Reaction time to visual targets as a function of the proximity of a contour
by Stephen Charles Murphy

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology
Montana State University
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Abstract:
Recent investigations have found that the larger the display diameter, the faster the subjects' reaction times to targets presented in that display. Three alternative explanations have been proposed for these results. The first, which, involved the Gestalt principle of internal cohesion, does not provide a viable explanation. The second explanation involved contour interference effects. The third was based on simultaneous contrast effects. It has been impossible to determine which of the latter two explanations is superior, due to confounding in earlier research. In order to obtain a clean test of the contour interference explanation, all potential simultaneous contrast effects have been eliminated from the display used in the present study. The subjects' reaction times to targets presented within a simple contour ring were recorded. The four angles of separation between the contour and the targets were 1° , 3°, 6°, and 8&deg,. Contrary to what would be predicted by the contour interference explanation, no significant difference in reaction times was found as the separation between the target stimuli and the contour increased. Thus, contour interference effects can be rejected as an explanation for the earlier findings. The simultaneous contrast explanation, therefore, remains the only viable alternative of those considered.

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STEPHEN CHARLES MURPHY

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Abstract

Recent investigations have found that the larger the display diameter, the faster the subjects' reaction times to targets presented in that display. Three alternative explanations have been proposed for these results. The first, which involved the Gestalt principle of internal cohesion, does not provide a viable explanation. The second explanation involved contour interference effects. The third was based on simultaneous contrast effects. It has been impossible to determine which of the latter two explanations is superior, due to confounding in earlier research. In order to obtain a clean test of the contour interference explanation, all potential simultaneous contrast effects have been eliminated from the display used in the present study. The subjects' reaction times to targets presented within a simple contour ring were recorded. The four angles of separation between the contour and the targets were 1^{0}, 3^{0}, 6^{0}, and 8^{0}. Contrary to what would be predicted by the contour interference explanation, no significant difference in reaction times was found as the separation between the target stimuli and the contour increased. Thus, contour interference effects can be rejected as an explanation for the earlier findings. The simultaneous contrast explanation, therefore, remains the only viable alternative of those considered.

Introduction

Bell, Symington, and Bevan (1974) have investigated the effect of the size of a display on the reaction time to targets presented in the display. In this study, a square stimulus array, consisting of four small, brightly illuminated disks, was presented for .1 seconds in a circular display area. Two display area diameters were used; one diameter was 20 inches and the other diameter was 30 inches. The two display diameters were used in both a near and a far viewing condition. This combination of display diameter and viewing distance resulted in four display sizes, each subtending a different visual angle. In the far viewing condition, the 20-inch display subtended a visual angle of 9°, while the 30-inch display subtended an angle of 14°. In the near viewing condition, the 20-inch display subtended an angle of 28°, while the 30-inch display subtended a 38° visual angle. The display area, in all conditions, was surrounded by a black field. Figure 1 is an example of the display used by Bell et al. The subject's task was to report, as quickly as possible, whether or not a cross (target) had been presented in place of one of the disks (nontargets) in the array. The subject responded either positively (cross presented) or negatively (cross not presented) by depressing one of two keys. The time which elapsed between the onset of the stimulus array and the

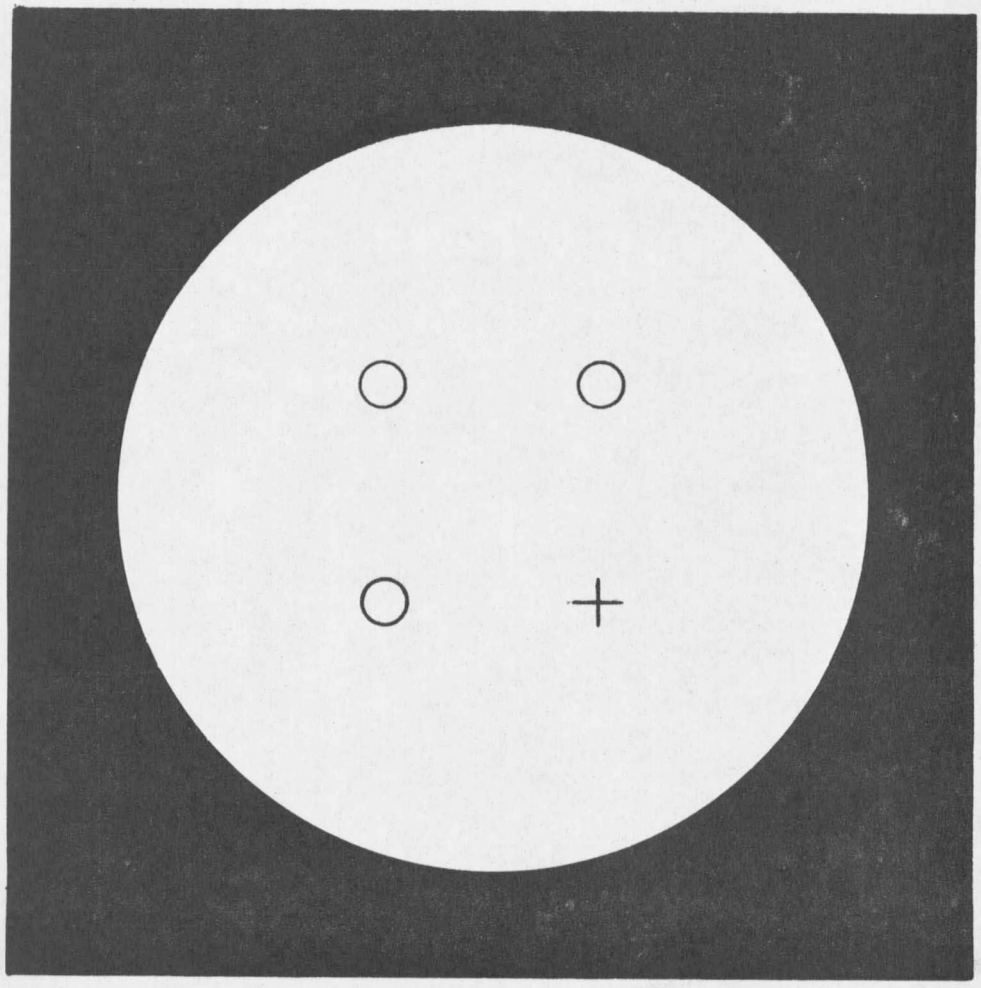


Figure 1. Display used by Bell, Symington, and Bevan (1974). The black surround measured 35 x 35 inches. The light display area had a diameter of either 20 or 30 inches. The stimuli (crosses and disks) were lighter than the display area.

depression of one of the response keys was recorded as the subject's reaction time.

Bell et al. found that the reaction times to targets presented in the 30-inch display conditions were significantly shorter than the reaction times to targets in the 20-inch display conditions, regardless of viewing distance. Since the stimulus array subtended a visual angle of 6° in all display conditions, dispersion was not considered to have influenced the results.

