NIGHT VISION AND PSYCHIATRIC DISORDERS: A REVIEW OF EXPERIMENTAL STUDIES

By

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I. Introduction

In recent years a number of studies have been undertaken in which the "night vision" or dark-adaptation of psychiatric patients has been compared with that of normal subjects. These studies have their origin in a wartime observation that the incidence of "night-blindness" among neurotics was higher than among normal Service personnel. Evidence of functional disorders of vision is of interest from several points of view, psychiatric and ophthalmological as well as psychological and physiological. The aim of this article is to make a critical evaluation of the results so far obtained, determine what generalizations are possible and consider implications for further research.

The paper is divided into four parts. The first involves a description of experiments and results, the second deals with a psychophysical evaluation of the results, the third considers hypotheses as to possible mechanisms involved from a psychophysiological point of view, and the fourth implications for further research.

II. Experimental Studies

The first study to be considered was undertaken by Livingston and Bolton (67) using the Livingston Rotating Hexagon test. This consists of an apparatus for presenting letters and objects (aircraft, arrows, ships, etc.) for identification under conditions of low illumination. In all, four tests are given at different levels of illumination, ranging from 0·0012 to 0·00015 equivalent foot-candles, each test involving six letters and two objects. Subjects are dark-adapted for forty minutes prior to the test and record their answers on a Braille card in the dark, one minute being allowed for this purpose for each test. From the distribution of scores for 50 R.A.F. personnel and 50 neurotic patients, the authors conclude that the neurotic group as a whole produce a far greater number of poor results. This conclusion seems justified from the data shown in Figure 1. Within the neurotic group anxiety states (of whom there were 30) appeared to give particularly poor results as compared with depressives.

Rees (93) compared the results of 36 anxiety states, 33 (neurotic) depressives and 27 hysterics with those of 6,062 R.A.F. aircrew personnel and found the same general picture for the total neurotic group as Livingston and Bolton (67) obtained, as will be seen from Figure 2. In line also with a tendency noted in Livingston and Bolton's study is the fact that anxiety states do worse than other neurotic patients. Thus, when patients are graded according to a list of categories drawn up by Steadman (113), it is found that only about 3 per cent. of anxiety states have "above average" grades, compared with 15 per cent. of depressives and 18 per cent. of hysterics. At the same time, 81 per cent. of anxiety states have "below average" scores, compared with 67 per cent. of depressives and 63 per cent. of hysterics.

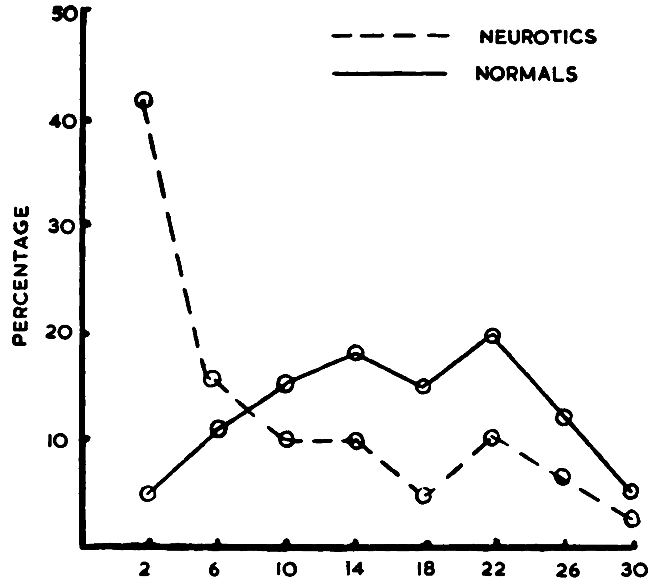

FIG. 1.—Frequency distribution of scores. (Livingston and Bolton (67).)

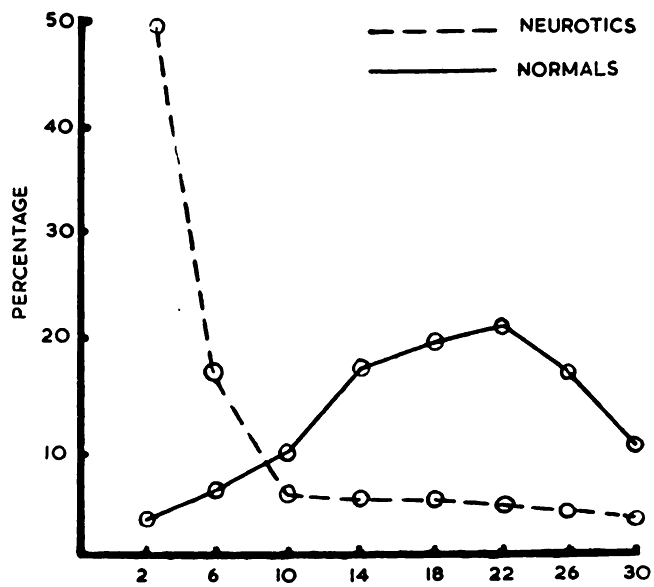

FIG. 2.—Frequency distribution of scores. (Rees (93).)

Age and intelligence seem to be relatively unimportant factors in determining these results, the correlation with intelligence being almost zero and with age about —·4. Unfortunately, both correlations were calculated for the neurotic group only; information is not available on the normal group nor are the age and intelligence of the normal group given. However, even though we cannot make a precise estimate of the effect of either variable, such evidence as is available gives no reason to suppose that intelligence and age could account for differences of the size observed.

Rees comments on the fact that the comparison is based on neurotic soldiers and R.A.F. aircrew personnel. The latter do not constitute an "ideal" control group, for standards of enlistment in the R.A.F. are more rigorous than in the army so that the "R.A.F. results may be higher than those of the general population of the British Isles". As data on the general population are not available Rees presents results for the men of an A.A. unit who had taken the test. This army group obtained lower scores than the R.A.F. group, but there is still a difference between them and the neurotic group. In the absence of data one can only speculate as to the reason for this difference; it may be due to age, intelligence, "neuroticism", or other factors.

An unfortunate feature both of Livingston and Bolton's (67) and Rees's (93) study is the fact that no information is provided concerning performances of subjects at each of the four different luminance levels. Although not necessarily a serious omission from the psychometric viewpoint it makes psychophysical evaluation of their investigations difficult, for the range of luminance covered by the test involves both photopic and scotopic vision; to what extent the test scores are determined by the former or the latter cannot be determined.

Himmelweit, Desai and Petrie (50) compared the "dark vision" of 105 neurotic patients (all returned P.O.W.s) with that of 93 surgical cases, matched in respect of age and educational background. The apparatus used for testing dark vision was the U.S. Radium Plaque Adaptometer. After being dark-adapted for forty minutes the subject was required to give the direction, up, down, left or right, of the letter "T" appearing against a uniformly illuminated background. Details concerning the luminance of this background are not given, but it would appear from data which the author has obtained from the Medical Research Laboratory reports of the U.S. Navy that the luminance level was probably about $10^{3\cdot 9}$ micromicrolamberts, i.e. toward the final brightness threshold of "rod" vision. A red fixation point was used so that the test-object fell outside the fovea but the precise retinal location is not specified. The visual angle subtended by the test-letter appears to have been large (about 3°)* judging from M.R.L. reports, but the authors do not specify the size. The procedure was to change the position of the test-letter twenty times during the test and to allot one mark for each position correctly reported.

Details of mean scores and scatter for the two groups are not provided but there appears to have been a very slight tendency for the neurotic group to have lower scores for a small positive correlation (·27) was found between the dark vision test and the "normal/neurotic" dichotomy. The authors note that their test does not discriminate so well as did that of Rees. This they explain as probably due to the fact that the difference in "neuroticism" between their two groups was smaller than in Rees's study. The discrepancy could, however, also be due at least in part to differences in experimental conditions (luminance level, size and type of test object, viewing conditions, etc.). These differences are completely ignored by the authors who appear to assume that they were using essentially the same test of "dark vision" that Rees used.

Gravely (45) made use of yet another different set-up to study differences between 62 neurotic soldiers and 94 normal controls (R.A. personnel from a re-allocation centre). The adaptometer she used covered a luminance range from $3\cdot 961 \times 10^{-7}$ to $7\cdot 847 \times 10^{-3}$ e.f.c., i.e. the entire range of luminance examined

* Judging from the acuity value (·025) given in M.R.L. reports the test-letter would make minimal demands upon detail perception.

https://doi.org/10.1192/bjp.103.430.48 Published online by Cambridge University Press

in the usual studies of the dark-adaptation curve. Gravely however made use of only the upper part of this range.*

Subjects were required to report upon the position of a black triangular shaped test object which could be rotated into any one of eight different positions against a uniformly illuminated field subtending about 4° visual angle, the viewing distance being about six feet. No fixation point was used but the subject was encouraged to employ peripheral vision when perception became difficult. Starting at a luminance of $10 \cdot 37 \times 10^{-4}$ e.f.c., intensity thresholds were recorded for the perception of the test-object at 3, 6 and 10 minutes after the room light was switched off. In accordance with the usual practice (i.e. in the British Navy where it is used) in administering this test, no period of controlled light-adaptation preceded the dark-adaptation measurements, and thresholds were recorded in terms of brightness grades.

Significant differences were found between the mean dark vision grades of normal and neurotic groups, the extent of the differences increasing with time in the dark from about 1·5 grades at 5 to nearly two grades at 10 minutes. Variances for the two groups were about the same at three minutes but thereafter the neurotic group had a larger variance than the normal.

Very small differences were found also between the mean grades of 31 anxiety states and 31 hysterics comprising the neurotic group, the former having lower thresholds, but the differences did not reach an acceptable level of statistical significance. The variance of the anxiety states was about twice as large at 5 and about three times as large at ten minutes as that of the hysterics. Neither age nor intelligence appeared to influence the grades of the neurotic group, as shown by near-zero correlation coefficients.

Granger (38) compared intensity thresholds for the same type of test-object as Gravely had used of 106 normal subjects (soldiers from the same re-allocation centre as Gravely's came from) with those of 20 neurotic and 20 psychotic patients from the Bethlem Royal and Maudsley hospitals. Threshold measures were taken at five-minute intervals over a thirty minute period of dark-adaptation, the criterion of success at a given brightness level being two consecutive correct reports of the position of the test-object. There was a slight tendency for neurotics to have lower thresholds than psychotics but the differences failed to attain statistical significance. Differences between normals and psychotics were highly significant at 5, 10, 25 and 30 minutes ($P<0 \cdot 005$, $<0 \cdot 02$, $<0 \cdot 05$, and $<0 \cdot 02$ respectively) but only toward the latter part of the adaptation period did differences between normals and neurotics reach statistical significance ($P<0 \cdot 05$ and $<0 \cdot 02$ at 25 and 30 minutes).

