NBSIR 77-1306

Levels of Illumination and Legibility

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FOREWORD

The National Bureau of Standards (NBS) research described in this document was jointly supported by the Department of Commerce (DoC) and the Department of Energy (DoE). The Department of Energy has continued its support to verify and extend these results. The follow-on effort is under the DoE/NBS Building Energy Conservation Criteria Program, Task Order No. A008-BCS to DoE/NBS Interagency Agreement No. EA-77-A-01-6010. The Illumination Engineering Research Institute, supported by the University of Virginia, is currently associated with the NBS in the follow-on research activity.

CONTENTS

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Abstract: The visibility of tasks encountered in the working world ranges from easy to difficult. The assumption that experiments performed for threshold targets (difficult to see) can be extrapolated to higher contrast tasks (easy to see) was tested. The experiments indicate that threshold level studies should not be extrapolated to suprathreshold levels. The performance of the eye is not the same at the two levels. The threshold function is monotonic, that is, contrast required for detection decreases monotonically as luminance is increased, whereas the suprathreshold experiments result in a function with a minimum or optimum luminance level. Recommendations are made to expand the empirical base from which lighting level recommendations are derived to include the more commonly occurring situation involving visual task performance for suprathreshold tasks.

Key Words: Lighting; lighting design; illumination levels; task lighting; energy conservation.

INTRODUCTION

The visual tasks encountered in the working world range from highly visible to tasks that are difficult to see even under the best lighting conditions. In office work the visual tasks vary from high contrast printed materials to barely legible fifth carbon reproductions. The frequency of occurrence of these different levels of difficulty will vary from office to office, but that they all exist at some frequency can be recalled from our everyday experience. In some cases, the task may be inherently difficult, e.g., the detection of defects in manufactured goods (detection of cracks in a crankshaft). This is a difficult visual task where the eye is performing in its simplest mode--perceiving the presence or absence of a nonuniformity in a homogeneous field. We call this level detection. We can require that the observer not only detect the presence of an object, but recognize it as a member of a specific class of objects (e.g., recognizing that the object is a ring, square or letter). This level of visual performance we call recognition. The next higher level of visual capacity requires the ability to discriminate between members of the same class, as in "That letter is an E and not a B, a Landolt C because of the break in the ring, etc". This level we call identification. All of the above can be and are, generally, studied at threshold levels, and the response measured is usually the number of correct responses. An example of a laboratory investigation of detection is the minimum contrast required to detect the presence of a disc against a uniform background. The minimum separation between two parallel bars and the discrimination of form are examples of acuity threshold and recognition studies. The Snellen Chart is a well known example of identification, the task being to name a letter correctly at a distance of 20 feet. All of the above are threshold tasks -- just barely being able to perform at some criterion level. In most everyday tasks involving predominantly a visual component, we are not working at threshold or would be unhappy if we had to. For example, a reproduction which is so poor that all you can state is that something is on the paper (detection) is impossible to accept. If the reproduction were slightly better so that we could state that it was printed matter, it would still be intolerable. One can have an improved copy such that we can with some uncertainty identify the letters, i.e., discriminate between an E and B, etc. But just barely being able to discriminate is still unsatisfactory. What we really want is the situation where we can state that the visual conditions are acceptable, that is, "I can read the printed page with little effort". The criterion for visual performance should be goodness of seeing, i.e., "I see better under condition A than condition B", and not just barely being able to detect, recognize or identify an object. This level will be defined as the suprathreshold level. The experimental basis from which lighting recommendations are derived should resemble the end-use conditions, or be valid although the experimental conditions differ significantly from the real world. The criteria for acceptance should meet the requirements or needs of the user.

The current lighting level recommendations are based on empirical data obtained from experiments in which the observers were required to detect the presence of a luminous disc, that is, the detection threshold level.[1] The analogy in office work would be a reproduction so poor that all the worker can say is: "There is something on the paper, but I have no idea what it is". The visual performance data from acuity threshold studies, more specifically the threshold for determining the gap in the

Landolt Ring, are also considered. The analogy in the real-world work situation would be the ability to just discriminate between two symbols, e.g., an E and a B. Both the detection and acuity thresholds are visual conditions that would be judged unacceptable by most workers. In most cases it would not be possible to raise the visibility of a reproduction that poor to an acceptable level by increasing luminance.

The preceding discussion has argued that the present lighting level recommendations are based on empirical data obtained under threshold conditions that differ significantly from most real-world conditions. The obvious conclusion would be to base light level recommendations on data obtained by having workers perform routine visual tasks in the real working environment. The controversy over the validity of studies done in the laboratory as opposed to studies done in the working world using working world tasks had its heyday in the late forties. The two primary antagonists were Luckiesh and Tinker. Luckiesh[2] based his recommendations on threshold acuity experiments, whereas Tinker[3] based his recommendations on task performance under actual conditions using real tasks, e.g., reading comprehension. Luckiesh felt that the levels recommended by Tinker were too low, and Tinker felt that Luckiesh's recommendations were too high, with Bitterman[4] pointing out the difficulties or limitations of their methods in arriving at a valid recommendation.

A similar controversy exists today. There are designers who feel that the current recommended levels are too high. They argue that workers performing under levels lower than those recommended by the IES perform satisfactorily. The IES rebuts by stating that their recommendations are based on years of systematic laboratory studies. Their studies indicate that visual performance continuously increases as luminance is increased, up to the luminance level investigated, 10,000 cd/m^2 (2920 fL).

A compromise between the two former antagonists Tinker and Luckiesh is an approach that might also be acceptable to the present-day antagonists. Tinker felt that threshold studies should not determine is lighting level requirements since the visual element of most tasks not the type that require responding to something that is barely detectable. Luckiesh strongly felt that production level indices are influenced by factors other than sensory (physiological) parameters. He argued that visual performance measured by production, reading comprehension and other whole-task performance measures is confounded by variables not under the control of the experimenter. Both points of view are legitimate objections. What is needed is a study in which visual performance is investigated by a psychophysical technique, under laboratory-controlled conditions, but at suprathreshold levels. It is also essential that subjective contributions, e.g., brightness preference, mood, motivation, etc., as well as other nonvisual components (motor skills, intelligence, etc.) be controlled, or at the least minimized. The laboratory experiment should be of the form: For a definitely detectable task (non threshold) is it more legible under illumination level A or B?

Yonemura and Kohayakawa[5] conducted a study that fulfilled the above requirement. They had their observers equate the contrast of gratings of different mean luminance but equivalent in all other respects; this was done for both sinusoidal and square-wave gratings at near threshold and suprathreshold levels. The methodology differs significantly from the threshold technique in that the grating patterns were visible at all times. The observers were asked to adjust the contrast of one grating pattern so that it appeared to be equal to an adjacent grating pattern, that is, equal in contrast -- hence the term equal apparent contrast contour.

The results of their study agreed with laboratory studies at threshold, but not at suprathreshold. For targets near threshold (just barely visible) the data resembled the classical threshold data. As luminance was increased the contrast required for equality of contrast decreased. However, a departure from classical data was observed in the equality of apparent contrast contours for suprathreshold contrast levels. Instead of a monotonically decreasing function, the equal apparent contrast contour initially showed a decrease in contrast required for a match as luminance was increased, but further increases resulted in a reversal, more contrast was required. That is, there was an optimum luminance level, above or below which the apparent contrast of the grating being measured decreases.

