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A PILOT STUDY OF EXPERIMENTER-SUBJECT EFFECT ON DARK ADAPTATION--ETC(U)
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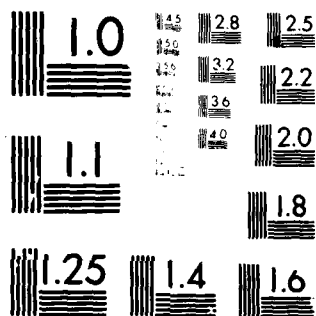
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(6) A PILOT STUDY OF EXPERIMENTER-SUBJECT EFFECT
ON DARK ADAPTATION THRESHOLDS.

by

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(11) October 1969

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Work Unit NIGHTSIGHTS: Work Sub-Unit II

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PREFATORY NOTE

This paper is the summary of a preliminary study of the effects of experimenter influences on dark adaptation. The study was conducted under Work Sub-Unit II, NIGHTSIGHTS. The purpose of Work Unit NIGHTSIGHTS is to identify critical human factors problems in the use of new night operations devices, and to develop effective techniques of training men to use the devices. The objective of Sub-Unit II is to study the factors that influence the course of dark adaptation, in an effort to identify those that facilitate or impair performance under conditions of dark adaptation in combat situations.

The results of this pilot work are being reported at this time because plans for follow-up research in this area have not been made.

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ABSTRACT

✓ To extend the findings of studies of experimenter-induced effect on research data to the area of sensory research, in which the experimenter often serves as his own subject (ES), a pilot study was designed to permit the operation of ES-induced bias during the collection of foveal dark adaptation data. An attempt was made to instil an expectancy in the ES before data collection, by acquainting him with the often-reported finding of a positive relationship between preadaptation duration (PD) and threshold elevation (TE) in dark adaptation. During the experiment, PD was frequently misrepresented as being longer or shorter than the actual PD. The data provided some support for the notion that expectancy of a positive relationship between PD and TE (apart from PD per se) may determine the elevation of the visual threshold in dark adaptation. But more of the data supported the post hoc notion that expectancy of a curvilinear relationship between PD and TE determined TE in this experiment. Reasons for inferring that this expectancy of a curvilinear relationship originated during data collection are discussed.

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A PILOT STUDY OF EXPERIMENTER-SUBJECT EFFECT
ON DARK ADAPTATION THRESHOLDS

INTRODUCTION

A provocative review (1) has cited recent learning studies in which the experimenter was treated as one of the independent variables. The results of these studies show that research data can be affected by the experimenter. In two of the cited studies, student experimenters were divided into research teams. Rats were randomly assigned to research teams and exposed to typical learning situations. One group of teams was told that its animals were "bright," the other that its animals were "dull." The performance of the "dull" rats was significantly inferior to that of the "bright" rats in all but one of numerous comparisons. Such findings, along with evidence from other fields of psychology, suggest that the expectations, biases, and attitudes of the experimenter can prompt a disturbing number of "significant experimental effects" in the laboratory. Thus, it becomes a matter of concern when the data gathered by an experimenter confirm a research hypothesis which reflects his theoretical convictions and individual assumptions. The authors of the review (1) acknowledge the scope of the problem by noting that the "conflicting theories of Hull, Tolmon, Guthrie, and others" have been buttressed by the results of experimenters partial to one of the given theories.

The review mentions two ways in which an experimenter may unwittingly translate his research hypothesis into an experimental effect. First, he can inadvertently provide overt cues which guide his subject's responses. Second, he can misinterpret his subject's responses. Although not mentioned in the review, the misreading of data might introduce a third method of translation (2).

There is nothing in the review which suggests that these three methods of translation do not prevail in all fields of psychological investigation. However, a fourth method is inherent in the methodology of basic sensory research. In many of these investigations, in contrast to the typical learning study, the experimenter often acts as one of the research subjects. His expectations and biases--which may contaminate his laboratory behavior--may therefore directly affect the generation of data. This possibility of experimenter-subject (ES) bias (almost unique to sensory psychology), coupled with the perceptual errors and experimenter-cued behavior common to all psychological investigations, makes the results of sensory investigations especially vulnerable to speculation. Furthermore, this vulnerability is increased by the fact that few subjects are employed in these investigations--a practice which tends to accentuate the contributions of the experimenter-subject.

To date, the existence of ES-induced biases in sensory research is only a logical possibility, not a demonstrated fact. Accordingly, this report describes a pilot attempt to generate sensory data that reflect the expectations of an ES. Specifically, the susceptibility

of visual dark adaptation to ES-induced bias was examined in the pilot investigation, an approach consistent with the sizable proportion of sensory research devoted to the study of fundamental visual processes.

Dark adaptation refers to the temporal increase in visual sensitivity that occurs in the dark after stimulation by supraliminal light, e.g., preadaptation light. This increase in sensitivity, the exact nature of which is said to depend on the characteristics of the preadaptation light, usually continues for only thirty minutes or less. Most laboratory investigations of dark adaptation, including this one, follow the same procedure. All light is withheld from the eye of the subject for about thirty minutes by either placing him in darkness or occluding the eye. The subject's eye is then exposed to a preadaptation light which falls upon a considerable segment of the retina. Then the subject produces a succession of absolute thresholds in the dark by repeatedly adjusting the luminance of a light striking a portion of the retinal area previously stimulated by the preadaptation light. The adjustments of luminance are directed toward keeping the light at a barely perceptible level. The decrease of luminance that appears when the absolute thresholds are plotted over time defines the increase in visual sensitivity known as dark adaptation; the threshold stabilization that gradually occurs marks the completion of dark adaptation and the existence of maximum sensitivity. The period of darkness initiating the laboratory procedure insures that the effects of earlier light stimulation have worn off before the preadaptation light is presented.

In dark adaptation studies, one of the manipulated characteristics of the preadaptation light is its duration. Wald and Clark (3) published the classic findings of preadaptation duration (PD) in 1937. They showed that prolonging the exposure to the preadaptation light increased the elevation of the visual thresholds and further delayed the completion of dark adaptation. These findings, still graphically presented in prominent secondary sources (4,5), helped to confirm experimental predictions which arose from the senior author's photochemical conceptions of the visual process. The one female subject from whom the findings were entirely obtained was probably the junior author, although she is not so identified in the publication.

It is fairly clear that the Wald and Clark data were not collected by experimenters totally disinterested in its outcome. It is also fairly obvious that their findings may be responsible, at least in part, for the expectations of experimenter-subjects who investigated preadaptation duration after acquainting themselves with the relevant literature. Hence there is a basis for questioning the evidence of a positive relationship between preadaptation duration (PD) and threshold elevation (TE) during dark adaptation. This basis, as well as the suspicion earned by all sensory research with ES-generated data, will be empirically strengthened if supposed--in contrast with actual--preadaptation durations (PD's) also can be shown to influence threshold

elevation (TE). The present pilot study was designed to introduce such an ES-induced influence.

