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An analysis of U-shaped metacontrast*

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Using a brightness-discrimination task similar to that employed by Bernstein, Proctor, Proctor, and Schurman (1973), masking functions were obtained in two experiments. In Experiment I, test stimulus (TS) and mask stimulus (MS) energies were held constant but luminance and duration were varied reciprocally. The obtained masking functions, plotted as a function of stimulus onset asynchrony (SOA), were of an essentially identical U shape. This suggests that (a) SOA is a more suitable measure of delay than interstimulus interval, and (b) Bloch's law holds for the requisite discrimination. In Experiment II, TS luminance and MS luminance were varied independently. This was to see whether the MS served as a frame of reference at short SOA, as suggested previously (Bernstein et al, 1973). The results were that this was, in fact, the case and that the transition from comparative to absolute judgment strategies as SOA increases is a major contributor to U-shaped masking functions.

The presentation of two nonoverlapping but adjacent stimuli in close temporal succession impairs perception of the first or test stimulus (TS). This phenomenon is known as metacontrast. The masking function is the relation between some performance measure and the delay in presentation of the second or masking stimulus (MS). Two measures of delay have been used. The more common is the *stimulus onset asynchrony* (SOA), which is the time difference between TS *onset* and MS *onset*. The other is the *interstimulus interval* (ISI), which is the time difference between TS *offset* and MS *onset*.

Bernstein, Proctor, Proctor, and Schurman (1973) employed a brightness-discrimination task to study metacontrast. They used what Kahneman (1968) has termed the three-object display, which had previously been employed by Fehrer and Smith (1962) and Kahneman (1966), among others. One of two TS alternatives were presented for 50 msec. Both were small transilluminated squares differing in luminance by .2 log units. Pilot work had indicated that the bright TS and the dim TS could be discriminated from each other with slightly less than perfect accuracy in the absence of a MS. The MS was a pair of flanking squares. Each was of the same dimensions, duration, and luminance as the bright TS. The SOA was varied from 0 to 150 msec, and TS alone appeared in a control condition. A signal-detection analysis was used to define the area under confidence-rating receiver operating characteristic (CR-ROC) curves as the measure of performance.

Using SOA as the measure of delay, the masking functions were clearly U-shaped. Accuracy was poorest at 25 or 50 msec SOA in each of two experiments, one in which SOA was held constant within blocks of trials and another in which SOA varied randomly over individual trials. However, these masking functions would have been essentially monotonic had they been defined in terms of ISI rather than SOA, because the exposure durations were 50 msec. Hence, maximum masking was obtained when the stimuli were consecutive (ISI = 0).

Experiment I of this paper was designed to contrast SOA and ISI as measures of delay. As Lefton (1973), among others, has noted, SOA has generally been preferred over ISI. The reasons for this preference are theoretical (in the main), since there are relatively few studies which have attempted to disentangle these two normally confounded measures. Nonetheless, it is fairly easy to justify the use of ISI as a measure. For example, suppose that U-shaped masking functions

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are not due to the differential latencies of excitation and inhibition produced by the TS and MS (Weisstein, 1968) or to impossible apparent motion (Kahneman, 1966, 1968), to consider two possibilities. Instead, suppose that the "on" response to MS produces an inhibitory interaction with the "off" response to TS in some way. Here, the critical variable might be ISI rather than SOA if the physiological duration of the TS paralleled its physical duration. Though the purpose of this study was not to test this hypothesis, it is not altogether implausible since there is a well-known antagonism between "on" and "off" mechanisms in perception (Granit, 1955).

Experiment II was designed to test a hypothesis stated by Bernstein et al (1973) to explain U-shaped masking. Though they noted that their data were compatible with many existing theories, the authors indicated that the MS could serve as a comparison stimulus or frame of reference when it and the TS were approximately concurrent. That is, Ss might judge TS and MS on a same-different (comparative) basis rather than judge TS alone on a bright-dim (absolute) basis. As SOA increased, Ss would be forced to rely upon absolute judgments to a greater extent because the icon of the TS would fade by the time MS appeared. Both TS alternatives, then, would appear much dimmer than the MS, and the value of MS as a frame of reference would be reduced as the delay increased. The normal superiority of comparative over absolute judgments would tend to offset masking effects. As long as the two processes changed over SOA at different rates, the composite would be U-shaped. This hypothesis is called the "comparison stimulus" hypothesis throughout the rest of this paper. It is derived in part from Eriksen, Collins, and Greenspon's (1967) observations on the possible role of a ring mask in helping Ss make "O" vs "D" pattern discriminations, Kahneman's (1968) discussion of the role of what he terms "criterion content" changes over SOA as a factor in metacontrast masking functions, and Schurman's (1972) observations on practice effects.