The following study was performed to validate the equality of apparent contrast methodology for words, a frequently encountered real-world task. The procedure is similar to the earlier grating study, but since the methodology is an important aspect of the compromise between two opposing points of view, the methodology will be described in detail.

METHOD

Observers

The observers were three males and one female. Three of them were experienced in visual psychophysical experiments, and their ages ranged from the middle twenties to forties.

Stimuli

The targets were semigloss photographic reproductions of the Jaeger Chart used in eye tests at reading distance.* The Jaeger Chart is shown in Fig. 1. Two sets with a 1X magnification were reproduced, one set with a background reflectance of 0.82 and the second with a background reflectance of 0.41. See Figures 2 and 3. Each set was composed of about 35 charts with contrast ranging from approximately .04 to 0.94 in roughly equal steps. Contrast is defined as: $(L_b - L_t)/L_b$, where L_b is the background luminance and L_t is the luminance of the target. Contrast was measured by a micro-photometer that was capable of measuring a portion of the target subtending 0.4 x 10 min of visual angle, or 20 x 500 micrometers. The three sizes used in this study, Jaeger 12, 8 and 6, subtended 6.5, 4 and 3.2 min of visual angle, respectively. The Jaeger Chart subtended 27 x 34 degrees and the reflectance of the area surrounding the charts was 0.63, approximately the average of the light (0.82) and dark (0.41) backgrounds.

Apparatus

The light source was a single U-shaped T-12 40W coolwhite instant start fluorescent lamp mounted under the viewing platform. Reflectors were added so that the illuminance was equal over a 100 cm^2 central area. Photometric measurements were made over the task area at the beginning of the study and after several months of running. No appreciable change in the absolute luminance levels was observed, and the distribution of light over the task area was found to be homogeneous in both instances.

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*We gratefully acknowledge the contribution of William Smallwood of the Optical Physics Division, Institute for Basic Standards for reproducing the charts.

Stimuli were viewed through a 5 x 15 cm window located 33 cm from the task. The luminance was varied by Wratten neutral density gelatin films placed over the viewing aperture.

Procedure

The observer was seated so that he viewed the target at a distance of 38 cm and at an angle of 25 degrees from the normal to the task surface. Two charts, one from each set, were placed side by side so that the angular separation between the test word on the two charts was 3.3 degrees. Th observer (O) was instructed to look at the target word on the standard (high reflectance background chart) and compare its apparent contrast with that of the corresponding word on the comparison (low reflectance background chart). If he thought the word on the comparison chart had more contrast than on the standard chart, he was to ask the experimenter for a new comparison chart having less contrast. If O felt the word on the comparison chart had less contrast than on the standard, then he was to ask for a comparison chart with more contrast. The process continued until the observer thought the word was equal in apparent contrast on the two charts. Five such matches were made, and the median physical contrast of the comparison charts chosen in these matches was recorded. The standard chart was then replaced by one of the same physical contrast as the median comparison chart contrast recorded above. The illumination level was halved by adding a 0.3 neutral density filter to the viewing window. Thus, the background luminance and the contrast of the target word on the new standard chart were equal to those on the previous median of the matched comparison charts. The subject then made five more matches, a new standard was determined, and the luminance was again halved. This process was repeated until O required more contrast for his matches than was available in the charts. The range of luminances in the experiment was from 810 cd/m^2 to about 0.2 cd/m^2.

Each run lasted approximately one hour, interspersed with rest periods of two minutes after each series of five matches while the charts and filters were changed. In half the runs the high reflectance background chart was on the left of the low reflectance one; in the rest of the runs these positions were reversed. To check for an order effect, several runs for each subject began at lower luminance levels instead of the highest one. In these instances, the low reflectance background chart always served as the standard and the high reflectance one as the comparison. Each subject was run under at least nine conditions (three target sizes x three contrast levels). The first three sessions were practice sessions where the concept of apparent contrast was demonstrated followed by practice in making equal contrast judgments. See Appendix A.

RESULTS

The results of the experiment are presented separately for each of the four subjects in Figs. 4-7. The curves represent equal apparent contrast contours, i.e., all of the connected data points are perceived as being subjectively equal in contrast at different levels of illumination. The three symbols represent different stroke widths of the letters, where the circle = 6.5, square = 4 and cross = 3.2 min of visual angle. Unless specified by a number in parenthesis on the right of each curve, each data point is the result of a single trial. Where the data points represent the mean of more than one trial, the number in parentheses on the right gives the number of trials.

The form of the lowest set of curves appears to be different from the others. In general, for the lowest set of curves as we increase luminance the contrast required for the letters to be subjectively equal in contrast decreases monotonically. This observation holds for all of the observers. See lowest set of curves in Figs. 4-7. But for the equal apparent contrast contours at higher contrast levels, the contrast-luminance relationship is different. The contrast decreases initially, reaches a low point, then increases with further increases in luminance. The shape of the curves is similar for all observers.

The results for all of the observers have been averaged for a given size and are presented in Fig. 8. For the range of stroke widths used in this study, 6.5 to 3.2 min of visual angle, the shape of the curves are not significantly different. Therefore, the data were averaged over the four observers and the three stroke widths and are presented in Fig. 9, which summarizes the principal findings of the experiment. At near threshold contrast levels the function decreases monotonically as luminance is increased, but at suprathreshold levels of contrast the curves exhibit a minimum value.

DISCUSSION

The experiment indicates that the suprathreshold methodology gives similar results when letters are used as the targets instead of gratings. For near threshold contrast levels the function is monotonic, that is, as luminance increases the contrast required for apparent equality of contrast decreases in agreement with classical data. But for contrast levels larger than near threshold levels, the equal apparent contrast contours exhibit an optimum luminance level. As luminance is further increased the contrast required for equality of apparent contrast decreases, reaching a minimum, followed by increases in contrast as luminance is further increased. In terms of practical visual task performance, "goodness of seeing" increases as lighting level is increased, reaching an optimum luminance level. However, increases in luminance beyond this optimum level lead to a decrease in the clarity of the detail to be perceived.

What are the implications of the data from this new methodology? First, they raise questions about the current basis for recommending levels of illumination, but probably more importantly they provide an objective basis for setting levels of illumination at plus or minus a given number of footcandles rather than specifying a minimum as recommended by current practices. The existence of an optimum rather than a continuously increasing performance with increases in illumination levels should not be surprising in the general context of sensory physiology. As Simonson and Brozek[6] point out, " . . . the other environmental components such as temperature, humidity, barometric pressure, have a physiological optimum. There is no reason why visual performance should behave differently." The non-specification of a minimum will discourage over-design, encouraged under current practices. That is, the consequence of a "more light, better sight" mentality can be the addition of a significant "safety" factor, the rationale being that the safety margin results in increased performance.