Distributions of individual thresholds at each level roughly follow a normal distribution for both normal and psychiatric groups with variances reducing in size as adaptation proceeds.

The study has not been repeated with psychotics but a second group of 20 neurotics taken from a different mental hospital gave essentially the same mean thresholds and variances as the first group over the whole of the adaptation curve.

Worth noting is the fact that the mean final threshold of the normal group reached after thirty minutes was 0·25 log unit $\mu\mu$L higher than that of a group of naval ratings.† Testing conditions were different in that the naval group did

* Calibration data are not available for the particular adaptometer which Gravely used but from data that are available for a similar type of instrument it appears that she was probably working between luminance levels of about 6·0–4·0 log $\mu\mu$L.

† Data were kindly supplied by the Admiralty Research Laboratory.

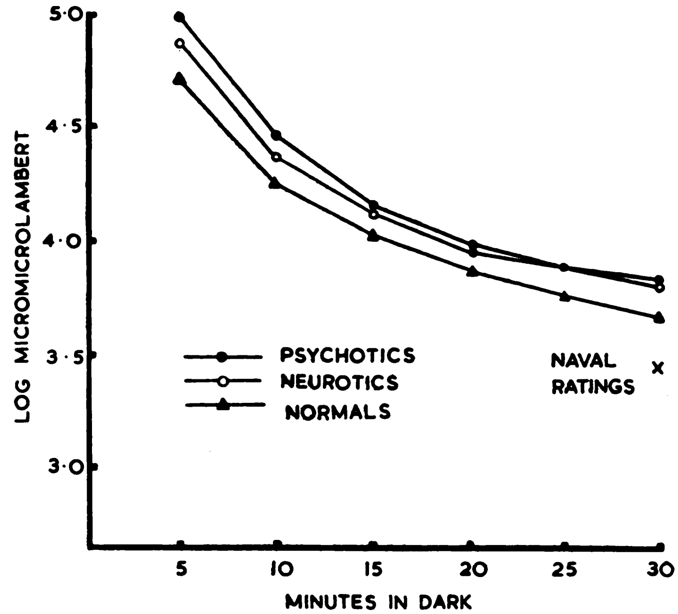

FIG. 3.—Dark adaptation curves. (Granger (38).)

not have thresholds taken throughout the thirty-minute period but only at the end. Although repeated threshold determination throughout the test would tend to raise the thresholds of the army group due to the effects of light-adaptation it is very improbable that this factor alone would account for the difference between them and the ratings. If the final threshold of the psychiatric groups is compared with that of the naval group the difference amounts to as much as 0·4 log unit (i.e. the patients need about two and a half times as much light to see the test object).

As there were significant differences in age between the groups, correlations were determined between age and intensity thresholds at 5 and 10 minutes after the beginning of dark-adaptation.* The correlation in the former case was —0·033 and in the latter —0·216, indicating that age had no significant effect. These results accord fairly well with previous findings (96, 114) in which only small positive correlations have been found with age although it should be noted that McFarland and Fisher (76) using the Hecht-Shlaer adaptometer have recently reported a very high correlation (·89) between age and the final (rod) threshold.

Correlations with intelligence, as measured by the Nufferno test, were 0·143 and +0·353 for intensity thresholds at 5 and 30 minutes respectively. No significant differences in intelligence existed between normals and psychiatric patients, so intelligence cannot explain the results. Correlations with visual acuity as determined by the Snellen chart were small (·033 at 5 minutes and ·237 at 30 minutes) in line with expectation. Also in line with other findings (48, 49) was the relatively small correlation of 0·44 between intensity thresholds at 5 and at 30 minutes. An incidental finding of this study, which formed part of a much larger research project, was the very low correlation between

* Unfortunately no correlations with age are available for the final thresholds at 30 minutes.

thresholds at 5 and 10 minutes and other sensory and perceptual tests of a visual nature (29).

Apart from this study the only other experiment in which psychotic patients have been used appears to be an unpublished study by Brown and Marshall (15); using a Crookes Adaptometer they found no evidence of any gross disturbance in the dark-adaptation of six schizophrenics but unfortunately they had reason to believe that their instrument was not consistently giving the specified amount of light. In a later experiment Marshall and Day (81) investigated the ability of 12 schizophrenic patients to discriminate bar grids, with detail ranging from 10′ to 40′, presented against a test-patch subtending 10° visual angle. Viewing was binocular with normal pupils and "little or no control over fixation". Compared with a group of 13 normal subjects all 12 schizophrenics had higher intensity thresholds for perception of the bar grids. Both patients and normals had approximately 6/6 vision. While the investigation is not yet complete intelligence as measured by the Binet or Wechsler seems, according to the authors, unlikely to account for differences between the two groups.

Granger (39) in a further experiment on dark-adaptation compared the dark-adaptation curves of 20 normal and 20 neurotic patients using the Crookes Adaptometer and again found evidence of differences between the two groups, the patients having higher thresholds throughout the "rod" portion of the adaptation curve, for recognition of the position of a 7° test-object in the form of an arrowhead. In accordance with the standard procedure for administering the test, viewing was not controlled by means of a fixation point. Before the test the eyes were adapted to a luminance of 750 ml. at an approximate colour temperature of 2,500° K for a period of five minutes. Results are shown in Figure 4, the extent of the difference between groups ranging from about 0·2 to 0·5 log unit at different levels of adaptation. Differences reached statistical significance at the ·05 level only between 8 and 22 minutes.

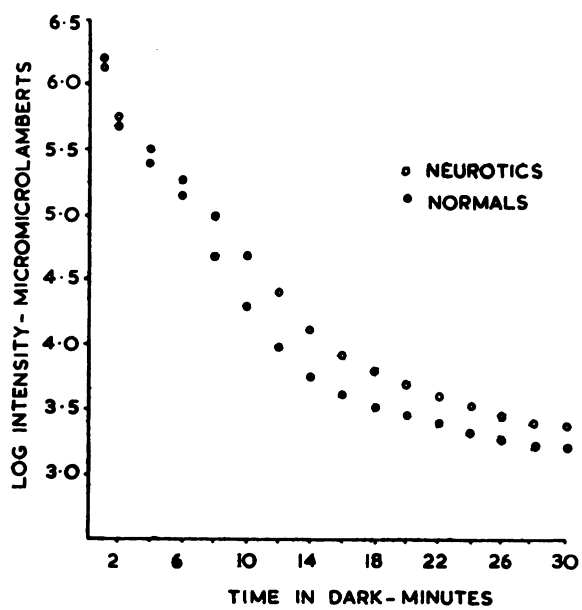

FIG. 4.—Dark adaptation curves. (Granger (39

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In addition to differences in means other interesting trends appeared, anxiety states tending to show "plateaux", periods during which sensitivity did not improve, hysterics tended to have high final rod thresholds and psychopaths low final thresholds. Unfortunately, the composition of the neurotic group did not enable any definite conclusion to be drawn about these various sub-categories.

In a later experiment Granger (41) compared 10 anxiety states with 10 hysterics, thresholds being obtained for perception of a 3° test-field displaced 7° degrees horizontally from a fixation point in the nasal field over a thirty-minute period. The adapting luminance prior to the dark-adaptation test was 270 ml. viewed for five minutes.

Comparison of the mean dark-adaptation curves for the two groups showed a significant difference in level, the curve for the hysterics being displaced upward along the intensity axis by amounts varying between 0·2 and 0·35 log unit (see Figure 5). A significant tendency was also found for the hysterics to take longer to recover from the effects of light-adaptation in the early stages of dark-adaptation. While the mean adaptation curve of the hysterics was normal in shape, the individual curves of several hysterics tended to have a shallower slope.

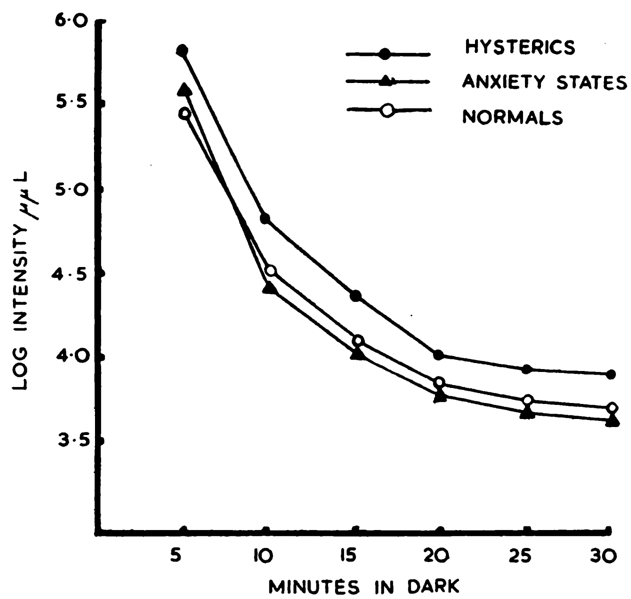

FIG. 5.—Dark adaptation curves. (Granger (41).)

Data available from ten normal subjects who had also taken the same test when corrected for the effects of age (they were a younger group) suggested that the curve for a group of normal subjects of the same age as the neurotic groups would fall about midway between the curves of the anxiety states and hysterics.

Two further studies which have in common the fact that thresholds were taken only at the very beginning of the dark-adaptation period were undertaken by Janda (56) and Granger (40). In Janda's study the general object was to observe the effects of the subject's "general or chronic level of stress" upon night vision by comparing "high stress" (neurotic) with "low stress" (normal) subjects. Two experiments were carried out; in the first of which 25 neurotics and 25 normals took part, both groups being given the MMPI as part of the selection procedure. Besides being classified on the basis of high and low stress, subjects were further sub-divided according to their usual method of handling stress into "expressors" whose mode of handling stress is characterized by frequent and abundant expressions of manifest anxiety and "repressors" who attempt by various means to prevent the direct expression of anxiety.

Following light-adaptation for three minutes to a luminance of 1,600 foot lamberts the subject viewed a rectangular-shaped test object 2 in. $\times \frac{5}{8}$ in. in size at 0·008 foot L., the viewing distance being 9 in. Some control of fixation was provided by asking the subject to look in the direction of his finger so placed on a small knob at the side of the test-light that the test-object fell at about 14 degrees from the fovea. The time in seconds was recorded from cessation of light-adaptation to correct report of the test-object's position (horizontal, vertical or diagonal). A second trial was given about 15 minutes later.

