELSON and WILLIAM BEVAN

*Kansas State University*



In 6 different experiments the part-whole proportion illusion reported by Paterson and Tinker was confirmed. The absolute error was most pronounced with proportions of intermediate magnitude but the relative error was greatest with smallest proportions of central area to total area. The error was found to be essentially invariant with changes in the range of relative magnitudes, the orientation of the rectangular stimulus area, and overall field size. However, when a null method of measuring the illusion was employed, the error was severely reduced with an inflection point at a proportion of 70%. The importance of contextual factors in judgments of a relative area is indicated by an inverse relationship between judged size and overall field size of the stimulus series when the comparisons are made within Ss rather than across groups of Ss. This last finding has methodological importance in determining the role of contextual factors in judgment.


A literature of long standing indicates that in judgments of area the constant error is usually one of overestimation (Anastasi, 1936; Paterson & Tinker, 1938). Curious about the tendency of *S*s to overestimate the proportion of the printed page occupied by print (printers, as a rule of thumb, set up about 50% of a book page as marginal space), Paterson and Tinker (1938) found that *S*s overestimated rectangular areas consisting of white or black on cards of contrasting color on representative book-page areas, about 18%, and actual printed matter in a wide variety of books by 25%. These writers simply referred the overestimations to the "part-whole proportion illusion." A number of possible explanations or sources of this tendency of judgment immediately suggest themselves: according to Piaget's (1947) Centration Effect, centrally fixated objects appear larger than objects in the periphery; Hollingworth's (1910) Central-Tendency Effect suggests that if the range of areas were extended, larger areas should be underestimated; the vertical-horizontal illusion suggests that perhaps the tendency to overestimate the vertical compared with the horizontal may be responsible since printed pages and the cards used by Paterson and Tinker were rectangular; the illusion may be a function of total field size; and there is the possibility that it may be an artifact of the method of measurement or the type of judgment demanded of *Ss*. Accordingly, six experiments are reported in this paper investigating each of these possible explanations of the part-whole proportion illusion.


[1] These experiments were performed under Contract Nonr-3634(01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. The writers are indebted to Joan Faye Pritchard, Edward D. Turner, and James R. Haines for their assistance during the course of the work.


## Experiment I

The first series of experiments began with the speculation that this error of overestimation might have resulted from a limited range covered by the stimulus series. Paterson and Tinker size of the central area varying from 42.7% to 71.9%. It was conjectured that if the series had been extended to cover a wider range, the Central-Tendency Effect might have been in evidence. Hollingworth, in his first test of this principle (1910), employed the estimation of the size of squares. More recently, a demonstration of the effect involved rectangles (Bevan & Dukes, 1953).

Experiment I thus consisted simply of the construction of a psychophysical function for judged relative area with two extended ranges of stimuli.

## Method

*Subjects.*—Forty students in introductory psychology served as *S*s. They were divided at random into two groups except that there were 10 men and 10 women in each.

*Materials.*—Group I judged a series of 15 cards. Each card was 6 × 8 in. overall. These dimensions represent the median width and length of 100 books measured at random in the Kansas State University library. The cards were cut from heavy white posterboard (Crescent No. 600). The centers to be judged were made of black matt construction paper. The black areas judged in these experiments in being solid and were like the stimuli used by Paterson and Tinker in this respect. The center areas ranged from 0.41% to 88.0% of the total area of each card. Group II judged a 21-card series with centers ranging from 0.02% to 96.4% of the total area.

*Procedure.*—Each card was presented 10 times for judgment. Group I thus received a total of 150 trials, with the order randomized in blocks of 15. Group II received 210 trials randomized in blocks of 21. (In all of the present experiments the stimulus series consisted of either 150 or 210 trials depending on whether the 15-item or the 21-item series was used.) Testing was done in groups. The method was that of absolute judgment, *S*s being instructed to record their estimates of the proportionate size in per cents of the black centers on a record sheet provided for this purpose. The stimulus cards were concealed from *S*'s view and presented, one every 10 sec., for judgment. For each presentation the stimulus card was placed at eye level on a card rack for 5 sec.

## Results

Figure 1A presents the average estimated per cent black plotted against actual per cent black for the 15-card series. Figure 1B presents similar data for the 21-card series. It is immediately apparent that the overestimation described by Paterson and Tinker