We find that the controversy between Tinker and Luckiesh cited earlier could have resulted from the fact that the former used supra-threshold tasks, whereas the latter used threshold tasks as well as a different measurement technique. The results of this study agree with Luckiesh in that, for near threshold tasks, visibility continuously increases as illumination is increased, but they differ in that when the same methodology is used with suprathreshold tasks, the monotonic function changes to one with an optimum illumination level. This study also agrees with Tinker in that the visual performance on threshold and suprathreshold tasks differs. Tinker found no change in reading performance (7-point newspaper type) occurred above an illumination level of 7 fc. He did not find a decrement in reading performance at higher illumination levels, and furthermore his critical illumination level (the illumination level beyond which no further change in reading performance occurs as the illumination is increased) of 7 fc appears to be lower than that found as the optimum in this study. No definitive explanation can be given for this discrepancy, but it is possible that the differences may be due to uncontrolled psychological variables. In comparing the method of equal apparent contrast discussed in this paper with real-world task performance measurements, two important distinctions are apparent. First, in the equal contrast technique, subjects were asked to respond directly to "goodness of seeing", that is, how well the details stood out from the background. Second, since the methodology involved simultaneous direct matching for equality, psychological variables affecting one target should have equally affected the other. It is possible that

Tinker's low critical illumination level resulted from a greater effort by the subject to offset the lower visibility. The same explanation can be postulated for the higher levels, where no decrement in performance was observed. In the first case, the goodness of the task was directly measured, whereas in the other, visibility was indirectly evaluated through performance measures.

The performance of a worker is affected by physiological and psychological factors. In one case, we are describing the sensory capacity or process and in the other, cognitive factors usually expressed as preferences. The special case we are concerned with in this discussion is when the two processes are the resultant of the same physical variable, e.g., luminance. As far as the sensory processes are concerned, an environment in which the total visual field is of the same reflectance is optimum for sensory performance, but we also know that this bland (limited light and shadows) visual environment is not conducive to worker comfort, thus indirectly affecting productivity. It is indirect in the sense that it does not affect productivity by increasing or decreasing the sensory capacity of the worker, but by influencing his attitude toward the visual environment. The difficulty with these preference variables is that they are susceptible to individual differences. A preferred condition for one individual may be an undesirable one for another. For example, in color harmony preferences for clothing, some individuals may prefer a subdued color combination, shades of gray, whereas others may prefer extreme hue combinations like red and green.

What we are suggesting is that performance is a function of physiological and psychological factors. Subject response based on physiological factors can generally be predicted with confidence, but the psychological factors show large individual differences, in some cases the preferences run to opposite extremes, which makes prediction difficult. We must face the fact that they exist, with one important consideration. On the one hand we have biological factors that have similar effects on most people, and on the other hand we have highly individualistic preferences formed by past experiences.

CONCLUSIONS

Threshold studies are not a valid basis for recommending levels of illumination for tasks that are not at threshold levels. Real-world performance studies also create difficulties in interpretation because of the confounding by psychological variables not easily under the control of the experimenter. Production and work performance measures obtained from the working environment bring in nonsensory contributions that make it difficult to separate that portion due to the visual process from that contributed by psychological factors.

The empirical basis for recommending levels of illumination should be obtained from controlled laboratory studies that approximate conditions encountered in the real working environment. A single reference base, however, may not be sufficient. At least two, and probably three, visual performance criterion functions are needed to adequately handle the different degrees of task legibility and the apparent differences in the behavior of the eye for threshold and suprathreshold tasks.

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APPENDIX A

INSTRUCTIONS

THIS IS AN EXPERIMENT ON CONTRAST, THAT IS HOW WELL WORDS STAND OUT AGAINST THEIR BACKGROUNDS. I AM GOING TO CHANGE THE AMOUNT OF LIGHT REACHING YOUR EYES BY COVERING THE RECTANGULAR SLOT IN FRONT OF YOU WITH A VARIETY OF FILTERS. EVERY TIME A FILTER IS CHANGED, I SHALL ASK YOU TO LOOK AT THE WORD "RANSOM" ON THE CHART ON YOUR LEFT AND COMPARE IT WITH THE WORD "RANSOM" ON THE CHART ON YOUR RIGHT.

E PUTS IN #15, LIGHT
#32, DARK

THE WORD ON THE WHITE CHART HAS MORE CONTRAST THAN THE WORD ON THE GREY CHART. WHEN THIS HAPPENS, SAY "MORE" AND I SHALL PUT IN A DARK CHART THAT HAS MORE CONTRAST.

ON THE OTHER HAND, THE DARK CHART MAY LOOK MORE LIKE THIS.

E TAKES OUT #32, DARK AND
PUTS IN #3, DARK

"RANSOM" NOW STANDS OUT MUCH MORE ON THE DARK CHART THAN IT DOES ON THE LIGHT CHART. WHEN THIS HAPPENS, SAY "LESS", AND I SHALL PUT IN ANOTHER DARK CHART THAT HAS LESS CONTRAST.

NOW THE WORD ON THE DARK CHART IS MORE EQUAL IN CONTRAST TO THE WORD ON THE LIGHT CHART.

E PUTS IN #15, DARK

LET'S LOOK AT A FEW MORE CARDS.

E TAKES OUT BOTH LIGHT AND DARK CARDS, PUTS IN #28 LIGHT AND #35 DARK

AGAIN YOU SEE THAT THE WORD ON THE LIGHT CARD STANDS OUT MORE THAN THE WORD ON THE DARK CARD.

HERE IS THE DARK CARD THAT WAS PREVIOUSLY VERY SIMILAR TO THE PREVIOUS LIGHT CARD.

E PUTS IN #15 DARK

NOW "RANSOM" ON THE DARK CARD STANDS OUT MORE THAN "RANSOM" ON THIS LIGHT CARD.

REMEMBER THAT WE WANT YOU TO FIND A CARD THAT LOOKS EQUAL IN CONTRAST TO THE OTHER CARD. THIS CARD OBVIOUSLY DOES NOT HAVE ENOUGH CONTRAST.

#32 DARK AGAIN

AND THIS ONE OBVIOUSLY HAS TOO MUCH CONTRAST.

#3 DARK

SO YOU WOULD HAVE TO FIND A CARD SOMEWHERE BETWEEN THE TWO TO MATCH IT.

LET'S TRY TO FIND ONE THAT MATCHES.

