Bulletin of the Psychonomic Society
1979, Vol. 14 (4), 271-274

Enhancement and diminution of simultaneous brightness contrast by extended practice

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In 15 spaced sessions of 10 trials apiece, each of 18 paid, volunteer, graduate-student subjects viewed and judged a display that produced simultaneous brightness contrast. Fully informed, the subjects made equations in terms of apparent physical luminance. Half the subjects were allowed a noncontrast view of the result of each of their equations; half were not. Individual trend analyses demonstrated significant tendencies toward enhancement as well as toward diminution of contrast effect. The factor of postviewing was nonsignificant. It is suggested that the anomalous enhancement effect is a result of a change in perceptual set over sessions, from one that is "analytic" to one that is "holistic." It is pointed out that any significant trend in contrast effect, either upward or downward, is inconsistent with an explanation of simultaneous brightness contrast in simple retinal terms.

The current Zeitgeist sides strongly with Hering's classical position that visual contrast is simply a result of how the visual system functions (Hering, 1920/1964; Ratliff, 1965). The fact remains, however, that a considerable body of modern literature (Berman & Leibowitz, 1965; Coren, 1969; Festinger, Coren, & Rivers, 1970; Kitterle, 1973; Parrish & Smith, 1967; Smith & Guilkey, 1972; Wist & Susen, 1973) suggests that simultaneous brightness contrast in particular is at least in substantial degree a judgmental phenomenon, one owing to processing by cortical structures beyond those which are specifically visual.[1] That literature is, of course, consonant with another classical view, the theory of "illusion of judgment" favored by Helmholtz (1911/1962, see especially pp. 294ff).

If there is indeed a considerable element of judgment entailed in simultaneous brightness contrast, we should expect the latter to be susceptible to modification, as Helmholtz (1911/1962, p. 295) himself suggested, by repeated experience. Other visual effects that seem to depend upon judgmental factors, notably the Müller-Lyer illusion, have been found to be modifiable in such fashion. There is no reason to presume that simultaneous contrast in particular should not be.

In the instance of such illusions as the Müller-Lyer, the general finding has been that repeated inspection tends to produce a lessening of the illusory effect. At least two attempts have been made to demonstrate a similar diminution in brightness contrast. In the first (McClure, 1968; McClure & Smith, 1969), five subjects knowledgeable as to simultaneous brightness contrast carried out 50 matching trials per day for 10 successive days. One of the subjects showed essentially no change in perceived contrast. Each of the remaining four subjects displayed an unexpected enhancement of the contrast effect, resulting in a mean increment for the entire group that was of marginal statistical significance ($p = .054$). In the second investigation (Smith & Guilkey, 1972), more subjects (eight) were utilized; trials were fewer in number (250 per subject) but distributed much more widely than before; and an attempt was made to provide particularly clear instructions to the subjects, all of whom were again knowledgeable. A new variable was also introduced: Four of the subjects were informed immediately of the degree to which each of their judgments approximated veridicality, and the other four remained uninformed. Results were once more surprising. The group ANOVA was totally nonsignificant. When each subject's data were submitted to a separate, within-subjects ANOVA, however, the F ratios were significant ($p < .01$) in every case. Although exact tests of linear tendency were not performed, only two subjects showed trends that appeared to be, as expected, decremental. Three showed no consistent direction at all, and three displayed enhancement, two of them rather spectacularly.

This pattern of findings is, of course, puzzling. It is true that some investigations of the effect of practice upon the Müller-Lyer illusion have also found instances of no change or even of enhancement (cf. especially Day, 1962, Dewar, 1967; Lewis, 1908; Seashore, Carter, Farnum, & Seis, 1908). On the basis of his own results, in fact, Day (1962) concluded that a decrement in the Müller-Lyer can be expected confidently only if the

The present investigation was reported in brief at the 1977 meetings of the Psychonomic Society. It was made possible by Research Grant 836 of the Research Council of the University of North Carolina at Greensboro. Empirical data were collected by the two junior authors under the direction of the senior author. Statistical analyses were carried out by Marie Meeler under the senior author's direction and in consultation with William A. Powers, III. The assistance of both Ms. Meeler and Professor Powers has been invaluable, and we wish to express our thanks to them.

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subject understands clearly that judgments are to be made in terms of physical, objective–rather than apparent, subjective–equality. The possibility implied by Day's conclusion is that Smith and Guilkey (1972), in spite of their attempts to define the subjects' task precisely, did not actually do so, and that the resulting ambiguity led to anomalous effects.

We accordingly decided to repeat the Smith and Guilkey (1972) study, making a particular effort to provide experimental instructions that were truly unequivocal. The procedural details were to be strengthened in other ways, also, as will become apparent. Finally, an exact test for the existence of any linear trend in each subject's judgments was to be employed.

