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Eye Movement Research with Schizophrenic Patients and Normal Controls Using Corneal Reflection-Pupil Center Measurement

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Summary. The eye movements of 20 partially remitted outpatient schizophrenics (ICD 9), for the most part receiving neuroleptic maintenance medication, and 20 normal controls were recorded using corneal reflection-pupil center measurement. Performance was investigated on the basis of widely varied measurement parameters during a fixation task and a visual search task (list of letters). Psychopathological data were additionally recorded for the group of patients by means of self and observer ratings, current social adjustment, and neuroleptic dosage. The schizophrenic patients showed the tendency to perform more poorly than the normal controls in the eye movement parameters recorded, and there was marked variation in performance within the group of schizophrenic patients. In particular, various abnormalities in fixation performance were connected differentially with individual psychopathological syndromes and neuroleptic dosage. Connections between fixation performance and search performance were found only within the group of patients. They are interpreted as an indicator of disturbed interhemispheric coordination in schizophrenics. Based upon specific pupillary findings one concludes that the processing load imposed on the attentional system by the search task is different for various schizophrenic subgroups.

Key words: Schizophrenia – Eye movements – Normals – Fixation task – visual search task

Introduction

Motor abnormalities are frequently observed in schizophrenic patients, e.g., Manschreck and Ames (1984) reported, that 60% of the schizophrenic patients they examined showed disturbances in the area of voluntary motor behavior as compared with only 9.5% of the patients with affective disorders. Men were affected by these kinds of disturbances more frequently than women. Moreover, a clear connection was found between motor disturbances and the extent of disturbed thinking. Besides motor abnormalities of the extremities one also finds indications of unusual features, particularly in oculomotor behavior. Stevens (1978) observed various abnormalities such as staring, eye-head synkinesia, episodic unexplained lateral glances and spontaneous lateral saccades, among other things, in almost 80% of the schizophrenics not on medication whom she examined. Until the present time disturbances in the smooth pursuit eye movements have been studied the most comprehensively (Lipton et al. 1983). Within the context of such studies attention has repeatedly been drawn to the inability of schizophrenic patients to hold steady fixation (Mialet and Pichot 1981; Schmid-Burgk et al. 1982; Mather and Putchat 1982/83).

If we assume, as von Weizsäcker did (1973), that perception and movement cannot be conceived of as independent from one another but rather as constituting a "biological act" then one can postulate that oculomotor disturbances lead to altered visual perception or are themselves an expression of altered visual attentional performance. Visual perception is based upon an attention-dependent integration of foveal and extrafoveal stimuli. It additionally presupposes to an extraordinary degree the adequate use of eye movements (Haber and Hershenson 1980). Thus, either more preattentive processes operating parallel to each other or more focal attentional processes operating serially involving more search movements are used during a visual search task depending on the local stimulus conditions (Neisser 1974).

Disturbed attentional functioning is considered to be the common denominator of widely differing cognitive deficits found in schizophrenics and detectable by experimental psychological means. In a psychophysiological theory of schizophrenia, Venables (1964) differentiated process stages with broadened attention from those with narrowed attention and attributed the former to acute schizophrenic patients and the latter to chronic schizophrenic patients. Agreeing with Venables' ideas concerning visual perception, Cegalis et al. (1977) were able to show that acute schizophrenics are capable of parallel processing over a larger visual field than are normal controls. The reverse is the case for chronic schizophrenics. Using Neisser's search paradigm (searching in a list of letters) with high-risk children of schizophrenic parents, Winters et al. (1981) were able to show that this group exhibited significantly longer search times than children of normal parents. However, in this study no information was provided as to whether differences occurred which were dependent upon the similarity between target and distractor letters. Therefore, the question concerning the disturbed functioning of preattentive or focal attention remained open. Such a differentiation would,

Offprint requests to: W. Gaebel at the above address however, also have locational implications, if one assumes that the method of functioning of the right hemisphere is connected more with parallel processing and sustained attention, and that of the left hemisphere with selective attention and sequential processing (Dimond and Beaumont 1973; Dimond 1979). Nevertheless, the results reached by Winters et al. (1981) showed that attentional processes employed within the context of search tasks are possibly dispositionally disturbed.

In the present study, which is part of a larger research project concerning the analysis of eye movements of schizophrenic patients, we investigated the question whether schizophrenics can be differentiated from normal controls with regard to their performance of a fixation task and a visual search task. In particular, we examined whether relationships exist between fixation performance and search performance in the two groups. We also investigated specifically for the group of patients the extent to which measurement parameters of the two tasks are related to the psychopathology in self and observer ratings and to the neuroleptic dosage. Recorded pupillary data were also taken into consideration in these comparisons.