EXPERIMENT I

The ISI and SOA were experimentally separated by holding test and mask energies constant and equal to one another but varying luminance and duration reciprocally. Each S participated in three luminance-duration conditions: bright/short, medium/medium, and dim/long. The TS luminance/duration and the MS luminance/duration were confounded in this study. However, we have obtained limited data in which TS luminance and duration were varied reciprocally and MS luminance and duration held constant, and vice versa. These data will not be presented, but they are consistent with the conclusions from this experiment.

Within each condition, the experiment was procedurally similar to Bernstein et al's (1973) Experiment I in that SOA was held constant within trial blocks. If SOA was the critical variable, then the masking functions for the three conditions should reach minimum at the same SOA. However, if ISI was the critical variable, the minima would be at different SOA, but at the same ISI. If the "physiological" ISI was identical to the physical ISI, the minimum might plausibly occur when TS and MS were consecutive, i.e., at 0-msec ISI. (This assumption, however, is not necessary to our experiment.)

This design also allows us to see whether Bloch's law (luminance/duration reciprocity) holds in metacontrast. To the extent that it does, the masking functions, plotted either as a function of SOA or ISI, whichever is more appropriate, would be identical.

Method

Subjects. Four advanced undergraduates served as Ss. Two Ss had served in the Bernstein et al (1973) experiment, whereas two other Ss had not. The latter two were given additional practice to compensate for this deficiency. All Ss were paid for this participation and had normal or corrected-to-normal eyesight. They were theoretically unsophisticated.

Apparatus and Stimuli. The apparatus was identical to that employed in Bernstein et al (1973). A three-channel tachistoscope (Scientific Prototype Model GB) was used to present the three-object display, consisting of a bright or dim TS square and a pair of flanking MS squares. Viewing was monocular through a 2-mm artificial pupil. A telegraph key was used by S to initiate trials.

Exposure Fields I and II contained the bright and dim TS alternatives. As before, each was .67 deg of arc/side and the base was .33 deg of arc above fixation. The "blank" field of the tachistoscope contained the MS, a pair of transilluminated squares which also were individually .67 deg of arc/side and .33 deg of arc above fixation. A small, externally illuminated circle which remained on continually was also contained in this field and served as a fixation device.

The luminance/duration pairings for the bright TS (and also the MS) in the bright/short, medium/medium, and dim/long conditions were 63 cd/m^2 x 15 msec, 31.5 cd/m^2 x 30 msec, and 15.75 cd/m^2 x 60 msec, respectively. As before, the dim TS was .2 log units dimmer than the bright TS, but of the same duration. These energies are roughly one-quarter of those previously used. This was necessitated by the joint considerations of keeping the longer duration within the critical duration of Bloch's law and of the maximum luminance obtainable by the tachistoscope bulbs. Pilot work, however, suggested that the overall energies were high enough for Weber's law to hold in the no-MS conditions. Hence, we expected similar brightness accuracy to that previously obtained, i.e., slightly less than perfect.

Procedure. The procedure also closely follows Bernstein et al (1973). Each condition was run as a block over five 1-h sessions, during which 168 trials were run per session. The trials were equally divided among bright and dim TS presentation and seven SOAs: no MS, and SOAs of 0, 7.5, 15, 30, 60, and 120 msec (functionally, we regarded the no-MS case as an "infinite" SOA control).

With these geometrically spaced delays, performance could be assessed with concurrent (SOA = 0) as well as successive (ISI = 0) presentation in all three luminance/duration conditions, as the exposure durations were also geometrically spaced. Trials were organized in blocks of 24 at a given SOA. A different order of conditions was used for each S, and order of block presentation was randomized over sessions and Ss. The S's response was a 6-point CR with "1" denoting high confidence that the dim TS had been presented. Then, CR-ROC curves were obtained for each Stimulus Condition by Luminance/Duration Condition by S combination. The several sensitivity measures agreed with one another, as did the several bias measures. Following our previous work, we shall only present the area under the CR-ROC curves as a measure of sensitivity and the negative natural logarithm of Luce's (1963) beta measure, $-\ln(b)$, as a measure of bias. The latter was obtained by disregarding the confidence ratings and dichotomizing responses into "bright" and "dim." Further minor procedural details, e.g., reversing the location of the TS alternatives during the experiment to minimize field-specific cues, may be found in Bernstein et al (1973).