In the second study instructions were changed to allow "flexible fixation" and meaningful forms as well as the simple rectangular test-object were used. These forms, depicting various military objects, were presented immediately after correct report of the simple test-object's position. Two groups of subjects, normal and neurotic, took part in the experiment, each consisting of 14 "expressors" and 14 "repressors", selection again being based on psychiatric diagnosis and the MMPI.

Results from the first study showed a slightly longer perception time for neurotics as compared with normals, although the difference was not significant statistically. The same tendency was found on re-test. Mean perception time for expressors was longer than for repressors on the first trial, but shorter on the second. There was a significant tendency for all subjects to have shorter perception times on the second trial, but the relative improvement was larger for expressors than for repressors.

In the second study the mean perception time for stimulus position of the neurotic group was again longer than that of the normal group, but the difference in means was significant only on the first trial. As in the first study, expressors as a group had longer perception times for stimulus position than did the repressors on the initial trial, but shorter perception times on the second; in neither case were differences statistically significant. Particularly long were response times of neurotic expressors on the first trial.

No difference was found between mean perception times of normals and neurotics on the first trial for form identification, but there was a (statistically insignificant) tendency for neurotics on re-test to have longer perception times than normals. Results for expressors and repressors tended to parallel those obtained for stimulus position, perception times being longer for expressors on the initial trial and shorter on re-test; again, differences between the two groups were insignificant. As in the first experiment, perception times were in general shorter for all groups on re-test and relative improvement was greater for expressors than repressors.

Janda makes comparisons between his results and those of Rees (93) and considers they confirm Rees's major finding that the night vision performance of normal subjects is superior to that of neurotics, but points out that this finding applies only to the first trial and using uncontrolled viewing. Under these conditions it is the high stress expressors, whom Janda considers similar to Rees's dysthymics (anxious and depressed patients), who are most impaired.

Rees's finding, that hysterics were not as impaired in "night vision" as dysthymics is, in Janda's view, paralleled in his own study, in that neurotic repressors had significantly lower stimulus position thresholds on the first trial than did neurotic expressors, under uncontrolled viewing conditions. His failure to confirm Rees's findings on form identity thresholds Janda considers may be due to differences in experimental conditions. It is certainly true that there were marked differences in conditions; in fact the differences are so great that it is very doubtful if the results of the two studies can be compared except in terms of a very broad and rather vague concept such as "night vision".

Similar in certain respects to Janda's study was an investigation by Granger (40) in which in response to a request for a short psychiatric screening test a preliminary technique was tried out on 100 neurotic and 40 normal subjects. Following three minutes' light-adaptation to an adapting-field of 675 ml. at a colour temperature of 6,500° K, the subject reported upon the position of a faintly-illuminated triangular-shaped test-object of 4° angular subtense. The luminance of the test-field was set at $10^{-3 \cdot 04}$ mL and was viewed binocularly at a distance of six feet. The time in seconds between the cessation of light-adaptation and correct verbal report on the position of the test-object (up, down, right or left) constituted the subject's score.

Marked differences were found between normal and neurotic groups, the latter having longer perception times. Differences were particularly striking at the upper and lower ends of the time scale; whereas 42 per cent. of normals had perception times of less than 100 seconds, only 6 per cent. of neurotics fell into this category and whereas 34 per cent. of neurotics had perception times of 300 seconds or more no normal had a perception time exceeding 300 seconds. For convenience in making a statistical comparison a log transformation was used and a t-test of the difference in mean log times gave $P < \cdot 001$ (see Figure 6).

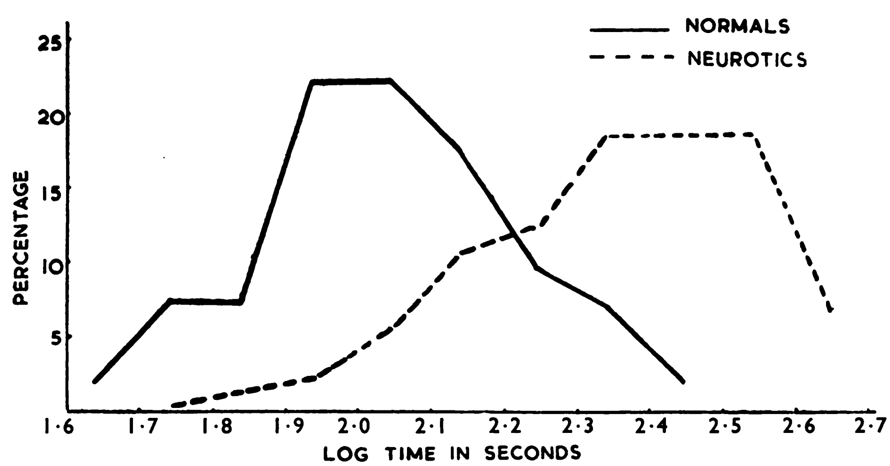

FIG. 6.—Frequency distribution of perception times. (Granger (40).)

An almost zero correlation was found between "perception time" and intelligence, as measured by Progressive Matrices, for the neurotic group but a small positive correlation (·21) was found with age. There was no significant difference in age between normal and neurotic groups.

III. Psychophysical Evaluation of Results

Perhaps the most striking feature of the researches reviewed above is the diversity of techniques and experimental conditions that have been used. Certainly all the studies involve "tests" of "night vision" in that they deal with visual functioning under conditions of low illumination, but in spite of this general similarity there are marked differences between them in respect of size and type of test-object, state of adaptation of the subject's eyes, criteria of "visibility", method of threshold measurement, range of luminance, etc.

This variation in conditions is particularly apparent in the case of luminance. By converting the luminance levels used in the different experiments to a common unit (log micromicrolambert) and plotting these ranges it is clear for instance, that Himmelweit, Desai and Petrie's test of "dark vision" is, psychophysically, a very different test, from that of Rees. Whereas Rees was working at luminance levels between $10^{6 \cdot 1}$ $\mu\mu$L and $10^{5 \cdot 2}$ $\mu\mu$L, involving both "photopic" and "scotopic" vision, Himmelweit, Desai and Petrie's test was administered at a much lower luminance level of about $10^{3 \cdot 9}$ $\mu\mu$L. Difference in luminance level is not the only difference in experimental conditions between the two experiments; there were other differences in respect of the size, shape and type of test-object, retinal area tested, viewing distance, method of recording responses and so on.

Numerous other differences occur between experiments. Thus Janda's study of form discrimination was carried out in the early stage of dark-adaptation at a luminance level of approximately $10^{6 \cdot 9}$ $\mu\mu$L immediately following a period of controlled light-adaptation whereas Rees presented forms for discrimination to fully-dark-adapted subjects. Gravely made threshold determinations for perception of the position of a test-object during a ten-minute period of dark-adaptation, without controlling previous light-adaptation or fixation and using binocular vision, whereas Granger (41) employed a fixation point to test a specific retinal region, used monocular vision, and his subjects were merely required to report upon the presence of a circular patch of light during a thirty-minute period in the dark, following a period of controlled light-adaptation.

The great diversity of techniques makes comparison between one study and another difficult, just as comparison was made difficult between the numerous wartime studies devoted to the search for a "test of night vision", as Verplanck (8) has pointed out. Marked differences in experimental conditions have been ignored by some investigators when making comparisons between their own investigation and someone else's. Thus, Himmelweit, Desai and Petrie, in comparing their results with those of Rees, seem to assume that they are using essentially the same "test" of "dark vision" as was used by Rees, although as we have seen above there were many differences between the techniques employed in the two investigations.

A second feature of much of the research is its purely psychometric nature, the chief object of many studies being to discriminate between normal and psychiatric groups by means of a "test" of "dark vision". This is, of course, a perfectly legitimate aim, but in certain cases it has tended to make psychophysical evaluation difficult. This is seen for instance in Rees's study where the total score for the test is obtained by summing scores of performances at four different luminance levels. The luminance range covers both "photopic" and "scotopic" vision, but it is impossible to determine whether differentiation occurred primarily under photopic or scotopic conditions. Particularly difficult to evaluate from the psychophysical viewpoint is the study by Himmelweit, Desai and Petrie (50) owing to the almost complete lack of information concerning experimental conditions. Further difficulties arise in connection with Gravely (45) and Granger's (38) experiments in which scores were allotted in terms of "brightness grades" rather than in terms of units of luminance, although it is possible to make an approximate estimate of the equivalent values in terms of log $\mu\mu$L.

In the third place, judged in relation to the standards of research customary in visual psychophysics, all of the investigations leave much to be desired in the way of physical, physiological and psychological controls. To take but one variable, the light-history of the eye immediately prior to the test, in several studies this factor is completely uncontrolled yet it is known to affect the subsequent course of dark-adaptation, particularly in its early stages. Or, to cite another example, the lack of control over viewing conditions in many experiments means that some subjects may have employed more sensitive areas of their retinae than others when viewing the test-field.

Fourthly, there is an almost complete absence of re-test data and repeat studies, except in the case of Janda's (56) and Granger's (39) experiments. There are practical difficulties involved in re-testing the same patient on different occasions in that even a single session of the test may be quite stressful but the lack of re-test data nevertheless makes evaluation of results difficult. It is known that there may be considerable day-to-day variation in individual threshold measurements of as much as $0 \cdot 3$ log unit (49) and reliability coefficients of "night vision" tests seldom exceeded $0 \cdot 8$ in the numerous wartime studies that were carried out, usually they ranged between $0 \cdot 6$ and $0 \cdot 8$ (8).

Fifthly, considerable heterogeneity has been observed in the reactions of psychiatric groups under some experimental conditions. Thus, in Granger's (39) study differences were found within a group of neurotics with regard to the shape of their dark-adaptation curves which limit the descriptive value of comparisons based on level alone. Lack of homogeneity in the experimental data often makes averaging of results in visual experiments of dubious value, as Crozier (65) has pointed out.

