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March 1993

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ABSTRACT

In a previous study with young adults ages 20 to 40 years, we demonstrated that low contrast Landolt C recognition was better with smaller pupils than with larger pupils even though task retinal illuminance was higher for larger pupils. Pupil size in these studies was controlled by the spectrum of the far surround illumination which was prevented from affecting task luminance.

The present study used the same procedures as our previous study with 7 healthy elderly adult subjects between the ages of 61 and 66. Because senile miosis is a characteristic of the aging eye, spectral changes in the surround might be expected to produce relatively smaller changes in pupil size and hence performance. Surprisingly, although the scotopically enhanced surround lighting produced relatively smaller pupil size changes than in young adults, the performance enhancements were comparable to those of young adults.

As in the previous study the task was recognition of the orientation of the gap in the C that was presented on a CRT with contrasts varying from 18% to 80%.

Two surround illuminants were compared, both provided a luminance of 53 cd/m^2 on the front wall at visual angles larger than 30°. Subjects had at least 20/20 vision and perform the task with their spectacles if normally used.

INTRODUCTION

In a previous study[1] of low contrast Landolt C recognition by young adults ages 20 to 40 years, we demonstrated that performance was better when the surround luminance spectrum was scotopically enhanced, with concomitant smaller pupils (even though there was constant surround photopic luminance). The performance increase occurred despite reduced task retinal luminance due to the smaller pupil (task luminance being constant). Note that we were able to independently vary the task luminance and the surround luminance, whereas, many prior studies vary surround and task luminance together. By increasing the task luminance under conditions of larger pupils, we also estimated that a significant increase of task luminance would be needed to achieve the same level of performance as occurred with smaller pupils and lower task luminance. These results are consistent with the hypothesis that decreasing pupil size in turn reduces the effects of optical aberrations on performance to a greater degree than does the loss of retinal illumination from the decreased pupil size. We have not found any prior studies of visual performance examining the competition between increased retinal illuminance and decreased pupil size.

Having found these results in young adults, it was not clear as to whether there would be similar results in elderly subjects where visual function is generally reduced and where it is believed that higher light levels are necessary.[2,3] Because of senile miosis, it was also uncertain whether differences in pupil size resulting from spectral changes in the surround illumination would be sufficient to affect visual performance. Knowledge of the sensitivity of vision in the elderly to changes in surround spectrum is essential if recommendations are to be made with regard to changing indoor lighting guidelines.

In this study we examined 7 healthy adult subjects between the ages of 61 and 66 years using the same procedures as in our previous study. Not only have we found similar phenomena in these elderly subjects, but we have also found that they achieve approximately the same increase in performance with about half the pupil area change, as compared with young adults.

METHODS

Subjects: A sample of 7 subjects (all Caucasian) were recruited through the San Francisco VA Hospital's pool of elderly healthy control subjects. The age range of the subjects was 61 through 66. There were 5 females and 2 males. Upon arrival at the laboratory, subjects' distance acuity was measured with a Snellen chart at 6 m distance. If glasses were used as part of the subjects' daily activities as it was for 5 of the 7 subjects, distance acuity was measured with glasses and the subjects wore the glasses during the Landolt C testing. All subjects had at least 20/20 corrected vision. In prior studies, we developed procedures to exclude all subjects who could not produce an operational pupil image for pupillometry (see below) due to excessive blinking or cosmetics. No subjects for this study were excluded.

General Experimental Procedures: The procedures here are the same as in our previous study[1] and are described briefly below. The experimental situation was designed in such a way that surround lighting and task lighting could be controlled separately, and that change in surround lighting had almost no effect on task illumination. The experimental room dimensions were 2.5m x 2m x 2m, with walls and ceiling painted with a spectrally flat white paint (Kodak). Task stimuli were presented on a video display terminal, with surround lighting generated via indirect illumination of the front and side walls of the room using F40, T12 fluorescent lamps. We specify the photometric units as photopic candelas (pcd), or scotopic candelas (scd). Lamp spectral power distributions (spd) as a function of wave length, were determined by direct measurement using a Pritchard Spectrophotometer (model 1980A) operated in the wave length scanning mode. A similar method was used to determine that the reflectance of the white paint in the chamber was spectrally neutral. Scotopic luminances are then determined by folding the spd against the standard scotopic sensitivity [$V'(\lambda)$] of the eye.[4]

The face of the video display was covered with a matte black surface and the screen of the Landolt C task was shielded from the surround lighting by a rectangular tube 46 cm long, with an opening 5 times higher and 6 times wider than the C. The task was at a visual distance of 2.4 m, accomplished by placing the display terminal behind the subject, who viewed it on a front surface mirror in such a manner that no direct light rays from the lamps or wall behind the subject was seen in the mirror. A black curtain placed behind the subject assured the absence of any reflected light onto the video screen via the mirror. In addition, the remaining central 30 degrees on the wall, directly in front of the subject, was covered with a matte black curtain in order to decrease any possible confounding effects of glare. Thus, surround luminance was present primarily on surfaces beyond the 30 degree central field. Figure 1 shows a photograph of the experimental arrangement.