One explanation offered for the results was based on the Gestalt principle of internal cohesion. According to Koffka (1935), when a contour line is closed (such as a circle) the area inside the contour becomes a unified entity, completely separate from the area outside the contour. The enclosed area is said to be internally cohesive because it tends to resist the formation of any other figure within its boundaries. The enclosed figure is most easily viewed as being homogeneous (Wertheimer, 1955). Bell et al. suggest that the border between the display area and the black surround constituted an enclosing contour. Thus, the internal cohesion of the display area interfered with the detection of the targets. Bell et al. implied, but never directly stated, that the larger display diameter had less internal cohesion than the smaller

display diameter. Less internal cohesion would mean less interference with the detection of the target and, therefore, faster reaction times in the larger display.

Internal cohesion, however, is a uniform property of the figure and is lost only when the figure is no longer perceived as being a figure (Koffka, 1935). It is not a function of the size of the figure or the distance from the enclosing contour. In the Bell et al. study, internal cohesion was a constant in both display diameters and, therefore, should have had no effect on the reaction times.

Furthermore, Craik and Zangwill (1939) have empirically tested the internal cohesion assumption. In the first experiment reported by these authors, the threshold for a test spot was higher when the test spot appeared inside a figure than when the test spot appeared outside the figure. In the second, and more important, experiment, the threshold at which the test spot was just detectable rose as black lines were added to the field around the test spot. The rise in the threshold was the same, regardless of whether the lines were arranged to form a good figure (a square) or merely to form a set of parallel lines on either side of the test spot (see Figure 2). Craik and Zangwill considered the second finding incompatible with the principle of internal cohesion. While the authors offered no firm expla-

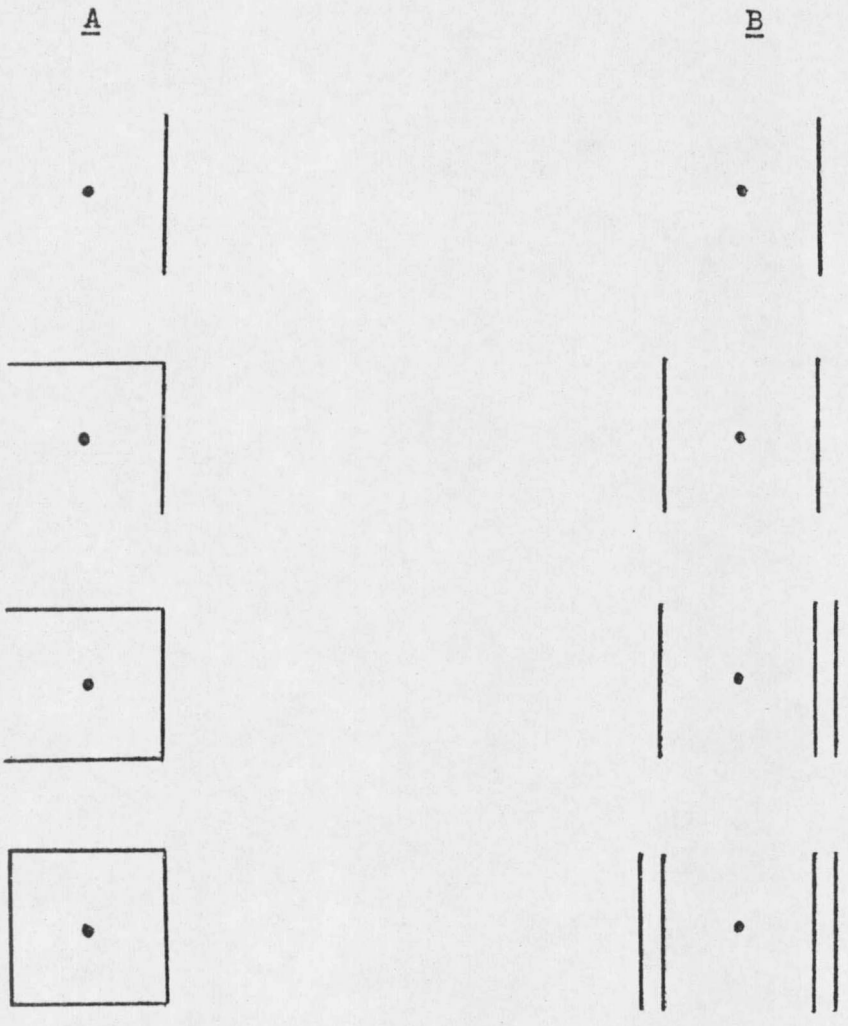


Figure 2. Stimuli used by Craik and Zangwill (1939). The stimuli in column A were arranged so that as more lines were added they formed an enclosing contour. The stimuli in column B were arranged so that as more lines were added they formed sets of parallel lines to the right and left of the test spot (dot). While the threshold of the test spot rose as the number of lines increased, the arrangement of the lines had no effect.

nation for their findings, they did mention the possibility that the change in the amount of light stimulating the retina, which was a result of the addition of the black lines to the field, may have influenced the threshold for the test spot. Youniss and Calvin (1961) have confirmed the basic findings of Craik and Zangwill.

A second explanation offered by Bell et al. involves contour interference effects. They suggested that the strong contour created at the point where the light display area met the black surround interfered with the subject's ability to distinguish the targets from the nontargets. The closer the contour to the target stimuli, the stronger should be the interference effect. Thus, in the 30-inch display conditions, where the contour was separated from the targets by a greater distance than in the 20-inch displays, there would be less interference with the differentiation between targets and nontargets. Easier differentiation of the targets would result in faster reaction times for the subjects. It should be noted, however, that Bell et al. reported their results in terms of display diameter, rather than angle of contour-target separation.

The support for the contour interference explanation cited by Bell et al. is based on an experiment reported by

Fry and Bartley (1935). Using the display shown in Figure 3, they found that when the distance between the test spot A and the contour line B was varied, the contrast threshold at which A was detactable also varied. As the separation between A and B increased, the threshold at which A was detectable decreased. The explanation offered was that the edge of contour B interfered with the differentiation of a boundary between A and the background. The further B was from A, the less the boundary was affected by this interference. This effect, however, was not found when the separation between A and B exceeded 4° of visual angle (see Figure 4).