Near V. E. %: 5 Jaeger 14	*24 Point*	*Acuity: Approx. 0.12 (20/170)* *Sight-saving texts.*
man oxen	25 37 84 90	oxxo oxxx
Near V. E. %: 10 Jaeger 12	*18 Point*	*Acuity: Approx. 0.15 (20/130)* *Books, children 7-8 yrs.*
raw see van	90 89 76 60 54	xoxxx oxooo
Near V. E. %: 15 Jaeger 10	*14 Point*	*Acuity: Approx. 0.2 (20/100)* *Books, children 8-9 yrs.*
noon even mew	38 72 80 93 54 60 76	xxox xxxx ooox
Near V. E. %: 20 Jaeger 8	*12 Point*	*Acuity: Approx. 0.25 (20/80)* *Books, children 9-12 yrs.*
war use worm eve avenue ransom err	40 53 8 809 42	xoox oooxo ooxxx remo romero suma
Near V. E. %: 30 Jaeger 7		*Acuity: Approx. 0.28 (20/70)* *Adult textbooks.*
scum crease nervous cocoon cannon saucer	98 67 45 456 309 5	xooo oxxo oxxx xxxx saca zarco cascarron
Near V. E. %: 40 Jaeger 6		*Acuity: Approx. 0.3 (20/65)* *Magazines.*
arrow scour noose razor zone reverence sorceress	35 98 20 82 740 203 96	xxxo ooxx oxoox xoxox remanso semana asma
Near V. E. %: 50 Jaeger 5		*Acuity: Approx. 0.4 (20/50)* *Newspaper text*
amaze wares curve scarce snooze caress sewer wax	82 34 65 90 426 397 564	oxxo oooo xoxx xxxx ooox remesa suave arrancar
Near V. E. %: 90 Jaeger 3		*Acuity: Approx. 0.5 (20/40)* *Telephone directory.*
comma worse reason measure vase census arrears recover crane now	75 23 68 90 44 890 375 204 53	xoxx ooxo oxxo oxoo xxox oooo resaca carecer crecer sazonar
Near V. E. %: 95 Jaeger 2		*Acuity: Approx. 0.6 (20/30)* *Want ads.*
success numerous assurance consume cocoa convex morocco uncommon err	56 87 92 30 47 209 354 872 40	xoxx ooox ooxo ooxxx xoxo xxox oxoo sesos sucesor vaso zamarra azar
Near V. E. %: 100 Jaeger 1		*Acuity: Approx. 0.8 (20/25)* *Small bibles.*
occurrence nevermore successor romance worm craze areon crew amorous scow aroma samovar	72 98 40 58 284 454 306	xxxox xxoox ooxxo xoxox ooxxo xoxx comarcano rosca serrano amanecer
Comparable: Jaeger 1 +	*3 Point*	*Acuity: Approx. 1.0* *Mailorder*
		xoxxo xxooo ooooo ooxoo serrano avance
Letter height— 0.3493 mm.	*2 Point*	

Fig. 1 Jaeger Chart.

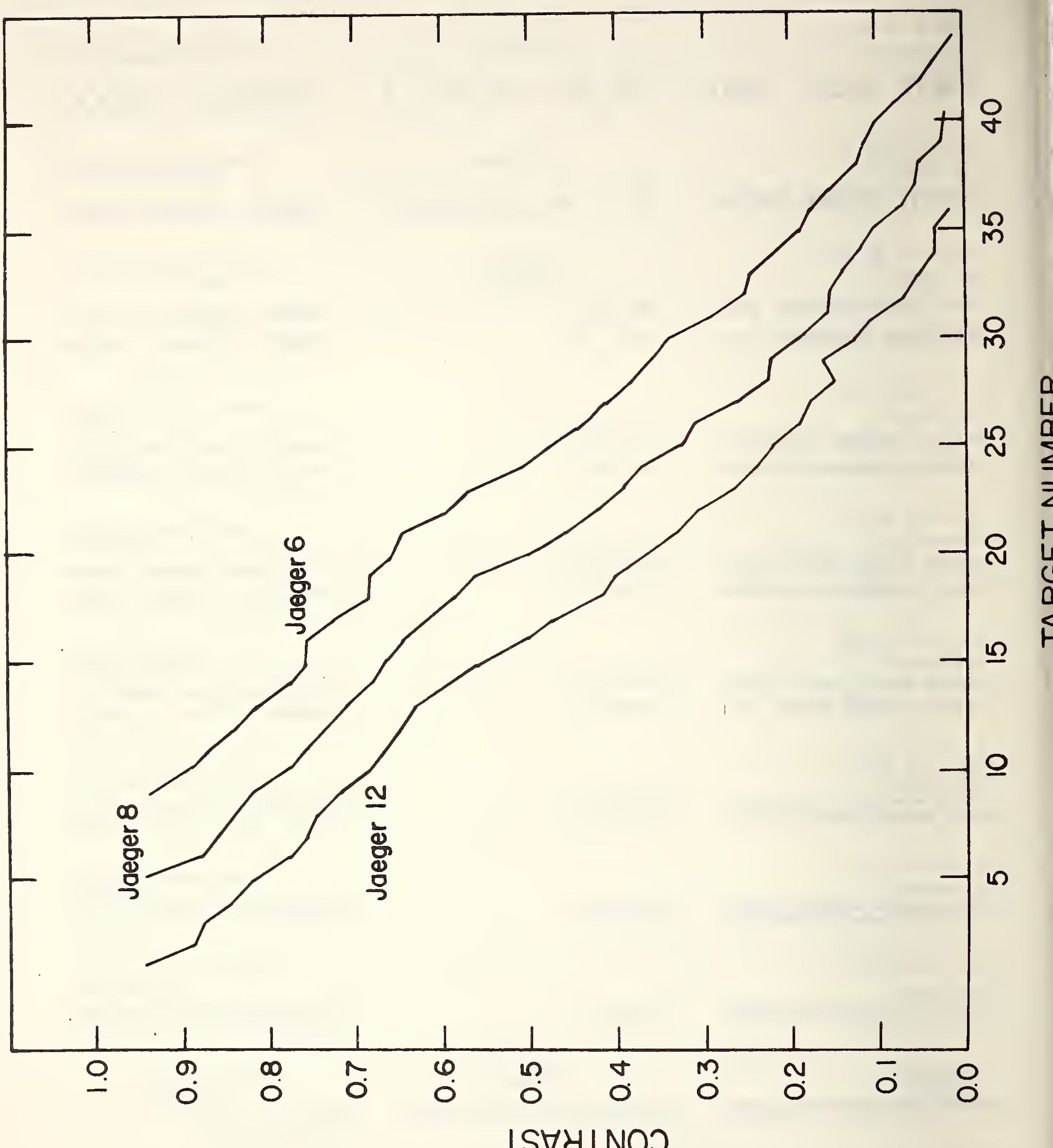

Fig. 2 Contrast of high reflectance background targets. The target numbers have been displaced by 4 for Jaeger 8 and 8 for Jaeger 6.