A variable contrast "Landolt C" of approximately 15 minutes angular subtense of outer dimension and an approximate 2 minute gap in the C was presented in four different orientations for a period of 200 milliseconds on a white VDT screen. The C was oriented 45 degrees from the horizontal, so as to distribute across all orientations any possible effect of horizontal astigmatism that the subjects might have. A small area of the VDT screen (which entirely included the area within the viewing tube), was set to the background luminance of 13.2 pcd/m^2. The small amount of surround lighting that managed to enter the tube did not increase the screen luminance by more than 0.3 pcd/m^2.

The task was presented on a Mitsubishi VGA monitor, using a Matrox graphics board. A specific Landolt C contrast was generated by separately setting the intensity of the VDT background pixels, and the Landolt C pixels; with the Landolt C contrast achieved by setting the C luminance lower than its immediate background (where contrast is defined as the difference luminance divided by the task background luminance). For each experimental condition, we measured the actual C and background luminances directly. The C luminance was measured using a 6 minute aperture on the spectrophotometer. This aperture allowed sighting within the strokes of the C, but included only 6 pixels such that slight differences in sighting resulted in variability of the measured luminance. Measurements were taken at twelve different locations on the C, and averaged. The task background luminance was measured and averaged over four different locations, using a 20 minute aperture. The contrasts were adjusted for the very small leakage of the surround lighting onto the VDT screen.

Data was collected in blocks, which included 20 presentations of the C for each of four levels of task contrast, with orientation of the C and task contrast randomly varying over presentations within a block, while surround illumination and task background luminance was held fixed within the block. The sequence of luminances and surrounds was randomly varied across subjects. The subjects' task was to press one of the four buttons on a keypad indicating the orientation of the Landolt C just presented (forced choice). Each 200 millisecond C presentation was preceded by a 2.5 second pupil size measurement. The pupil size measurement prior to the next presentation was initiated one second after the subject responded to the previous presentation. Six blocks of data were collected for each of the two respective surround lighting conditions. As mentioned above, the order of lighting conditions was randomized for each subject and at each lighting change the subject was adapted for at least 2-1/2 minutes before starting testing. A short training period with relatively high values of the C contrast allowed subjects to become familiar with the test procedures.

Data Analysis: The SAS Logit procedure[5] uses Maximum Likelihood methods to fit the data to an S shaped probability of seeing curve (performance vs. log contrast) with asymptotes at $p = 0$ and $p = 1$ (0% and 100% performance). Since our Landolt C data has its performance ranging from 0.25 (i.e., totally random performance) to 1.0 (perfect performance), use of the SAS formalism required transforming the Landolt C data from the (0.25, 1.0) domain to the (0, 1) domain via $f(p) = 4/3\ (p - .25)$ before performing the logistic regression procedures, and then back to the (0.25, 1.0) domain via $f(p) = (3/4\ p) + .25$ after the logistic regression. The slope of the logistic regression (i.e., the slope at the midpoint of the 'S' shaped curve) and the inflection point of the fitted probability of seeing curve (i.e., the log contrast at which the probability of seeing was 62.5%, halfway between random and perfect performance which is referred to here as the threshold contrast) were then compared across surround lighting conditions using a repeated measures ANOVA a within-subject comparison.

Pupillometry: Figure 1 shows the placement of the pupillometer at the right side of the subject. The source of the infrared radiation for the pupillometer was a 12V incandescent lamp with a Hoya RM90 infra-red filter (passing a negligible amount of radiation in the visible spectrum) which directly illuminated the eye. An infrared sensitive video camera (RCA), fitted with an identical filter, was trained on the eye via the mirror. The output from the camera was displayed on two monitors. The first monitor showed the unprocessed video camera output, while the second showed the image of the eye as processed by the computer. The unprocessed image was monitored by the experimenter to ensure that subjects remained in the camera's plane of focus (ensuring stable image calibration), and that eye position did not change. Pupil area was measured by the pupillometer, by methods previously described by summing the lengths of Raster lines in the pupil area. The pupillometer was calibrated using artificial pupils of various sizes, and the relationship between pupil area and the output of the pupillometer was confirmed to be linear and unaffected by up to about 15 degrees of gaze deviation.

Test Lighting Protocol: The experiment was designed to test whether changing surround spectrum affected Landolt C recognition when the task and surround photopic luminance's were fixed.

To accomplish the spectral change, two different illuminants were used. One was a combination of 3 red and 1 pink hue fluorescent lamps, and the other was a single greenish-blue hue lamp. The phosphor coating in this latter lamp is Sylvania phosphor #213 which has its peak output at the maximum of the scotopic sensitivity curve. The ratio of scotopic to photopic luminance (S/P) for the red/pink combination was 0.24, while for the F213 lamp it was 4.31. For this experiment, the photopic output of both of these illuminants was set so that the front wall luminance was 53 pcd/m^2 as measured on the viewed walls, while the scotopic luminance of necessity varied from 13 scd/m^2 for the red/pink combination to 230 scd/m^2 for the F213. According to our previous studies, this choice of illuminance having a large difference (a factor of 18 fold) in scotopic luminance, should produce significant differences in pupil size. In order to cover a range of contrast where performance varied, five of the subjects had contrast levels for the Landolt C of 12, 16, 27, 38 and 47 percent, while for the other two subjects the contrast levels for the Landolt C were 47, 60, 70 and 80; and 65, 70, 75 and 85 percent, respectively.