In a related study, Flom, Weymouth, and Kahneman (1963) found that a nearby contour line can adversely affect visual resolution. Flom et al. used Landolt C's, surrounded by four tangentially arranged black contour lines, as stimulus patterns (see Figure 5). The separation between the Landolt C and the black contour lines varied between 0° and $2^{\circ}38'$ of visual angle. Each subject viewed the stimulus pattern from a distance at which he could, 80% of the time, correctly identify the position of the gap in an unsurrounded C. When the contours were within $\frac{1}{3}$ of a degree of the Landolt C, the probability of the subject correctly identifying the position of the gap was reduced by as much as 0.80. When the contours

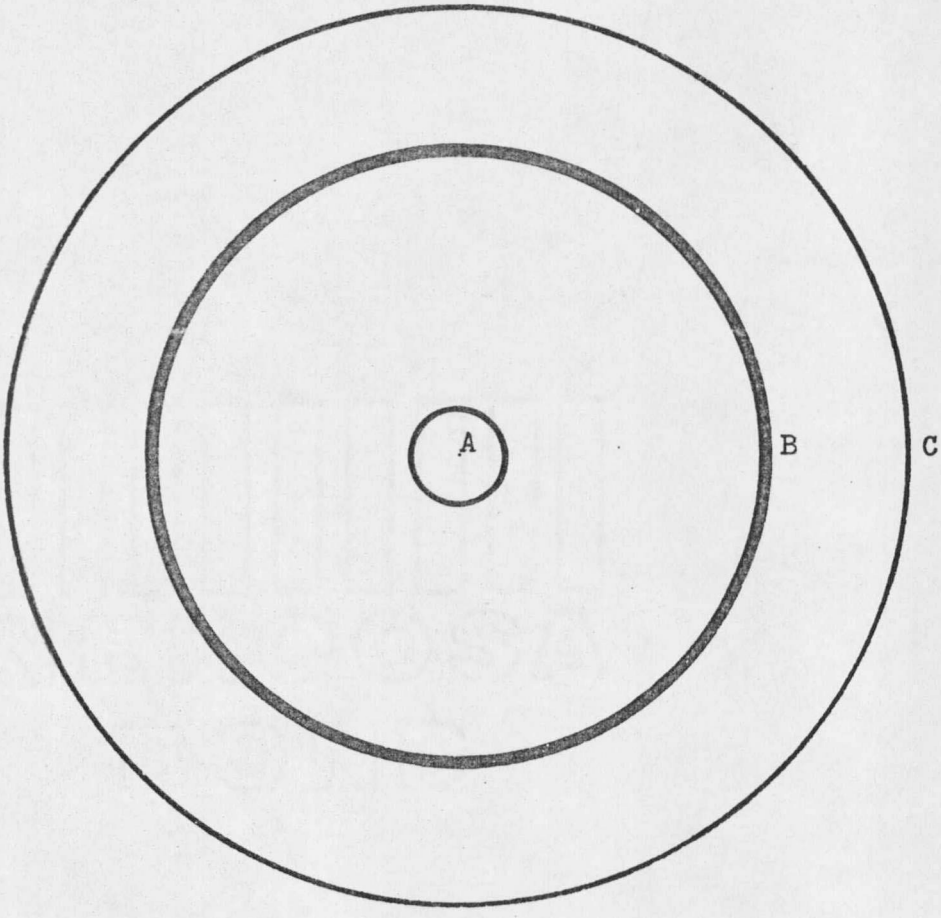


Figure 3. Display used by Fry and Bartley (1935). (A) is a brightness test spot. (B) is a contour ring. (C) is the edge of the display. The distance between A and B was varied and the threshold for A was established for each level of separation.

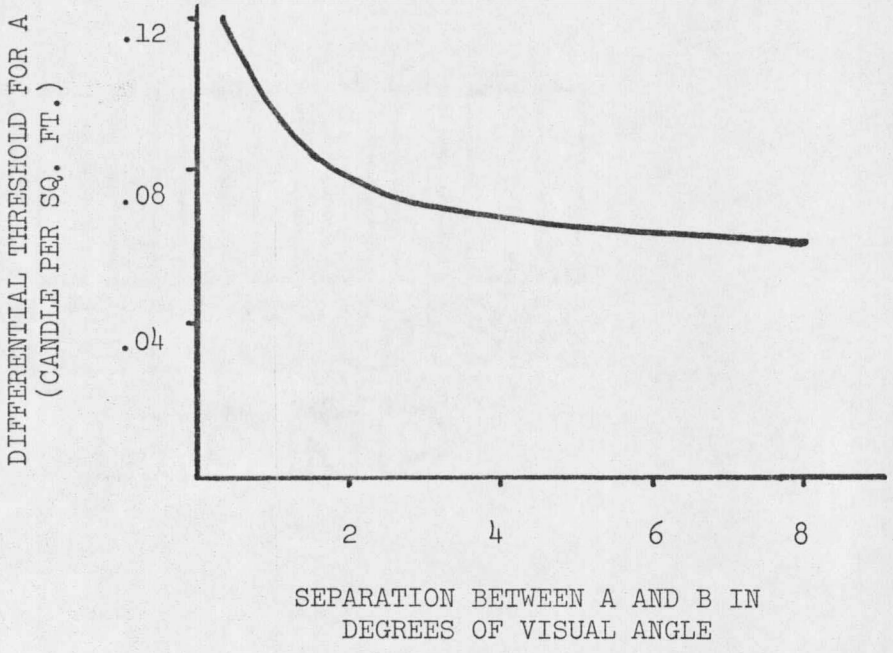


Figure 4. Results obtained by Fry and Bartley (1935). As the separation between A and B increased, the threshold for A decreased. The effect is most noticeable when the separation between A and B is less than 4^{o} of visual angle.

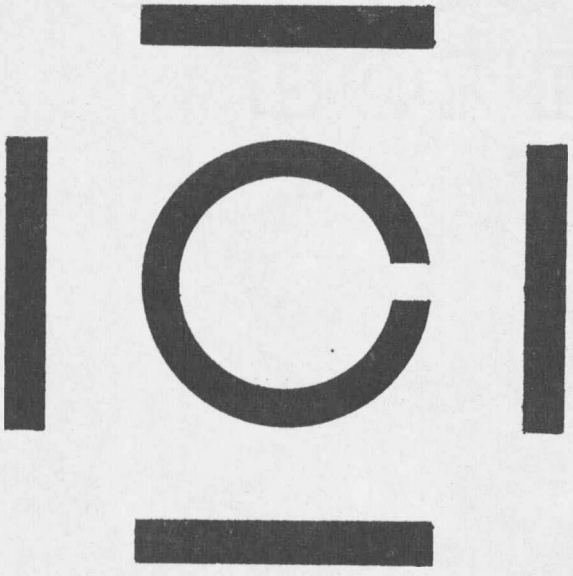


Figure 5. Stimulus pattern used by Flom, Weymouth, and Kahneman (1963). The bars were the same width as the gap in the Landolt C. The distance between the bars and the C varied between 0° and $2^{\circ}38'$.

were placed beyond 1/3 of a degree of the Landolt C, there was no significant reduction in the subject's performance. The explanation offered for these results was that when the contours were within 1/3 of a degree of the Landolt C some sort of lateral inhibition took place between the receptive fields involved. This lateral inhibition reduced the sensitivity of the receptive fields and, thereby, interfered with the resolution of the stimulus pattern.

Bell et al. had four angles of separation between what they defined as the contour and the stimulus array. In the far viewing condition, the angle of separation between the contour and the stimulus array was 1.5° for the 20-inch display and 4° for the 30-inch display. In the near viewing condition, the angle of separation between the contour and the stimulus array was 11° for the 20-inch display and 16° for the 30-inch display. The angle of separation between the contour and the stimulus array, thus, was larger in the 20-inch display in the near viewing condition than in the 30-inch display in the far viewing condition. According to the contour interference explanation, then, reaction times to targets in the 20-inch display in the near viewing condition should have been faster than reaction times to targets in the 30-inch display in the far viewing condition. However, it

is impossible to confirm this, because Bell et al. reported their results only in terms of display diameter.