Results and Discussion

Figure 1 contains the masking functions (areas under the ROC curves as a function of SOA) for the three luminance/duration conditions. All three functions are similar in shape and level. Performance at 0 msec SOA is slightly superior to the no-MS level but declines to this control level by 15 msec SOA. Of greater importance is that all three functions reach their minimum at the same 60 msec SOA, which, of course, is a different ISI in each case. Performance at 0 msec SOA was slightly below the no-MS level in Bernstein et al (1973), Experiment I and their masking functions were somewhat less sharply U-shaped, but these functions are otherwise quite similar to theirs. The average of the three individual masking functions is presented in Fig. 2.

An analysis of variance (luminance/duration, SOA, and Ss) indicated that the only significant effect was SOA, $F(6,16) = 33.39$, $p < .01$. A trend analysis revealed that the difference between the no-MS control SOA and the average of the six experimental SOAs was highly significant, $F(1,18) = 9.69$, $p < .01$, even though it accounted for but 3% of the total variation and 4% of the SOA effect. Variation among experimental SOAs was a much more potent effect, accounting for 78% of total variation and 96% of the SOA effect, $F(5,18) = 38.21$, $p < .01$. This latter effect, in turn, was approximately equally determined by its linear component, accounting for 47% of the SOA effect, $F(1,18) = 93.46$, $p < .01$, and its quadratic component, accounting for 45% of the SOA effect, $F(1,18) = 88.47$, $p < .01$. Bernstein et al (1973) found that the linear component of their trend accounted for negligible variance. However, their SOAs were equally divided between the ascending and descending regions of the masking function and our SOAs fall almost entirely on the descending region. The lack of a 150-msec SOA in this study further contributes to this slight discrepancy. The observation that our masking function is more sharply U-shaped than theirs was supported; the SOA by Ss error term in this study (.0052) is very close to that obtained in their Experiment I (.0046), yet the overall F ratio is approximately six times greater here. Finally, neither the luminance/duration condition main effect [F2,6) < 1] nor the interaction [$F(12,36) = 1.85$] approached significance.

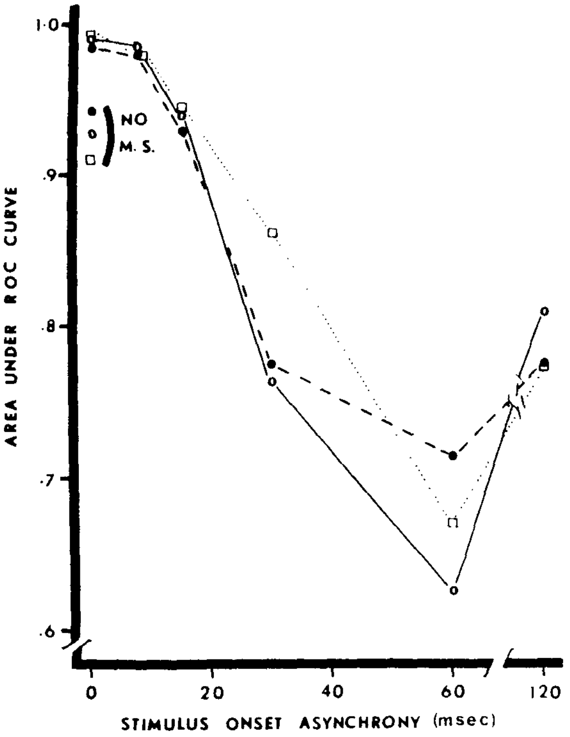

Fig. 1. Area under the ROC curve as a function of SOA for the three luminance/duration conditions, Experiment I (square = bright/short condition; filled circle = medium/medium condition; open circle = dim/long condition).