METHOD

General Approach

One adult male served as the ES in this pilot study. The principal features of his introduction to the study were as follows. He was acquainted with the positive relationship that has been shown to obtain between threshold elevation and preadaptation duration. He was then told that his performance on a newly-constructed dark adaptometer should reflect that relationship if the instrument was effective. He was given to understand that he would provide numerous instances of foveal dark adaptation; one-third of these instances would follow 20 seconds of preadaptation, one-third would follow 40 seconds of preadaptation, and one-third would follow 60 seconds of preadaptation. He was also informed that his threshold could be expected to be most elevated after 60 seconds of preadaptation and least elevated after 20 seconds of preadaptation, and that 40 seconds of preadaptation would produce an intermediate amount of threshold elevation (TE).

Presumably, ES's introduction to the study established an expectancy which was comparable to the expectancies of previous ESs in the area of dark adaptation.

The design of the study insured ES's awareness of preadaptation duration before every exposure to the adaptometer by having him select at random the PD that ostensibly preceded each instance of dark adaptation. However, the actual PD's corresponded only part of the time to the PD's he selected. At other times, they corresponded to first one and then another of the two he did not select. In this manner, the study involved an attempt to arrange a conflict between ES's expectations and the actual preadaptation durations.

Apparatus¹

The dark adaptometer diagrammed in the upper half of Figure 1 provided the preadaptation stimulus and threshold light in a monocular Maxwellian view to the left eye. The light source (S) is a G. E. 6-volt microscope-illuminator run by alternating current. The current is controlled by a constant voltage transformer (SOLA, Type CV-I). An infrared filter (IF) absorbs infrared light. Lens L_1 produces a filament image in the plane of diaphragm D_1 . The aperture of this diaphragm (D_1) lies within the image and has a diameter of .018 inches. Lens L_3 brings the light of the optical path to a focus in the plane of the

¹The experimental use of any device whose trade name appears in this report does not constitute an endorsement of the device.

SCHEMATIC DIAGRAM OF ADAPTOMETER AND ADAPTATION STIMULI

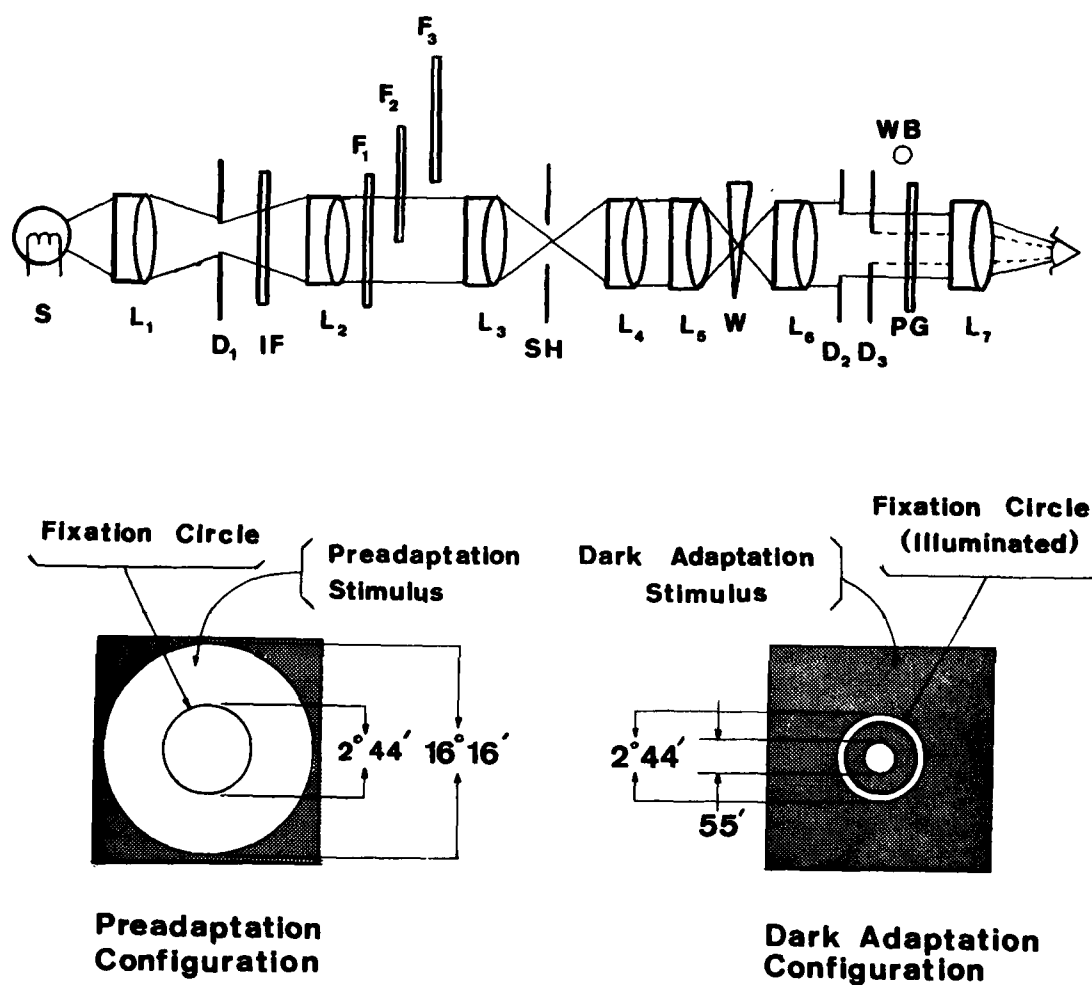


Figure 1

solenoid-operated shutter (SH) ; lens L_5 in the plane of the gelatin of a neutral-tint wedge (W); and lens L_7 in the plane of the observer's (ES's) pupil. Lenses L_2 , L_4 , and L_6 collimate the light of the optical path and are located one focal distance away from preceding positions of maximum light convergence. Diaphragms D_2 and D_3 determine the diameter of the latter portion of the optical path, and in conjunction with the focal distance of lens L_7 , set the visual angle of stimulation. A circle scratched in a plate of clear plexiglas (PG) serves as an object of fixation.

Light falling on the plate (PG) from a grain of wheat bulb (WB) illuminates the circle. This bulb (WB) lies outside the optical path. Two rheostats in series with the bulb (WB) regulate the amount of flux received by the fixation circle and therefore its brightness. The observer's (ES's) head is fixed by dental impression.

For preadaptation, neutral-tint filters F_1 , F_2 , and F_3 , as well as the wedge (W) and diaphragm D_3 , are removed from the optical path. The duration of preadaptation is determined by Hunter timers in one of the two circuits activating the shutter (SH). This circuit is managed by the experimenter (E).² The second circuit contains no timers and is controlled by the observer (ES). The preadaptation stimulus has a diameter of $16^\circ 16'$ visual angle and a luminance of 7.37 millilamberts. The fixation circle, which is not illuminated during preadaptation, has a diameter of $2^\circ 44'$ and is located in the center of the preadaptation light, as illustrated at the lower left in Figure 1.