There is another problem with the contour interference explanation. While the effect reported by Fry and Bartley (1935) would seem to account for a difference between the 1.5^{o} and 4^{o} angles of separation, it cannot account for any differences between the larger angles of separation. In fact, their results suggest no differences would be obtained between any angles of separation over 4^{o}. The results reported by Flom, Weymouth, and Kahneman (1963) are even less in accord with those obtained by Bell et al. The findings of Flom et al. suggest that no differences should be obtained between any of the four angles of separation.

Close examination of the methodology used by Bell et al. suggests another factor which may account for the results obtained. The stimulus array, which subtended a visual angle of 6^{o}, was presented for only .1 seconds. This short exposure duration would not permit the subject to appreciably change his point of fixation while the stimulus array was being presented. Even assuming that the subject fixated the center of the array in an attempt to minimize the distance between his fixation point and the four possible positions in which the targets could appear, his fixation point would still be

3^{o} from the target. Visual acuity falls off extremely rapidly, however, as the distance from the center of the fovea into the periphery increases, as shown in Figure 6 (Llewellyn-Thomas, 1968). This would considerably increase the difficulty of the task for the subject.

Under presentation conditions quite similar to those of Bell et al., McDonnell (1970) found that subjects make considerable use of target albedo and the contrast between the target and the background in selecting a target to respond to. Bell et al. provided just such a brightness cue. The brightness of the target stimuli differed from the surface of the display by only 3 foot-lamberts, while the nontarget stimuli differed from the display surface by 6 foot-lamberts.

Subjects may have made use of the brightness information in the following way. The levels of brightness of the different areas of the array could have been compared to one another. If all four quadrants were judged to be the same brightness, the subject could report that there were no targets presented. If, on the other hand, one quadrant was judged to be less bright, the subject could report the presence of a target. Anything which interfered with the subject's ability to make the brightness judgment would also lengthen the subject's reaction time.

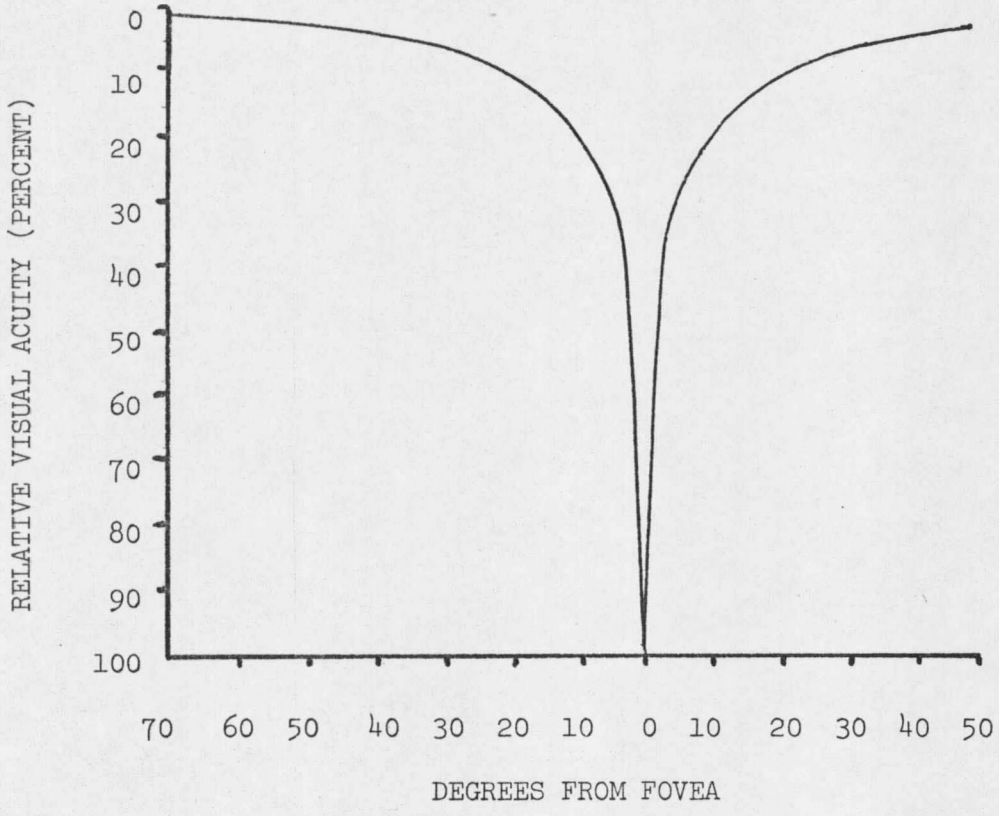


Figure 6. The decrease in visual acuity as the distance from the fovea increases. Taken from Llewellyn-Thomas, E. Movements of the eye. Scientific American, 1968, 219, 93.

If the subjects adopted the brightness-judgment strategy, a third explanation for the Bell et al. data is suggested. It involves the phenomenon of simultaneous contrast. We know, for example, a dark gray piece of paper on a white background looks darker than the same piece of paper on a medium gray background. Hurvich and Jameson (1966) state that the size of a contrast inducing area affects the perceived brightness of the test area in brightness-contrast experiments. The larger the inducing area, the greater the contrast effect. If one had a large black field of fixed size with a small gray circle in the middle, the gray area would be perceived as being brighter than it really was. If the size of the circle was increased, then the area of the black field would be reduced. Following Hurvich and Jameson, then, the larger the circle, the less its brightness would be enhanced by the black field.

This same type of simultaneous contrast situation existed in the Bell et al. study. The size of the black surround was held constant at 35x35 inches. When the diameter of the display area was increased from 20 inches to 30 inches, the area of the black surround was reduced. We may assume, therefore, that the apparent brightness of the display area was enhanced to a lesser extent in the 30-inch display condition

than in the 20-inch display condition. Thus, the display area in the 20-inch display condition should appear brighter than the display area in the 30-inch display condition, regardless of viewing distance.

The simultaneous contrast phenomenon also applies to the relationship between display area and stimulus array elements. The actual brightness of the display area was less than the actual brightness of the array elements. The display area, therefore, also acted as an inducing field which affected the apparent brightness of the array elements. As Hurvich and Jameson (1966) have shown, the apparent brightness of the elements of the stimulus array, when viewed under these conditions, would actually decrease as the apparent brightness of the display area (their surround) increases. As the apparent brightness of the display area increases, the apparent contrast between the array elements and the display area background decreases. The inverse is also true. Since the apparent brightness of the display area was enhanced less in the 30-inch condition than in the 20-inch condition, the apparent contrast between the array elements and the display area background was greater in the 30-inch condition. Increased contrast between the array elements and the display area background facilitated the detection of any brightness-

contrast differences between the different parts of the display area. Thus, faster reaction times would be expected for the 30-inch display conditions than for the 20-inch display conditions.