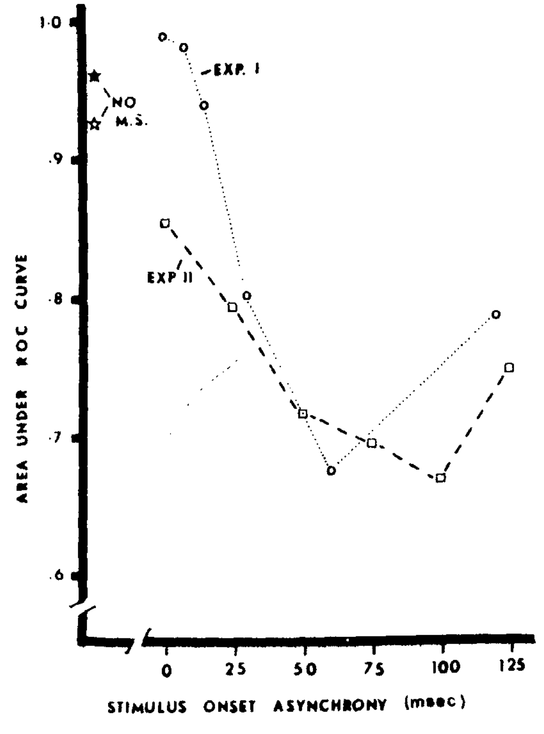

Fig. 2. Area under the ROC curve as a function of SOA for Experiments I and II. The data for Experiment I are averaged over luminance/duration condition, and the data for Experiment II are averaged over MS luminance. (The open star is from Experiment I and the filled star is from Experiment II).

The same format analysis of variance was applied to the bias data. None of the effects (luminance/duration condition, SOA, or the interaction) approached significance. This was also true in Bernstein et al's (1973) Experiment I. In both cases, SOA was held constant within each block of trials. Using this procedure, Ss tend to maintain the same ratio of "bright" to "dim" responses for the various SOA. This is not true when SOA varies from trial to trial, as in Bernstein et al's (1973) Experiment II.

Our primary conclusion is that the SOA provides the better measure of delay thanISI in this task because the results are simpler and describe an invariance. The point of maximum masking is not when TS offsets coincidentally with MS onset. This does not mean that some form of offset/onset antagonism may not be operative, since the physical and physiological durations of the events need not be equal. In particular, the physiological duration of a brief flash may follow its total energy rather than its physical duration. If this had been the case, we would not have manipulated physiological duration. All we wish to document in this context is that Bloch's law seems applicable to the discrimination between the two TS alternatives.

At the same time, however, we stress that what may hold for brightness tasks may not hold for letter-recognition tasks. Eriksen et al (1967), in particular, found maximum masking at 0 msec ISI, even though they did include a 0-msec SOA condition. The term "metacontrast" has been applied to both brightness and recognition data because of the common property of a nonoverlapping MS. This similarity may be more apparent than real.

EXPERIMENT II

The comparison stimulus hypothesis was tested by varying both the MS and the TS luminance. Four equiprobable combinations of TS and MS luminance were used: bright TS-bright MS, bright TS-dim MS, dim TS-bright MS, dim TS-dim MS. The bright TS and bright MS were identical in luminance and duration, as were the dim TS and dim MS. The S's task was, as before, to respond on the basis of TS luminance; hence, MS luminance was an irrelevant attribute that varied randomly over trials in contrast to our previous studies, in which it was held constant.

The strongest possible support for the comparison stimulus hypothesis would be a monotonic masking function. However, at least one potential factor could have produced nonmonotonicity along lines consistent with this hypothesis; the bright TS alternative appeared either with an MS of the same or lesser luminance, whereas the dim TS alternative appeared either with an MS of the same or greater luminance. The MS was, therefore, informative on half of the trials when it and TS were of equal luminance (i.e., bright TS-bright MS and dim TS-dim MS). Hence, our expectation was that the masking function would be less U-shaped than previously found, though not necessarily monotonic.

Method

Subjects. Three graduate students and one faculty member from the Emory University Psychology Department served as paid Ss. All Ss had normal or corrected-to-normal vision in the dominant eye.

Apparatus and Stimuli. The stimuli were similar to the three-object display used in Experiment I and consisted of transilluminated squares (0.67 deg of visual angle/side at the viewing distance of 1.5 m) presented in an edge-to-edge horizontal array. In this experiment, however, the center square could be bright or dim and the two flanking squares could, independently, also be bright or dim. Each stimulus was presented in a separate field of a four-channel tachistoscope (Iconix Model 6192). The bright stimuli were 30 cd/m^2 (9 fL) and the dim stimuli were 20 cd/m^2 (6 fL) in intensity. These stimulus intensities were calibrated and checked weekly throughout the experiment by means of a Pritchard spectra spotphotometer. Color matching of the fields was done by eye, using yellow and blue reflective paper in the light boxes. A fixation cross was provided by a green light-emitting diode, masked to appear as a cross, 0.25 deg of angle in height and width. The fixation cross was always present 0.25 deg of angle below the bottom of the center square position. All stimuli were presented for 50 msec. These durations and those of the SOA used were periodically checked by means of an oscilloscope (Tektronix 564b). All viewing was monocular with the dominant eye.