RESULTS

Pupil Area: For one subject no valid pupil data was obtained but the subject was included in the performance data analysis. For the 6 subjects there was an average of 27.0% (s.e. = 4.2%) reduction in pupil area under 53 pcd/m^2 of F213, compared to 53 pcd/m^2 of red/pink ($F_{1,12} = 19.2$, $p = 0.0009$). Pupil size was unaffected by the contrast of the Landolt C stimulus ($F_{3,12} = 0.015$, $p = 0.99$). Under the F213 surround average pupil area was 9.9 mm^2 ± (0.77 mm^2 s.e.), while under the red/pink surround average pupil area was 13.7 mm^2 ± (1.1 mm^2 s.e.). Average values of the change of pupil area between the F213 surround and the red/pink surround for each subject are shown in Figure 2a. Note that in Figure 2a, all subjects showed a pupil area change, though the amount of change was generally less for the elderly, as compared with the young adults (plotted from our previous study results[1]).

Landolt C Performance: Landolt C performance was recorded for all seven subjects. For each surround illuminant, the accuracy data for each subject was fit versus $\log_e$ percent contrast using the SAS Logit procedure for logistic regression.[5] Figure 3 shows the probability of seeing fits generated for a typical subject, i.e., neither best or worst case in terms of the amount of performance difference that occurred between the two surround conditions.

The mean inflection point (threshold contrast) for both lighting conditions and slope of the logistic for each subject was determined. There were no significant effects of surround lighting on the logistic regression slope ($F_{1,6} = 0.98$, $p = .37$). This suggests that differences in the slopes of the probability of seeing curves under the two surround lighting conditions are due to chance, and on average are parallel. Across subjects there was a highly significant shift of the probability of seeing curve towards a lower contrast threshold under the F213 compared to the red/pink surround lighting ($F_{1,6} = 26.81$, $p = .002$). The inflection point in the probability of seeing curve was shifted on average from 3.54 ± 0.53 $\log_e$ s.e. (percent contrast) for the red/pink surround illumination to 3.17 ± 0.60 $\log_e$ (percent contrast) for the F213 surround illumination. Removing the $\log_e$ term, this corresponds to a shift in threshold contrast of 11% from 35% to 24%. Figure 2b shows the difference in threshold (percent) contrast obtained for each subject. The amount of increase in threshold contrasts range from 3% to 18%. Note that the effects for all subjects were in the same direction, i.e., higher threshold contrast for the red/pink surround.

Comparison With Data From Young Adults: We have previously reported data from a similar experimental in young adults but that data analysis did not employ the probability-of-seeing method reported here.

In order to compare this elderly adult data with the data from the young adults, we have reanalyzed the young adult data using the same logistic model we used for the elderly, at the same value of task background luminance. We found no effects of surround illuminant on the slope of the logistic regression curves (all F's less than 2.19, p's > 0.18). In contrast, the inflection point (threshold contrast) of the probability of seeing curve was strongly affected by the surround illuminant ($F_{1,9} = 29.2$ $p < .0004$) such that increasing the scotopic intensity of the surround illumination shifted the probability of seeing curve toward greater sensitivity, i.e., lower threshold contrast. For each of the twelve subjects of the young adult study, Figures 2b shows their average threshold contrast change and Figure 2a their average pupil area change that occurred when the surround illuminant was shifted from red/pink to F213. Averaged over all 12 of the young adults, pupil size changed from 18.2 ± (1.3 s.e.) mm^2 under the red/pink illuminant to 11.1 (± 0.6 s.e.) mm^2 under the F213 illuminant while average threshold contrast went from 27% to 18%. Note in Figure 2b that all young adult demonstrated performance difference in the same direction, and that the range of change in performance in the elderly was comparable to that in the young adults.

DISCUSSION

Although the pupil size changes obtained in this study of elderly subjects were about one-half of that occurring in our previous study of young adult subjects, the data of Figure 2 shows that the performance changes were comparable. Our elderly subjects had an average pupil diameter decrease of 18% associated with a mean threshold contrast decrease from 35% to 24%. The young adults had, on average, twice the change in pupil diameter and mean threshold contrast decreased from 27% to 18%.

For the scotopically enhanced surround lighting the average pupil area for our elderly subjects was about 28% smaller than for the scotopically deficient surround lighting, so task retinal illumination was concomitantly decreased by 28%. Yet, performance was significantly better despite the decreased retinal illuminance. This result is consistent with the hypothesis that the improvements obtained in visual performance by increasing light levels for older people[6] is primarily due to the decrease in pupil size resulting from increased ambient luminances, rather than an increase in retinal illuminances.