METHOD

Subjects

The subjects were 18 (6 female, 12 male) graduate students in psychology. All were paid volunteers, each receiving $15 for serving throughout the investigation. There was no subject attrition.

In an introductory briefing, which was recorded on tape and preserved by transcription, the subjects were fully informed as to the theoretical background, the purpose, and the nature of the investigation. It was emphasized that they were being treated as colleagues and that it was their responsibility to render serious, conscientious judgments. The nature of the judgment required (described below, under "Procedure") was carefully defined and heavily stressed. All questions were answered frankly. The subjects arranged their schedules of experimental appointments.

Apparatus

The apparatus required was located in a large, quiet, air-conditioned, lightproof room.

The principal instrument employed was the "brightness comparator" (Model V-0659).[2] The device permits the independent control of each of four achromatic, electroluminescent plaques: two disks each of 10.5-cm diam; and two annuli, each of 20-cm diam, immediately surrounding the respective disks. In the present case the plaques were mounted in what was to be the subject's frontal plane. Their centers were 107 cm above floor level (and thus at eye level for the subject) and 22 cm apart horizontally. The subject's chair was placed at a viewing distance of 195 cm, and viewing was actually done through a tunnel of reflection-damping black velvet cloth (cf. Smith & Guilkey, 1972). The situation produced the following visual angles: diameter of disk, 3 deg 5 min; diameter of annulus, 5 deg 50 min; distance between centers of disks, 6 deg 30 min.

Directly behind the subject's chair was the experimenter's desk, upon which rested the unit controlling the brightness comparator display. The control unit embodied small pilot lights that did not affect the subject; it was silent in operation.

A Macbeth illuminometer was used to make periodic checks upon the calibration of the comparator. Subjects who normally required corrective glasses wore them during the experimental sessions.

Procedure

When a subject reported for an experimental session he/she was seated in the viewing chair, the room lights were extinguished, and there followed a dark-adaptation period of 5 min. The subject's eyes were then closed while the experimenter set the right-hand (standard) disk at 1 fL; the left-hand (variable) disk at one of five different values well below 1 fL or five different values well above 1 fL, according to a table of random numbers; and the left-hand annulus at 4 fL.[3] The right-hand annulus was left completely dark at all times.

Before the first trial of each session, the subject was reminded emphatically, in repetition of instructions given during the group briefing session, that he/she was to: (1) instruct the experimenter in adjusting the variable disk until it "looked equal to the standard disk in terms of absolute amount of light energy being radiated" (the subject was warned against making intellectualized judgments, and was told to set the variable disk in such a way that "if you didn't know about the contrast effect, you would honestly believe that both disks were giving out the same amount of light"); and (2) make all comparisons by fixating alternately upon the two disks (rather than, for instance, by fixating constantly upon one point in the display).

The experimental instructions having thus been reiterated, the subject opened his/her eyes and proceeded with the first trial of the session. When the judgment had been made, it was recorded by the experimenter. Nine further trials were then carried out; each of the 10 starting values for the variable stimulus was used once during the session. On Trial 4, 5, or 6 of the session, the subject was once again reminded of the requirements of the judgmental task.

Each subject participated in 15 sessions of 10 trials apiece. Each session typically lasted about 20 min. In general, a subject experienced two sessions per week, but there was considerable variation; sessions for a given individual were, however, always at least 24 h apart. The most expeditious subject finished service in 41 days, the least, in 85.

As has been indicated, the variable of knowledge of results was also introduced into the procedure. Each of the 18 subjects was designated by table of random numbers as either a "nondemonstration" or a "demonstration" subject; 9 subjects were placed in each category. A nondemonstration subject was treated precisely as described above. A demonstration subject's treatment differed only in that, after each judgment had been made and as it was being recorded, the experimenter switched off the annulus encircling the variable disk and allowed the subject to make a direct visual comparison between the variable as set and the standard stimulus. All subjects had been advised in the initial briefing that this treatment was to be introduced, and it had been pointed out that demonstration subjects would have to be especially careful to avoid intellectualization in their judgments.

RESULTS

The statistical analyses employed, as in the earlier investigation (Smith & Guilkey, 1972), treated the data from each subject as arising from a single subexperiment.

The first analysis consisted of a simple ANOVA, across sessions, for each subject separately ($df = 14$ and 135). Each of the 18 Fs proved to be significant ($p < .01$), indicating a genuine variation among sessions for every subject.