Procedure. Ss were given a minimum of two 150-trial practice sessions in which the TS were presented alone in random order. When Ss could correctly identify the TS as bright or dim at an accuracy level of 75% or more, the experimental sessions were begun. For all trials, Ss were instructed to initiate each trial, by means of a hand-held switch, when the fixation cross appeared sharp and clear. All Ss were additionally insructed to close their eyes between trials and to wait until any afterimages had faded before initiating the next trial.

Each S served in 10 experimental sessions, which consisted of one block of the no MS (warm-up and baseline) and one block of the TS-MS combinations at each of the six SOAs of 0, 25, 50, 75, 100, and 125 msec. The order of presentation of the SOA blocks was partially counterbalanced across Ss and sessions by a randomized Latin square design. Each block consisted of 24 trials; thus, 240 trials were run at each SOA, per S. Each combination of TS and MS (bright-bright, dim-bright, bright-dim, dim-dim) was presented equally often in each block of trials in otherwise random order.

Each block of trials was preceded by two presentations of each of the possible stimulus combinations at that SOA. The Ss were told before each presentation whether the bright or the dim TS was being presented. During each block of trials, Ss simply stated whether the bright or the dim TS had occurred by using a 6-point confidence rating scale, as in Experiment I. The Ss were not informed about their performance on the SOA blocks until after the experiment was finished. The first (baseline) block was often halted at 10 trials when it was plain that the S was performing at 90%-100% accuracy for discrimination between the TS presented alone.

Results and Discussion

Figure 2 contains the masking function obtained from these data. The data points are pooled over MS luminance, as accuracy differences between the two levels were slight. The composite masking function obtained in Experiment I is also presented in this figure. Though the energies used in the two experiments differ, the relative energy difference between bright and dim TS were similar. To the extent that Weber's law holds at these energy levels, the basic energy differences should not influence performance greatly. As can be seen from the no-MS data, these differences were slight and performance of the two sets of individual Ss did overlap. Note further that the Ss in this experiment did slightly better in the control SOA but slightly worse in the six experimental SOAs than those of Experiment I. Thus, the difference in energy levels did not materially contribute to performance differences.

The masking function obtained in this experiment is somewhat flatter than that obtained in Experiment I. The standard deviation of the mean areas over the six experimental SOAs was .07 in this experiment and .13 in Experiment I, which is consistent with this observation. However, the standard deviations of the mean areas in Bernstein et al (1973) were also .07, so that it is not safe to conclude that the masking function obtained with varying MS luminance is flatter, contrary to our expectation. A second trend observable in Fig. 2 is that the point of maximum masking in this study is at 100 msec, whereas it was at 60 msec in Experiment I. Experiment I's minimum is relatively consistent with our previous work as the minima in Bernstein et al (1973) occurred either at 25 or 50 msec SOA.[1] We do not conclude that these differences are sufficient to support the comparison stimulus hypothesis. Data pertinent to this issue will be presented below.

An analysis of variance was conducted upon the area measure (MS luminance, SOA, and Ss). Neither main effect nor any of the interactions was significant. Lack of a main effect of MS luminance and interaction was not surprising, given the relatively slight luminance difference between the two MS. The nonsignificant SOA effect, $F(5,15) = 2.27$, requires further discussion.

The comparison stimulus hypothesis predicts, in essence, a reduction of the F ratio due to overall flattening of the function. However, the conclusion that the function is completely flat seems unwarranted on at least three grounds. First, a planned trend analysis revealed that both the linear and the quadratic components of the trend were significant, $F(1,15) = 5.98$ and 4.75, respectively, $p < .05$. These trends account for 53% and 42% of the SOA and 17% and 13% of the total variation. The significant quadratic trend, showing nonmonotonicity, is in agreement with our previous studies.

In addition, the range over which temporal integration effects occurred was much greater for one of the four Ss, while the latter three were quite consistent with one another and our previous Ss as well. Accuracy for the deviant S had improved. When tested at longer SOAs (300 and 400 msec), his accuracy rose to normal levels. His masking function as the same shape as the other Ss' except that it spanned twice to three times the range of SOAs. The difference between this S and the other three strongly inflated the Stimulus Conditions by Ss error term from the .0052 value of Experiment I to .0166.

Finally, unlike our previous analyses, the no-MS conditions were excluded from the stimulus conditions main effect, because this point was not crossed with the two MS luminances of this study. This further diminished the power of the test of the main effect because the contrast of the no-MS vs the average of the TS/MS pairings typically contributes systematic variance to the main effect of SOA.