Finally, there is a complete lack of objective data on the more general psychological characteristics of the groups to which the night vision measurements can be related. Groups are classified only on the basis of crude descriptive categories such as "neurotic" and "psychotic". How great a limitation is the use of psychiatric labels depends on one's viewpoint. Regarded as an anomaly, in the sense of an apparent deviation from the type of dark-adaptation curve ordinarily obtained under a particular set of experimental conditions, the dark-adaptation function of a patient labelled "hysteric" becomes a starting point for an enquiry into the mechanisms responsible for the "discrepancy". Whether these mechanisms have any significant relation to psychiatric criteria and labels or implications for psychiatry is another matter. This would be the viewpoint of visual research. From the viewpoint of personality research the position is perhaps less satisfactory owing to the absence of any measurements on personality variables although the studies may still be regarded as suggestive for further research (see below in section dealing with Sensory Factors).

Bearing in mind the above comments and criticisms, the next problem is to consider the experimental conditions under which differences between normal and psychiatric groups occur and to what extent results of the various studies are consistent with one another. Considering first differences between neurotics and normals, Gravely (45) found evidence of higher intensity thresholds in the neurotic group over the first ten minutes or so of dark-adaptation, at luminances below about 5·5 log unit ($\mu\mu$L). Her results are consistent with those of Granger (38) who found evidence of higher thresholds also over the subsequent twenty-minute period of dark-adaptation. It is difficult to be precise about the extent of the difference in the case of Gravely's experiment, but it would appear to be of the order of approximately 0·15–0·20 log unit ($\mu\mu$L). Threshold differences in Granger's study (repeated with a second group of neurotics) varied between 0·25 and 0·40 log unit. Consistent also with Gravely's (45) and Granger's (38) results are those of Granger (39) using a somewhat different experimental procedure. In the latter experiment the dark-adaptation curve for the neurotic group was shifted along the log-luminance axis by amounts varying from 0·2 to 0·5 log unit. The results of Himmelweit, Desai and Petrie's (50) experiment, although difficult to evaluate in view of the lack of information concerning experimental conditions, also seem to be in line with the other findings in that some tendency was found for neurotics to have higher intensity thresholds at a luminance level of (probably) 3·9 log unit ($\mu\mu$L), i.e. toward the final "rod" threshold of the adaptation curve.

Following this statement about differences between neurotics as a group, and normals, it is necessary to consider the results of Granger's (41) experiment in which it was found that although hysterics had higher thresholds than normal subjects (on an average of about 0·2 log unit), anxiety states had normal or superior sensitivity and adaptation curves of normal shape. These results were obtained using a different threshold criterion from the type used in the studies referred to in the previous paragraph, viz. a simple light stimulus rather than a geometrical test-object, so it seems that differences may occur *within* the neurotic group depending upon experimental conditions for threshold determination. Anxiety states do not apparently have higher thresholds for light *per se*, in fact they tend to have lower thresholds, although they *may* have higher thresholds than normals when the visual task makes demands upon form perception in the sense of requiring the location of a simple geometrical object against a dimly-illuminated background. In view of the fact that the intensity thresholds for form location do not coincide with those for awareness of light as such but tend to be higher (55, 82), the results of Granger's (41) experiment with light thresholds are not inconsistent with the experimental results obtained using form location as threshold criterion (Gravely, 45).

Nor are they inconsistent with the results of experiments by Livingston and Bolton (67) and Rees (93) on form discrimination at low intensities in which they found a tendency for neurotics to have inferior performances to normals. It is perfectly possible for a person with a low absolute threshold for light to have a high threshold for form discrimination and identification (20, 55). The poor performance of anxiety states on the Livingston Rotating Hexagon test are therefore not inconsistent with their normal (or superior) performances in Granger's (41) experiment. The inferior performances of hysterics on the Livingston test are also not inconsistent with their having higher light thresholds in Granger's study for perception of the test-objects must depend in the first instance upon light sensitivity.* An individual with a high light threshold would tend to see the illuminated panel bearing the test-objects less readily than an individual with a normal light threshold. On this suggested analysis, two individuals could have the same (low) score on the Livingston test for different

* Although there is no direct evidence for *superior* form discrimination in hysterics, it may be significant that Gravely (45) found a higher C.F.F. in hysterics than in anxiety states, using a test batch of photopic intensity.

reasons, in the one case due to impairment of the light threshold and in the other due to impairment of form perception. It would seem then, to return to the original statement about higher intensity thresholds in the neurotic group, that differentiation between neurotics and normals depends upon the composition of the neurotic group (i.e. the relative numbers of anxiety states and hysterics) and the type of threshold criterion employed.

So far consideration has been given to results obtained mainly at "scotopic" levels of illumination (i.e. conventionally below about 10^6 $\mu\mu$L). Data are also available for the higher levels at which "cone" vision is functioning or at the cone-rod transition point where a change-over from "photopic" to "scotopic" mechanisms occurs. Granger (40) found that following a period of light-adaptation, neurotics took longer than normals on the average, to perceive a test-object presented at a pre-determined luminance. His results tend to be broadly consistent with those of Janda (56), although whereas Granger obtained highly significant differentiation between groups, Janda obtained very few significant differences. Among the differences in experimental conditions between the two experiments, light-adaptation and test-object luminances may be important factors in accounting for the less significant results of Janda. Whereas Granger used a pre-adapting field of 675 ml. and a test-field luminance of $10^{6\cdot04}$ $\mu\mu$L, Janda employed a pre-adapting intensity of 1,722 ml. and a test-object of $10^{6\cdot9}$ $\mu\mu$L. The effect of the higher intensities used in Janda's experiment would mean that his threshold measurements relate to an "earlier" part of the cone adaptation curve than Granger's. That the relative values of the pre-adaptation and test-field luminances may play a part in determining differences between normals and neurotics is indicated by the fact that in Granger's study (39) no differentiation occurred between normals and neurotics until about $10^{6\cdot2}$ $\mu\mu$L and not until the test-field luminance was below $10^{6\cdot0}$ $\mu\mu$L did the differentiation become at all significant.*

In a further study (41) involving the detection of light rather than location of a test-object it was found that hysterics had longer perception times than normals, following a period of light-adaptation, whereas anxiety states had normal perception times. As in the case of the results obtained at lower levels of illumination, it seems as if the type of threshold criterion may be an important factor in producing differences *within* the neurotic group.

Information on psychotic patients is meagre, but it appears from Granger's (38) study that psychotics also tend to have higher intensity thresholds than normals and from Marshall and Day's (81) study that schizophrenics have higher thresholds for perception of visual detail during dark adaptation.

Summarizing the discussion, the following general conclusions emerge, *provided trends in the data are taken into account as well as statistically significant findings:*

1. Psychiatric patients tend to have higher intensity thresholds than normals during the course of dark-adaptation. Their dark-adaptation curves, although of the same shape as the normal, tend to be displaced upward along the intensity axis by amounts varying between 0·2 and 0·5 log unit. In other words, patients require between one and a half and three times as much light for perception as compared with normal subjects.

2. Evidence for differences between normal subjects and patients is clearest under conditions of scotopic rather than photopic vision (i.e. at luminance levels below about 10^6 $\mu\mu$L).

* This finding is not apparent from the data plotted in Figure 4 where the two groups were compared in terms of intensity level.

3. The time taken to recover from the effects of light-adaptation as determined by their initial threshold responses tends to be longer in psychiatric patients than in normal subjects.

4. Differences *within* psychiatric groups occur depending upon the threshold criterion. Anxiety states have normal or superior light thresholds, but impaired thresholds for form perception, whereas hysterics have high light thresholds and results are consistent with the hypothesis that their form thresholds are normal or lower than normal.

IV. Possible Psychophysiological Mechanisms

Having attempted a psychophysical analysis of the various test results and found a certain amount of consistency in the experimental data, the next problem is to consider some of the possible psychophysiological mechanisms that may underlie the observed differences. First* to be considered is the possibility that sensory mechanisms involved in dark-adaptation and night vision may be affected. These may be considered under two headings, photochemical and neural. Any photochemical changes that occur must occur in the retina, but neural changes could occur either in the retina or at higher levels of the visual system. The possibility of retinal changes will be considered first, for available evidence indicates that the retina is the locus of the dark-adaptation process. Thus, Craik and Vernon (19) found that the dark-adaptation curve obtained from an eye which was temporarily blinded by applying pressure to the sclera during light-adaptation was essentially normal as regards shape and level. As the primary stimulation was prevented from reaching the higher visual centres, their results indicate that adaptation is primarily a retinal phenomenon, although the matter is by no means conclusively settled (see for instance (62)).

1. *Sensory Mechanisms*

That photochemical changes occur during dark-adaptation has long been accepted, and some investigators (e.g. 84) still maintain that such changes are the *only* ones that occur. Briefly, photochemical theory claims that during light-adaptation rhodopsin and other visual pigments are bleached with the formation of products that are insensitive to light. As a result of the bleaching process the concentration of sensitive material in the retina is lowered and in consequence the visual mechanism becomes less sensitive to light. When the eye is put in darkness a resynthesis of the sensitive material from its photoproducts occurs and sensitivity is recovered. In terms of this theory, the absolute light threshold is conceived as some simple function of the concentration of visual purple and other sensitive material in the retina.

Is it possible that in psychiatric patients the regeneration process is disturbed with consequent reduction in sensitivity? Examination of the individual dark-adaptation curves of neurotics in two of Granger's (39, 41) studies reveals a few cases (all hysterics) where the shape and level of the "rod" portion of the adaptation curve correspond fairly closely to the type of curve that has been obtained from subjects suffering from vitamin A deficiency. (As is well known, this vitamin is a constituent part of the photosensitive pigment or pigments.) Although there is no evidence of any marked deficiency in vitamin A intake among psychiatric patients. it is not improbable that some patients may suffer from conditions which can lead to a deficiency. Among the conditions which can

* Anomalies of the dioptric apparatus of the eye, such as refractive errors and opacities of the eye media may also have to be taken into account. Craik and Vernon (20) found, for instance, an association between a high perceptual threshold and high refractive error in their study of dark-adaptation.

either prevent or hinder the proper absorption or storage of vitamin A (110) are elevated metabolic rates, disturbances of the gastro-intestinal tract and others reported to occur as somatic features of neurosis and psychosis (2a). However, at least two factors make it appear unlikely that a photochemical explanation would have very wide application. First, recent evidence indicates that unless previous light-adaptation has been to a high intensity photochemical changes play a relatively insignificant part in determining the course of subsequent dark-adaptation. At ordinary room illuminations Rushton (102) could detect no appreciable change in the level of rhodopsin in the human retina, so it seems unlikely that photochemical effects would determine the results of most of the experiments reviewed above. With only one or two exceptions (39, 56) pre-adapting luminances have been comparatively low (below 300 foot L., the intensity used in Rushton's experiments) although admittedly the duration of light-adaptation has been for several minutes. In one experiment (39) light-adaptation was to an intensity of 750 ml. for five minutes and in another (56) to 1,720 mL for three minutes, and it is possible that photochemical changes played a significant role in both instances. However, Granger observed high thresholds in hysterics in a study using an adapting intensity of only 270 mL. viewed for five minutes, and under these conditions a photochemical explanation seems inapplicable. In the second place, although psychiatric textbooks list a number of somatic features of neurosis that might hinder the proper absorption of vitamin A, there is no experimental evidence (2a) to show that these tend to occur more frequently in patients with high light thresholds (i.e. hysterics) than in other types of psychiatric patient.