Our data for young adults also allows for testing the alternative hypothesis that disability glare caused by the surround lighting is the mechanism responsible for their difference in performance. Because pupil size is smaller under the scotopically enhanced surround (213), the photopic retinal veil caused by light scatter in the eye should be less than the veil produced by the larger pupil occurring under the scotopically deficient surround (red/pink). In the young adult experiments, in addition to the data presented above which was gathered at a task background luminance of 11.89 cd/m^2, the study was also carried out at task background luminances of 27.7, 47.0, and 73.4 cd/m^2, with the surround illuminant conditions unchanged. Since the veil resulting from the surround illuminants was of constant luminance, the effect of this veiling glare should decrease as the task background luminance increases. From the expressions of Vos[7] on disability glare, we can calculate that the veil due to light scatter would have resulted in reductions in contrast that went from 2.1% at 73.4 cd/m^2 task background luminance to 12.0% at 11.89 cd/m^2 task background luminance. If these effects were responsible for the performance differences in the experiment, then those performance differences should have been larger under conditions of lower task background luminance; however, there was no significant interaction effect between surround illuminant and task background luminance (F3,7=0.83, p=0.52). For disability glare effects to be at work in the current experiment, one would have to postulate that such effects are specific to the elderly. Nevertheless, even without specific knowledge of the mechanisms the scotopically enhanced lighting does provide a higher level of performance compared to the scotopically deficient lighting for our elderly subjects.

There is yet another alternative hypothesis that we cannot presently rule out and which is not based on pupil size changes as the mechanism responsible for our observed performance effects. Under this hypothesis the performance changes are due to a spectrally dependent interaction between the periphery and fovea of the eye and that this interaction causes better performance when the surround has the blue/green spectrum rather than the pinkish spectrum. This kind of interaction has not been reported in the literature and would be of interest if true. At this time pupil size effects seem the more likely mechanism.

The performance of the elderly subjects for a given surround condition is generally poorer than that of the young adults of our previous study, i.e., threshold contrasts are higher. On the other hand, we speculate that the reason why the change in performance of the elderly and young adult subjects are comparable despite a smaller pupil size change, is that our elderly subjects may have an increased amount of ocular aberrations, as is known to occur with senescence of the eye.[8] Thus, it is possible that small changes in the pupil size of the elderly can have a large effect on their performance of difficult visual tasks. For the parameters and conditions of our study, our results suggest that both neural degradation and dioptric factors affect Landolt C recognition (although this may not be the case if the size of the task is sufficiently small[9]).

The results of this study coupled with our previous study,[1] show for a large age range of the population that a shift in the spectrum of lighting to greater scotopic luminance with photopic luminance fixed will lead to smaller pupil sizes and improvements in visual performance. As we have stated previously, this suggests that it might be possible to maintain present standards of visual performance by substituting scotopically enhanced surround lighting while operating at reduced photopic luminance levels. Depending on the overall efficacy of such lighting, there could be energy savings.

ACKNOWLEDGMENT

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FIGURE CAPTIONS

Figure 1. Rear view photo of subject in the test room with head on pupillometer chin rest viewing the task. The task is viewed via a front surface mirror situated in the middle of the black curtain. The VDT surface is covered with matt black except for the viewing tube. The IR camera portion of the pupillometer is located at eye level on the right side of the subject. (LBL ZBB 916-4500)

Figure 2a. The change (increase) in average pupil area (mm2) that occurred when the surround illuminant was changed from F213 to red/pink is shown for each elderly subject and for each of the young adult subjects of our previous study.

Figure 2b. The change (increase) in threshold contrast in units of percent contrast that occurred when the surround illuminant was changed from F213 to red/pink. The values shown are for each elderly subject and for each of the young adult subjects of our previous study, as determined by the probability of seeing analysis (see text).

Figure 3. The percent correct response data for a typical subject (neither best or worst case) under the two different surround illuminants. The continuous functions are the fitted probability-of-seeing logistic functions with the solid circles showing the desired threshold contrast (inflection point).

Discussion

I commend the authors on what appears to be a logical extension of their earlier work on performance related to scotopic sensitivity. A few specific questions about the study.

It is not clear from the experimental description nor discernible from the xerographed photograph exactly what the subject saw when presented with the task. The surround luminance was presented on the surfaces beyond the thirty degree central field and the Landolt C subtended approximately fifteen minutes of arc. There is no indication of what occurred between these two regions other than the statement that a "small" area of the VDT screen was set to a background luminance of 13.2 cd/m^2 . How was the balance of the visual field treated and what was its luminance? This immediate surround would seem to have an important influence on the performance results. Also, was the 13.2 cd/m^2 background luminance a photopic or scotopic luminance value?

The authors also indicate that the contrasts were adjusted for the small leakage of surround lighting onto the VDT screen. How were these adjustments made and were they made based upon photopic or scotopic luminance values?

There is no explanation why the 53 pcd/m^2 surround luminance was chosen, although, I assume it was done so to correlate with the surround luminance of the earlier study. It would be helpful to know why this particular surround luminance was chosen over other possibilities, if other surround luminances have or will be tested, and also how uniform the surround luminance was.

Five of the subjects were presented with one set of contrast levels, while the remaining two subjects each had a different set. This seems to be an odd split and I'm curious if there was a specific reason for it. Further, no valid pupil data was obtained for one subject but no explanation is offered. An explanation would be helpful since the subject was included in the performance data.

There appears to be an error when comparing this study with their earlier study of young adults. The authors offer the observation that in the earlier study the young adults had twice the change in pupil diameter and mean threshold contrast *increased* from 27% to 18%. Although this is trivial, it would be helpful to talk about the same direction of change in both pupil size and threshold contrast shown in Figures 2a and 2b. There are several points in the text where the order is reversed while discussing the graphs, leading to a bit of confusion.