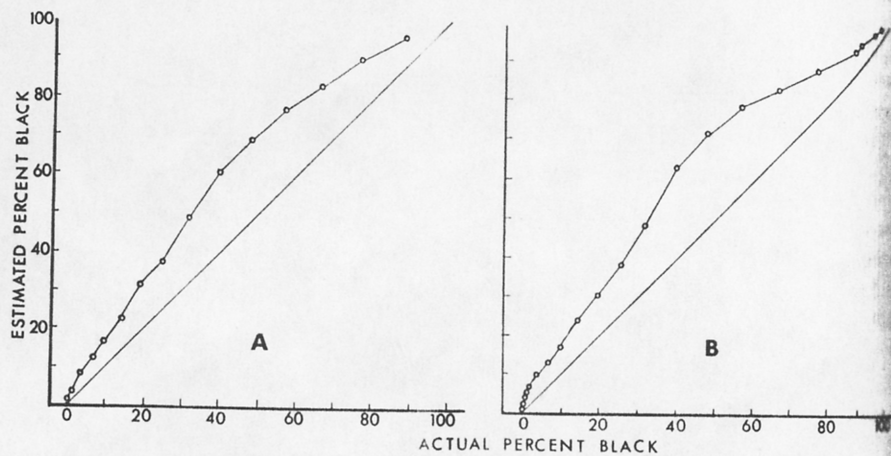


FIG. 1. Overestimation of the proportional size of a black rectangle on a white field. (Figure 1A presents data for the 15-item series Fig. 1B for the 21-item series. The straight line indicates veridical judgment.)

lus range, for overestimation predominates when almost the complete range of possible proportions is included. It is also clear that the greatest absolute overestimation occurs in the intermediate range of relative areas. For Group I the error of overestimation averaged 12.2%, with a range from 1.3% to 21.6%. In Group II the average was 9.5% with a range from 0.5% to 24.5%. Plots of the *relative* magnitude of the error (the ratio of the estimated to the actual per cent black) against actual relative size, result in a curve that is monotonic and negatively accelerated with the greatest effect at the low end and the smallest at the high end of the series. Thus in the 15-item series the log relative error is 2.49 for Card 1, and .92 for Card 15.

## Experiment II

With a clear demonstration that overestimation is not attributable to limited series range, an intuitive search for variables related to this constant error was begun. One that immediately suggested itself was field size. The stimulus cards of Exp. I were the same size as an average-sized book, and it was conceivable that habitual attitudes associated with books could have been responsible for the obtained judgments. Paterson and Tinker had varied overall stimulus size, but only within a narrow range. Their series were 4 × 7 in., 5 × 8 in., and 6 × 9 in., respectively. Accordingly, a second experiment was undertaken.

## Method

*Subjects.*—Sixty *S*s were involved in Exp. II, Group I of Exp. I and two additional groups of 10 men and 10 women each.

*Procedure.*—The 15-item series was reproduced at one-sixteenth and 16 times its original areas. One of the additional groups

in. cards. The procedure was that of Exp. I.

## Results

Again, there was only overestimation. The average magnitude of error (13.3%) was approximately that of Exp. I, and there was no difference in the amount of overestimation as a function of field (card) size—1.5 × 2 in., 14.0%; 6 × 8 in., 12.2%; 24 × 32 in., 13.6%; $F_{groups}$ (2, 54) = 1.01, $p > .05$. There was, however, a tendency for the female *S*s to display slightly larger error than the males—14.9% vs. 11.7%; $F_{sexes}$ (1, 54) = 8.02, $p < .01$—that is reminiscent of the greater field dependence reported for females by Witkin, Lewis, Hertzman, Machover, Bretnall, and Wapner (1954).

## Experiment III

Another plausible consideration in accounting for the results is the role of the horizontal-vertical illusion. If one dimension of a plane figure is overestimated, one might expect the relative area associated with this figure to be overestimated, since area is a product of linear dimensions. Earlier Peters (1933) reported that overestimation increased with an increase in the disparity of linear dimensions in rectangles, and Anastasi (1936) found a correlation of .83 between degree of overestimation and the greatest linear dimension. This latter, however, could have reflected a simple relationship between judged area and actual area. Accordingly, the role of the horizontal-vertical illusion was checked in a third experiment by having figures judged with the long dimension in both the vertical and horizontal orientations.

## Method

*Subjects.*—Forty *S*s were included in Exp. II, Group II of Exp. I, and an additional group of 10 men and 10 women.

*Procedure.*—Data obtained with the rectangles of the 21-item series presented in the vertical orientation (Group II) were compared with judgments of the same series turned 90°. The procedure was that of Exp. I.

### *Results*

Overestimation of relative error averaged slightly greater for the vertical orientation than for the horizontal (12.0% to 9.8%). However, this difference clearly failed to be significant, $F_{groups}$ (1, 36) = .02; and thus the horizontal-vertical illusion cannot, with confidence, be regarded as a determinant of this constant error in areal judgment. Furthermore, there were no systematic sex differences in judgment, $F_{sexes}$ (1, 36) = 2.93, $p > .05$, in these observations.