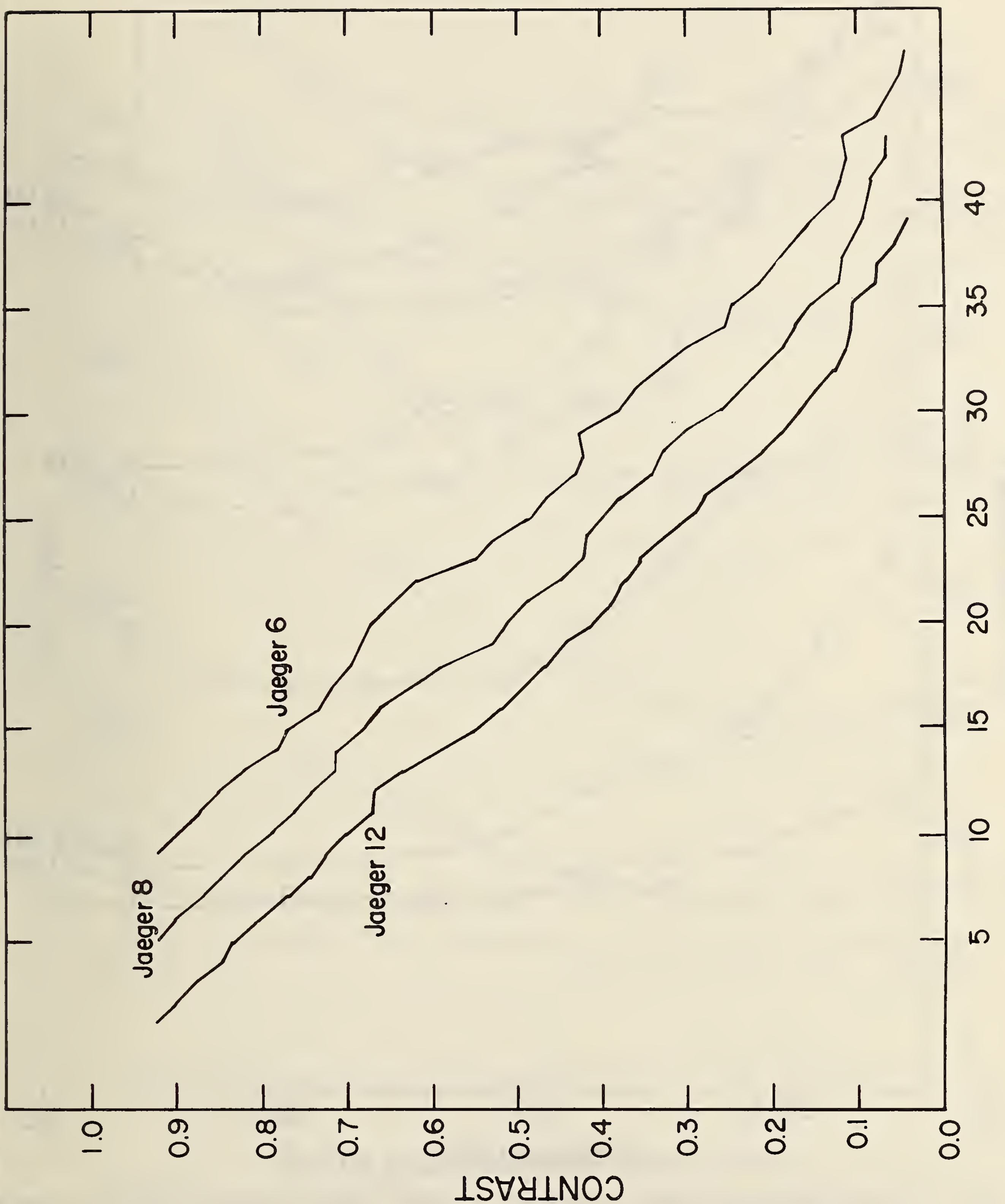

Fig. 3 Contrast of low reflectance background targets. The target numbers have been displaced by 4 for Jaeger 8 and 8 for Jaeger 6.

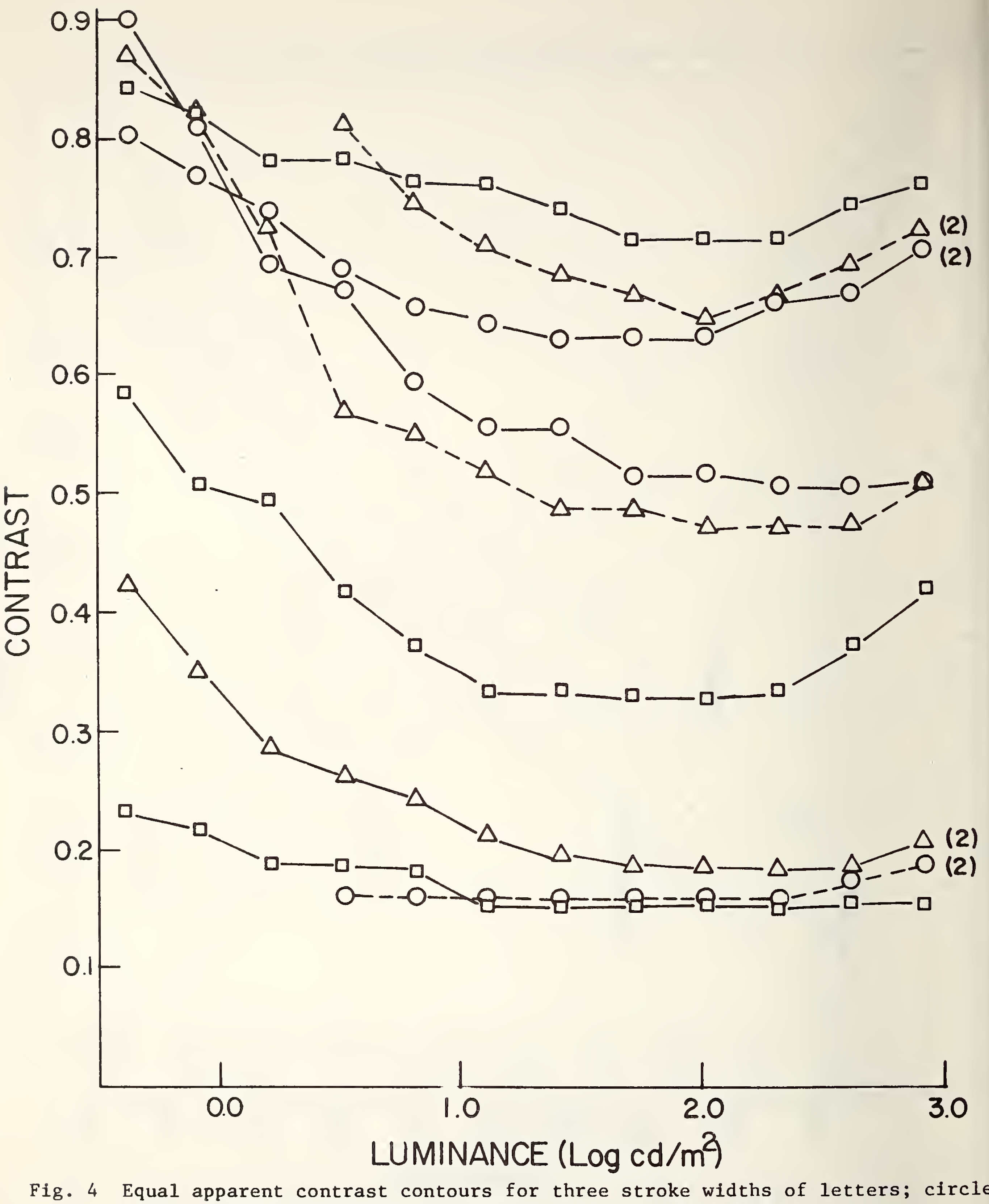

Fig. 4 Equal apparent contrast contours for three stroke widths of letters; circles = 6.5, squares = 4 and triangles = 3.2 min of visual angle. Subject WB. The numbers in parentheses are the number of repetitions. The data points are the arithmetic mean of the repetitions.