The finding that MS luminance did not affect accuracy does not mean that Ss disregarded the MS in making judgments. Figure 3 contains the bias measures, $-\ln(b)$, as a function of SOA for the two MS levels. [The higher the value of $-\ln(b)$, the stronger the bias towards use of the "bright" response category.)as can be seen, there is a "contrast" effect at short SOA; the Ss tend to report both TS as brighter if they are accompanied by the dim MS as opposed to the bright MS. The two functions cross to yield an "assimilation" effect between 25 and 50 msec SOA. At long SOA, Ss are more likely to respond "bright" if the MS is also bright. Analysis of variance confirmed this MS Luminance by SOA interaction, $F(5,60) = 5.60$, $p < .01$. Neither main effect was significant.

Thus, as with our previous experiments in which SOA was blocked, Ss tended to balance their ratio of "bright" to "dim" responses in the same proportion

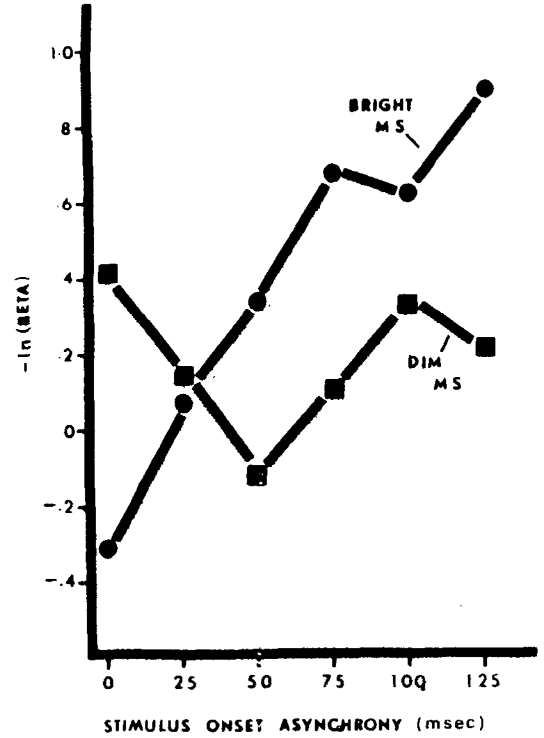

Fig. 3. Bias, defined in terms of —ln(b), as a function of SOA. Positive scores denote a tendency to respond "bright" and negative scores denote a tendency to respond "dim," Experiment II.

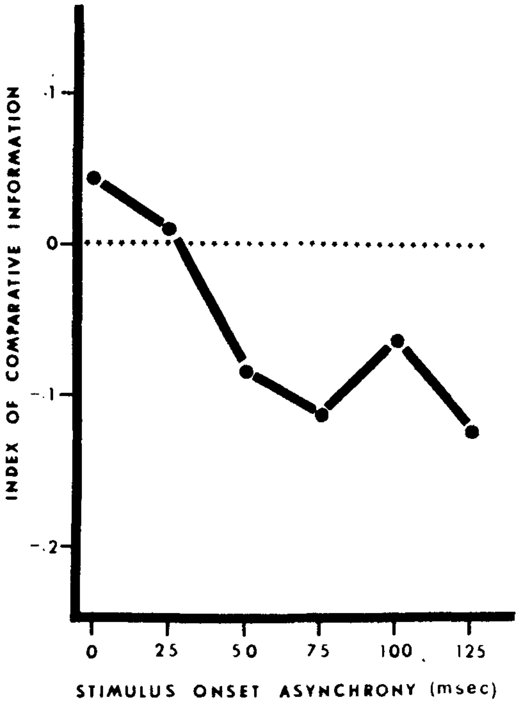

Fig. 4. Indices of comparative information, defined as the difference in percent correct responses between trials on which MS and TS luminance were the same vs different. Positive scores as a function of SOA denote that accuracy was higher when TS and MS luminance differed, and negative scores denote that accuracy was higher when TS and MS luminance were the same. Experiment II.

at each SOA. However, they did not divide their responses equally to the two MS luminances within each block, and the effect of MS luminance varied according to the SOA used for that block.

These bias functions are generally consistent with the comparison stimulus hypothesis as they indicate Ss do respond on the basis of MS luminance. However, these data do not bear directly upon the hypothesis in its specific form, because they do not indicate that Ss' accuracy improved at short SOA because of this information. There are various ways in which the MS luminance may influence judgments about TS luminance that are only remotely relevant to the comparison stimulus hypothesis. For example, S might respond, in part, on the basis of MS luminance. Evidence that Ss may confuse relevant and irrelevant attributes and respond on the basis of the latter does exist in other contexts (Hake, Rodwan, & Weintraub, 1966). What must be demonstrated is that accuracy was *aided* at short SOA by the presence of comparative information.