An obvious question about the results of this paper and perhaps its predecessor would seem to be, "does scotopic surround illumination have a greater influence at threshold levels than it might have at supra threshold levels?" In other words are differences in performance evident here significant enough that they would also appear under more realistic conditions within an environment. Perhaps the authors could address this question in their response.

Finally, the authors offer an alternative hypothesis that changes in performance are due to a spectrally dependent interaction between the periphery and fovea of the eye, but state that they believe that pupil size effects are the more likely mechanism. It would be helpful to know the basis for the latter statement since no specific support or explanation is offered in the paper.

Craig A. Bernecker
Penn State University

Response to C.A. Bernecker

We thank Dr. Bernecker for a careful reading of our paper and for his comments.

The physical layout of our study is pictured in Fig. 1 and described in the test. The layout is the same as in our previous study of young adults(a) and further details showing a close-up of the visual task and the details of the Landolt C are given there. As stated in the text, the surround field, i.e., the region beyond the black curtain, was roughly uniform with a luminance of 53 cd/m^2. The portion of the VDT screen seen through the tube was set to the task background luminance while the remaining approximately 30° of central field was black. The purpose of the illumination in the surround was to control pupil size. The other specific points mentioned are discussed below.

All luminances are always photopic unless specified as scotopic.

As mentioned in the text, about 0.3 cd/m^2 of light leaked into the tube. Although this is small compared to the 13.2 cd/m^2 task background luminance we corrected for it by including it as part of the background luminance in the usual (Weber) expression for contrast.

The value of 53 cd/m^2 for the surround lighting was not entirely arbitrary. It was dictated by the maximum number of lamps we could place in our fixture and the low lumen output associated with red fluorescent lamps.

As explained in the text, the contrast values were chosen so that subjects would be presented the test Landolt C in a range where the score would vary, i.e., not at a guessing level and not at clearly seeing-it level. Pupil data was not obtained for one subject because the subject was an excessive blinker.

We agree that the word in the original text should have been "decreased" from 27% to 18% and not "increased". To refer to this as an error is perhaps stretching the tone somewhat. This change has been included in the present text.

The question asked about threshold and supra threshold indicates a fundamental conceptual gap in the purpose of this study and most studies on lighting and visual performance. Threshold conditions are chosen because this is the region where lighting parameters will showing readily measurable effects (see response below to the discussion of M. Rea).

The precise meaning of the last comment is difficult to understand. We suggested in the text alternative hypotheses to explain the observed effects. However, we showed both pupil size changes and performance changes are in accordance with our hypothesis that smaller pupils allow improved performance. The alternate hypothesis of a foveal-peripheral interaction would be extraordinary but the present experiment could not rule it out.

A more interesting explanation is based on a postulated decrease in disability glare caused by the smaller pupil which decreases the retinal veil associated with the stray light coming from the surround walls.

Discussion

The authors demonstrate again (a) that the natural pupil size can influence performance at threshold tasks. It is difficult to imagine, however, a more difficult visual task; the targets are of low contrast and small size and seen briefly on a low background luminance. Again (a), I disagree with the authors assertions that these results can be extrapolated to realistic situations where, say, a person is reading printed text of the type commonly available. Simply put, I believe that natural pupil size has little practical relevance to realistic task performance.

From a more basic research point of view, however, I would ask the authors to please plot the data in Figure 2a and 2b against each other for every subject. By plotting the change in pupil area against the change in threshold for every subject, one may see the robustness and consistency in the relationship between pupil size and contrast threshold.

(a) Berman et. al., J.IES 22(2), 1993m p. 150.

