PUPILLARY REACTIONS TO LIGHT IN SCHIZOPHRENIC
PATIENTS AND NORMALS

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In the literature on psychopathology one finds numerous references to abnormalities in the pupillary reactions of patients of all diagnostic categories. Bumke in 1904 and Bach in 1908 summarized the pupillary studies of mentally ill patients which had appeared up to that time. It appears from these two reviews that there was no consensus as to the type of pupillary abnormalities which were present in psychiatric patients. Often contradictory observations were reported for a particular diagnostic category. Both unusually small and large pupils were reported for schizophrenic patients. Bumke tried to relate specific pupillary abnormalities which were present at the beginning of the illness to the eventual outcome of the psychosis. He proposed that the absence of pupillary dilation to painful stimuli in the early stages of the illness would be indicative of poor prognosis. Unfortunately, there are no longitudinal studies to verify this statement. In 1907, Westphal described a pupillary abnormality he had observed in catatonic schizophrenics. In these patients the reactivity of the pupil to light stimuli varied from moment to moment — at one moment the reaction might be prompt and extensive, at another there might be absolute rigidity. He called this symptom the "catatonic pupil" or "spasmus mobilis." Levine and Schilder in 1942 reported similar findings. An extensive study of the pupillary reactions of schizophrenic patients to a number of sensory and conceptual stimuli was performed by Lowenstein and Westphal in 1933. The authors compared the pupillary reactions of these patients with the reactions of normals and found greater variability within the patient group. They were able to distinguish four types of pupillary contractions and dilations in response to the onset and cessation of a light stimulus. One of these is more frequently found in patients and consists of a sluggish contraction in response to light and a slow redilation after cessation of the stimulus.

The pupil is a muscular organ which is innervated by both divisions of the autonomic nervous system (sympathetic and parasympathetic), and its diameter at any moment in time is the resultant of the relative excitation of these two components. The contraction to light may be considered the parasympathetic component which acts in opposition to two sources of sympathetic control of pupillary di-

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lation. One of these is the excitation of the dilator muscle via the cervical sympathetic chain and the second is the tonic inhibition of the contractor muscle via the Westphal Edinger nucleus. The tonic inhibition is under the control of the hypothalamus and descending reticular formation and is referred to as supranuclear or central sympathetic inhibition.

The observations of deviant reactions in psychiatric patients as well as the consideration of the nervous pathways controlling pupillary diameter indicate the usefulness of further study of the pupillary reaction in schizophrenic patients. Another reason for the use of pupillary reactions as an indicator of autonomic reactivity in psychotic patients is the fact that instruments have been available to obtain objective recordings of pupillary diameter. Lowenstein (1956) is mainly responsible for the development of methods which allow the recording of pupillary diameter in complete darkness and with a minimum of error.

The experimental group consisted of 37 acute and 41 chronic schizophrenic patients. The 22 normal controls were psychologists, graduate students, nurses and hospital employees. Table 1 gives the distribution of subjects by sex and age.

**Table 1**

**Subjects in Sample by Diagnostic Group, Sex, and Mean Age**

<table>
<thead>
<tr>
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<th>Normals</th>
<th>Acutes</th>
<th>Chronics</th>
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<tr>
<td>Male</td>
<td>13 25</td>
<td>16 27</td>
<td>27 29</td>
<td>56 28</td>
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<tr>
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<td>44 29</td>
</tr>
<tr>
<td>Total</td>
<td>22 26</td>
<td>37 28</td>
<td>41 30</td>
<td>100 28</td>
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Since the pupillary reaction changes with age (Kumnik, 1956), we limited our groups to the age range between 18 and 37. The acute patients were first admissions to Brooklyn State Hospital and had a history of recent onset of the psychosis. The chronic patients had been in the hospital for at least five years without interruption. In order to decrease the heterogeneity of the patient groups, only patients who manifested auditory hallucinations or who produced delusional material during an interview immediately before testing were selected. None of the patients had been given tranquilizing
drugs or somatic treatment in the two weeks preceding the experimental session, and none had any known neurological or ophthalmological disorder.