Thus far, three explanations have been offered for the results obtained by Bell et al. The first involved the concept of internal cohesion. However, internal cohesion, as defined by Koffka (1935), was a constant in all display conditions in the Bell et al. study. The findings of Craik and Zangwill (1939) and Youniss and Calvin (1961) cast further doubt upon the concept of internal cohesion. Thus, the principle of internal cohesion does not appear to provide a viable explanation for the Bell et al. results.

The second explanation was based on contour interference effects. The findings of Fry and Bartley (1935) and Flom, Weymouth, and Kahneman (1963) do not totally support this explanation. These investigators have not found contour interference effects to be present at angles of separation exceeding 4^{o}. This is in apparent conflict with the findings of Bell et al.

The third explanation, proposed in this study, is based upon simultaneous contrast effects. This explanation is superior to the contour interference explanation in that it

can account for the difference in reaction times between the 20 and 30-inch display conditions, which Bell et al. obtained without regard to angle of separation. However, it is impossible to discount either the contour interference explanation or the simultaneous contrast explanation, because they are confounded in the Bell et al. study.

These two explanations are confounded partially because of the definition of a contour used by Bell et al. They defined a contour as the border which separated the display area from the large surround area. In other words, the contour was the line along which two large contrasting fields met. The contour used by Fry and Bartley, on the other hand, consisted of a single, thin line in the shape of a circle. Flom et al. used four thin, unconnected lines arranged around the Landolt C. The potential for simultaneous contrast effects is far greater for the type of contour used by Bell et al. than for the type of contour used by Fry and Bartley and Flom et al.

It is impossible to differentiate between the contour interference explanation and the simultaneous contrast explanation. By eliminating all potential sources of simultaneous contrast differences from the display and controlling for the confounding effect of different contrast values for the target and nontarget stimuli, it would be possible to determine

whether contour interference effects account for the results obtained by Bell et al. If contour interference effects were not found to account for the results, the simultaneous contrast explanation would remain the only viable explanation of those considered.

Method

Subjects

The subjects were 40 volunteers from an introductory psychology course. The volunteers received points that could be applied to their final grades in the course. The subjects were randomly assigned to four experimental groups. In each group there were five males and five females.

Apparatus

A Gerbrand 300 Series two-channel tachistoscope was used to present the displays to the subjects. The displays were made from gray-colored paper. The paper's level of reflectance was measured by a Spectra Model 1815-SB brightness spot meter. The measurements were taken in the tachistoscope, under the same lighting conditions that were used during the experimental sessions. The brightness of the black paper that was used to make the contour ring was approximately 2 foot-lamberts. The brightness of the paper that served as the surface of the display was approximately 13 foot-lamberts. The brightness of the paper that was used to make the target and nontarget stimuli was approximately 20 foot-lamberts.

Figure 7 shows a typical display containing a stimulus array. The nontarget stimuli were circles 4 mm in diameter. The target stimuli were squares having the same area as the nontarget stimuli. The target and nontarget stimuli were cut

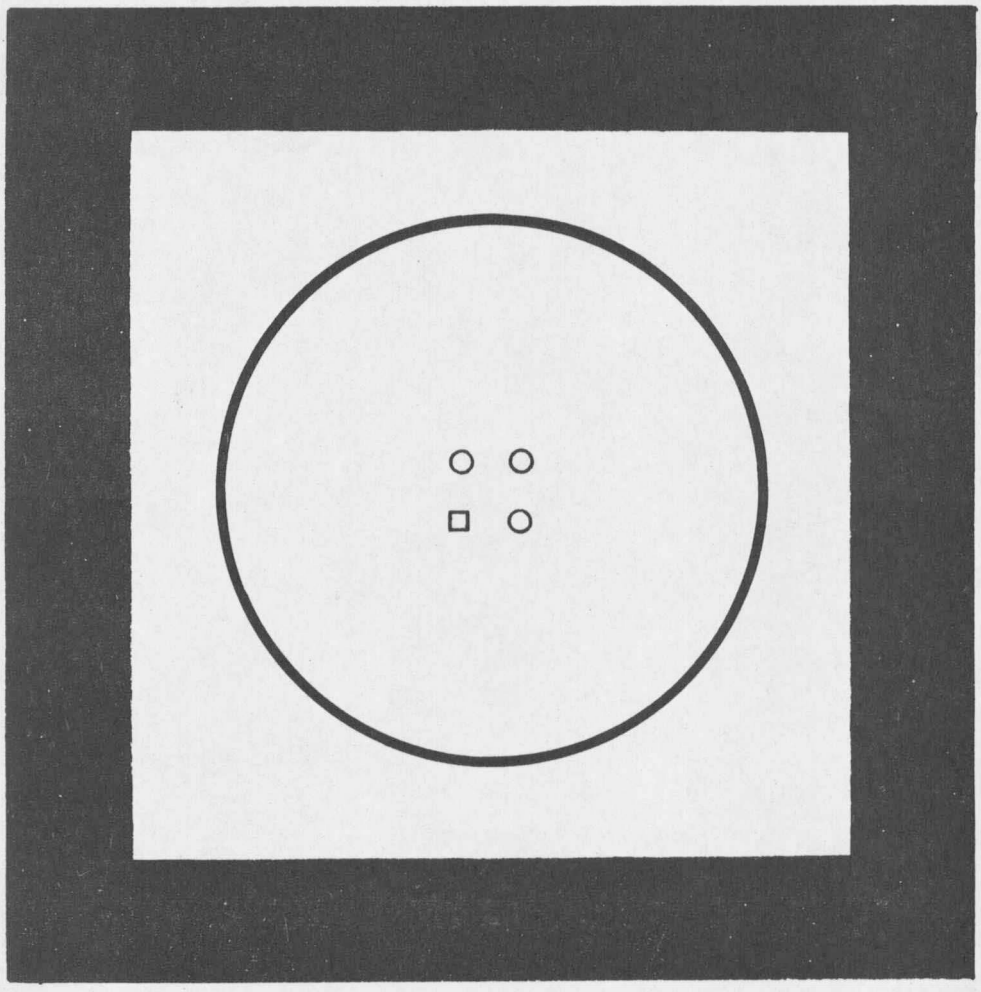


Figure 7. Example of the display used in the present study. Stimulus array has a target in the lower left position. The thick black border was created by the walls of the tachistoscope. Stimuli were actually lighter than the display area surface.

from the same paper. Since the nontarget and target stimuli were equal in area and made from the same material, they were equal in brightness.

The stimulus array consisted of four stimuli arranged in a square pattern. The array subtended a visual angle of $1^{\circ}20'$. There were two basic types of array. One type of array consisted of four nontarget stimuli. The other type of array contained one target stimulus and three nontarget stimuli. The target appeared in each of the four possible positions in the array. Thus, there were four variations of the second type of array. Each array was mounted on the gray paper which served as the surface of the display area. Four copies of each of the five arrays were made. This provided one copy of each array for each of the four levels of contour-target separation.

Around the outside of each array was placed a contour ring. The contour was quite similar to that used by Fry and Bartley (1935). It consisted of a ring, $\frac{1}{8}$ inch wide, which was cut from the black paper. The size of the rings varied, so as to provide four different angles of separation between the array and the inside diameter of the contour ring. The four angles of separation were 1°, 3°, 6°, and 8°. While these angles were not the same as those used by Bell et al.