Although an explanation along photochemical lines seems unlikely to have a very wide application, more detailed investigation of observed anomalies of dark-adaptation in specific cases might reveal significant differences due to interference with photochemical mechanisms. There is no doubt at all that regeneration of visual purple occurs after the eye has been exposed to the more intense illuminations (Tansley (115); Rushton (99)), and there is considerable evidence to show that patients suffering from vitamin A deficiency have impaired dark-adaptation (49), so it seems necessary to first exclude the possible effect of photochemical factors before considering alternative explanations in terms of nervous mechanisms. Rushton's (101) ingenious technique for measuring the rhodopsin level in the human eye should be useful in this connection.

Having considered the photochemical aspect of dark-adaptation, we will next consider neural mechanisms. Objections to a purely photochemical theory of dark-adaptation have been advanced by Lythgoe (70), Granit (44), Elsberg and Spotnitz (26), Thomson (117), Rushton (100), Baumgardt (7), and others, one of the most telling objections being that the rhodopsin concentration in the retina at a given time during dark-adaptation does not correspond to the visual sensitivity.

It now appears that in addition to any photochemical changes that occur, changes must also occur in the nervous apparatus of the retina. The exact nature of the mechanism involved remains to be determined, but interesting suggestions concerning its nature have been made by Lythgoe (70). This author was impressed by the fact that during dark-adaptation light sensitivity improves, but at the same time the finer visual judgments are impaired. This he suggests may be due to a re-organization of the neural connections in the retina, so that each fibre serves several elements by a spread of its synaptic connections: in other words, there is an increasing amount of convergence which makes possible the integration of feeble light stimuli, but at the same time there is a reduction in the eye's capacity for the finer discriminatory reactions, for such reactions depend on the segregation of individual pathways. In other words, Lythgoe suggests that a type of "synaptic switching" occurs which has the effect of changing the properties of the retina from *differentiating* to *integrative*.

A similar idea has been put forward by Adrian and other authors. Adrian considers that ". . . the interaction of nerve cells in the retina may change in degree or in sign, darkness favouring mutual summations over wider and wider areas and light converting the effect to inhibition" (1, p. 110). Adrian goes on to say that it may be that ". . . as the light increases the sheets of nerve cells no longer act as a general collecting net for signals over a wide area, but begin to develop the local peaks and troughs of activity which make a detailed visual pattern" (1, p. 111).

While there is no direct evidence for the Lythgoe-type of theory, it seems to accord fairly well with electrophysiological as well as sensory data. Thus it has been shown that the size of the receptive field of a retinal element decreases with light-adaptation but increases with dark-adaptation (63, 64) while the summation area (15), and probably the summation time (100), and integrative ability of the eye (3), as measured by psychophysical methods, increase with dark-adaptation. Lythgoe's theory also seems broadly consistent with sensory work on the effects of light- and dark-adaptation on visual acuity and C.F.F. (72) as well as with Granit's studies of changes in the electroretinogram in the light- and dark-adapted retina of mixed type (i.e. containing both rods and cones). On the basis of Granit's studies it appears that ". . . a cone system is a mechanism for differentiation, a rod system one for integration. The properties of a rod system do not differ very much from those of an isolated receptor. The extensive convergence of a large number of receptors on to one final common path seems to be the main feature of the organization of a rod system, and this is of obvious importance in the integration of the feeble light stimuli characteristic of the scotopic eye. The cone system, on the other hand, seems to be organized for the interpretation of *changes* in the visual field, changes of illumination, of the area stimulated, of 'locus' in the field as a whole and . . . of colour" (42, p. 167). Elsewhere Granit writes that the rod-dominated retina is "highly sensitive and slow like a ballistically recording galvanometer, integrating the total amount of light reaching it", whereas the light-adapted eye is much faster though less sensitive.

Both Lythgoe and Adrian claim that light-adaptation gives rise to some sort of "inhibitory" effect, whereby the spread of impulses arising from individual receptors is prevented so that they tend to work more as individual units. When the eye is put in darkness this "inhibition" presumably "dissipates" to be replaced by summative interaction in the retina. On this view light sensitivity and visual acuity are regarded as in a certain sense antagonistic functions, conditions favouring the one tending to militate against the other.

In proposing his model Lythgoe refers to the work of Schouten (103) on the so-called alpha-adaptation effect, a very rapidly occurring "inhibitory" effect which occurs when a glare source is applied to the eye. The effect of the glare source in depressing sensitivity is not confined to the specific area stimulated, but "spreads" to adjacent areas of the retina. It is possible that alpha-adaptation may operate at the fovea to prevent the spread of impulses from individual cones, thus ensuring the segregation of individual pathways and a high degree of visual acuity. In Lythgoe's view the uniformly-illuminated field used for light-adapting the retina before a dark-adaptation experiment may be regarded as composed of a multitude of contiguous glare sources. On this theory, the subsequent dark-adaptation curve would represent to some extent a recovery from inhibition (52).

Even if Lythgoe's account of the nature of the changes in retinal *organization* should prove to be grossly inaccurate and be replaced by an alternative explanation such as that of Pirenne (89, 90), there can be little doubt on sensory and electrophysiological grounds that changes in retinal *properties* occur under conditions of light- and dark-adaptation, the light-adapted eye *apparently* making greater use of inhibitory mechanisms than the dark-adapted eye which seems to depend more on summative processes. Accepting such a change in what may be termed the "excitation-inhibition balance" of the eye, the possibility may be considered that some of the anomalous dark-adaptation curves observed in psychiatric patients may be due to some disruption of this balance.

The raised light thresholds of hysterics and their slower recovery from light-adaptation might result from an exaggeration of inhibitory and a weakening of summative processes. On this hypothesis the hysterics would be expected to behave like normal subjects whose eyes had been exposed to a light-adapting field or "glare source" of greater intensity, or to one of the same intensity acting for a longer time (46). The greater "inhibitory" effect of light in the hysteric would show itself in the modification of such features of the adaptation curve as the initial threshold value, the slope, the time of the cone-rod transition point and the time course of subsequent adaptation. A weakening of summative mechanisms would show itself by reducing the summation area of the retina, i.e. the hysteric would behave like a normal subject confronted by a test-field of reduced size, with consequent upward displacement of the dark-adaptation function along the log-luminance axis and shallower slope. Experimental data are not available on all these "deductions", but existing data tend to be consistent with the type of hypothesis proposed, so far as the initial threshold value is concerned. Also consistent is Gravely's (45) finding* of a higher C.F.F. in hysterics than in anxiety states.

In anxiety states apparently the summative mechanisms are unimpaired or even enhanced during dark-adaptation so as to produce normal or lower than normal thresholds, but the integrative ability of the retina is perhaps achieved at the expense of differentiation due to impairment of lateral inhibitory processes. Although able to integrate feeble light stimuli due to summative interaction between adjacent retinal areas, the retina of the anxiety state may be unable to "inhibit" the spread of impulses sufficiently to enable him to appreciate the contour or detail of test-objects. In consequence, although his eye would readily detect the presence of light in the visual field, in such a test as the Livingston Rotating Hexagon the outlines of objects would tend to merge into the background and appear blurred and indistinct. Such a process would be expected to operate in the perception of test-objects of fairly complex contour at the higher "photopic" levels of illumination covered by this test, but it seems less likely to play a part in perception of the simple geometrical test objects in the adaptometer tests at the lower intensities.

In addition to possible interference with the retinal mechanism of dark-adaptation, the possibility should also be considered that impairment may occur in the transmission of impulses along the conducting pathways between the retina and cortex while the receiving areas in the visual cortex itself might be affected. Even the staunchest proponents of photochemical theory, such as Hecht and his co-workers, have never denied that the state of the nervous system beyond the photoreceptors can affect the value obtained for the threshold

* Not statistically significant.

energy during the course of dark-adaptation. (What they do deny is that sensitivity changes can occur in the nervous system *in response to light*.) Any factor which interferes with the transmission of impulses from the retina would mean that the light energy required to produce a threshold sensation would differ from the normal value and might result in the dark-adaptation curve being shifted along the intensity axis.

Assuming that neural effects occur in the receptors, retinal synapses, optic nerve fibres, lateral geniculate bodies, or at higher levels of the visual mechanism, the problem arises as to the factors underlying such effects. How could anxiety, hysteria and other psychiatric conditions affect the neural mechanisms involved in night vision? Here unfortunately there is hardly any information that bears on the problem either from psychiatric or from visual research so that only a few tentative suggestions can be made. One possible lead comes from studies of the effects of drugs and physiological stresses on visual thresholds. McFarland has shown for instance that anoxia (75) has the effect of elevating the dark-adaptation curve along the log-luminance axis by amounts varying between about 0·2 and 0·4 log unit, without changing its shape. This effect seems to be due not to changes in the photochemical system of the retina, but rather to alterations in the central nervous system. It is well known that nervous tissue is particularly sensitive to a deficit of oxygen, and it is quite possible in view of the close relationship between the retina and the brain, embryologically and physiologically, that changes may occur in the retina itself, although this cannot be established from McFarland's findings, However, there can be little doubt that there is a depression of neural activity somewhere in the visual system.

Similar results have been obtained from subjects suffering from insulin hypoglycaemia (77). When the blood-sugar level is lowered by injecting insulin the dark-adaptation curve becomes elevated by amounts varying between 0·1 and 0·4 log unit. Return to normal follows either from the inhalation of pure oxygen or from the administration of dextrose. Elsewhere McFarland and Forbes (76a) have shown that hyperglycaemia produced by the injection of dextrose can partially counteract the effects of anoxaemia on light thresholds. It appears from these results, as McFarland (76a) has pointed out, that oxygen deprivation and hypoglycaemia have similar and additive effects on dark-adaptation. Raised light thresholds have also been reported in subjects under the influence of alcohol (78) the effect being attributable presumably to depression of central nervous activity.