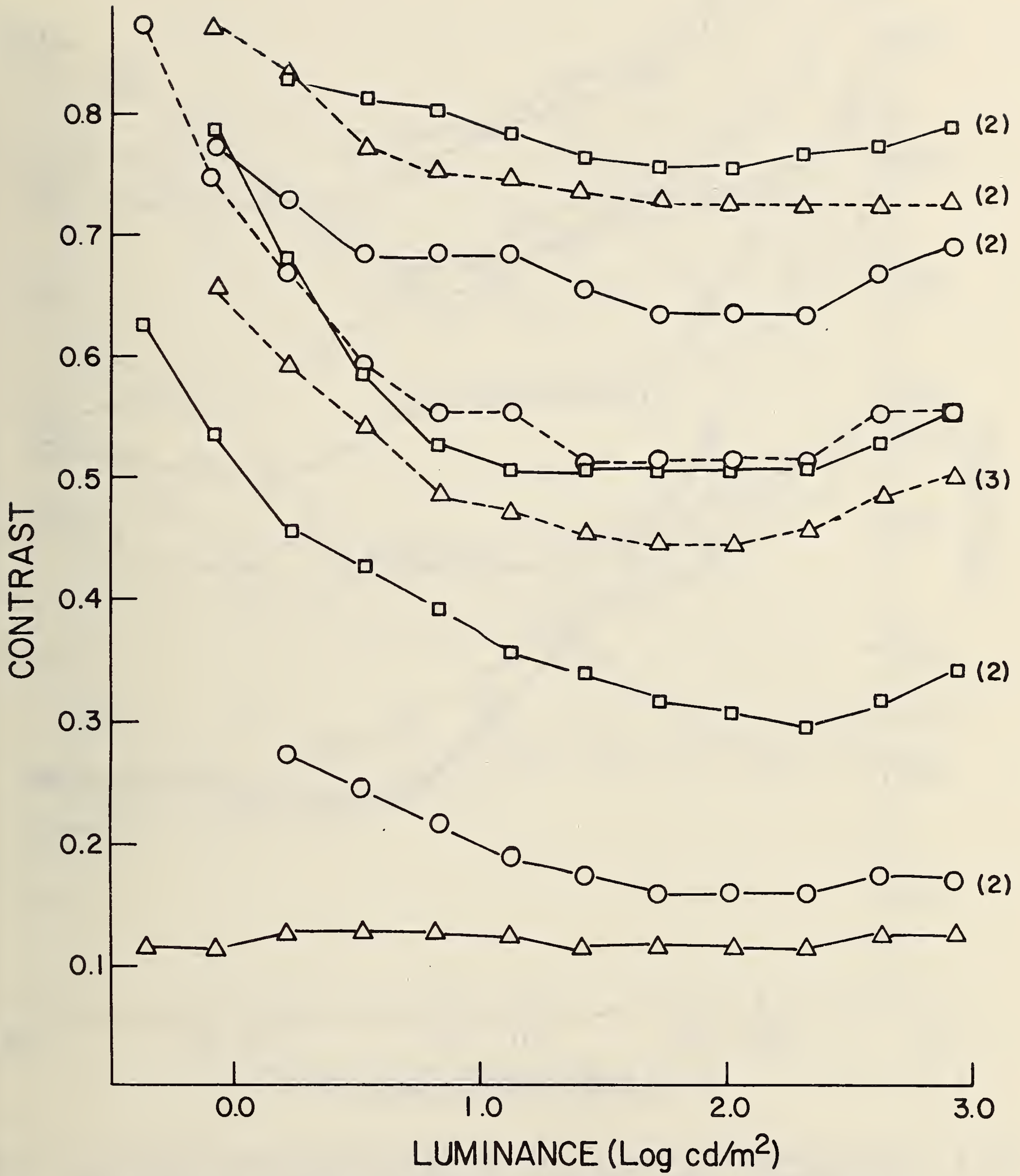

Fig. 5 Equal apparent contrast contours for three stroke widths of letters: circles = 6.5, squares = 4 and triangles = 3.2 min of visual angle. Subject RT. The numbers in parentheses are the number of repetitions. The data points are the arithmetic mean of the repetitions.

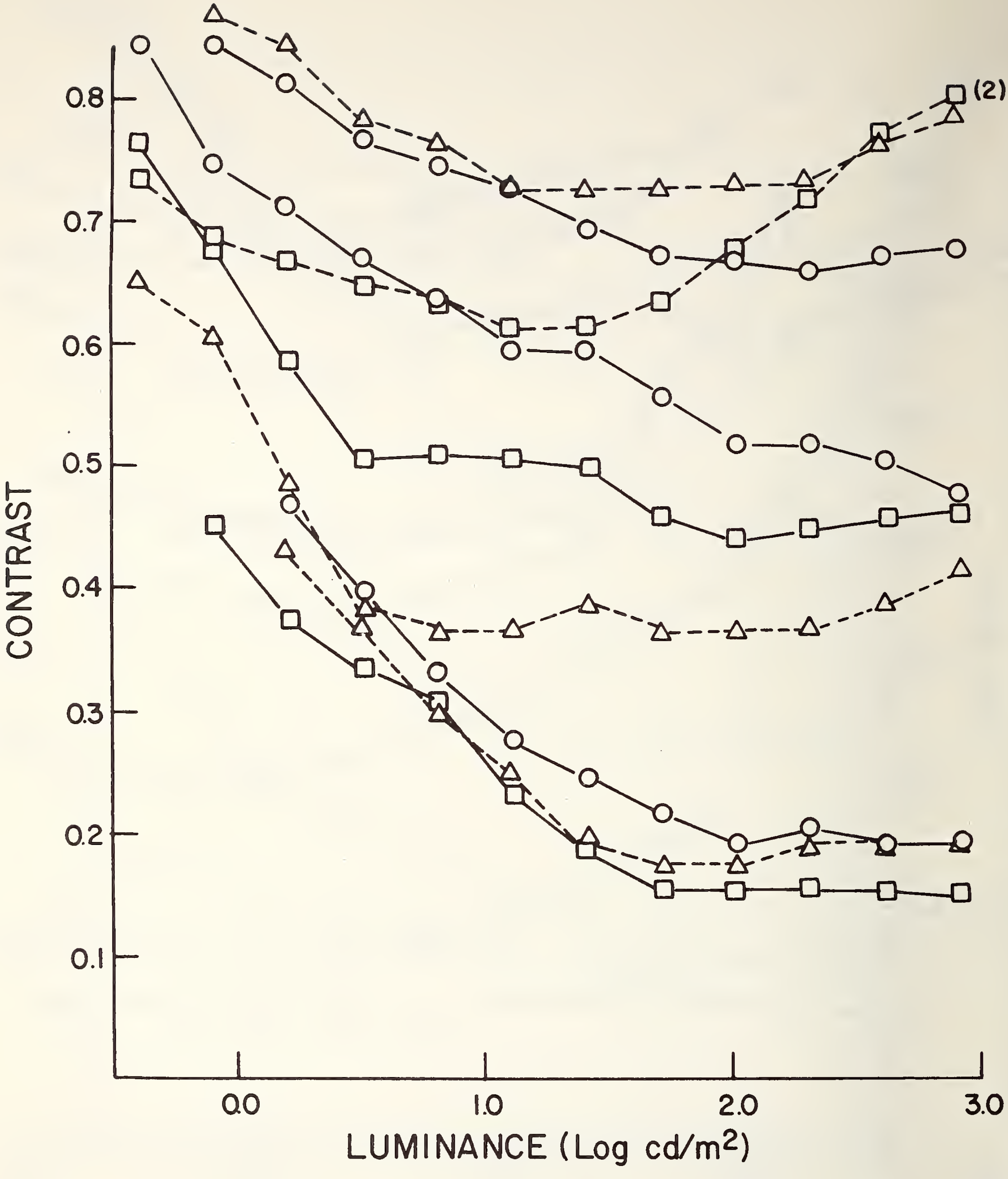

Fig. 6 Equal apparent contrast contours for three stroke widths of letters; circles= 6.5, squares = 4 and triangles = 3.2 min of visual angle. Subject BG. The numbers in parentheses are the number of repetitions. The data points are the arithmetic mean of the repetitions.