(1974), they cover the critical range of separation over which contour interference effects have been noted.

One additional display was constructed for each angle of separation. In these four displays, a contour ring of the appropriate size surrounded a simple fixation cross (see Figure 8).

All displays were mounted on a thin piece of cardboard, in order to facilitate loading them into the tachistoscope.

The displays consisting of a contour ring and a fixation cross were placed in channel 1 of the tachistoscope. These displays were used to maintain intertrial illumination and to insure that the subject was fixating the center of the array when it was presented. The displays containing stimulus arrays were presented in channel 2 for .1 seconds each. Each subject saw the displays corresponding to only one angle of separation.

Thus, the subject was looking at a fixation cross, centered inside a contour ring, prior to each presentation of channel 2. When channel 2 was presented, the fixation cross disappeared and was replaced by the stimulus array. Since a contour ring was present in the display in each channel, the subject noticed no change in the contour during the presentation of channel 2.

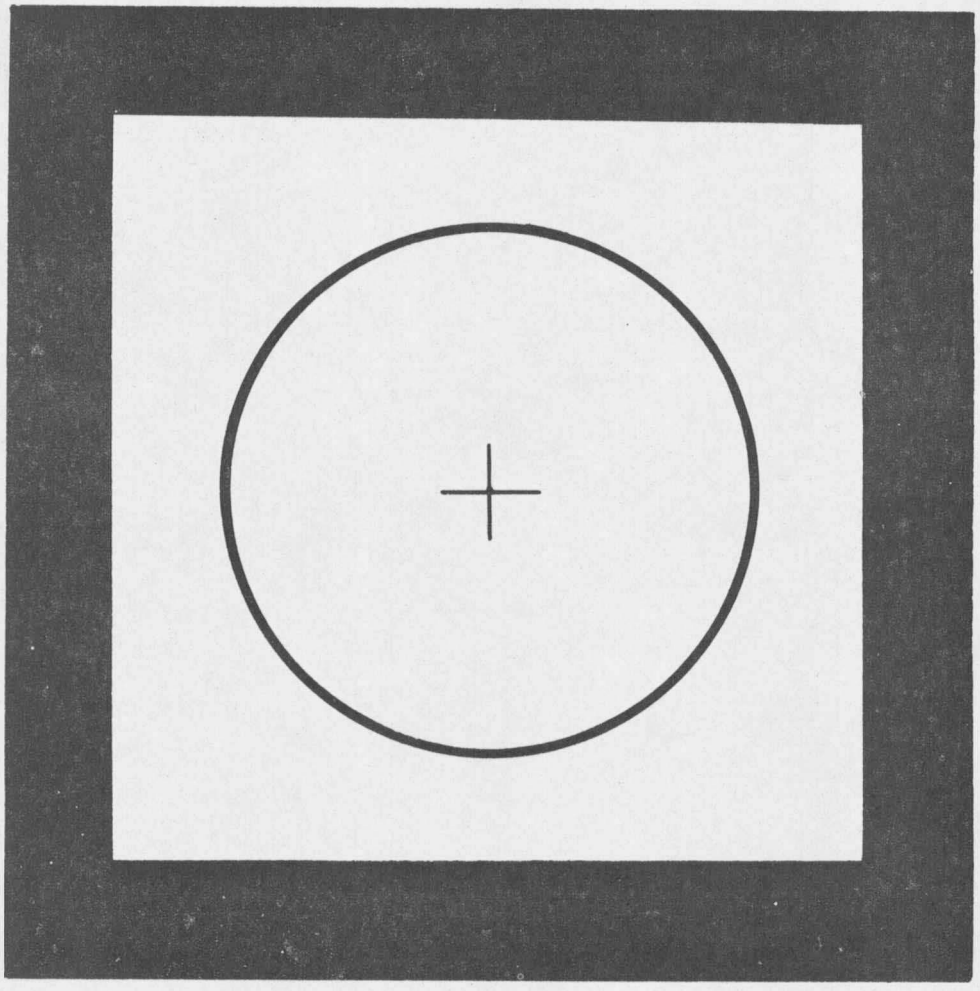


Figure 8. Example of the constant illumination display.

The subjects' reaction times were measured by a Hunter Model 120C Klockounter. The counter started when channel 2 of the tachistoscope was triggered. A three-position toggle switch with a neutral center position was also wired into the circuitry of the Klockounter. The counter was terminated when the subject moved the switch to either peripheral position.

Procedure

When the subject arrived, he or she was comfortably seated at the tachistoscope and was read the following instructions:

> The experiment you are about to participate in deals with visual target recognition. If you look in the tachistoscope, you will see a lighted gray surface with a black ring on it. Inside the ring is a black cross. From time to time there will be some circles and squares flashed in place of the cross. Just before each presentation I will give you a ready signal. At that time you should look directly at the center of the cross so you won't miss the presentation. It will be your job to tell me if there were four circles in the display, or three circles and a square in the presentation. If there was a square in the presentation, push the toggle switch to the "yes" position. If there were all circles in the presentation, push the switch to the "no" position. Whichever way you push the switch, let it stay in that position for a second or two and then recenter the switch. When you recenter the switch, tell me whether your response was a "yes" or a "no."
>
> Speed and accuracy are both very important in this experiment. You should try to respond with the switch as quickly as you can without making any mistakes. Are there any questions?

After any questions were answered, the subject was given 12 warm-up trials. The displays were presented for .2 seconds

during the warm-up trials. The subject then received the 96 experimental trials. On 48 of these trials there were no target stimuli present. On the remaining 48 trials the target stimulus appeared in each of the four possible positions 12 times. The subjects were not told what proportion of the presentations would contain a target. Ten different orders of presentation were randomly developed. Each order was used for only one randomly selected subject in each group.

The positions of the toggle switch which corresponded to "yes" and "no" were also randomly determined for each subject. This was done to control for any movement preferences on the part of the subjects and for any mechanical bias in the switch.

Having the subject vocally report whether his response was "yes" or "no," facilitated the recording of the data. Subjects were checked on a minimum of 20 trials to insure that their verbal reports consistently matched the switch position selected. During the practice trials the subjects were also trained to respond with the switch before making their verbal reports.

On any given experimental trial, the experimenter first loaded the appropriate display into channel 2 of the tachistoscope. The next step included pushing a momentary contact

switch which started a two-second delay period, while, at the same time, saying "Ready" to the subject. At the end of the two-second delay, the display appeared in channel 2 of the tachistoscope for .1 seconds. A relay connected to the lamp drive circuit started the Klockounter at the same time that the lights went on in channel 2. As soon as the subject responded with the switch, the experimenter recorded the reaction time and reset the Klockounter. The subject's verbal response was then recorded on an answer sheet which was keyed so that any errors could also be noted. The experimenter then changed the displays in the tachistoscope and the process was repeated.

A postexperimental interview was conducted in an effort to gain information about the strategies employed by the subject.