## Experiment IV

The conditions considered to this point as determinants of the error of overestimation have been stimulus related. Response-related processes also suggest themselves as possible sources of error. Piaget (1947) insists that all perceptual—at least, visual—judgments have one essential property in common, the systematic overestimation of fixated items. This he calls the Centration Effect. Thus perceptual space is conceived to be spatially expanded at the focus of attention and progressively more contracted toward the periphery of the perceptual field. The fact of attention shifts causes multiple centration effects with compensation for the field distortion associated with a single fixation. Therefore, if the overestimation of the black centers was due to processes underlying centration, then a comparable effect should be produced for the white surround by having *S* fixate upon this portion of the visual field.

### *Method*

*Subjects.*—Forty *S*s were used. Group II of Exp. I served as the control group for center estimation. A second group of 10 men and 10 women was used for border estimation.

*Procedure.*—The control group had been instructed to fixate upon the central area of each card and estimate its relative size. The experimental group was now told to look at the white borders of the card and indicate the proportion of white to the total stimulus area.

### *Results*

The centration hypothesis was not confirmed. While the control condition displayed the usual overestimation (12.0%), the group judging the white border showed a complementary error of underestimation of comparable magnitude (10.4%; $F_{groups}$ < 1.00). Again, there was no significant sex difference in judgment ($F_{sexes} < 1.00$).

## Experiment V

Experiment V was concerned with the error of overestimation as a reflection of method. The procedure utilized heretofore involved at least two judgmental operations: a comparison of areas in the stimulus field and the expression of this comparison in a conceptual system of per cents. Thus it is conceivable that the constant error is less a matter of perception than one of judgment of what constitutes specific relative magnitudes of particular dimensions. In a recent applied psychophysical experiment, Trumbo, Adams, Milner, and Schipper (1962) had *S*s make simple stimulus judgments, with estimates in per cents, of various properties of systematically programed heterogeneous samples of wheat. They found a general tendency to overestimate the proportions of undamaged wheat of different grades in each sample, and at the same time, they found constant errors of underestimation of the proportion of foreign material and damaged grain present. Therefore, Exp. V involved a null method, in which *S*s matched the areas to be judged against a standard series.

### *Method*

*Subjects.*—Twenty-one undergraduates, 11 women and 10 men, served as *S*s.

*Procedure.*—The 21-item series of Exp. I was used as stimulus material and served also as standards. The *S*s were shown these cards, one at a time, 10 times each, randomized in blocks of 21 trials, for a total of 210 trials. After each 5-sec. presentation, *S* identified one card from among the 21 cards in the standard series judged to be the same as the experimental card. The cards of the standard series were arranged in random order on a wall at a 90° angle to the left of the position of the experimental card and were presented at eye level, mounted against a soft tan background. Since classical time-order error involves comparison of a set of variables with one standard, the conditions used here minimized, if they did not completely obviate, this type of error.

### *Results*

Figure 2 presents the results of Exp. V. Several things are immediately apparent. The change in psychophysical method is associated with a marked reduction in the magnitude of the error. Maximum overestimation, however, is the same with both the null and absolute methods and occurs at 40% area. In addition there is an inflection point in the function in the region of 70% relative area with larger black centers being slightly underestimated. However, the error is still predominately positive, $F$ (1, 20) = 6.29, $p < .01$, and the inflection point is curiously displaced above the center of the series. Meanwhile, if this function is taken at face value it is suggestive of a central-tendency effect, with values below the inflection point being typically overestimated and those above underestimated. Again, there was no evidence of a sex difference in judgment ($F < 1.00$).

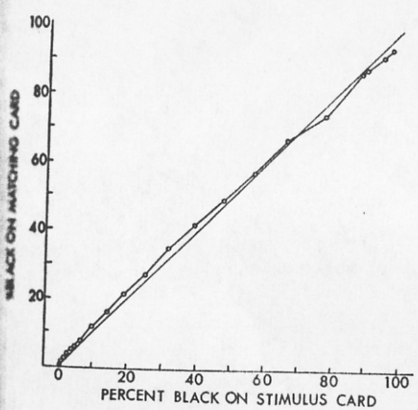


Fig. 2. Judgments of relative area involving the null method.

## Experiment VI

Experiment II indicated that field size had no effect upon the magnitude of the overestimation. However, the adaptation-level literature (Helson, 1947) has demonstrated that the role of contextual factors is most readily identified when these variables are allowed to vary within the experience of the individual. Experiment I followed the common procedure of varying context across groups while holding it constant within groups. Experiment VI was performed as a complement to Exp. II. Here the relative size of the central black area was held constant and the overall card size was varied over the series.

### *Method*

*Subjects.*—Sixty undergraduates, 30 men and 30 women, were used as *S*s. They were divided at random into three equal-size groups.