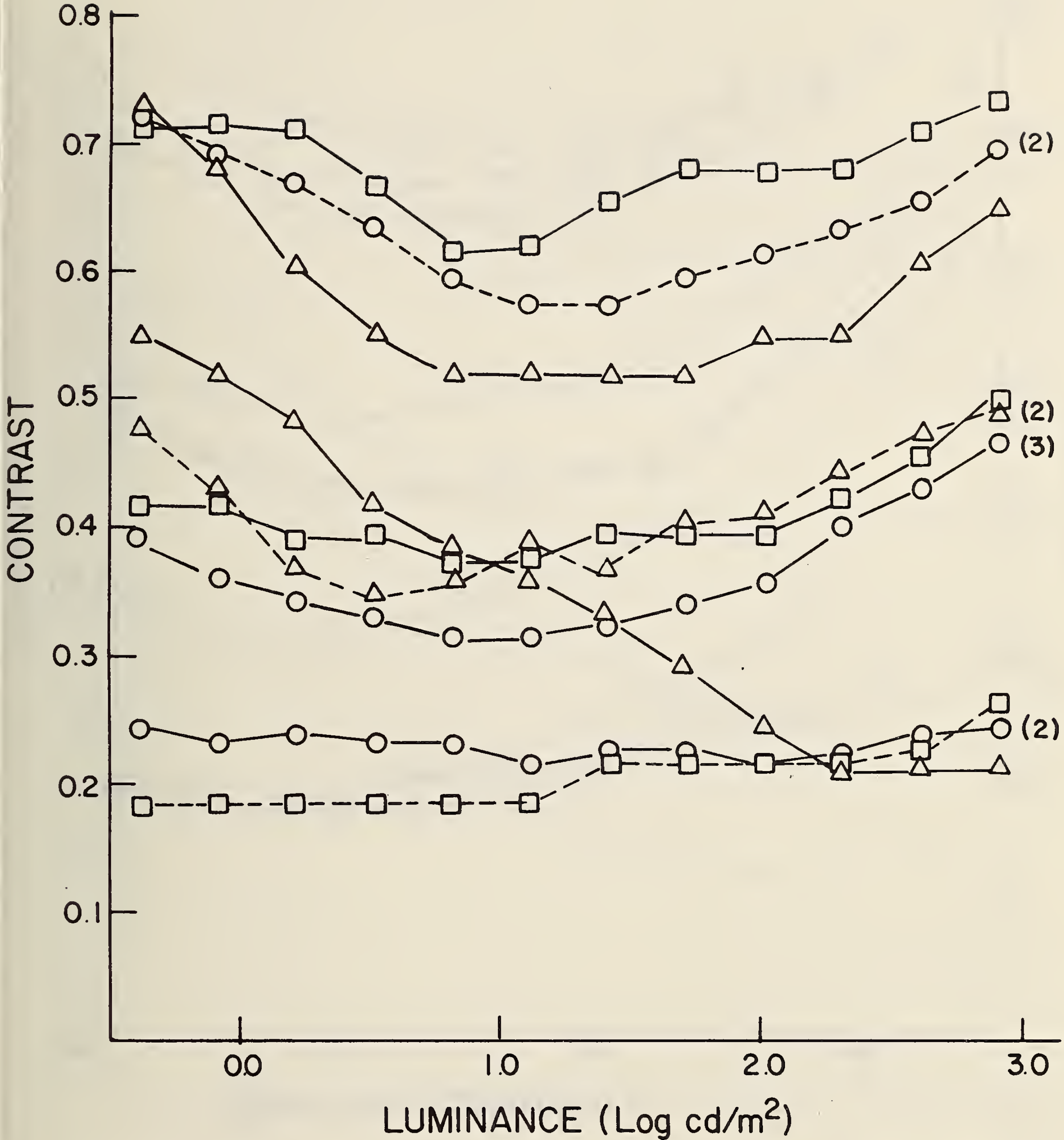

Fig. 7 Equal apparent contrast contours for three stroke widths of letters: circles = 6.5, squares = 4 and triangles = 3.2 min of visual angle. Subject BC. The numbers in parentheses are the number of repetitions. The data points are the arithmetic mean of the repetitions.