For dark adaptation, diaphragm D_3 is inserted into the optical path, reducing the visual angle to $0^\circ 55'$. With the insertion of diaphragm D_3 , collimated light now passes through a center portion of the fixation circle. By careful adjustments of the rheostats associated with the bulb (WB), the fixation circle becomes visible without any perceptible brightening of the plate (PG). Accordingly, during dark adaptation the observer (ES) sees the view given at the lower right in Figure 1. The light in the optical path is reduced to threshold by traversing the wedge (W) along the focal plane of lens L_5 and introducing filters F_1 , F_2 , and F_3 . Movement of the wedge is pen-recorded.

The fixation circle is orange. The color of the preadaptation stimulus and the threshold light is discussed later.

²Psychological investigations of "the experimenter effect" contain the unusual circumstance of an experimenter studying another experimenter. To avoid confusion and promote brevity in the write-up of such investigations, a standard notation needs to be adopted to distinguish between the experimenter who conducts the research and the experimenter whose behavior is the object of concern. In the absence of such notations, E will be used in this report to designate the former and ES the latter.

Procedure on the Dark Adaptometer

The observer ES centrally fixated the circle on the plate (PG) during both preadaptation and dark adaptation.

For preadaptation, the shutter (SH) remained open for either 20 seconds, 40 seconds, or 60 seconds. As soon as the shutter was closed, ES placed diaphragm D_3 in the optical path and illuminated the fixation circle. He next moved the denser portion of the wedge (W) into the optical path, opened the shutter, and moved the less dense portions of the wedge out of the optical path until an absolute threshold was secured. It took, as a rule, seven or eight seconds to establish the first threshold after termination of preadaptation. The ES continued to produce absolute thresholds for approximately 10 minutes. E put the neutral-tint filters F_1 , F_2 , and F_3 into the optical path individually and in various combinations during dark adaptation, to compensate for the limitation of the wedge (W).

The luminance of the absolute thresholds was obtained at 15-second intervals during each 10-minute period of dark adaptation. For each period of dark adaptation, then, forty measures of luminance were obtained. These were secured throughout the study after the recording of several preadaptation/dark adaptation sequences with a photomultiplier photometer (Gamma Scientific, Model 700). The diffusing surface of the photometer's cosine receptor (Model 700-4) was placed in the focal plane of lens L_7 , a plane occupied by the pupil of the eye during preadaptation and dark adaptation. The positions of the wedge (W) in the optical path, and the attenuation given by filters F_1 , F_2 , and F_3 at each 15-second interval, were reproduced; and a measure of illumination was read from the photometer. At the end of data collection, all measures of illumination were converted to equivalent units of luminance.

Laboratory Procedure

The ES was given 10 practice trials on the adaptometer to familiarize him with the operations of the apparatus and to acquaint him with the terminology of dark adaptation investigations. Five of the trials had a preadaptation duration (PD) of 60 seconds, two had a PD of 40 seconds, and three had a PD of 20 seconds. No more than 5 minutes of dark adaptation was recorded for each of the 10 trials.

The ES was allowed to inspect individual practice recordings so that grossnesses associated with his threshold adjustments could be identified and possibly eliminated in future trials. However, he was not allowed to compare the recordings from separate trials, nor did E give him any indication of the absolute illuminance values represented on the recordings. It was felt that such strategies would reduce ES's inclination to develop preconceptions about the relationship between preadaptation duration (PD) and threshold elevation (TE) during practice.

The practice trials had two additional functions. First, they gave E some idea of the sequence in which the neutral-tint filters should be inserted into the optical path. Second, they demonstrated to ES an elementary characteristic of many dark adaptation studies; namely, that more than one presentation of a given PD occurs in the course of data collection.

As an introduction to the commonly accepted relationship between PD and TE, the following statement was read to the ES after the practice trials.

One of the most common findings in the area of fundamental vision is that the longer the duration of the preadapting light, the greater the loss of sensitivity. Here is a set of curves that shows this.

At this point, the ES was shown Figure 3 from Wald and Clark (3), in which dark adaptation is plotted over time as a function of pre-adaptation duration.

Note that six different preadaptation times were used and that the curves become progressively higher and take longer to come back down to a stable level as the preadaptation durations increase.

Since our apparatus has just been constructed and is untried, one way of checking its worth is to compare dark adaptation curves after exposure to preadapting light of different durations. If the apparatus is effective, your thresholds should become more elevated and take more time to quit dropping as the duration of the preadapting light is increased.

In this study, three preadapting durations will be used: 20 seconds, 40 seconds, and 60 seconds. Obviously, we can expect the 60-second duration to have the most effect on your threshold, and the 40-second duration to have more effect than the 20-second duration.

The ES was now told that he would provide forty-five instances of dark adaptation, each lasting for slightly less than ten minutes; that fifteen of the forty-five instances would follow 60 seconds of preadaptation, that fifteen would follow 40 seconds of preadaptation, and that fifteen would follow 20 seconds of preadaptation. He was then told that during the experiment he would randomly determine the order in which the PD's occurred.

The left eye of the ES was occluded for at least thirty minutes before each preadaptation/dark adaptation sequence. During the latter part of this period, ES shook a 6 fl. oz. Dixie cup containing three poker chips, each designating one of the three PD's. He then withdrew

one of the chips and announced its designation to E. When he had selected a chip fifteen times, that chip was removed. As ES fixed himself on the adaptometer, E apparently adjusted the length of the shutter (SH) opening to correspond with the chip designation. The ES now removed the eye occlusion and preadaptation began.

In reality, E matched the PD, the time the shutter was open, with the chip designation for only one-third of the 45 trials. For the rest of the trials, the PD (time the shutter was open) agreed with one of the two other PD's. Thus, during the course of data collection, ES chose a 60-second PD fifteen times, but on only five of the fifteen occasions did 60-seconds of actual PD follow. On five occasions, 40 seconds of actual PD followed, and on five occasions 20 seconds of actual PD followed. The same procedure was used when ES chose a 40-second PD and when he chose a 20-second PD. The order of presentation of the actual PD's was randomized by E.

Under this procedure, then, ES was exposed to nine treatment conditions. With selected PD's listed first and actual PD's listed second, these treatment conditions, expressed in seconds, were 20-20, 20-40, 20-60, 40-20, 40-40, 40-60, 60-20, 60-40, and 60-60. In three of these conditions, 20-20, 40-40, and 60-60, selected and actual PD's were the same. For each of the nine conditions, ES had five trials, producing five instances of dark adaptation, each lasting approximately 10 minutes.

RESULTS

The log of the median threshold elevation (TE) at each 15-second interval of dark adaptation is shown in Table 1 for each of the nine treatment conditions. Each median was the middle value of five measures of dark adaptation (one value per trial). Under each treatment condition, the initial measure for each trial was obtained seven to eight seconds after the termination of preadaptation. (The median of these five measures is the first value listed in Table 1 for each condition.) The second five measures were obtained 15 seconds later, the third five measures were obtained 15 seconds thereafter, and so forth, for approximately 10 minutes.

The medians in Table A 1 are plotted as a function of time in Figures 2, 3, and 4. The curves which describe the trends of these medians were visually fitted.

Figure 2 shows the median logs for the three treatment conditions in which the actual PD was 20 seconds. Figure 3 shows the median logs for the three treatment conditions in which the actual PD was 40 seconds. Figure 4 shows the median logs for the three treatment conditions in which the actual PD was 60 seconds.