*Procedure.*—Each group made a total of 70 judgments, randomized in blocks of seven. The overall dimensions of the seven series stimuli varied from $1\frac{1}{2} \times 2$ in. to $10\frac{1}{2} \times 14$ in., with each next larger card being $1\frac{1}{2}$ in. wider and 2 in. taller than the preceding card. For one group the central black area represented

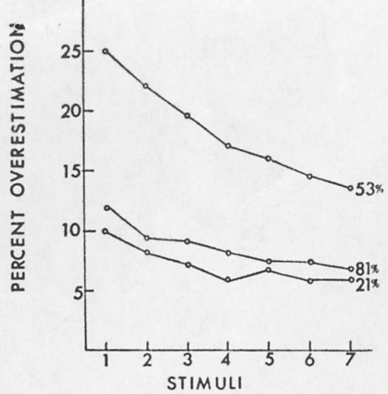


FIG. 3. Error of overestimation with judged area held physically constant and size of background varied. (Background size was increased from Stimulus 1 to Stimulus 7. The parameters indicate relative size of the area judged.)

21% of the total area of the card; for the second, 53% and for the third, 81%. The procedure was the same as that used in Exp. I and II.

### Results

As in the earlier experiments, the error of overestimation was pronounced (Fig. 3). Again, it was greatest for the intermediate-sized black area (53%) and about the same for the complementary high and low values (81% and 21%). Finally, unlike the results of Exp. II, where each *S* was allowed to experience no variation in overall stimulus size, the error of overestimation is here seen to be clearly related to stimulus field size in an inverse fashion, the largest error in the case of all groups being associated with the smallest overall field size (Fig. 3). These results were statistically confirmed, $F_{\text{stimuli}}$ (6, 324) = 41.41, $p < .01$; $F_{\text{black areas}}$ (2, 54) = 14.46, $p < .01$; $F_{\text{S×BA}}$ (12, 324) = 5.32, $p < .01$. They are reminiscent of the data of Bevan, Pritchard, and Reed (1962) on the direction of series effects with loud and soft series of tones.

## DISCUSSION

The present series of experiments confirmed the overestimation of relative area reported by Paterson and Tinker (1938) by exploring a wider range of situational variables, both stimulus and response, in its production. It is manifestly clear from the results that this constant error is strong and pervasive over a variety of conditions. Furthermore, as might be expected, it is greatest for relative magnitudes of intermediate size.

Experiments I through V strongly suggest that response variables are more potent determinants of the error than are stimulus variables. While the error did not vary as experimental groups differed in overall range of relative areas judged, overall field size, and orientation of the stimulus figures, a shift in psychophysical method from single-stimulus to the matching method, with a coincident change in the response language from a statement of proportion to that of simple discrimination was accompanied by a marked reduction in the constant error and the appearance of an inflection point above the midpoint of the series. However, the latter at 70% is so markedly discrepant from both the middlemost series value (32%) and the average stimulus size (36%), that it emphasizes the strength of the error and casts doubt on the inflection point as an indicant of the Central-Tendency Effect.

On the other hand, the importance of contextual factors anticipated by AL theory is demonstrated in the final experiment. Here field size as an independent variable was allowed to vary within the experience of each *S* and the overestimation was then found to be inversely related to total field size. This suggests an important methodological rule of thumb: since psychophysical judgments occur within a judgmental frame of reference, their competent investigation calls for designs in which stimulus variables are manipulated *within* rather than *across* groups if the role of contextual factors is to be identified.

## REFERENCES

ANASTASI, A. The estimation of area. *J. gen. Psychol.*, 1936, **14**, 201–225.

BEVAN, W., & DUKES, W. F. Color as a variable in the judgment of size. *Amer. J. Psychol.*, 1953, **66**, 283–288.

BEVAN, W., PRITCHARD, J. F., & REED, W. G. Single-stimulus judgments of loudness as a function of presentation interval. *Amer. J. Psychol.*, 1962, **75**, 612–618.

HELSON, H. Adaptation level as frame of reference for prediction of psychophysical data. *Amer. J. Psychol.*, 1947, **60**, 1–29.

HOLLINGWORTH, H. L. The central tendency of judgment. *J. Phil.*, 1910, **7**, 461–469.

PATERSON, D. G., & TINKER, M. A. The part-whole proportion illusion in printing. *J. appl. Psychol.*, 1938, **22**, 421–425.

PETERS, W. Versuche über den Einfluss der Form auf die Wahrnehmung der Flächengrösse. *Z. Psychol.*, 1933, **129**, 323–337.

PIAGET, J. *The psychology of intelligence.* London: Routledge & Kegan Paul, 1947.

TRUMBO, D. A., ADAMS, C. A., MILNER, M., & SCHIPPER, L. Reliability and accuracy in the inspection of hard red winter wheat. *Cereal Sci. Today*, 1962, **7**, 62–71.

WITKIN, H. A., LEWIS, H. B., HERTZMAN, M., MACHOVER, K., BRETNALL, P. M., & WAPNER, S. *Personality through perception.* New York: Harper, 1954.

(Received May 23, 1963)