The possible bearing of these studies on our problem comes from the fact that similar upward displacement of the dark-adaptation curve is found in psychiatric groups, and it may be that some of the same mechanisms are involved. Several studies have suggested the presence of oxygen deficit in schizophrenics (73) while Gellhorn *et al.* (33) have reported more insulin under stress conditions in psychotics than in normal subjects. It is possible that such factors may be partly responsible for the raised intensity thresholds found in Marshall and Day's (81) and Granger's (38) studies. Such factors seem less likely to operate in neurotic groups, although McFarland (74) found that neurotic patients of the "chronically fatigued type" had a lower "altitude tolerance" than normal subjects: a large percentage of both male and female neurotics either collapsed or approached collapse at simulated altitudes of 14,500 feet (12 per cent. oxygen) and 19,000 feet (10 per cent. oxygen) than did normal subjects.

Perhaps significant also is the fact that hysterics who show raised light thresholds and behave like normal subjects under the influence of central nervous system depressants, appear to have lower than normal sedation thresholds for sodium amytal (108) as determined by Shagass' (107) index of sedation tolerance. To use Shagass's terminology, his results suggest a lowered "cerebral excitability" in hysterics as a group, and particularly in hysterics showing conversion symptoms. The index which Shagass uses is based on certain quantitative EEG changes associated with the onset of slurred speech. The EEG changes are recorded from transverse frontal electrodes. Whether the lowered "excitability" extends to the visual cortex or other parts of the visual system is unfortunately not known.

A further observation that seems worth noting in connection with depressant drugs is Trent's (118) finding of enhanced contour acuity following the administration of Nembutal. This result suggests that Nembutal may have some effect on lateral synaptic connections in the visual system, enhancing form acuity by reducing summative interaction between adjacent areas. The effect of Nembutal on contour acuity may be analogous to that of light-adaptation or a "glare source" applied at some distance from the test area (103), acuity being increased by a reduction in light sensitivity. If Nembutal were shown to have a depressing effect on the light sense its action might parallel that of hysteria in a test of the Rotating Hexagon type involving form discrimination at low (photopic) intensities.

The depressing effect of Nembutal may be contrasted with the facilitating effect of strychnine which, from electrophysiological as well as psychophysical studies (2, 43) is known to increase areal interaction in the retina. It has also been shown to lower light thresholds and improve dark-adaptation (34)* and although part of this effect may be due to increased excitability of the conducting pathways between the retina and the brain, the above studies and others (35) suggest that strychnine may have a local effect upon the retinal synapses, and increase the summative ability of the retina. Therman's studies (116) have shown that the application of strychnine tends to enhance the PII component of the electroretinogram which is associated with excitation in the optic nerve. Unfortunately, as in the case of Nembutal, the relative effect of strychnine upon the light and form senses is not known. Its ability to increase the degree of interaction between adjacent areas of the retina would suggest that it may enhance the summative and integrative ability of the eye at some expense to differentiation and acuity. If so, it might be tempting to consider its effect as analogous to that of anxiety, although here we are going somewhat beyond the experimental evidence. It will be remembered that anxiety states had light thresholds that did not differ significantly from normals, whereas strychnine *improves* light thresholds. However, a tendency was noted particularly over the last twenty minutes or so of dark-adaptation for anxiety states to have lower thresholds than normal. This tendency would probably become significant if a normal group strictly comparable in age to the neurotic group were used. If this were the case, it might be possible by means of drug studies to relate these visual effects of anxiety to Shagass's (108) finding of increased "cerebral excitability" in anxiety states, as determined by their "sedation threshold" for sodium amytal.

Another line of approach comes from studies on the so-called "adaptive influence" of the sympathetic nervous system on the "visual analyser", following Orbeli's (86) theory. Babskii (4, 5) has shown, for instance, that adrenalin tends to lower light thresholds and improve dark-adaptation, while sympathectomy impairs these functions. The effects appear to be independent of changes in

* Some investigators (78, 97), however, report no effect.

pupil size. These results may be considered in relation to the view often put forward by clinicians that manifest anxiety tends to be reflected in increased sympathetic activity and also to Cannon's well-known theory of the role of the sympathico-adrenal system in emergency (fear) responses. Looked at from a biological viewpoint it is possible that a fear reaction might have as part of its effect the enhancement of the more primitive light sense at the expense of the more recently acquired form sense. The fear response might be triggered off by darkness acting as a kind of conditioned "stimulus" in anxiety states. Perhaps worth noting is the fact that anxiety states tend to form conditioned reflexes readily (30). Here again it would first be necessary to demonstrate conclusively that anxiety can actually *improve* light sensitivity before going on to test further hypotheses.

Somewhat difficult to reconcile with Babskii's (4) results on the beneficial effects of adrenalin on dark-adaptation are Therman's (116) electrophysiological results, which show that adrenalin tends to depress the b-wave of the E.R.G. and optic nerve discharge and Marazzi's (79, 80) work on the inhibitory effects of adrenalin on the visual system. The effects of adrenalin on the E.R.G. are very remarkable, although very complex. Its most pronounced effect is probably that of slowing down all the reactions and producing an enormous prolongation of the latent period (116). The depressor action of adrenalin on the retina may be compared with results obtained elsewhere in the C.N.S. (105) where from time to time increased excitability also occurred. Therman's remarks that adrenalin ". . . may have something to do with excitation in the retina . . ." are worth considering in relation to the Russian theories of the "adaptive influence" of the sympathetic nervous system on the visual mechanism. In some way adrenalin may affect the "excitation-inhibition" balance of the eye, but its effects seem likely to be rather transient. Momentary depressions of light sensitivity such as one might expect on the basis of the electrophysiological results might reveal themselves in a dark-adaptation curve,* provided thresholds were taken at sufficiently short intervals of time, by "plateaux" or periodic oscillations, although other explanations are possible (see below). Such oscillations have been reported by Lee (66), while Granger (39) found evidence of "plateaux" in the curves of anxiety states.

Relevant also to the discussion of sympathetic activity and anxiety are effects of breathing pattern upon the visual threshold. Increasing the rate of breathing room air by 50–100 per cent. is known to result in a fall in the absolute light threshold to about one-half its value within 5–10 minutes (120). This effect appears to be due to alkalosis associated with hyperventilation and is probably due to changes occurring in the visual system at some point or points central to the photoreceptors. Such an effect might occur as a consequence of increased sympathetic activity in anxiety states although it must be noted that increases in respiration rate have been found also in other types of neurotic (2a). Of possible significance also in connection with the distinction drawn earlier between the integrative and differentiating ability of the retina is the fact that rapid breathing has been found to *raise* the threshold for brightness discrimination in one study (32).

If anxiety involves both central and autonomic components, as has been suggested, a drug that would seem to be of particular interest for further research is ephedrine which is not only a central nervous stimulant but is also a potent sympathicomimetic agent which simulates in its peripheral actions

* Rothan (97a) found a decrease in the capacity of an eye for dark-adaptation following instillation of Adrenalin into the conjunctival sac.

results obtained by stimulating adrenergic nerves. Holzer (51) noted an improvement of dark-adaptation following administration of this drug but his findings have not been confirmed by other investigators (37, 97). Apparently discrepant findings are very common in experimental work on the effects of drugs on dark-adaptation (see for instance reviews by Rose and Schmidt (97) and Segal (106)) and this must be borne in mind in connection with the suggestions made in the preceding paragraphs. While some of the discrepancies are undoubtedly due to physiological factors, it seems likely that many are due to the use of different physical conditions of experimentation, threshold criteria and test-objects. For instance, it is possible that a given drug may have a stimulating effect on absolute light sensitivity, as measured by the "fixation-and-flash" method, and yet impair the eye's ability to perform the finer visual tasks. So far there has been no serious attempt to study the differential effects of drugs on specific dimensions of visual functions; such research is urgently needed. Also needed is research employing more satisfactory experimental designs and statistical techniques than have been used in some of the earlier studies.

Before concluding this section on sensory factors, reference should be made to Eysenck's (27) theory of anxiety and hysteria in which he claims that differences in conditioning, learning and various perceptual functions between these two clinical groups reflect differences along a personality dimension of "introversion-extraversion". Briefly Eysenck claims that introverts and extraverts and their neurotic counterparts, anxiety states and hysterics, differ with respect to the speed and strength with which *reactive inhibition* is generated and the speed with which it is dissipated. Following Hull (53) Eysenck regards reactive inhibition as a molar property of the central nervous system. Individual differences in the development of reactive inhibition Eysenck regards as largely due to heredity. So far Eysenck's theory has been developed mainly in relation to the variables of learning experiments (28, 30) but it seems likely that, given a more molecular formulation, it may be applicable to certain psychophysical data from visual experiments. This possibility will be considered in some detail in another paper. Suffice it here to say that the recovery of sensitivity following light-adaptation (i.e. a period of continuous stimulation) may represent in part a recovery from "reactive inhibition". On Eysenck's hypothesis one might expect (other things being equal) recovery to be more rapid in anxiety states than in hysterics while an unselected group of normal subjects would fall about midway between the two clinical groups. While it is difficult, owing to lack of data, to accurately locate the position of normals from Granger's (41) study, it is worth noting that anxiety states had more rapid recovery times than hysterics, as determined by their initial perception times.

2. *Motor Mechanisms*

Seeing under conditions of low illumination does not only involve sensory mechanisms, and one must consider possible effects of psychiatric illness on threshold responses to be mediated through the intra- and extra-ocular muscles of the eye. Pupil size is of obvious importance in that it governs the amount of light entering the eye at any given time. An unusually constricted pupil during dark-adaptation tends to raise the light threshold, whereas a very dilated pupil tends to lower it (87). Again, a large pupil during light-adaptation prior to the dark-adaptation experiment tends to increase the time taken to perceive the initial test-field and affect the early course of dark-adaptation. On the other hand, a small pupil has the opposite effect.