The second analysis attempted to determine whether those variations took the general form of linear trends. A computer program[4] that, in this instance, essentially applied the method of orthogonal polynomials (McNemar, 1969; Ray, 1960) to the data of each subject individually was employed. Of the 18 individual records, 12 showed significant ($p < .01$) linear trends toward increased contrast with successive sessions, 3 showed significant trends toward decreased contrast, and 3 showed no significant trend. The probability of finding 15 significant records in 18, by chance alone, is vanish-

ingly small (Wilkinson, 1951), thus disposing of the problem of Type I error with multiple outcomes.

Five illustrative records are set out in Figure 1. They represent (1) the case in which the positive linear trend was greatest (S:6), (2) that in which the negative linear trend was greatest (S:12), and (3) three others in which the effects were intermediate in magnitude. All of the trends illustrated, except that of S:16, are statistically significant. Each curve is drawn upon an abscissa that lies at an ordinal level of 1 fL, the level of veridical judgment, and it may be noted that subjects differ considerably, not only in the temporal trend of their judgments, but also in the general level of luminance at which equations are made.

There remains the question of whether the effects of practice upon brightness contrast are a significant function of demonstration vs. nondemonstration. There

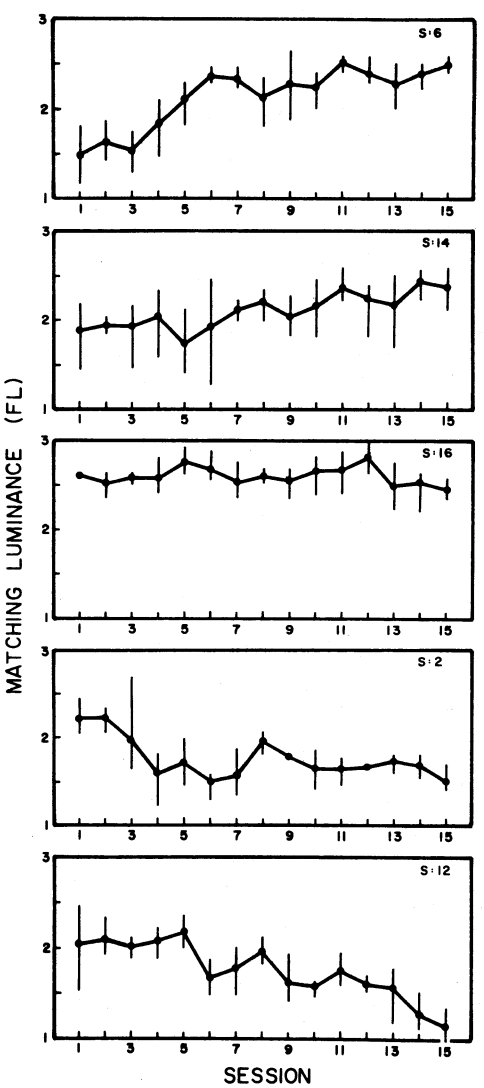

Figure 1. Representative performance curves for five subjects. Abscissas represent successive sessions; ordinates represent the luminance of variable disk at subjective equation. Curves connect session means; vertical bars represent ranges of judgments per session.

Table 1
Number of Subjects in Each Group Displaying Each Trend in Contrast (Across 15 Experimental Sessions)

Trend	Group: Nondemonstration	Group: Demonstration	Total
Increasing	8	4	12
Decreasing	0	3	3
Nonsignificant*	1	2	3
Total	9	9	18

*$p > .01$.

is some indication (see Table 1) that they might be: The nondemonstration subjects showed an incidence of increasing contrast that was twice that shown by the demonstration subjects (eight cases as compared with four), and the nondemonstration group included no cases of decreasing contrast, while the demonstration group included three.

It is possible to extend the principle of Fisher's test of exact probability to a six-celled array like that constituting Table 1. When such a test is in fact made, the results summarized in Table 1 are found to fall short of significance ($p = .14$). There is thus no trustworthy support for the suggestion conveyed by Table 1 that direct demonstration tended to enhance veridical perception.

DISCUSSION

The essential hypothesis underlying the series of studies by McClure and Smith (1969), Smith and Guilkey (1972), and ourselves has been that simultaneous brightness contrast tends to diminish with practice. A few cases in which it did, in fact, do so were identified by the first two studies; those cases were, however, accompanied by others that manifested either no obvious change in contrast or even an outright increase.

In a sense, the present investigation actually supports the experimental hypothesis: Of 18 subjects, 3 showed significant ($p < .01$) diminution in perceived contrast; the probability of obtaining such a result by chance alone is only .0007 (Wilkinson, 1951). For at least some individuals, then, the effect of practice is indeed that of diminishing contrast. The difficulty, of course, lies in the fact that 12 of the 18 subjects displayed significant increases in contrast, indicating that, for some other individuals, practice enhances the contrast effect.