The recording apparatus consisted of a 35 mm. motion picture camera which was driven by a synchronous motor at a speed of 10 frames per second. A double-lens system (Wollensak f. 4.5 Fl 101 mm.) was used to photograph each eye separately, thus permitting more effective use of the exposed film area. Kodak infrared sensitive film (421 H-IF) was used and condenser lamps with General Electric bulbs (6.5 V.) served as photographic light sources. A Kodak Wratten 88A filter which passes only wavelengths above 720 m\textmu; was mounted in front of each lamp. The emitted light was visible to the subject as two dark red spots if looked at directly. The infrared light was directed on the eye from below at an angle of 45 degrees.

A stimulus light source was mounted on the camera and a collimated beam directed on the subject’s left or right eye. At the level of the cornea, the light patch was 10 mm. in diameter and 15 ft. candle in intensity. A coupled episcotister controlled the duration of the light and dark periods.

The subject was seated in a comfortable chair which could be adjusted for height. Fixed position of the head was maintained by a dentist-type head rest and a chin rest. A pinpoint beam of light was directed on the subject’s forehead on which a small black dot had been painted. By this device the position of the subject relative to the camera and to the stimulus was monitored and controlled.

The subject was dark-adapted for 10 minutes and then presented with a series of eight cycles of one second of light followed by three seconds of darkness. This is the sequence used by Lowenstein in his numerous experiments, and this procedure was adapted in order to permit comparison with his work. First the right eye was stimulated and then, after a new dark adaptation period, the left eye was stimulated. Both eyes were always photographed. Since we did not find an inequality of pupillary size (anisocoria) in any of our subjects, we considered only the measurement obtained from the right pupil. The film was processed and the pupillograms recorded by a method described by Lowenstein (1956).

Results

An inspection of the obtained pupillograms revealed large variability within each subject’s record and across subjects in all three groups. In figure 1, parts of such records are shown for illustration. The three subjects whose records are shown were those indi-
individuals whose average pupillary diameter between light flashes was at the median of their group. The first reaction after dark adaptation, the fourth reaction, and the seventh reaction are presented. As may

**FIGURE 1.** Sample reactions to light of one normal, one acute, and one chronic schizophrenic patients. The first, fourth, and seventh reactions of a series of eight reactions are presented. Light is present only during the first second of each cycle. Light is presented to the right eye and the measurements shown are for the right pupil.
be seen, the normal subject has a larger pupil and a slower rate of contraction than either patient. The patients show a slower recovery after cessation of light. No clear differences emerge between the three subjects in their reaction to the sequential light stimulation. Because of the large variation in pupillary reactions within and between subjects, an attempt to compare groups on each reaction did not appear to be a fruitful procedure. Therefore, several aspects of the pupillary curves were selected, and averages were obtained across all 16 reactions for each subject on these measures only.

The measures used were selected because of their theoretical importance as indicators of the balance between sympathetic and parasympathetic activity and reactivity.

The following indices were used:

- Initial diameter: the size of the pupil at the moment the light stimulus is presented.
- Extent of contraction: the difference between diameter at stimulus onset and point of maximal contraction.
- Time of contraction: the time it takes the pupil to reach its point of maximal contraction.
- Peak speed: the maximal decrease in pupillary diameter achieved in any tenth of a second during the contraction phase.
- Flatness of curve: the time the pupil remains at maximal contraction. This is obtained by measuring the length of time during which the pupillary diameter remains within 0.1mm. of its size at maximal contraction.

**Figure 2** summarizes the findings for three groups on initial diameter. The median of each group is indicated by the crossbar, and the arrow shows the position of the mean so that comparison provides an estimate of skewness. The height of the vertical bar gives the distance between the 25th and 75th centiles. It may be seen that the variability is largest for the acute patients. Each group was compared with every other group by Mann-Whitney U tests. Significance levels of the comparisons are shown in the figure. There is no difference between the normal controls and the chronic patients, while the acute patients have a smaller initial diameter than either the normals \((p<0.002)\) or the chronic patients \((<0.05)\). Figure 3 shows the same measures for extent of contraction and Figure 4 shows the measures for peak speed. No differences between groups are present. On peak speed, but not on extent of contraction, the acute patients again show the largest variability.
FIGURE 2. Average initial diameter for 16 reactions. Initial diameter is defined as the size of the pupil at the moment the light stimulus is presented.