DARK ADAPTATION CURVES FOR A 20-SEC. PREADAPTATION DURATION (PD)
UNDER CONDITIONS OF 20, 40, AND 60 SEC. OF EXPECTED PD

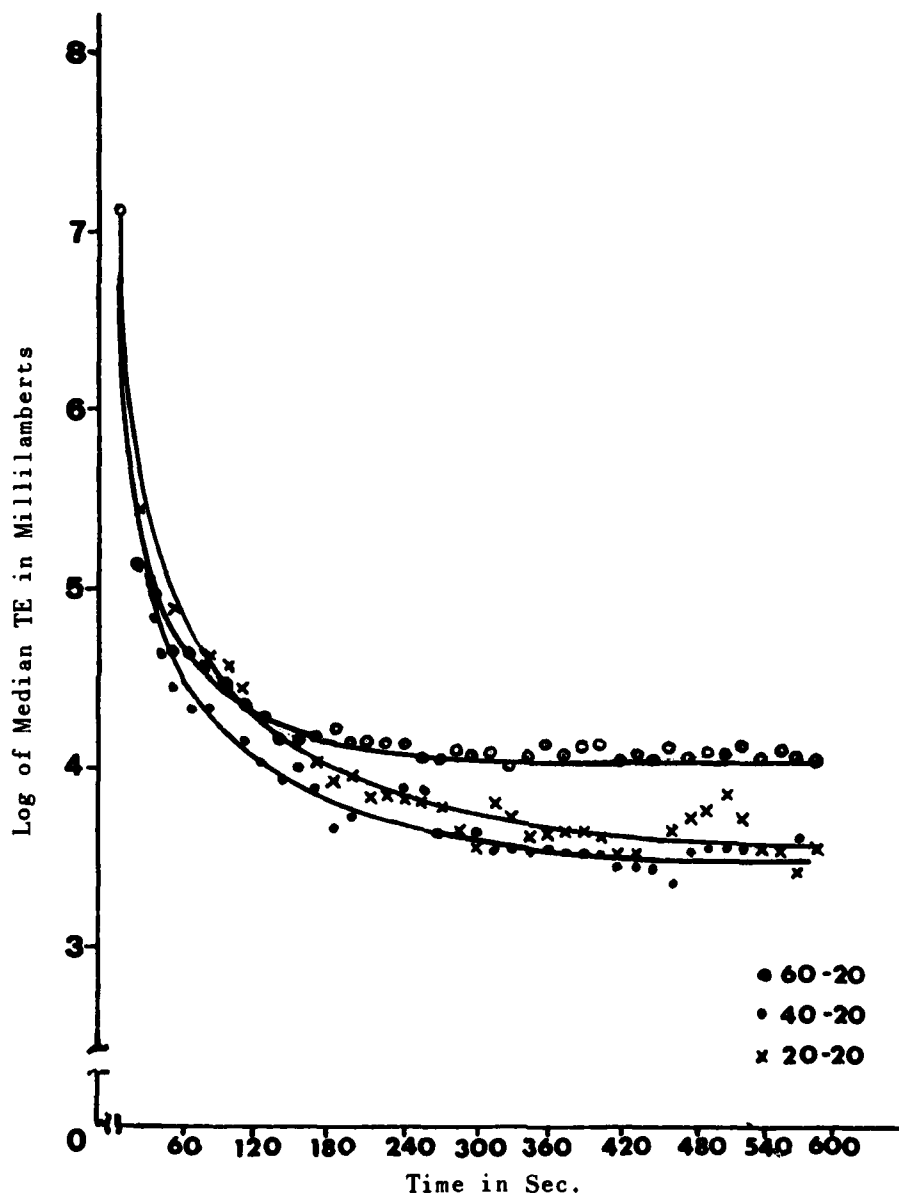


Figure 2

DARK ADAPTATION CURVES FOR A 60-SEC. PREADAPTATION DURATION (PD)
UNDER CONDITIONS OF 20, 40, AND 60 SEC. OF EXPECTED PD

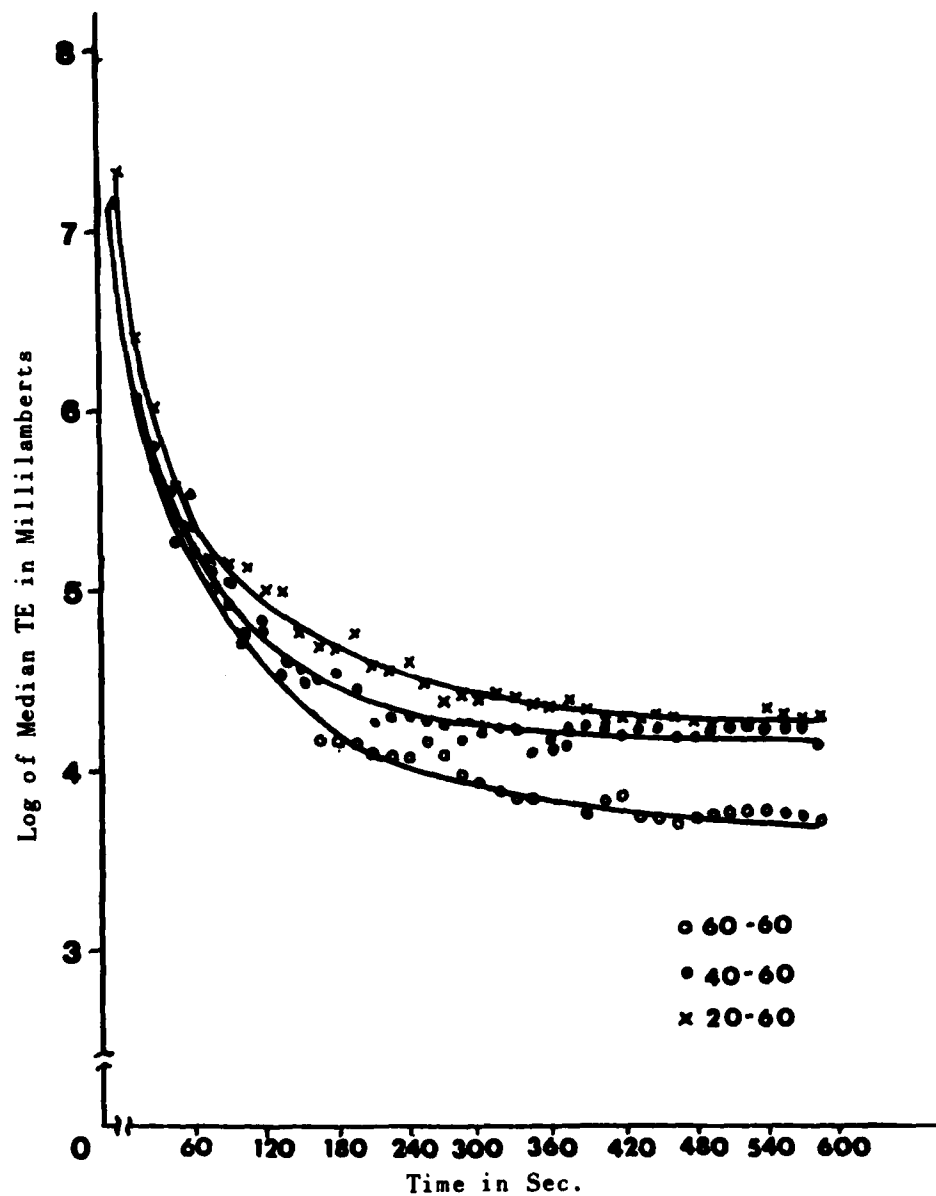


Figure 4

DARK ADAPTATION CURVES FOR A 40-SEC. PREADAPTATION DURATION (PD)
UNDER CONDITIONS OF 20, 40, AND 60 SEC. OF EXPECTED PD

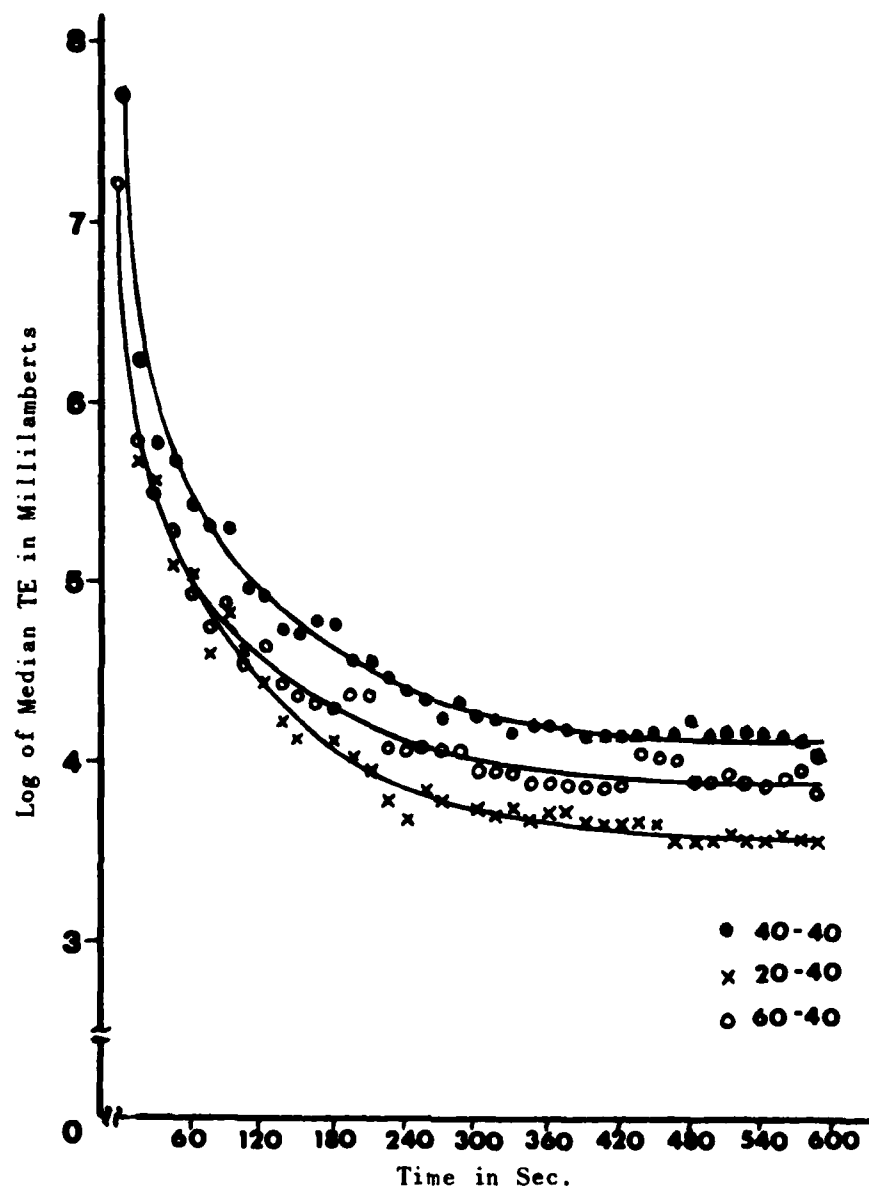


Figure 3

DARK ADAPTATION CURVES FOR ACTUAL PREADAPTATION DURATIONS THAT ARE IDENTICAL WITH EXPECTED PD

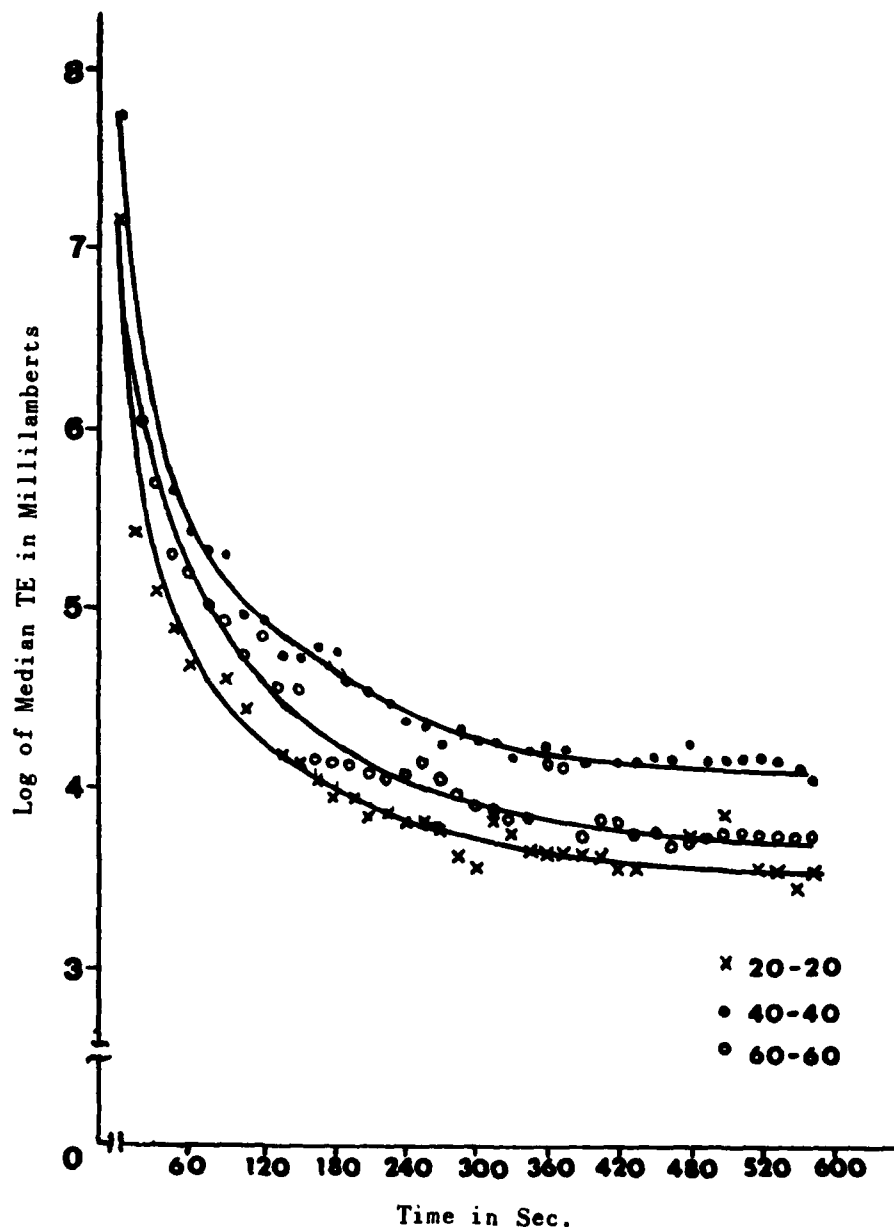


Figure 5

The Figures may be interpreted as follows. The three curves in each Figure summarize dark adaptation data gathered after the same actual PD. Thus, allowing for chance variation, the curves in each Figure should coincide if PD per se determined TE. However, expected PD and actual PD were different for two of the curves in each figure. So there should be a clear-cut separation among the three curves in each figure if (a) the attempt to establish an expectancy of a positive relationship between PD and TE was successful, and (b) if the expectancy was translated into ES-induced bias by his choice of PD's. Specifically, this separation should find the longest expected PD producing the highest TE, and the shortest expected PD producing the lowest TE. The expected PD intermediate in length should produce a TE between the TE elevations produced by the longest and shortest expected PD's.

Figure 2 suggests the partial operation of ES-induced bias when the actual PD was 20 seconds. A separation of TE curves begins to appear within the first two minutes of dark adaptation. It becomes both pronounced and stable after about five minutes of dark adaptation, amounting to approximately one-half log unit of luminance over the last half of the entire dark adaptation period. During this latter time, an expected PD of 60 seconds yielded a markedly higher visual threshold curve than an expected PD of either 20 seconds or 40 seconds. But an expected PD of 40 seconds failed to yield a threshold curve which differed markedly from the threshold curve produced by an expected PD of 20 seconds. In the absence of a complete positive relationship between TE and expected PD, then, the evidence for the operation of ES-induced bias is not unqualified when the actual PD was 20 seconds.