Results

The statistical analysis of the data was carried out with the aid of a Hewlett-Packard Model 9810A minicomputer. For each subject the mean reaction times for the positive and negative responses were computed separately. The errors, which averaged 2.175 per subject, were excluded from these calculations. An unreplicated nested model of analysis of variance, often referred to as a split plot analysis, was used to analyze the reaction time data. This particular analysis was employed because it permitted the reaction times for both the positive and negative responses to be simultaneously tested. This analysis also tested for any interaction between the type of response (positive or negative) and the various levels of separation.

As can be seen in Table 1, there was no significant difference in the reaction times between the various levels of separation. Thus, the data do not support the contour interference explanation which predicted that as the separation between the contour and the targets increased, the subject's reaction time would decrease. Furthermore, there was no significant difference in the reaction times between those levels of separation that were greater than 4° of visual angle and those levels that were less than 4°. This might have been expected on the basis of the Fry and Bartley (1935) results.

Table 1

Summary of Analysis of Variance for Positive and Negative Response Reaction Time Data

Source	SS	df	MS	F
Subjects (r)	3.1800	36	0.0830	-----
Levels of separation (B)	0.2820	3	0.0940	1.0641
Type of response (C) (positive or negative)	0.2432	1	0.2432	33.0213***
B x C	0.0142	3	0.0047	0.6418
rC/B	0.2651	36	0.0074	-----
Total	3.9845	79		

*p<.05
**p<.01
***p<.001

A significant difference (p<.001), however, did exist between the positive and negative responses. The negative responses had a significantly slower reaction time. The difference between the overall means of the positive and negative responses was .10226 seconds. There was no significant interaction between the type of response and the levels of separation, however. The mean reaction time for each level of separation is shown in Figure 9.

The average number of errors made by each subject was

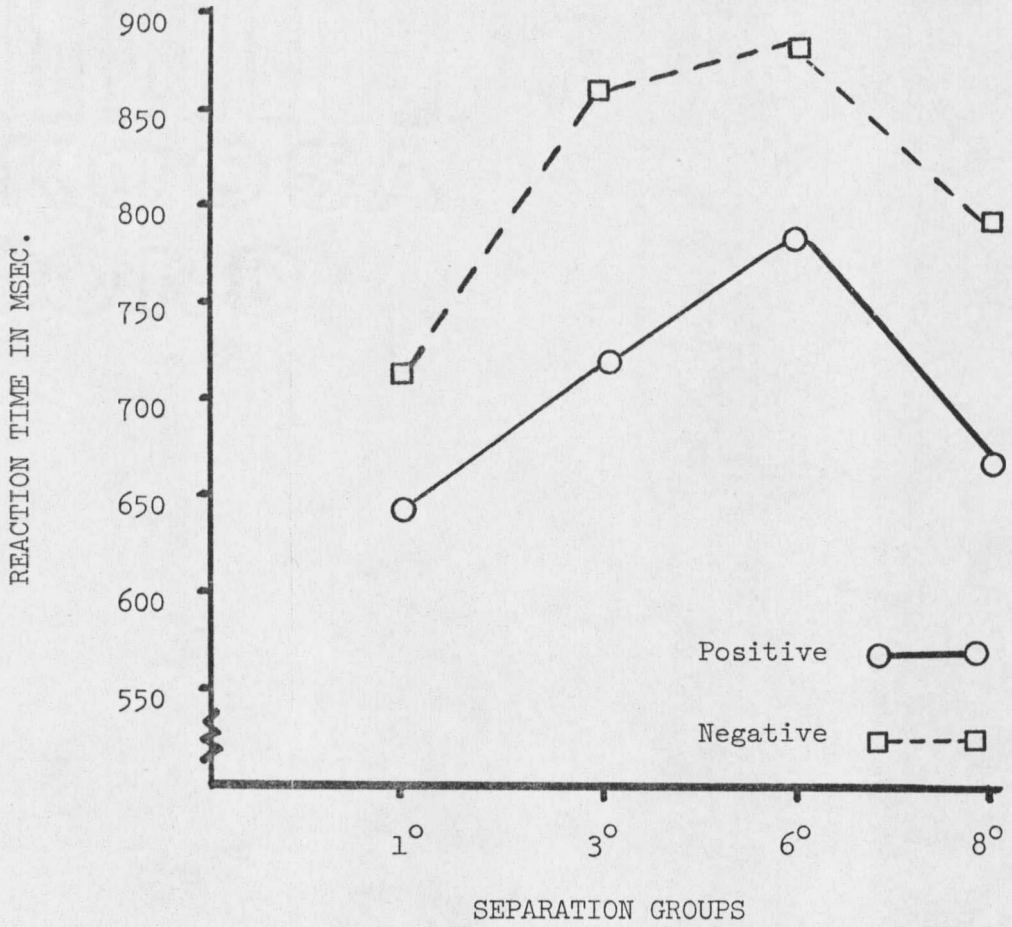


Figure 9. The mean reaction times for the subjects at each angle of contour-target separation.

2.175 errors. The errors were broken down into two types. The first type of error was a false positive, or an instance when the subject reported a target when none had been presented. The second type of error was a missed target, or an instance when the subject reported no target when, in fact, one had been presented. The error data were analyzed with the same type of analysis of variance as was used for the reaction time data. The results of this analysis are shown in Table 2.

Table 2

Summary of Analysis of Variance for Error Data

Source	SS	df	MS	F
Subjects (r)	72.0500	36	2.0014	-----
Level of separation (B)	13.8375	3	4.6125	2.3046
Type of error (C)	17.1125	1	17.1125	7.1759*
B x C	8.5375	3	2.8458	1.1934
rB/C	85.8500	36	2.3847	-----
Total	197.3875	79		

*p<.05
**p<.01
***p<.001

Table 2 shows that there was no significant difference

in the number of errors between the different levels of separation. There were, however, significantly ($p<.05$) more false positive errors than missed target errors. Figure 10 summarizes the error data.

Figure 10 shows an increase in the number of false positive errors as the angle of contour-target separation increases. While this increase is not statistically significant, it is, nevertheless, interesting. In the postexperimental interview 33 out of the 40 subjects reported that they were much more certain when a target had been presented than when a target had not been presented. The increase in the number of false positive errors at the larger angles of separation indicates that this uncertainty also increases at the larger angles of separation. This relationship seems to warrant further investigation.