FIGURE 3 Average extent of contraction for 16 reactions. Extent of contraction is defined as the difference between diameter at stimulus onset and point of maximal contraction.
FIGURE 4. Average peak speed for 16 reactions. Peak speed is defined as the maximal decrease in pupillary diameter achieved in any tenth of a second.

FIGURE 5 shows the data for the flatness measure. This is the length of time that the pupil remained within 0.1 mm of its smallest diameter before redilating in response to the cessation of light. Inspection of the figure indicates that normals seem to redilate earlier after having reached the point of maximal contraction. However, none of the group differences reach significance.

The range of the measurements for time of contraction, i.e., the time elapsed from onset of stimulus until the pupil reaches its smallest diameter, was rather small (0.8-1.3 sec.), and the unit of measurement was a tenth of a second. The data are, therefore, presented in the form of a bar graph (FIGURE 6). This graph shows the percentage of individuals in each of the three groups at any one of the six discreet measurements between 0.8 and 1.3 seconds. It is apparent from this figure that the normals take longer to reach maximal contraction. The Mann-Whitney test shows significant differences between normals and acutes ($p < 0.0005$) and between normals and chronics ($p < 0.001$), while the patient groups do not differ from each other.

In summary then, the acute patients have a smaller initial diameter and reach the point of maximum contraction earlier than the normals (time of contraction). The chronic patients have the same initial diameter as the normals and therefore they also show a significantly larger initial diameter than the acute patients. On the time of contraction measure, the chronic patients are similar to the acute patients and therefore show a more rapid contraction than the
Figure 5. Average flatness of curve for 16 reactions. Flatness of curve is defined as the time in seconds the pupil remains within 0.1mm of maximal contraction.

Figure 6. Distribution of the average time of contraction for 16 reactions. Time of contraction is the time it takes the pupil to reach its point of maximal contraction.
normals. There are no differences between groups on any of the other measures.

Since the extent of contraction does not discriminate between groups, while the time at which minimum diameter is reached is shorter in the patient groups, one would expect that there should be a difference between patients and normals on the peak-speed measure. However, no such difference was found. This seems to be due to the fact that the speed of contraction is biphasic. The initial speed of contraction seems to be the same in both groups but the speed decreases more slowly and the contraction ends later in the normals.

The average initial diameter, as used above, is a complicated measure, since for the first of the series of eight reactions the initial diameter represents the dark-adapted diameter while for subsequent reactions it reflects the ability of the pupil to redilate during the three-second dark period between stimuli. Therefore, each of the 16 reactions were analyzed separately. The results showed that the relative position of the three groups was the same whether one considered the dark-adapted initial diameter or whether one considered the initial diameter at the beginning of each light-dark cycle.

The average initial diameter would also mask any differences between groups in the degree of fatigue, i.e., in the ability of the pupil to recover from repetitive light stimulation. The data were, therefore, analyzed from this point of view. No differences between groups were found.

Correlations (rank order) were computed between initial diameter and each of the other measures. The values were as follows: with time of contraction 0.37 ($p < 0.01$), with extent of contraction 0.27 ($p < 0.01$), with flatness $-0.25$ ($p < 0.05$), and with peak speed 0.24 ($p < 0.05$). Of course, the correlation between initial diameter and point of maximum contraction is very high, rho = 0.85 ($p < 0.01$). Except for the point of maximum contraction the correlations are low and therefore, initial diameter only determines part of the variance on the other measures.