M. Rea (11 August 1993)

Response to M. Rea

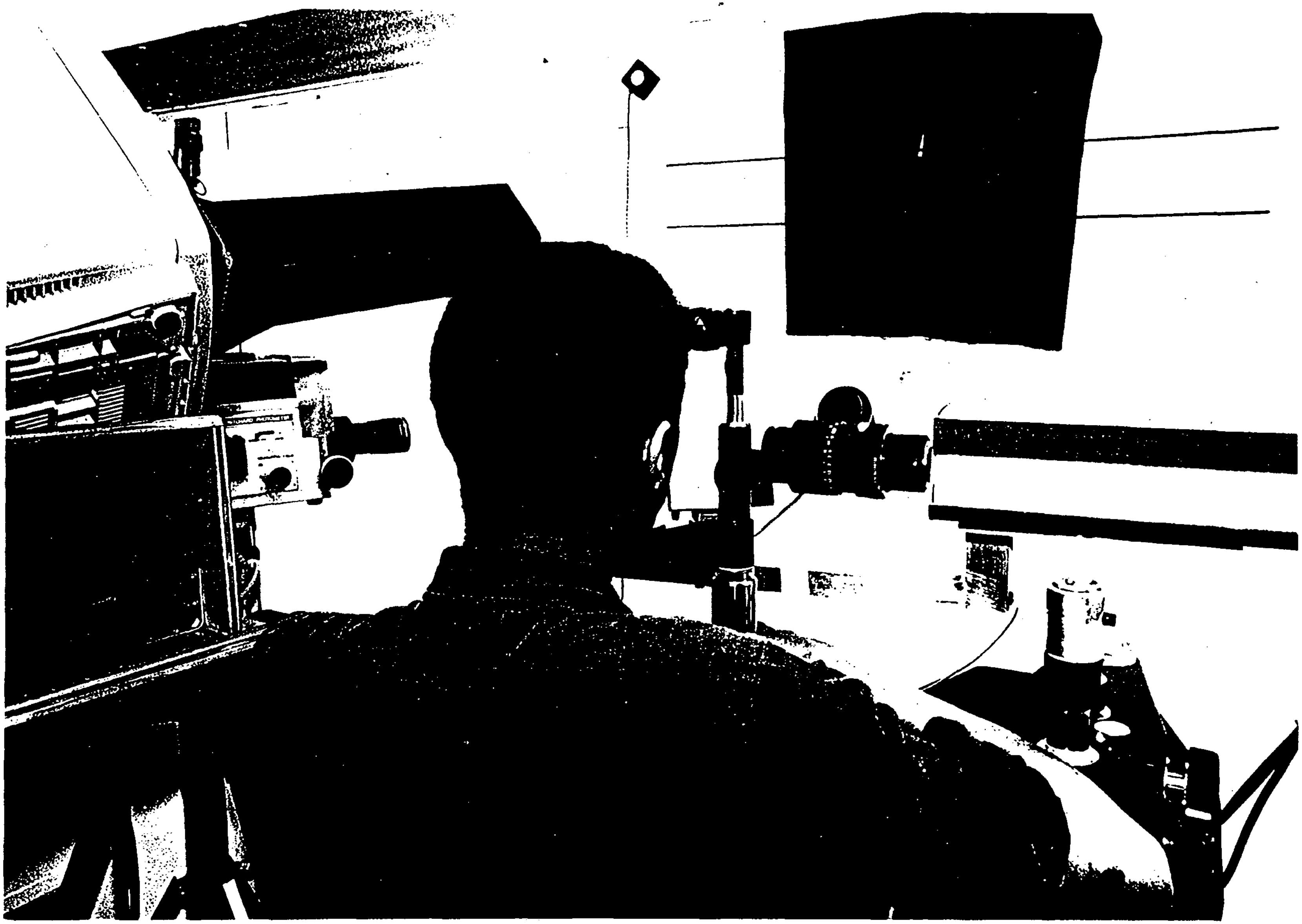
Dr. Rea argues that measurements near threshold are irrelevant to the effects of lighting on vision in situations where a person is reading normal-sized printed text. While we acknowledge that differences in contrast sensitivity threshold make no difference on a high contrast task, such as reading normal-sized text we argue that one visual test cannot serve to predict all visual functions. Dr. Rea suggests that a reading task is the only appropriate measure of visual quality for general office tasks. When contrast sensitivity is deficient, a scene is "stark" and lacking in detail, although not necessarily blurry. However, the quality of vision is certainly worse when contrast sensitivity is low, which can easily be verified by turning the contrast knob on a TV set, or wearing dark glasses indoors. Perhaps we need some studies as to whether the loss of contrast indoors due to wearing dark glasses is generally acceptable. On the other hand, the sales of prescription dark glasses that lighten when indoors may indicate that contrast is considered by subjects to be important to visual function, just as sharpness of edges is. We think that sharpness of edges *and* better contrast sensitivity are both needed visual qualities in everyday life. The ability to discern skin texture especially in facial nuance is an example of a typical visual task which contains a large range of contrast. One has only to look in a mirror under dim light with dark glasses to "see" many of the facial wrinkles of age disappear.

Dr. Rea, as well as other commentators, have remarked that threshold measures may not extrapolate to supra threshold tasks. Testing at threshold is merely an *objective means* to determine differences in visual experience, as affected by the experimental parameters. We consider such testing much preferable to subjective judgments of acceptability. For didactic purposes, let us consider eye testing for glasses. Different-sized letters are available, some sizes are above legibility threshold, some below. The large "E" is always above threshold, but if it is out of focus the edges will be blurred. While it is possible to have the subject judge the sharpness of the edges of the "E" as trial lenses are varied, the only *objective* way to determine the degree of sharpness is *by determining the threshold* size that the subject is barely able to read. The widespread use of small letter to judge ability to see (e.g., eye tests for glasses and drivers licenses), is not because it is assumed that the small letters will be encountered elsewhere, but because it is realized that the subject will be able to perceive the smallest size letters *and all details that are larger.*

The sharpness and clarity level of visual tasks may also be a factor in visual fatigue. To support this claim one need only look at large letters with spectacles that are just a little "off" (+0.05 diopters). No difficulty will be encountered in seeing or reading the large letters, but long-term continued use of the "off" spectacles is highly unlikely to be acceptable.

The word "threshold" might mislead, giving the impression that somehow sensation is minimal. A weight lifting championship is testing for the "threshold" increment that will exceed a competitor's maximum strength. But that does not mean that the weight is light, nor that the competitor will always be lifting that much weight is daily activities. But the weight lifted does suggest that lesser weights in daily activities will be lifted. In our studies, higher contrast scenes will be seen better under conditions in which contrast sensitivity is better.

Concerning Dr. Rea's second point, there is no direct correlation between the amount of change in individual subjects' pupil sizes and the amount of contrast threshold change. The elderly subject data emphasize this lack of correlation which may be more related to the location and density of aberrations in the subject's optical system.