An *Index of Comparative Information* was constructed. This index was defined to be the accuracy in identifying the TS when its luminance was different from the MS minus the accuracy in identifying the TS when its luminance was the same as the MS. Operationally, this meant disregarding confidence ratings and computing the following quantity: P("bright"/bright TS-dim MS) + P("dim"/dim TS-bright MS) - P("bright"/bright TS-bright MS) - P("dim"/dim TS-dim MS). The hypothesis predicts that this index should decline monotonically with SOA.

Figure 4 contains these indices averaged over Ss as a function of SOA. The trend is as predicted by the hypothesis, although the main effect just missed significance, $F(5,15) = 2.71$. (The F ratio needed for significance at $a = .05$ is 2.90.) The linear component reflecting this decline was significant, $F(1,15) = 6.56$, $p < .01$. This component accounts for 48% of the main effect and 14% of the total. Also, the range of these indices (.16) is the same as the range of accuracies (areas) obtained.

In Fig. 5, we have plotted the accuracy measures of Fig. 2 corrected for the comparative information indices of Fig. 4 as a function of SOA. If the comparative indices represent one of the two hypothetical components postulated, then these data constitute the other, by definition. The hypothesis states that this component should be monotonically increasing. Actually, the function declines slightly up to 100 msec SOA but then increases sharply between that point and 125 msec SOA.

A trend analysis of these data indicated that 67% of the variance is accounted for by the quadratic component. However, almost as much variance (59%) is accounted for by the post hoc contrast of 125 msec vs the remaining SOA. Only 18% of the variance is

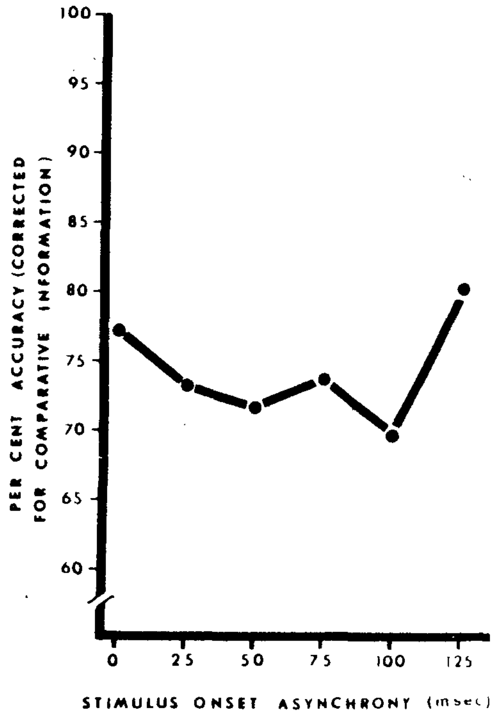

Fig. 5. Accuracy corrected for comparative information as a function of SOA. The dependent variable is area under the ROC curve with the index of comparative judgment covaried.

accounted for by the drop at 75 msec relative to the 0- to 100-msec SOA range, and only 19% of the variance is accountable for in terms of the rise at 0 msec SOA relative to 25 and 50 msec SOA. Thus, the single most prominent feature involving adjacent SOA is the rise at 125 msec SOA, a finding most consistent with our view. The correlation between the criterion (area) and covariate (comparative index) was .84, indicating that two-thirds of the variation in accuracy observed in the study may be identified as being due to brightness mismatch information.

The primary findings of this experiment are that it can be demonstrated that Ss use information provided by the MS in making brightness judgments and that this information is responsible, at least in part, for the superiority of performance at 0 msec SOA over that obtained with a slight delay. As of now, we cannot state whether the drop in performance manifest in the corrected masking function (Fig. 5) is due to not having fully corrected for these comparison stimulus effects or whether there is some nonmonotonicity in the masking function that arises from other sources, e.g., lateral inhibition.