Figure 3 also suggests the operation of ES-induced bias when the actual PD was 40 seconds. A separation of the threshold curves occurs early during dark adaptation and is maintained for the remainder of the dark adaptation period. The operation of ES-induced bias is supported by the fact that an expected PD of 20 seconds resulted in a threshold curve that was lower by about one-half log unit of luminance than that resulting from an expected PD of 40 seconds. But while an expected PD of 60 seconds resulted in a higher TE than an expected PD of 20 seconds, an expected PD of 60 seconds also resulted in a somewhat lower TE than an expected PD of 40 seconds. This lack of a complete positive relationship between expected PD and TE again weakens the evidence for the existence of ES-induced bias when the actual PD is 40 seconds.

Figure 3 does not suggest the operation of ES-induced bias when the actual PD was 60 seconds. A separation of the threshold curves is apparent within the first two minutes of dark adaptation, and becomes more definite as dark adaptation progresses. Contrary to what would be expected if ES-induced bias prevailed, an expected PD of 60 seconds resulted in the lowest TE during the latter portions of dark adaptation. An expected PD of 20 seconds resulted in the highest TE during this time, an elevation which represents approximately one-half log unit of

luminance more than the elevation associated with an expected PD of 60 seconds. Over the bulk of the dark adaptation period, an expected PD of 40 seconds resulted in a TE slightly lower than that yielded by an expected PD of 20 seconds. When the actual PD is 60 seconds, then, the relationship between TE and expected PD tends to be inverse.

Viewed in their entirety, then, the results of the study do not consistently support an interpretation in terms of an ES-induced bias which arose from ES's foreknowledge of the positive relationship between TE and PD. There are at least two possibilities which may account for the inconsistency. Neither possibility argues against the operation of ES-induced bias. The first possibility is that ES's expectancy of a positive relationship between PD and TE may not have been translated into modification of all the data. The second possibility is that ES's foreknowledge of the positive relationship may not have resulted in an expectancy of a positive relationship. The data plotted in Figure 5 would seem to support the second possibility.

Figure 5 shows dark adaptation curves generated under the three treatment conditions (20-20, 40-40, and 60-60) in which there was no misrepresentation of PD. So these curves, unlike some of the curves in the other figures, could not be a product of experimental deception per se. Therefore, Figure 5 probably gives the purest indication of ES's expectation.