Sample and Methodology

The sample of patients consisted of 20 schizophrenics from the special outpatient clinic of the Psychiatric Clinic and Policlinic of the Free University of Berlin. Those involved were 11 women and 9 men, with a mean age of 36.9 (19–63) years. With a mean age of 41.2 years the women were significantly older ($P = 0.05$) than the men (31.8 years).

The diagnostic classification (ICD 9) was as follows: 295.2 ($n = 3$), 295.3 ($n = 9$), 295.6 ($n = 4$), 295.7 ($n = 3$), 297.0 ($n = 1$). For 70% of the patients there was at least a 5-year history of illness, and all but 3 patients received neuroleptics. The mean daily dose was 228.8 ± 181.5 mg of chlorpromazine (CPZ) equivalents.

The control group included 20 healthy controls from the medical/technical personnel of the clinic, 15 were women and 5 men. The mean age of 34.7 (21–51) years was not significantly different from that of the group of patients. There were also no significant sex-related age differences in the control group (women: 34.0 years, men: 37.0 years).

The psychopathological data were documented by one of us (W.G.) on the day of the experimental study. The Brief Psychiatric Rating Scale (BPRS) developed by Overall and Gorham (1962; Overall 1976) served as the study instrument. The Clinical Global Impression Scale (CGI) (in: CIPS 1977) was used to record the degree of severity of the illness and the Global Assessment Scale (GAS) developed by Endicott et al. (1976) to record psychosocial adjustment. At the same time the patient filled out the Frankfurt Complaint Questionnaire (FBF) to subjectively record uncharacteristic "basic" symptoms (Süllwold 1977).

The eye movements were recorded in accordance with the corneal reflection-pupil center measurement (Young and Sheena 1975).

With this technique reflections produced on the eye with the aid of an infrared light source are recorded by a video camera. The respective gaze direction is derived from the different spatial location of pupillary and corneal reflections. The reference system of all gaze measurement trials is a person-specific table of correction, which was interpolated for each test person from three measurement repetitions against a given fixation screen (20 light diodes). The x- and y-coordinates of each gaze position are determined every 20 ms on the basis of this table of correction, and are stored for further calculation. The system's measurement precision is stated as 0.5° (System DEBIC 80).

All of the test persons had normal vision. Heterophoria had been excluded beforehand. All gaze measurements were performed on the right eye.

In the experimental study situation the subjects sat opposite a screen measuring 95.7 × 75.6 cm. The distance between their eyes and the screen was 2.27 m. Their heads were held lightly in place by lateral supports. The first task consisted of a 1-min binocular fixation on a point of light 5 min in diameter projected in the center of the otherwise dark screen in a largely darkened room.

Patients and controls had been instructed by the experimenter in advance to focus their eyes on the point but to keep them closed until the projection was started. The subject was alone in the room during the test. At the command "open your eyes" the point of light was projected onto the screen from a slide projector, and the test phase recording the eye movements began. This procedure was stopped automatically after 1 min.

After a tracking task to be completed in the meantime, a list of letters was projected in a second stage of the test. The list had 285 letters in all with 15 lines horizontal and 19 columns vertically.

The list was made up only of letters with a rounded shape except for the targeted angular "Z" hidden in the list (Fig. 1). The test persons had been instructed to use their eyes to search for this "Z" as soon as the projected list of letters appeared. Here too their eyes had been closed beforehand and the list was projected upon the command to "open your eyes". The subjects were instructed to close their eyes immediately upon finding the "Z". The measurement process recording the eye movements was then discontinued. Afterwards the experimenter made certain the "Z" actually had been found by asking and pointing.

The following factors were defined as the eye movement parameters:

a) Fixation Task. The mean individual pupil diameter over the entire measurement period and the individual standard deviation as an expression of the pupil variability (in units). Ac-

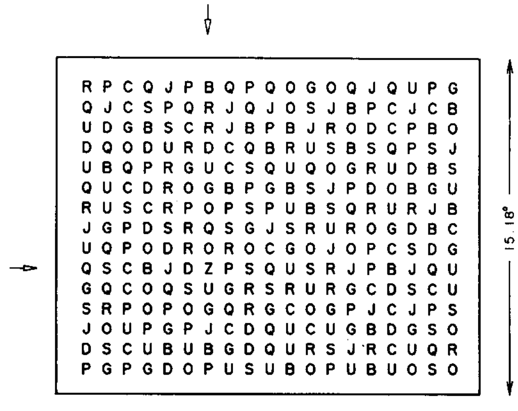


Fig. 1. List of letters (→ position of hidden "Z")