ZBB 916-4500 (LBL PHOTO)

FIGURE 1

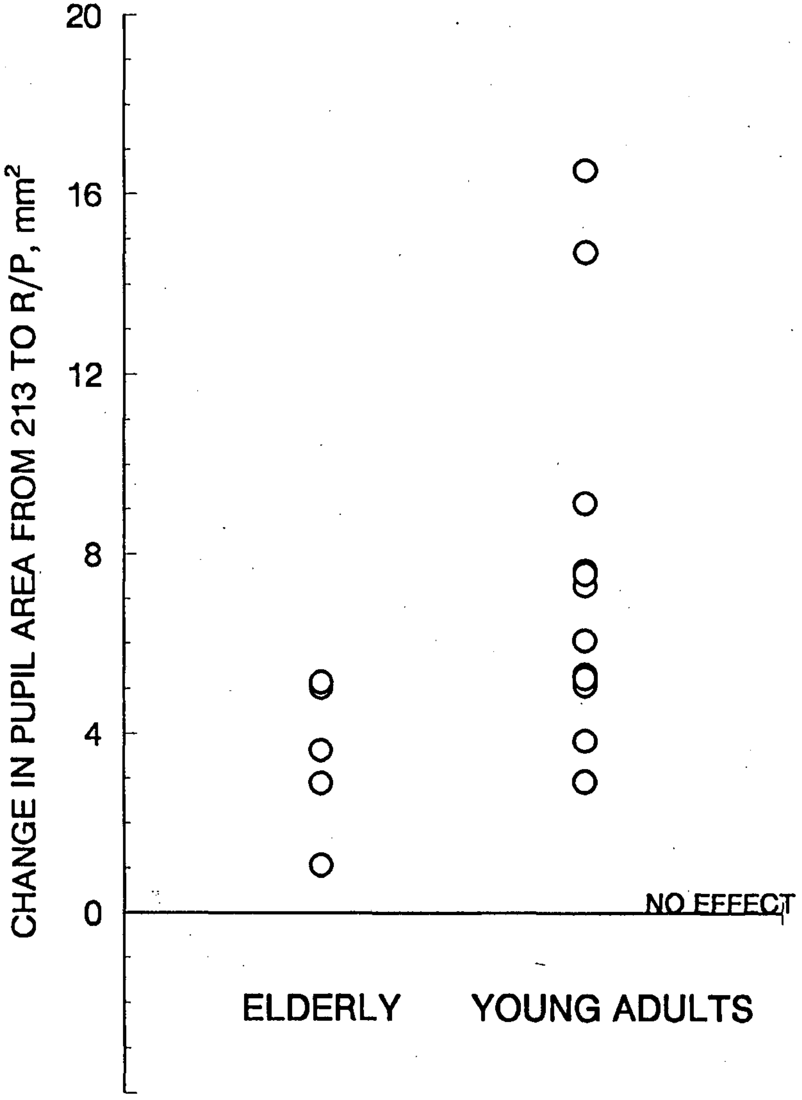

CHANGE IN PUPIL AREA FROM 213 TO R/P, mm²
20
16
12
8
4
0
NO EFFECT
ELDERLY
YOUNG ADULTS

FIG. 2A

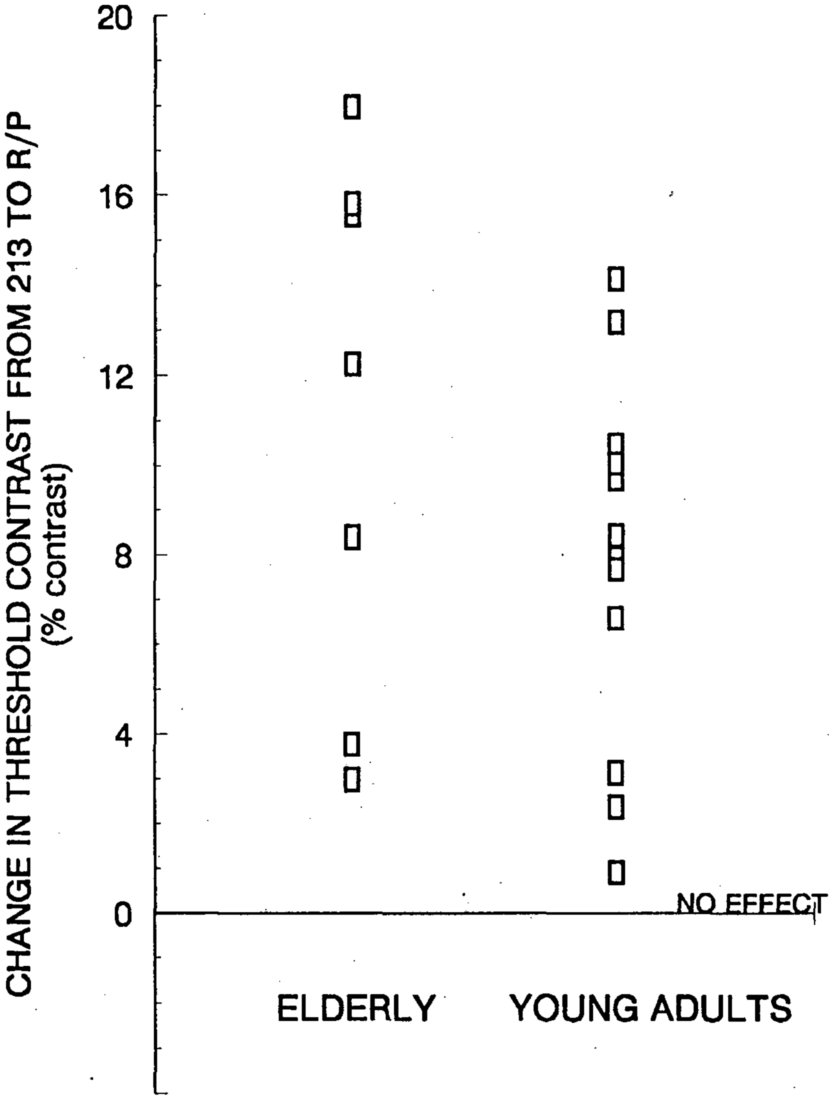
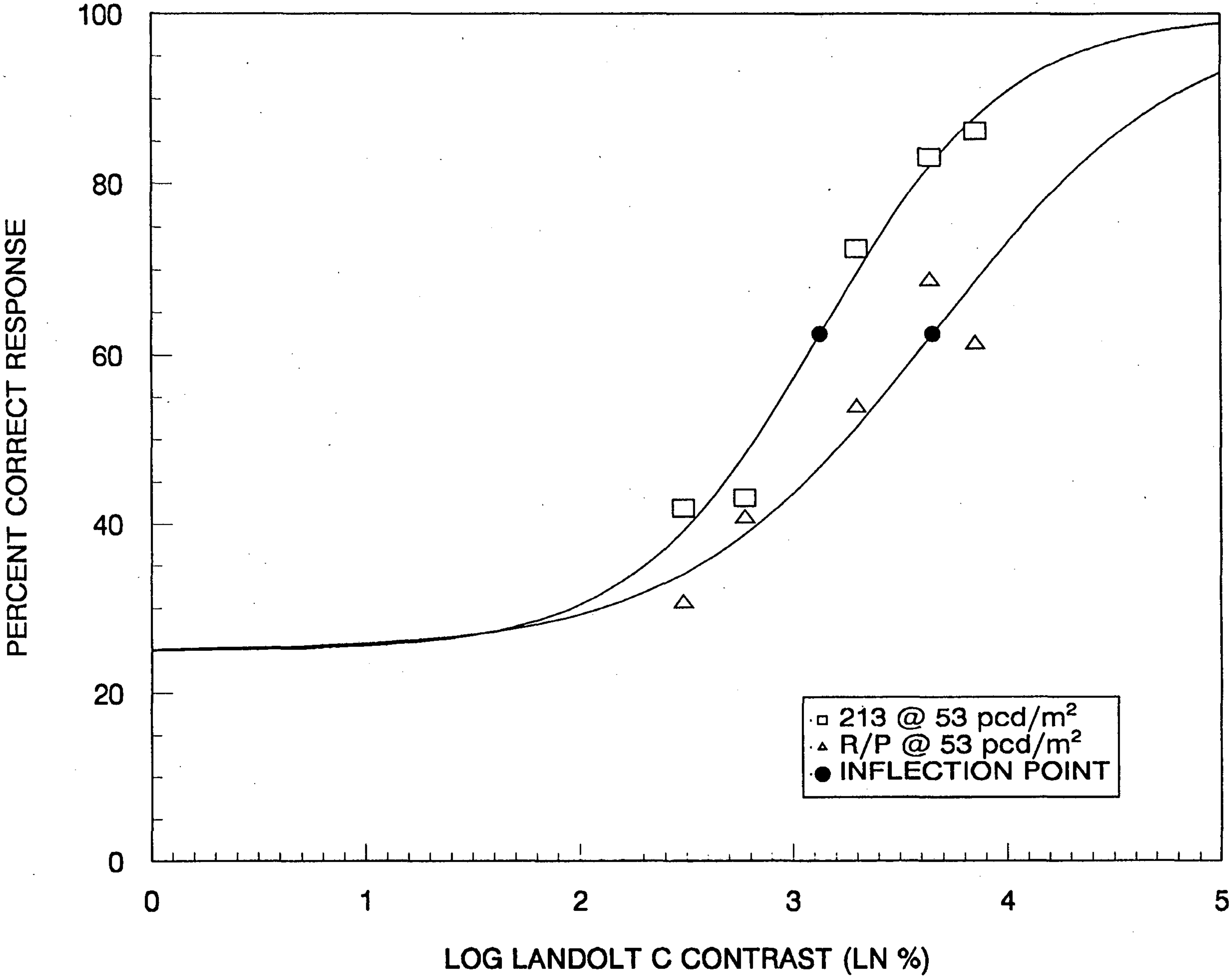

CHANGE IN THRESHOLD CONTRAST FROM 213 TO R/P
(% contrast)
20
16
12
8
4
0
NO EFFECT
ELDERLY
YOUNG ADULTS

FIG. 2B

FIG. 3


PERCENT CORRECT RESPONSE
0
20
40
60
80
100
LOG LANDOLT C CONTRAST (LN %)
0
1
2
3
4
5
□ 213 @ 53 pcd/m²
△ R/P @ 53 pcd/m²
● INFLECTION POINT

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