The separation of the curves in Figure 5 becomes quite pronounced and stable after about two minutes of dark adaptation. The separation suggests a curvilinear relationship between PD and TE. An actual PD of 20 seconds yielded the least TE, an actual PD of 40 seconds yielded the greatest TE, and an actual PD of 60 seconds yielded an intermediate TE. Over most of the entire dark adaptation period, the separation between the curves associated respectively with 20 seconds of PD and 40 seconds of PD amounts to about one-half log unit of luminance. Apparently, ES expected a curvilinear relationship between PD and TE rather than a positive relationship.

Making the ad hoc assumption that ES both expected and induced the curvilinear relationship depicted in Figure 5 brings the findings shown in the other figures into clearer focus. When the actual PD was 40 seconds (Figure 3), misrepresenting PD as being either 20 or 60 seconds decreased TE in complete accord with the curvilinear-expectancy assumption. In contrast, the positive-expectancy interpretation is only partially successful in handling the data of Figure 3. Both the curvilinear-expectancy and the positive-expectancy interpretations could explain the TE that was occasioned (Figure 2) by misrepresenting an actual PD of 20 seconds as being 60 seconds. Again, with respect to Figure 2, neither the curvilinear-expectancy nor the positive-expectancy interpretation could explain the fact that misrepresenting an actual PD of 20 seconds as being 40 seconds failed to markedly alter the TE. In Figure 4, the curvilinear-expectancy assumption may explain the

increase in TE that was caused by misrepresenting an actual PD of 60 seconds as being 40 seconds. But the same interpretation fails to explain the increase in TE that was caused by misrepresenting an actual PD of 60 seconds as being 20 seconds. However, the positive-expectancy interpretation completely fails to predict the relationship between PD and TE when the actual PD was 60 seconds. On balance, the ad hoc curvilinear-expectancy interpretation handles more of the data than the positive-expectancy interpretation.

DISCUSSION

The findings of the study provide evidence that the data of sensory investigation may be contaminated by an ES. Part of this evidence seems to indicate that foreknowledge of the results of similar investigations will produce a corresponding expectancy that will appear in the research data. More of this evidence seems to indicate, however, that--while the data may reflect ES's expectancy--his expectancy may not correspond to his foreknowledge. The source of ES's expectancy would appear, then, to be an experimental question insofar as he did not have a strong theoretical commitment to the outcome of the study.