The most important theoreical consequence of these data is that they illustrate a class of "higher order," judgmental, and contextual effects that permeate psychophysical data. The comparison stimulus hypothesis is designed to supplement, but not to replace, sensory effects like lateral inhibition, which we feel are also pertinent to visual masking phenomena. The simultaneous contrast that occurred at 0 msec SOA in the bias data (Fig. 3) seems to be one example of a lateral inhibitory phenomenon. Another example arises when MS is delayed and consequently onsets when TS has decayed somewhat. If these events arrive in the same "moment," i.e., if they are processed as a unit, strong lateral inhibitory effects could be expected to produce suppression. This need not occur at long delays where sequential processing of TS and MS can occur. What we specifically hope to achieve is a role for both "higher" and "lower" processes that does not require the rather strained assumptions made by Weisstein (1968) to account for lateral inhibition. As she indicates (pp. 498-500), the neurophysiological data that existed at the time of her article did not support her proposed mechanisms. Thus, while she justified one aspect of her model (the differential rise and decay times for inhibition and excitation) on neurophysiological grounds, she was forced to reject quite parallel data that suggested that masking functions inferred from neural firing rate were monotonic. Similarly, we find it paradoxical that her curves fit the then-existing data since they did not in general correct for the type of judgmental effects we have demonstrated.

The latter paradox can be resolved, of course, by assuming that these judgmental effects are peculiar to tasks, like ours, that involve accuracy, where Ss are motivated to use any available cues, and do not occur in phenomenal brightness tasks wher trained Ss are instructed to ignore these cues. There is little empirical data on this point simply because the latter types of studies typically make no attempt to assess judgmental effects. Moreover, the approach taken by Hake et al (1966) and Rodwan and Hake (1964) argues to our point in at least two ways. First, the former illustrates how, in a variety of tasks Ss cannot ignore context, even though use of contextual information, paralleling that produced by the MS at 50-100 msec SOA in this experiment, degrades performance. Secondly, they point out how one need not, as we have thus far done, limit attempts to isolate sensory and judgmental factors to accuracy tasks. Though the linear discriminant function was not as useful here as the procedure we employed, one of its main virtues is that it can be applied to tasks in which there is no accuracy criterion.

REFERENCES

Bernstein, I. H., Proctor, R. W., Proctor, J., & Schurman, D. L. Metacontrast and brightness discrimination. *Perception & Psychophysics*, 1973, **14**, 293-297.

Eriksen, C. W., Collins, J. F., & Greenspon, T. S. An analysis of certain factors responsible for nonmonotonic backward masking functions. *Journal of Experimental Psychology*, 1967, **75**, 500-507.

Fehrer, E., & Smith, E. Effect of luminance ratio on masking. *Perceptual & Motor Skills*, 1962, **14**, 143-147.

Hake, H. W., Rodwan, A., & Weintraub, D. Noise reduction in perception. In K. R. Hammond (Ed.), *The psychology of Egon Brunswik*. New York: Holt, Rinehart & Winston, 1966.

Granit, R. *Receptors and sensory perception*. New Haven: Yale University Press, 1955.

Kahneman, D. An onset-onset law for one case of apparent motion and metacontrast. *Perception & Psychophysics*, 1966, **2**, 577-584.

Kahneman, D. Method, findings, and theory in studies of visual masking. *Psychological Bulletin*, 1968, **69**, 494-425.

Lefton, L. A. Metacontrast: A review. *Perception & Psychophysics*, 1973, **13**, 161-173.

Luce, R. D. Detection and recognition. In R. D. Luce, R. R. Bush, and E. Galanter (Eds.), *Handbook of mathematical psychology*. Vol. 1. New York: Wiley, 1963.

Rodwan, A. S., & Hake, H. W. The discriminant function as a model for perception. *American Journal of Psychology*, 1964, **77**, 380-392.

Schurman, D. L. Predictive validity of a Rashevsky-Landahl neural net: Text of a model of masking for form. *Perception & Psychophysics*, 1972, **12**, 183-186.

Weisstein, N. A Rashevsky-Landahl neural net: Simultation of metacontrast. *Psychological Review*, 1968, **75**, 494-521.

NOTE

[1] Incidental observations by our more experienced Ss may be pertinent to this difference in minima. Regardless of whether MS luminance varies over trials or is held constant, the TS generally appears brighter at 25 to 60 msec SOA than it does at 100 msec SOA. Thus, maximum phenomenal suppression seems to occur at longer SOA. However, the contours of the stimuli are quite poorly defined and the stimuli appear heterogeneously illuminated at the shorter SOA; at longer SOA, the TS, though dark, appears more "object like" and is better defined. We would hypothesize that Ss gain some information at longer SOA from the brightness disparity between the TS and MS when MS luminance is held constant. Though less effective than same-different comparison at 0 msec, it still provides some information. When this source of information is further minimized through the introduction of MS luminance variation, the increment in accuracy at longer SOA is removed.

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