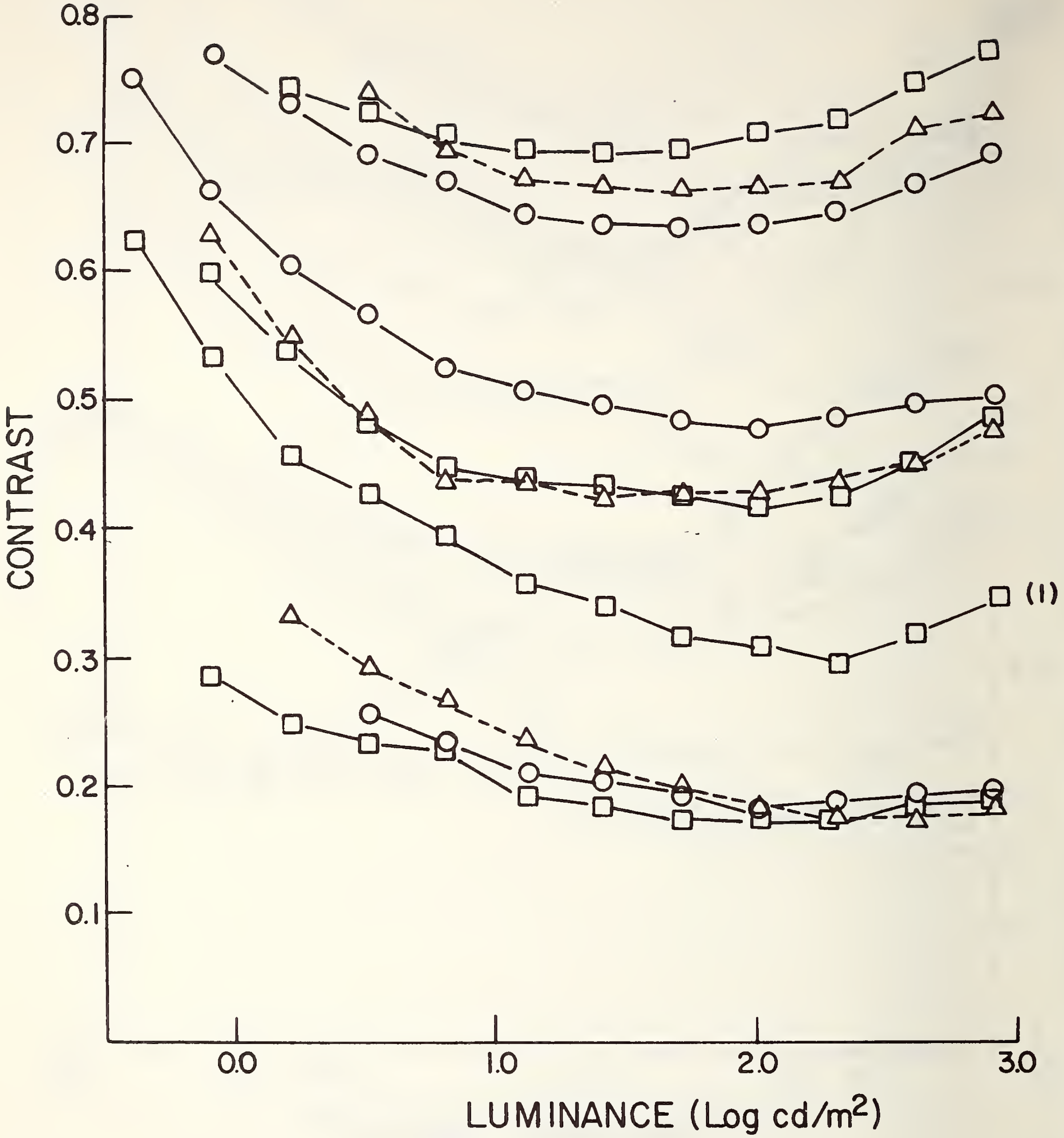

Fig. 8 Equal apparent contrast contours for three letter sizes. The stroke widths of the letters are: circles = 6.5, squares = 4 and trianges =3.2 min of visual angle. The data points are averages of four subjects, except for curve (1) which is the result of a single subject.

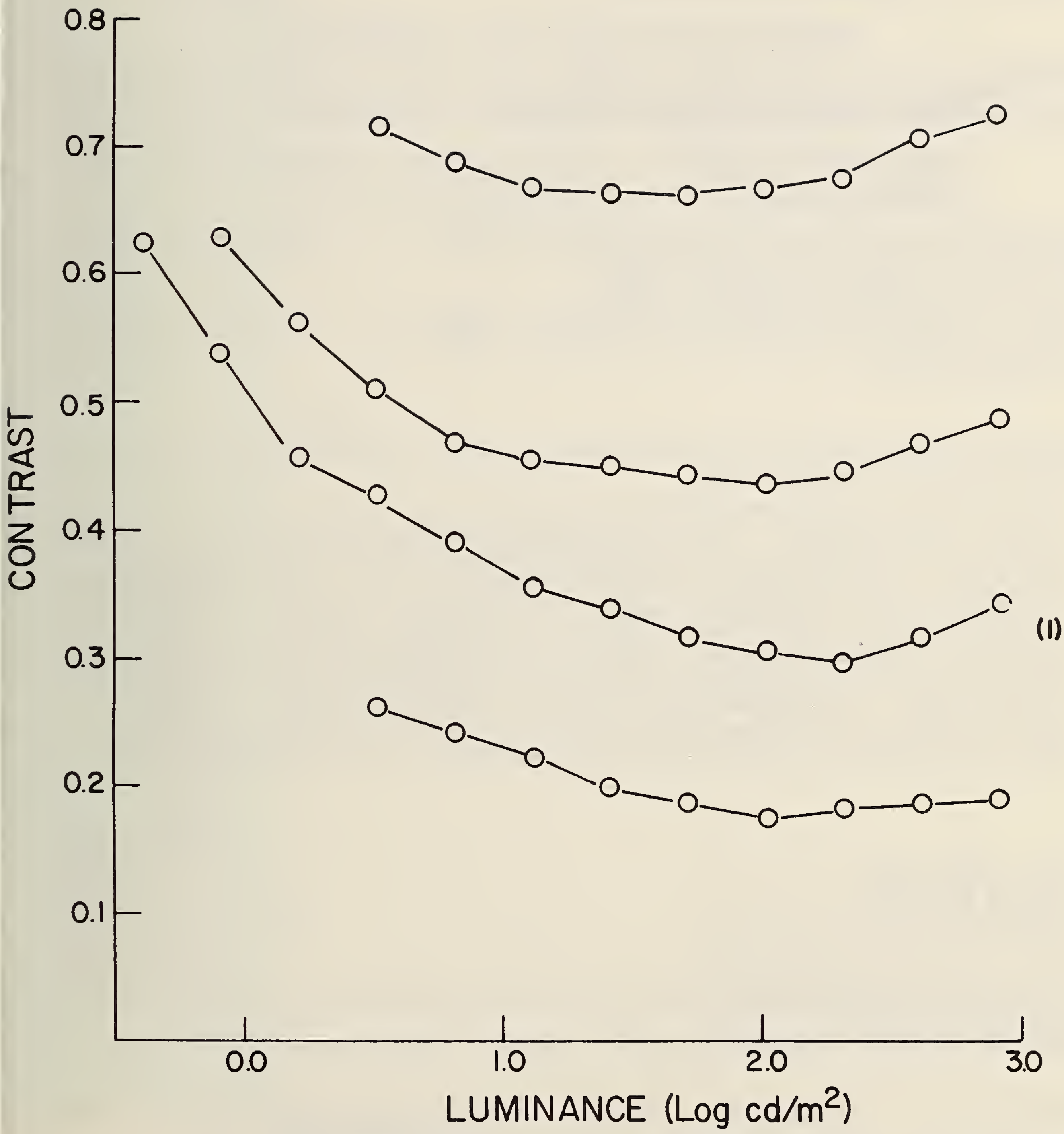

Fig. 9 Equal apparent contrast contours averaged over four subjects and three stroke widths, except for curve (1) which is the result for a single subject.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET**	1. PUBLICATION OR REPORT NO. NBSIR 77-1306	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Levels of Illumination and Legibility

5. Publication Date

November 1977

6. Performing Organization Code

7. AUTHOR(S)

G. T. Yonemura, W.N. Benson and R. L. Tibbott

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Architectural & Engineering Systems Branch
Division of Buildings & Community Systems
Office of the Assistant Secretary, Conservation & Solar Applications, Department of Energy, Washington, D.C. 20545

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The visibility of tasks encountered in the working world ranges from easy to difficult to see objects. The assumption that experiments performed for threshold targets (difficult to see) can be extrapolated to higher contrast tasks (easy) was tested. The experiments indicate that threshold level studies should not be extrapolated to suprathreshold levels. The performance of the eye is not the same at the two levels. The threshold function is monotonic, that is, contrast required for detection decreases monotonically as luminance is increased, whereas the suprathreshold experiments result in a function with a minimum or optimum luminance level. Recommendations are made to expand the empirical base from which lighting level recommendations are derived to include the more commonly occurring situation involving visual task performance for suprathreshold tasks.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Energy conservation; illumination levels; lighting; lighting design; task lighting

18. AVAILABILITY [X] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
UNCLASSIFIED	30
20. SECURITY CLASS (THIS PAGE)	**22. Price**
UNCLASSIFIED	$4.00