Assuming the absence of any such commitment in this study, the experimental question, when applied to the findings, concerns the source of the curvilinear expectancy between PD and foveal TE during dark adaptation. Several areas of visual research suggest that the relationship between the duration of light exposure and visual sensitivity is more complicated than the positive relationship found in former dark adaptation investigations. First, a study of light adaptation (6) has shown that increment (differential) thresholds³ taken in the presence of continued, constant-intensity light stimulation decrease at first, but then tend to increase. Second, when colored "high luminance stimuli" are persistently viewed, they change hue. Such stimuli in "the 'green-yellow' region of the spectrum (from about 560 to 580 millium) look green at first, turn a much deeper green, then back through yellow to orange. . . ." (7). Since the elevation of the visual threshold is also a function of hue, the fact that constantly-viewed stimuli from the upper-middle portion of the visible spectrum change in hue toward the middle portion and then back toward (and through) the upper-middle portion could be pertinent to the present study.

After achromatic preadaptation, photopic visual thresholds for colored lights from different portions of the spectrum are, when plotted in brightness units rather than energy units, related in a curvilinear manner to the physical wavelengths of the hues. These photopic thresholds are lowest for "long and short wavelength colors. . ." (8). Given the fact that constantly-viewed lights from the upper-middle portion of

³In this paper increment threshold (6) refers to the intensity of a just perceptible brightening of a portion of the visual field.

the visible spectrum appear to shift in hue along the lines given above, there is reason--but no empirical evidence--to expect that extending the duration of a preadapting light from the upper-middle portion of the spectrum would first raise and then lower the visual threshold if the preadapting stimulus and threshold light had the same hue. In other words, a curvilinear relationship between PD and TE could be expected insofar as "perceptual" hues and "physical" hues are behaviorally equal. Such an approach has pertinence to this study only if it can be reasonably argued that the present preadaptation stimulus and threshold light were not achromatic but were "physically" located in the upper-middle portion of the visible spectrum. There appears to be some foundation for such an argument.

The white light source in the apparatus employed (Figure 1) has a color temperature of about 3000° K. The radiant energy of an incandescent source of this temperature is greatest in the upper and middle portions of the visible spectrum (9). It is probable, however, that the infrared absorbing filter (IF) in the apparatus, like many infrared filters, also absorbed some of the radiation from the upper end of the visible spectrum. Thus, in subtracting radiant energy from the upper end of the spectrum, the filter could create a radiant-energy profile that peaks near the middle of the spectrum and thereby gives the preadaptation stimulus and threshold light a green-yellow emphasis. If so, there could be a tendency for prolonged viewing with this apparatus to change the "perceptual" hue of the stimuli, the preadaptation stimulus and the threshold light appearing green-yellow after an actual PD of only 20 seconds, green after an actual PD of 40 seconds, and yellowish-green after an actual PD of 60 seconds. There would be reason to expect a curvilinear relationship between TE, expressed in brightness units of luminance, and actual PD, insofar as a behavioral equality exists between "physical" and "perceptual" hues.

ES was questioned after the experiment about the appearance of the stimuli. In the questioning, E made no initial reference to the hue of the stimuli. ES began by noting that the preadapting stimulus "sometimes looked yellow." When asked if it continued to look yellow, ES qualified his original answer and supported the concept of hue shift by noting that at times the preadaptation light first looked white, then yellow, and then white again. Apparently, a tendency of the present apparatus could be for the preadaptation stimulus to appear white (rather than green-yellow) after an actual PD of 20 seconds, yellow (rather than green) after an actual PD of 40 seconds, and white (rather than yellowish green) after an actual PD of 60 seconds. In this event, however, there would still be reason to expect a curvilinear relationship between TE and actual PD on the present apparatus, since the photopic threshold for white light is lower than the photopic threshold for yellow light from the upper-middle portion of the visible spectrum (8).

As already noted, increment thresholds during light adaptation first decrease and then gradually increase in the presence of a light

of constant photometric brightness. Extending the duration of light stimulation therefore seems to decrease and then increase visual sensitivity when it is measured in terms of increment thresholds, the size of the increment being positively related to the degree of sensitivity. If increment thresholds and absolute thresholds secured during dark adaptation are a product of the same visual mechanism, there is another reason to expect a curvilinear relationship between PD and TE. Some confirmation of this line of reasoning comes from Rushton (10), who has argued that absolute thresholds are also increment thresholds. In the present study, a curvilinear relationship would be expected, then, if an actual PD of 40 seconds was analogous to the point at which increment thresholds are smallest during light adaptation. Increment thresholds also reflect changes in the "perceptual" brightness of persistently viewed lights of constant photometric brightness. Consequently, to use increment thresholds during light adaptation as a framework for interpreting dark adaptation data also reintroduces the possibility of a direct connection between TE during dark adaptation and the "perceptual" characteristics of the preadaptation light.

The foregoing speculation has pointed to both "perceptual" hues as an explanatory concept, and the temporal nature of increment thresholds as a descriptive basis for the curvilinear relationship between actual PD and TE in this study. Insofar as it can be argued that an expectancy may arise from corresponding laboratory experiences during data gathering, it seems appropriate to infer that ES's curvilinear expectancy arose during treatment conditions involving no misrepresentation, namely 20-20, 40-40, and 60-60. There is evidence that one's orientation can change during data gathering. Psychological investigations in various areas indicate that a subject's "anticipations" (11) and "expectancies" (12), as well as an experimenter's "mood" (1), can change during data gathering. Given the fact that an expectancy can contaminate data, these investigations strongly suggest that an expectancy which emerges during some phase of data gathering can influence the overall results of an investigation. In the present study, to hold that ES's curvilinear expectancy arose during some phase of data gathering requires a specification of the source of the curvilinear relationship which prompted the expectancy. And it is seemingly easier to explain the source of the curvilinear relationship between actual PD and TE in terms of the foregoing speculation than to explain how the same relationship arose, in the face of a positive set, under some of the treatment conditions containing misrepresentations, for instance 20-40 and 60-40, as shown in Figure 3. It seems most economical, then, to infer that the three treatment conditions containing no misrepresentations not only yielded data that was the "purest" indication of ES's expectancy, but also served as the source of ES's expectancy.

The study has both demonstrated that misrepresentation of PD can affect TE during dark adaptation, and found a curvilinear relationship between actual PD and TE. When Wald and Clark (3) first demonstrated a positive relationship between actual PD and TE during dark adaptation,

it confirmed Wald's photochemical conceptions of the visual process. His basic conception held that light, striking the visual receptors in the retina, starts a retinal chemical reaction whose nature determines the eventual course of dark adaptation. The chemical reaction had reference to the bleaching and resynthesis of visual pigment in the stimulated visual receptors. Wald's photochemical conceptions now seem incomplete or outmoded. He himself (13) has noted that subsequent investigations have demonstrated that considerable TE can be associated with "little bleaching of visual pigment. . . ." And Rushton (10) has cited evidence that the threshold of unstimulated receptors in the retina can be raised by stimulation of neighboring receptors. When imperfect conceptions like Wald's are supported by experimental data, there is certainly reason to suspect, among other things, the operation of induced biases. Coupled with the findings of this study, this suggests that the relationship between PD and TE during dark adaptation is in need of further examination.