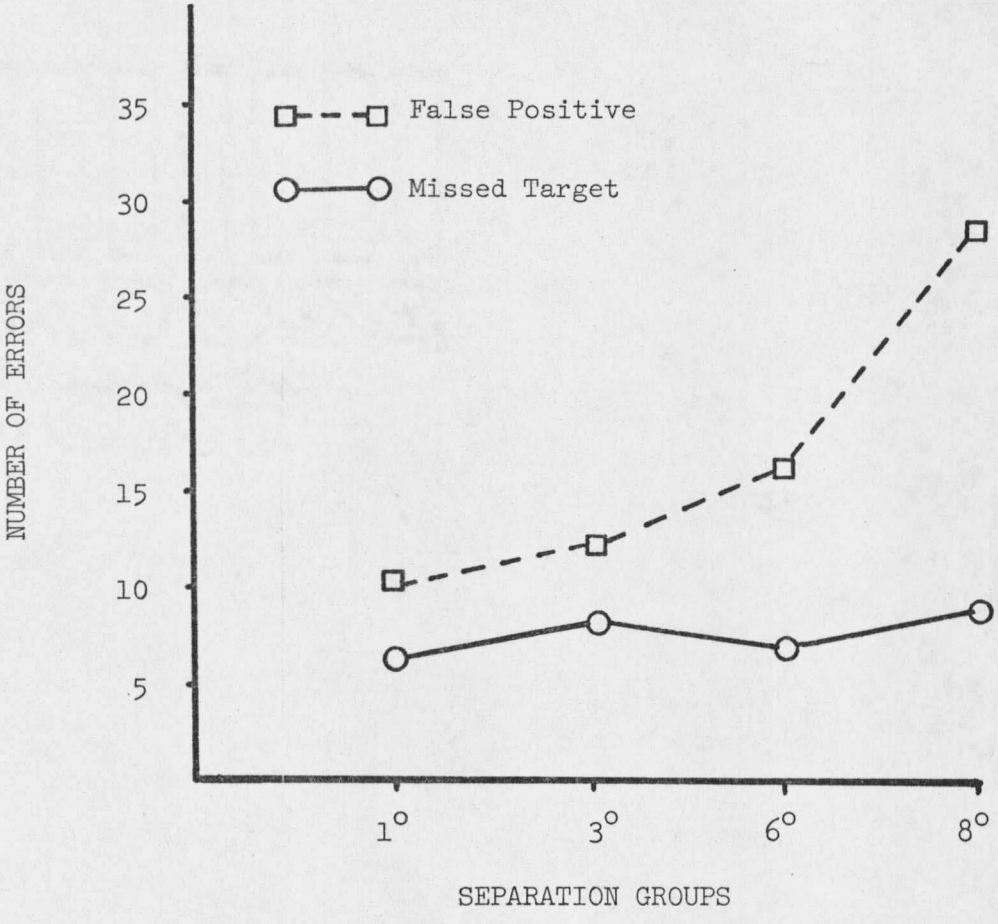


Figure 10. Total number of each type of error at each angle of contour-target separation.

Discussion

This experiment was conducted to determine whether or not contour interference effects could have accounted for the results obtained by Bell, Symington, and Bevan (1974). In order to obtain a clear test of this explanation, it was necessary to eliminate all potential simultaneous contrast differences from the display. This was accomplished by making two major changes in the display used by Bell et al. The first of these changes involved a modification of the contour. Bell et al. defined contour as the border along which the display area and the black surround met (see Figure 1). In the present study, as in other investigations concerned with contour interference effects (Flom, Weymouth, & Kahneman, 1963; Fry & Bartley, 1935), contour was defined as a thin line placed around the target stimuli (see Figure 7). The second major change involved the target and nontarget stimuli. In the Bell et al. study the target stimuli were dimmer and smaller than the nontarget stimuli. In the present study the target and nontarget stimuli were of equal brightness and area.

Using the modified displays, no significant differences in reaction time between the different angles of contour-target separation were obtained. The contour interference explanation offered by Bell et al. predicted that, as the angle of separation between the contour and the stimulus array increased, the

subjects' reaction times would decrease. Thus, the contour interference explanation was not supported by the data obtained in the present investigation. In light of these findings, the contour interference explanation for the findings of Bell et al. can be rejected.

The results of this investigation, thus, lend support to the simultaneous contrast explanation. It should be noted, however, that the simultaneous contrast explanation was not subjected to an empirical test. At this point, it remains a viable alternative explanation which merits further testing.

The results of the present study are compatible with the findings of Flom, Weymouth, and Kahneman (1963). These investigators found that contour interference did not affect visual acuity once the separation between the contour and the targets exceeded 1/3 of a degree of visual angle. Thus, the results of Flom et al. suggest that no contour interference effects would be found at angles of contour-target separation as large as those used in the present study.

The findings of Bell et al., interpreted in the light of the present investigation, at least suggest that simultaneous contrast effects may influence the detectability of targets under certain display conditions. The potential for this type of influence exists in any display situation in which the

operator makes use of brightness-contrast information to locate and/or identify targets. Any large, contrasting areas in close proximity to the display may interfere with the operator's ability to utilize this brightness-contrast information. This type of interference could inadvertently be incorporated into the design of a radar watchkeeping task. If a brightly lighted radar screen were mounted in a dark-colored panel, simultaneous contrast effects would enhance the apparent brightness of the screen. This could, in turn, decrease the apparent contrast between the surface of the screen and any stimuli appearing on the screen. If the amount of apparent contrast between the stimuli and the display surface of the screen was a factor in the operator's decision regarding the relevance of the stimuli, the operator's performance would be adversely affected. The more the apparent brightness of the screen is enhanced through simultaneous contrast, the more operator performance may be impaired. Design engineers should definitely consider these factors when designing displays.

There were two additional minor findings in the present investigation. The finding of a significant difference in the reaction times for the positive and negative responses can be partially accounted for in terms of a mechanical bias. The toggle switch that was used by the subjects to indicate their

responses offered more resistance when it was pushed toward the DOWN position than when it was pushed toward the UP position. This factor was to have been controlled for by the randomization of the response positions. The majority of subjects who were assigned the UP position of the toggle switch for the negative response and the DOWN position for the positive response reported in the postexperimental interview that this arrangement seemed backward to them and that it probably slowed their reaction times. Thus, while a mechanical bias definitely slowed the negative responses and facilitated the positive responses for half of the subjects, it is also possible that, because of stimulus-response incompatibility, both the positive and negative responses were slowed for the other half of the subjects. An arrangement in which the subject moved the switch to one side or the other to indicate his response would probably have been superior to the up-and-down arrangement used.

The strategy employed by the subjects was a second, and more important, factor which may have contributed to the significant difference between the reaction times for positive and negative responses, as well as the significant difference between the number of each type of error. In the postexperimental interviews, 33 out of 40 subjects reported that they

were much more certain when a target stimulus had been presented than when an all nontarget array had been presented. The majority of these subjects also reported that the corners of the target seemed to stand out from an otherwise blurry background. In the nontarget array presentations the subjects were much more uncertain of their responses. This uncertainty would contribute to longer reaction times for negative responses, as well as contributing to an increased probability of false positive type errors. If the subjects had been informed of the proportion of presentations in which a target appeared, the difference between false positive and missed target errors may have been reduced.

Numerous investigators (Kaufman & Richards, 1969; Mackworth & Morandi, 1967; Richards & Kaufman, 1969; Yarbus, 1967) have found that subjects attend to and/or fixate irregularities in a visual pattern. The corners of the targets would provide just such an irregularity in the displays used. This would account for the subjects reporting that the corners seemed to stand out to them. It would also account for the fact that the subjects were more certain if a target had been presented than if a target had not been presented.

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