**Discussion**

The results of this study can be interpreted by viewing the differences between the groups on the basis of prevailing knowledge of the pupillary reflex arc. Lowenstein and Loewenfeld (1950) have related the dynamic and static behavior of the pupil to specific centers and pathways of the nervous system. Based on their scheme, it would appear that acute patients show a deficiency in the inhib-
itory control of the Westphal Edinger nucleus by higher centers. This is expressed both in the significantly smaller initial diameter, as well as in the shorter time of contraction for the acute patients. Since there are no differences in extent of contraction or in peak speed between groups, it must be assumed that a high contraction speed persisted for a longer time in the patients and was not reduced by inhibitory elements acting on the Westphal-Edinger nucleus. Another indicator of deficient inhibition of the Westphal-Edinger nucleus would be a higher score on the flatness measure, i.e., the pupil would be expected to remain at its contracted diameter for a longer period of time in patients than in normals. By inspection of the records, it was observed that this persistence at the contracted diameter occurred in many single reactions in a number of patients, but was rarely present in normals (see FIGURE 1). After the averaging, the statistical analysis showed no difference between the three groups. (In a comparison between normals and all patients the differences did, in fact, approach significance.)

It is interesting to note that in the static measure of initial diameter chronic patients behave like the normals, while in their reaction to light (time of contraction), i.e., in a dynamic measure, they behave like the acute patients. Apparently, it is necessary to load the pupillary system and measure its dynamic action to observe a difference in the pupillary reactions of chronic patients and normals.

Lowenstein and Westphal (1933) have described a pupillary reaction type which is characterized by small initial diameter, fast contraction, and a prolonged stay of the pupil at its smallest diameter. They called this type of pupillary reaction, tonohaptic, and reported finding it in several catatonic patients. In clinical neurology, this type of reaction has been found in patients with lesions or disorders of the basal ganglia. It can be experimentally produced in animals by cutting the fibers from higher centers descending to the Westphal-Edinger nucleus. Except for the inconclusive findings on flatness, the present data are consistent with Lowenstein’s description of the tonohaptic curve. In the present study, diagnosis of the schizophrenic sample on the basis of sub-categories such as catatonia was not available and it was, therefore, not possible to make a direct check on Lowenstein and Westphal’s observation.

Lowenstein and Westphal also reported that they found a high frequency of their Type-IV response in the patient group. This type of pupillary reaction consists of a slow and inextensive contraction and a slow dilation. In the present study, such a trend was not discernible. We tend, however, to confirm Lowenstein and Westphal’s
statement that there is greater intrasubject as well as intersubject variability in the patient group.

A series of control experiments are necessary before a hypothesis of reduced inhibition of the Westphal-Edinger nucleus in schizophrenic patients can be accepted. For example, although reasoning from animal experiments would suggest that the sympathetic deficiency found in patients is a deficiency of central rather than peripheral origin, direct experimentation with stimuli mediated by the peripheral sympathetic system would be desirable.

Rubin (1962) has recently used pupillary measurements to explore the hypothesis that a disturbance in adrenergic-cholinergic reactivity to stress may be present in the functional psychoses. He used the reaction pattern of his normal controls as his criterion and found that his patients showed excess, as well as deficiencies, in his contraction and dilation indicators. However, it is not clear to the present writers in what way Rubin's findings are different from the general observation of greater variability among patients.

Summary

The pupillary reactions to light were studied in 37 acute and 41 chronic schizophrenic patients and compared with those of 22 normal controls. Several aspects of the pupillary reaction curves were selected as indicators of the balance between sympathetic and parasympathetic activity and reactivity. The three groups were compared on these measures, and significant differences between groups in initial diameter and in the time the pupil took to reach maximal contraction were found. The data were interpreted on the basis of Lorenstein's analysis of the neural centers and pathways controlling the pupillary mechanism.

It appears that the patient groups show a deficiency in the inhibitory functions acting on the Westphal-Edinger nucleus. This deficiency seems to be more manifest in the acute patients who show a smaller initial diameter and more rapid time of contraction than the controls. The chronic patients do not differ from the normal controls in the static measure (initial diameter) but react like the acute patients on the dynamic measure (time of contraction). Further experiments are necessary to validate the observations made here and to elucidate the exact nature of the differences in the pupillary reactions of schizophrenic patients and normal controls.

The present data is in agreement with studies by other authors in showing greater intra- and inter-subject variability in the patient group.
References