It is only fair, however, to point out a discrepancy between the data of the present study and the Wald and Clark data (3). In their study, TE's after different actual PD's were not markedly different from each other late in the dark adaptation period. The maximum separation among their dark adaptation curves occurred during the early and middle stages of dark adaptation. In the present study, misrepresentation of PD's had its most marked effect on TE late in dark adaptation. This discrepancy might be explained by the curves generated under the three treatment conditions that contained no misrepresentations of PD in the present study. The three curves were still distinctly separate--and falling--at the end of the ten-minute dark adaptation period. If ES's expectancy originated under these conditions, it is not unexpected that misrepresentations of PD induced similar curves. Or it might be that further investigations will show that the discrepancy between the two studies is due to the time at which an expectancy arises, expectancies associated with either theoretical commitments or foreknowledge being induced during early stages of the dark adaptation period and expectancies associated with data gathering being induced during a later stage.

It is possible that another interpretation could explain the results of this study more thoroughly than ES-induced bias. Since stimulus conditions were frequently misrepresented in the study, an obvious interpretation would begin by noting that this study falls into the general category of deception research. And psychological studies employing deceptive tactics do not always succeed in gulling the participating subjects (14). When questioned after data gathering, a certain percentage of the subjects in these investigations report that they recognized fictitious aspects of the experimental situation (14). Consequently, it might be possible in the present study to maintain that the changes in TE which were occasioned by misrepresentations of PD are connected not to ES's expectancy but to his recognition of and reaction to deception. This possibility is challenged by two considerations.

First, there seems to be no evidence at present that deception recognition contaminates data (14). Second, unlike studies in attitude change, conformity, and cognitive dissonance, perceptual investigations which employ deceptions are apparently immune to deception recognition (14).⁴

Insofar as this pilot study indicates the existence of ES-induced bias in sensory research, it should lead to further sensory investigations which seek to establish more firmly the distorting effect of the experimenter who also serves as an experimental subject. Hopefully, these further investigations will provide additional information with respect to the equality of physical and perceptual characteristics of preadapting stimuli, the effects of expectancies which arise at different times during experimentation, and the possibility of data contamination through deception discovery.

⁴ES's postexperiment comments as to his deception recognition would obviously have been enlightening. Unfortunately, he was not available when this possibility arose.

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APPENDIX: DATA FOR FIGURES 2-5

Table A1

Logs of Median Threshold Elevations for the Nine Conditions
(taken at 15-sec. intervals during dark adaptation)

Reading	Condition								
	20-20	20-40	20-60	40-20	40-40	40-60	60-20	60-40	60-60
1	7.16256	6.90940	7.30728	6.90940	7.71231	7.14208	7.15229	7.21932	7.16256
2	5.45056	5.69897	6.35851	5.13577	6.24304	6.09691	5.21511	5.76200	6.07445
3	5.09132	5.53618	6.00647	4.84850	5.76200	5.81704	4.98677	5.48940	5.67089
4	4.88734	5.09691	5.60874	4.46315	5.64098	5.59857	4.64444	5.29270	5.29754
5	4.68574	5.02449	5.33985	4.32510	5.42959	5.51601	4.63508	4.94532	5.20058
6	4.63508	4.59846	5.14953	4.32510	5.30707	5.09691	4.59813	4.72346	5.00604
7	4.59329	4.86906	5.14953	4.47611	5.29754	5.04218	4.42177	4.89949	4.92314
8	4.44979	4.56820	5.10653	4.17551	4.97197	4.70062	4.37621	4.52479	4.73711
9	4.26717	4.43600	4.99651	4.02325	4.92314	4.84850	4.28735	4.61700	4.86386
10	4.20030	4.20030	4.99651	3.92189	4.72346	4.58647	4.17551	4.40722	4.56820
11	4.16256	4.10653	4.72346	3.99607	4.70501	4.53605	4.17551	4.37621	4.54704
12	4.02325	4.09132	4.68574	3.89840	4.79000	4.50092	4.18808	4.30664	4.17551
13	3.94419	4.10653	4.68574	3.68753	4.77743	4.52479	4.21219	4.29181	4.14922
14	3.94419	4.02325	4.72346	3.73062	4.56820	4.45652	4.17551	4.35984	4.12123
15	3.84726	3.93232	4.57841	3.81921	4.54704	4.26717	4.16256	4.37621	4.09132
16	3.84726	3.77474	4.52479	3.89840	4.48869	4.28735	4.14922	4.05918	4.05918
17	3.80564	3.66596	4.5846	3.89840	4.39199	4.29710	4.12123	4.05918	4.07555
18	3.80564	3.82367	4.45712	3.89840	4.35984	4.27738	4.05918	4.09132	4.13545
19	3.78923	3.79637	4.36418	3.64316	4.24601	4.24601	4.05918	4.06707	4.07555
20	3.64316	3.71667	4.39967	3.64316	4.34282	4.17551	4.09132	4.05918	3.98556
21	3.57449	3.71105	4.36810	3.64316	4.25672	4.20030	4.09132	3.94419	3.90574
22	3.81251	3.69653	4.40722	3.54617	4.24601	4.21219	4.09132	3.94419	3.88332
23	3.72230	3.72230	4.39967	3.54617	4.18808	4.22376	4.02325	3.94419	3.81921
24	3.64316	3.68753	4.36810	3.54617	4.20030	4.09132	4.07555	3.89840	3.83455
25	3.64316	3.71105	4.34282	3.54617	4.21219	4.16256	4.10653	3.89840	4.14922
26	3.64316	3.71105	4.38417	3.54617	4.20030	4.24601	4.09132	3.87361	4.14922
27	3.64316	3.66596	4.31597	3.54617	4.14922	4.24601	4.12123	3.87361	3.72230
28	3.61909	3.64316	4.26717	3.53352	4.14922	4.24601	4.12123	3.86165	3.83020
29	3.55449	3.64316	4.26717	3.46864	4.14922	4.18808	4.05918	3.88711	3.82367
30	3.54617	3.66596	4.26717	3.47857	4.14922	4.22376	4.09132	4.05918	3.72230
31	3.72230	3.64316	4.29776	3.44295	4.17551	4.21219	4.07555	4.02325	3.71667
32	3.68449	3.57449	4.27738	3.38650	4.16256	4.17551	4.10653	4.01494	3.68753
33	3.72230	3.57449	4.24601	3.55449	4.22376	4.18808	4.05918	3.89840	3.71667
34	3.78923	3.58984	4.21219	3.54617	4.14922	4.20030	4.09132	3.89840	3.73062
35	3.84726	3.58984	4.21854	3.55449	4.16256	4.21219	4.09132	3.93571	3.75450
36	3.70526	3.54617	4.21219	3.56265	4.17551	4.21219	4.10653	3.89840	3.75450
37	3.54617	3.54617	4.31597	3.54617	4.17551	4.21219	4.05918	3.87361	3.75450
38	3.54617	3.58229	4.29776	3.55449	4.14922	4.21219	4.09132	3.89840	3.74406
39	3.44295	3.57449	4.27738	3.64316	4.12123	4.21219	4.07555	3.94419	3.71667
40	3.54617	3.54617	4.28735	3.59737	4.04258	4.10653	4.07555	3.83455	3.71667

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