Pupillary reactions at the time of change-over from light to dark-adaptation may also have important effects upon the threshold. During the first few minutes of dark-adaptation the pupil relaxes allowing more light to enter the eye and thus permitting progressively lower intensities to be perceived. As a consequence of changing pupillary diameter the speed of the first part of the "cone-adaptation" curve may be increased and the total range of adaptation increased slightly by an amount equal to the extent of pupillary dilation. Not only would anomalies of pupillary dilation exert some effect upon the adaptation curve, but spasms in the form of sudden constrictions, which are known to occur in some subjects (21), would have at least a momentary effect upon the light threshold. Although there is much suggestive clinical material (Granger (36)) relating anomalies of pupil size and pupillary light reactions to neurotic and psychotic disorders, there is unfortunately no experimental evidence* directly relevant to dark-adaptation. DeJong (23) claims that in the so-called vagotonic individual with cold skin, bradycardia and low blood pressure the pupils are contracted owing to overactivity of the parasympathetic, whereas in the sympathicotonic individual with warm skin, rapid pulse, and hypertension there is mydriasis. Anxiety states and certain schizophrenics are classified by DeJong in the second group. The consequences of a larger than normal pupil size would depend on whether the eye were light-adapting or dark-adapting. A large pupil during light-adaptation would delay recovery in the early stages of dark-adaptation but would tend to lower the light threshold later on. Duke-Elder (25) has noted that miosis can occur in hysterics, but here again the consequences for the dark-adaptation situation are difficult to predict, although a positive correlation has been found between pupil size in light and in darkness for *normal* subjects (9). Much depends on whether the miosis occurs under dark- as well as light-adaptation. It is possible that hysterics may have smaller than average pupils during dark-adaptation due to the longer persistence of light-adaptation effects in such subjects, for Thomson (117) has shown that the light-history of the eye for some time before a dark-adaptation experiment can affect pupil size (smaller pupil) even though the eye is in darkness, the effect being mediated presumably by off-fibres.

Changes in accommodation could possibly affect the experimental results either directly by causing blurring of vision or indirectly by affecting the pupil size. While it is difficult to see how accommodation could be a significant factor in affecting the perception of large test-fields at scotopic intensities, it is possible that accommodation might enter as a factor at the photopic intensities used in the Livingston Rotating hexagon test for Campbell (16) has shown that the accommodation reflex is activated when the light energy of the test-field exceeds about 1 mL for a 1° test-object. This luminance level corresponds to the lower limit of foveal vision (i.e. to the higher intensities used in the Livingston test). Campbell's results indicate that the threshold for the accommodation reflex is between 0·25 and 0·5 $\log_{10}$ unit higher than the visibility threshold. Under the conditions of Rees's (93) and Livingston and Bolton's (67) experiments where relatively small test-objects are viewed at short distances (1 yard) for a period of one minute, accommodation changes might affect perception.

Changes in accommodation would also affect the pupil size, and Ditchburn and Steele (24) have pointed to the necessity for ensuring that subjects hold the fixation spot in dark-adaptation studies not only as regards the general direction of viewing, but also as regards focus. Accommodation changes could play a part not only during dark-adaptation but also during light-adaptation by

* Unpublished data of Granger provide evidence of a significantly smaller pupil size (light-adapted eye) in psychiatric patients than in normal subjects.

affecting pupil size, if any stimulus were present to induce accommodation. Under the light-adaptation conditions of most of the experiments reported above there is no obvious stimulus to accommodation except in the case of one of Granger's (39) experiments where variations in texture of the hemispherical "bleaching bowl" may have caused some subjects, in spite of instructions to the contrary, to accommodate from time to time, with consequent change in pupil size.

Unfortunately, little is known about anomalies of accommodation in psychiatric patients, although they have been observed by Granger (29) in another context. It is interesting to note than any excessive sympathetic activity occurring in anxiety would tend to affect the accommodation mechanism as well as the pupil size and reactivity. Relaxed accommodation in tests involving form discrimination (93) might interfere with clear perception of the test-object at photopic intensities. Spasm of accommodation has been reported in hysteria first by Charcot and Galezowsky (18) and since by Borel (13), Morax (83), Plantegna (92) and Shastid (109), often in association with convergence spasm and miosis. In this condition the tone of the ciliary muscle is increased and has been regarded as due to hyperactivity of the parasympathetic nervous system, although hypoactivity of the sympathetic may also enter as a determinant.

Motor disturbances in the form of oculo-motor imbalance which appear to occur more frequently among psychiatric patients than among normal subjects (36, 29) might play some part in tests involving binocular vision. In dim illumination where the stimulus to fusion is low it is possible that binocular vision may not be attained so that no binocular summation (71) occurs to lower the threshold. Alternatively, the chances of the eyes receiving sufficient light quanta to elicit a visual sensation would be reduced owing to reduction in area of the receptor surface (Pirenne (88)).

Finally, eye movements associated with fixation could affect threshold responses depending on whether the light stimulus fell on a more or on a less sensitive area of the retina. In addition, very precise fixation could actually result in impaired sensitivity in a subject in a test in which a test-object was presented for several seconds with good light sensitivity, but relatively poor form perception. Accurate fixation would mean that a patch of light of suprathreshold intensity continued to stimulate more or less the same retinal area for a matter of seconds. After a period of approximately 5–10 seconds the brightness of the light stimulus would tend to diminish and eventually disappear altogether owing to "local adaptation" (see, for instance, Pirenne *et al.* (91)).

3. *Perceptual Factors*

In addition to effects on the sensory and motor mechanisms of vision it is possible that effects may occur also at the "higher" perceptual level. The hypothesis should be considered that differences in "night vision" between normal and psychiatric groups are *entirely* due to factors involved in the process of attending to the stimulus and making threshold judgments under conditions of low illumination rather than to differences of a sensory or motor nature. Many writers (8, 20, 122) have stressed the importance of such factors although relatively little experimental work has been done to determine their precise significance.

In subjective researches on "night vision" a subject's attention has to be directed to the stimulus by means of instructions from the experimenter. He must be instructed on "how to look", what criteria to use in making judgments, to react immediately he sees the test-object, etc. Learning how to look for objects under conditions of low illumination is a skill that may be acquired more readily by some subjects than by others, and those who acquire it readily will in consequence tend to see the test-object sooner and have lower thresholds, because they are quickly able to locate the stimulus on the most sensitive retinal area. Such a skill may be of importance in tests allowing unrestricted viewing of the test-field such as have been used by Rees (93), Livingston and Bolton (67), Gravely (45) and Granger (38, 39).

In several of the above experiments some attempt has been made to instruct the subjects on the best viewing procedures but in no case was there any special period of training involved and it is conceivable that individual differences in threshold may simply be due to the fact that individuals were not all looking in the right direction at the right time. However, several considerations make it seem unlikely that such an hypothesis is a probable one. In the first place, under the stimulus of light the eye tends, to some extent, to adopt a position whereby the most sensitive region of the retina is stimulated. In the second place, admitting that a certain skill must be developed in viewing the test-object, there is no evidence outside the "night-vision" experiments to suggest that psychiatric patients will in general develop this skill less readily than normal subjects. Third, if learning were a significant factor in accounting for the differences between normals and patients it might be expected that after the first few judgments in the early stages of dark-adaptation the dark-adaptation curves of normals and neurotics would converge; such is not the case however. Fourth, if it were argued that psychiatric patients as a group do not pay attention to the task as well as normal subjects, it would be difficult to explain their immediate reactions to sudden changes deliberately introduced into the stimulus situation in one of Granger's (41) experiments to check the vigilance of the subjects. Further, it would be difficult to argue on the basis of clinical observations that certain types of patient, for instance hysterics, would tend to pay less attention than anxiety states and therefore have higher thresholds in tests of night vision, for in Rees's experiment hysterics tended to have lower thresholds.

Nevertheless, even though hypotheses such as those considered above seem unlikely to have much *general* application to psychiatric groups it is conceivable that apparent anomalies shown by certain patients may be due to lack of training in peripheral viewing and it may be significant that in an experiment in which, according to one of the authors,* much time was spent in giving information about the nature of dark-adaptation and the importance of peripheral viewing, differences between neurotics and normals were insignificant. Certainly, at least so far as peripheral acuity is concerned, training procedures have been shown to produce marked improvement (68, 69).

As regards the variation to be expected from the use of different subjective criteria of perception, Hunt and Palmer (54) have shown that this can amount to as much as 0·5 log unit. They investigated the various stages of perceptibility of test-objects following thirty minutes dark-adaptation and found a mean threshold of 3·3 log unit for "bright image with form" compared with a mean threshold of 2·8 log unit for a just perceptible light with form absent. It is quite possible therefore that part or all of the differences observed between normal and psychiatric groups is due to the use of different criteria by the two groups. However, it seems unlikely that such a factor could account for all the experimental results. If it were argued (e.g. in (20)) that anxiety has the effect of making patients hesitate and delay making a judgment on the basis of their initial impression of light, why is it that anxiety states behave essentially like

* Personal communication from Dr. M. Desai.

normal subjects in Granger's (41) study? And if it were argued that hysterics in view of their personality characteristics would tend to be impulsive and reckless in making judgments, responding very rapidly to the first impression of light rather than waiting to be sure, why did they show raised thresholds in Granger's study? In spite of its apparently limited application in accounting for experimental results this "criterion" hypothesis may nevertheless be applicable in certain cases and cannot be rejected out of hand at the present stage of experimentation.

Other factors that might have to be considered include reaction time and the "meaning" visual stimuli have for particular patients. Even if a subject adopts the correct subjective criterion in making a threshold judgment, his response time in reporting upon his sensation would enter as a factor in determining his threshold value. It has been demonstrated that the reaction times of psychotic patients tend to be longer than those of normal subjects under a number of different experimental conditions (36) and it is possible therefore that this may be a factor affecting threshold measurements in night vision tests.

The problem of "meaning" is a very complex one. It is mentioned because Janda (56) has suggested that anxiety may have the greatest influence upon perception when meaningful complex forms have to be identified. If this were so, it might be that in Rees's experiment the factor responsible for the inferior performances of anxiety states was associated with the meaningfulness of the stimuli. That, in other words, the significant feature of the task was that it demanded form *identification* rather than merely form *discrimination*. However, in spite of Janda's suggestion, it is still difficult to see precisely how such a factor would operate. Should "meaning" prove to be important in subsequent analysis it would seem that the services of a learning theorist might be needed here as well as in analysing the more general aspects of the "dark vision" situation (e.g. darkness serving as a conditioned stimulus to a fear response).