It is the latter phenomenon that needs explanation. The growth in contrast as a function of experience appears to be, at least under the conditions employed in our studies, a real effect. It does not seem to represent a failure to convey to the subjects the requirements of their task. In attempting to account for the effect, we are led back to an argument adumbrated by McClure and Smith (1969). It has been demonstrated that the magnitude of brightness contrast is to a considerable degree a function of the viewer's attitude, of whether observation is carried out in a "whole-perceiving" or in a sharply "analytical" fashion (Parrish & Smith, 1967). Specifically, contrast in the latter mode of viewing is less than in the former. It seems likely that, in the present study and in the two that preceded it, the initial effect of the instructions was that of inducing a strongly critical perceptual attitude. Such an attitude is, however, difficult to maintain throughout many trials and sessions. It is thus not unrealistic to suppose that it often changes gradually to a more holistic and uncritical set and that the experienced effect changes correspondingly in the direction of enhanced contrast. There is,

in fact, independent evidence that such a process actually occurred in the present investigation. All of the subjects were invited to attend a postexperimental discussion of the study and its results, and 10 of them did so. Besides expressing astonishment at the fact that their judgments had changed at all, the subjects spontaneously made the point that, in spite of all the precautionary measures employed, there had been a distinct tendency for attention to the task to diminish over the course of their service.

It is accordingly our suggestion that the subjects in the present investigation all began the task with a strongly analytical set, but that, as the task progressed over its 15 sessions, many of them tended to drift away from that set. Those who did so tended to give ascending records; those who did not do so either showed no distinctive tendency over time or actually experienced a diminution of the contrast effect. It is of interest, parenthetically, that individual trends became evident surprisingly early in the experiment. Analysis even at the end of the fifth session shows 11 individual ANOVAs and 11 individual trends significant at the .05 level (for either overall result, $p < .0001$) (Wilkinson, 1951). Of the 11 individual trends, 7 were positive ($p < .001$) and 4 were negative ($p = .01$) (Wilkinson, 1951).

Little can be said about the failure of "demonstration" in the present study and of "information" in the previous one (Smith & Guilkey, 1972) to produce any dependable effect upon the subjects' judgments. One might have expected either sort of feedback to hasten perceptual learning. Evidence that it did so is lacking. The lack of evidence has its positive value, of course, in that it implies that the subjects were, as instructed, avoiding intellectualized judgments.

If the problem of perceptual learning in the realm of simultaneous brightness contrast is worth further pursuit, the next step would seem to be obvious. It would be to replicate the essential procedure of the present study, with the modification that directions to the subjects be kept carefully neutral, rather than being designed to induce a sharply critical perceptual attitude. What might be looked for, then, is the slow drift toward veridicality typical of the classical illusion studies. Essentially, the subjects would develop critical sets for themselves upon the basis of direct experience, rather than upon that of initial experimental instructions.

It remains to be emphasized, finally, that whether the drift in perceived contrast during the course of extended practice is positive or negative, the mere fact of progressive change is, in itself, important. Such change is apparently beyond explanation in simple retinal terms, and its existence implies that the simple retinal explanations of brightness contrast that continue to be offered (e.g., Marks, 1974, pp. 177ff) should not be accepted uncritically.

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NOTES

1. The psychophysical outcomes cited are complemented by an important electrophysiological finding. DeValois and Pease (1971), recording from single cells in the lateral geniculate nucleus of the monkey, found evidence of only minor contrast effects at that level: "The center-surround organization of the cells' receptive fields should, we believe, be considered as a contour-enhancing mechanism. Except perhaps for very small visual objects, it does not produce brightness (or color) contrast. For that effect some other presumably cortical process must operate upon the border information" (DeValois & Pease, 1971, p. 696).

2. Available from the Polymetric Company, P.O. Box D, Roseland, New Jersey 07068.

3. In the Smith and Guilkey (1972) study this value was 3 fL. The change to 4 fL was made on the basis of pilot studies that seemed to indicate that the effect of 3 fL would not be great in the context of the experimental instructions used in the present investigation.

4. North Carolina Triad Universities Computer Center "MANOVA." To use the program, it was necessary to reduce the number of scores per session for each subject from 10 to 6; that was done by dropping the scores from all Trials 1, 2, 9, and 10. The program then yielded for each subject an assessment of linear trend ($df = 1$ and 70), of any higher (from second- to fourteenth-) order trends ($df = 13$ and 70), and of any effects of trials within sessions ($df = 5$ and 70). It is of incidental interest here that 17 of the 18 subjects showed significant ($p < .01$) higher order effects; none showed a significant trials effect.

(Received for publication July 3, 1979.)