Discussion of the possible influence of meaning leads one to a consideration of the work of Klein (60), Frenkel-Brunswik (31) and others, on the effect of motivational factors in perception and to such concepts as that of "intolerance of ambiguity". According to Klein, individuals differ in their degree of tolerance of ambiguous perceptual situations. On this type of hypothesis it might be argued (see for instance (56)) that a test of "night vision" such as Rees used is an ambiguous situation in that the various stimulus shapes are only dimly seen and lack definite structure. In such a situation hysterics (who are supposed to repress anxiety) would *need* to impose a structure and remove ambiguity sooner than would anxiety states who could tolerate the ambiguity for a longer time. However, although such a "mechanism" might cause hysterics to respond sooner than anxiety states, there seems no reason why their responses should be more correct. Hypotheses of the Kleinian type have been given much prominence in the "personality via perception" movement and probably deserve some consideration, but it would seem necessary in all situations involving sensory factors to exclude their effects first before postulating differences at higher levels. While perceptual factors of the type discussed could operate independently of sensory and motor factors interaction is also possible. For instance, hesitancy in reporting upon the presence of light might in turn lead to a "local adaptation" effect resulting in further increase in the value of the threshold energy.

V. Implications for Further Research

It appears from the above discussion that psychiatric disorders may affect visual functioning at one or more of three different levels, sensory, motor and perceptual. All three types of factor probably enter as determinants of threshold responses in most of the studies reviewed, the relative involvement of the three types varying with different experimental conditions. Thus, perceptual factors seem likely to be more important in the Livingston Hexagon test than in Granger's (41) study of light thresholds.

To determine the relative importance of the three types of factor, future studies will have to be more analytical than some of those undertaken hitherto; in particular the psychometric studies need to be supplemented by psychophysical and psychophysiological experiments. This means that physical, physiological and psychological controls must be stricter if ambiguity is to be avoided in the interpretation of results. In this section a few general comments will be made concerning the implications for further research and type of experimental technique that seems to be demanded.

To prove the existence of physiological or psychological differences between normal subjects and psychiatric patients great care must be taken in the control and specification of physical variables in the stimulus situation, such as the previous level of light-adaptation, retinal area stimulated, duration, intensity and colour of stimulus object, etc. The importance of excluding variation due to physical factors cannot be too strongly emphasized at a time when there is a tendency to seize upon any observed variation between individuals as due to personality characteristics of a fairly permanent nature (e.g. the "personality via perception" approach (12)).

To prove the existence of sensory differences fairly lengthy periods of training may be necessary in order that the subject shall look in the right direction at the right time and in the right way. In other words, it may be necessary to make psychiatric patients as "sophisticated" as the observers used in psychophysical research on vision. It may also be necessary to use only certain psychophysical methods for obtaining threshold responses for Blackwell (11) has shown that some methods more than others allow processes other than "sensory excitation" to enter as determinants of threshold responses. Further, subjective techniques need supplementing by objective methods. It would be highly interesting, for instance, to compare the dark-adaptation curves obtained using sensory methods with those obtained using the electroretinogram (57, 58, 59, 94) or optokinetic nystagmus technique (17, 104) when these have been further developed.

To determine the significance of photochemical as contrasted with neural mechanisms Rushton's (101) optical technique could possibly be used, while the effect of extra-retinal factors could be determined by comparing dark-adaptation curves following binocular and monocular light-adaptation (6). Craik and Vernon's (19) "blinding" technique, previously referred to, although valuable for use with co-operative normal subjects could scarcely be applied to psychiatric patients.

In all studies more attention must be given to possible influence of drugs received as part of a patient's therapy. For instance, patients receiving insulin therapy may have elevated light thresholds due to insulin hypoglycaemia (77) rather than to psychiatric disorders as such. Little is known about the effect of barbiturates on dark-adaptation, but from what is known about their effects on related visual functions such as C.F.F. careful control of such drugs would seem to be demanded.

Assessment of effects due to motor mechanisms of the eye may be made by objective techniques. Pupil size and pupillary light reactions can be recorded in darkness using either flash photography or infra-red cine-photography.

Reasonably effective techniques have been developed for this purpose for use with trained observers although their application may prove somewhat difficult in the case of certain psychiatric patients. Elimination of effects due to pupil size can (in principle) be accomplished quite simply by placing an artificial pupil in front of the subject's eye or by using an optical system employing Maxwellian view. Here again, practical difficulties may arise in applying such techniques to psychiatric patients owing to the difficulty of centring the eye pupil relative to the apparatus. Should the recording of changes in accommodation during dark-adaptation become necessary Campbell's (16) technique would seem to be applicable. Campbell has determined accommodation changes by photographing the third Purkinje-Sanson image formed by reflection from the anterior surface of the lens; the size of this image depends on the radius of curvature and hence on the state of accommodation of the eye. For the recording of eye movements sensitive techniques are available (95) that could be adapted to the requirements of dark-adaptation experiments. Of particular interest would be the measurement of eye movements during fixation.

The influence of perceptual factors could be determined by a process of elimination of sensory and motor factors along the lines suggested above, although in order to distinguish between different types of perceptual factor it would be necessary to devise special experiments. The effect of "meaning" could for instance be investigated by comparing the effects of abstract stimuli with "meaningful" stimuli of the same visual acuity value.

As regards the type of experimental design required for further experimentation, the factorial type of experiment would seem to be necessary to determine under given experimental conditions the relative importance of different types of factor and interactions between them. In certain cases, however, the traditional psychophysical type of experiment would seem to be necessary for the detailed analysis of the effects of a single factor. As regards the analysis of experimental data, as these would take the form of adaptation *curves* rather than single "scores", methods of curve fitting would seem to be demanded. Hammond and Lee (47) have developed a useful technique for the treatment of data in individual dark-adaptation curves which depends on fitting an equation to the "rod" portion of the curve (obtained using the Hecht-Shlaer procedure).

Analytical studies of the type suggested could be undertaken with various psychiatric groups or with individual patients. Choice between the two approaches could be made only in the light of experimental results. Where evidence indicates that certain psychiatric categories show a fair amount of homogeneity in their visual reactions it would seem profitable to study the group as a whole. In other instances the study of sub-groups or particular individuals may be more appropriate. Intensive studies of relatively few individuals would seem to be the only practical possibility if experimental controls are to be rigorous. In this case the pattern of experimentation would follow that of visual psychophysics in which for the most part detailed measurements are made on only one or two observers. Such studies seem likely to prove more valuable in eliciting psychophysiological mechanisms than more cursory surveys of larger groups, although large-scale surveys may have their place in further psychometric development of a given "test".

As regards the most appropriate starting-point for further research, choice must depend largely on the viewpoint of the investigator and the writer can only indicate his own proposals. In his view, one of the most interesting problems raised by previous research is that of the possible differential effects of anxiety and hysteria on the light and form thresholds. Attacks could be made on this problem from several angles. Thus, recovery curves of hysterics following light-adaptation would be expected to differ in certain features (see earlier discussion) from those of normal subjects and anxiety states. Differences in integrative ability could be determined using test-fields of different sizes and calculating an index of integration (3) from the threshold differences between smaller and larger fields, while comparison of thresholds for simple light stimuli with those for complex forms of varying acuity values would provide information on the postulated differences between anxiety states and hysterics. Studies of this type could be supplemented by studies attempting to produce differential effects on light and form sensitivity by means of drugs similar to those produced by psychiatric disorders.

Before proceeding very far with such studies it would, however, be necessary to determine more precisely the position of anxiety states' dark-adaptation curves relative to those of normal subjects. It may be that it is only toward the final (rod) threshold that anxiety states differ from normal; the initial portion of their dark adaptation curves may follow the normal course. What is required initially here as elsewhere in this area of research are studies designed to specify more precisely the nature and extent of differences between psychiatric patients and normal subjects in terms of properties of the dark-adaptation curve such as initial threshold following light-adaptation, slope of both the cone and rod portions of the curve, cone-rod transition time and final threshold attained after a long stay in darkness. The results of such studies will almost certainly indicate the need for radical revision or rejection of some of the hypotheses suggested earlier in this paper to account for the experimental results so far obtained.

The future course and final outcome of experimentation in this relatively new field of research are impossible to predict but from the evidence reviewed here and from studies of critical flicker frequency (110a) and other visual functions (29) it seems likely that visual thresholds may prove valuable indicators of physiological imbalance occurring in psychiatric disorders. Compared with other possible measures visual thresholds have several features to commend them, as McFarland (76a) has pointed out. In the first place they appear to be particularly sensitive to stress conditions (for instance, changes in visual thresholds are among the first to appear in anoxia); second, the physical measurements involved can be made with considerable precision and data lend themselves to precise quantitative treatment; third, the control of experiments is simplified by the fact that the subject is unaware of changes in his sensitivity. "He does not know what changes in the physical intensity of the stimulus are necessary in order for him to see it, since at his threshold the stimulus always has the same appearance" (76a, p. 328). Temporary masking of impairment by exerting extra effort is impossible.

From the psychophysiological point of view the fact that the peripheral sense receptor in the case of vision is not only a sense organ in the strict sense of that term but is also part of the central nervous system gives to the investigation of visual dysfunctioning a possibly wider significance than merely that of studying disorders of a special sense. Investigations of visual thresholds become an avenue of approach to the central nervous system and its dysfunctions.

Although it is probably from this point of view that investigations of visual anomalies in psychiatric patients will chiefly be regarded, one should not overlook the fact that visual functions in which changes in the photochemical system of the retina play a significant role (e.g. the recovery of sensitivity in the dark following exposure to high intensities of illumination) may also serve as indices of physiological imbalance. Disturbances of the gastro-intestinal tract, hepatic and circulatory disorders reported to occur in various psychiatric illnesses (2a) can affect the value of the threshold energy and the course of dark-adaptation by interfering with the absorption and storage of vitamin A. Associated with some of these and other physiological dysfunctions occurring in emotional disorders is the autonomic nervous system and here again the eye serves as a valuable indicator of autonomic activity either directly via the effector mechanisms controlling pupillary reactions and accommodation or indirectly through possible effects on the sensory mechanisms of vision.

The many possible avenues through which various types of physiological imbalance may be reflected in visual and ocular terms perhaps helps to explain why anomalies have been observed in so many different groups of psychiatric patients, showing marked heterogeneity of symptoms. This sensitivity of visual and ocular functions to dysfunctions occurring in a number of different bodily systems although in certain respects an advantage (e.g. in larger-scale psychiatric screening procedures) presents difficulties when interpreting results obtained from psychiatric groups for disorders of dark-adaptation, critical flicker frequency, etc., are not specifically related to any particular stress or abnormal condition. Depression of sensitivity may have a variety of causes and it seems probable that many of the causes operating to produce reduced sensitivity in psychiatric patients are the same factors that produce lowered sensitivity in organic diseases, such as cardiovascular, metabolic, hepatic diseases, etc. In view of this it seems necessary if we are to understand the mechanisms underlying the effects of psychiatric disorders on vision to consider their effects in relation to those of other pathological conditions.

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