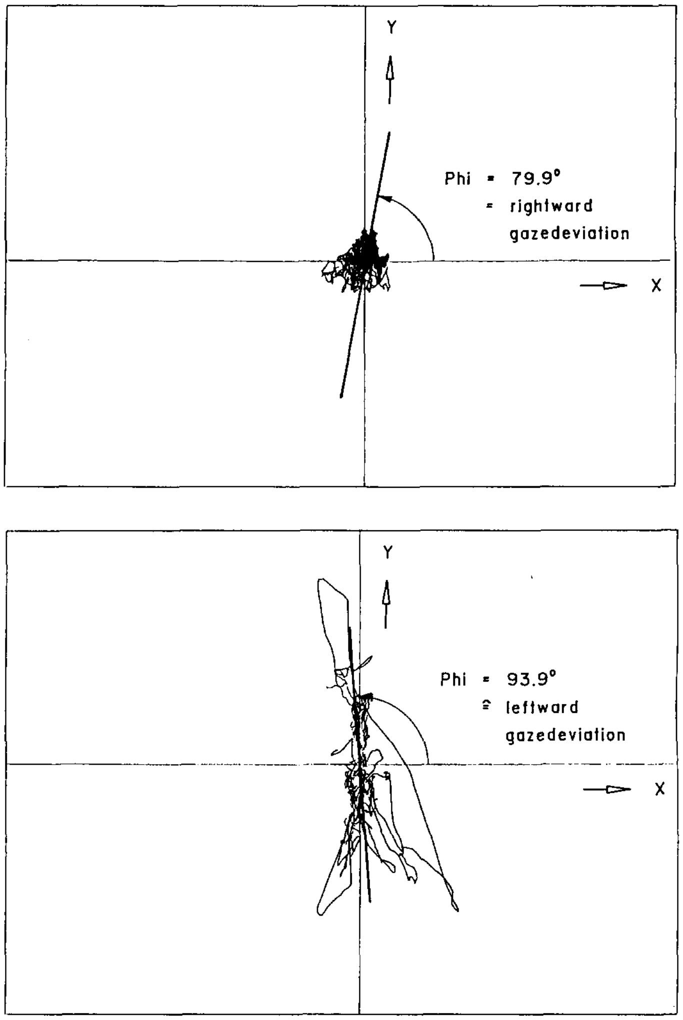


Fig. 2. Simultaneous presentation of successive gaze positions during fixation with PCA-derived lateral gaze deviation. (phi < 90° ≙ rightward, phi > 90° ≙leftward gaze deviation)

cording to the definition of a fixation of at least 5 consecutive gaze positions (100 ms) within a fixation window of 2° and 4° diameter respectively (see Kliegl and Olson 1981 concerning the procedure), the following factors were determined: fixation latency (s) from the start of the point projection until a defined window was focused upon for the first time; fixation frequency (≧100 ms) in a defined window; mean fixation duration (≧ms) in a defined window (ms); total fixation duration in a defined window (s). Moreover, all of the successive positions of the visual axis (Ditchburn 1973) were graphically represented in an orthogonal coordinate system (with the fixation point in the center) forming a cluster, which was subjected to a principal component analysis. The resulting main direction of visual axis was marked by an angle "phi". Corresponding examples are represented in Fig. 2.

The origination of axis deviation from the verticals can be interpreted as follows. More gaze positions are measured either to the left or to the right of the verticals, whereby the main vector is twisted out of the sagittal plane. We interpreted the angle phi as the lateralization measurement in the sense that an angle phi < 90° corresponded to a rightward gaze deviation and an angle phi > 90° to a leftward gaze deviation.

In addition, the time-dependent horizontal (x-axis) and vertical (y-axis) gaze positions were subjected to a regression analysis, and linear trends (left-to-right drift and vice-versa, up-down drift and vice-versa) were expressed using linear regression coefficients. Corresponding examples are found in Fig. 3.

b) Search Task. The measurement factors recorded here were search time (s), total length of search route (units) and search speed (search route/search speed). Figure 4 shows the graphic representation of various search strategies.

Also included in this measurement were recordings of the mean individual pupil size and individual standard deviation.

Due to losses in measured values (eyelid covered the pupil) blinks were automatically excluded from further calculations for all of the measurements.

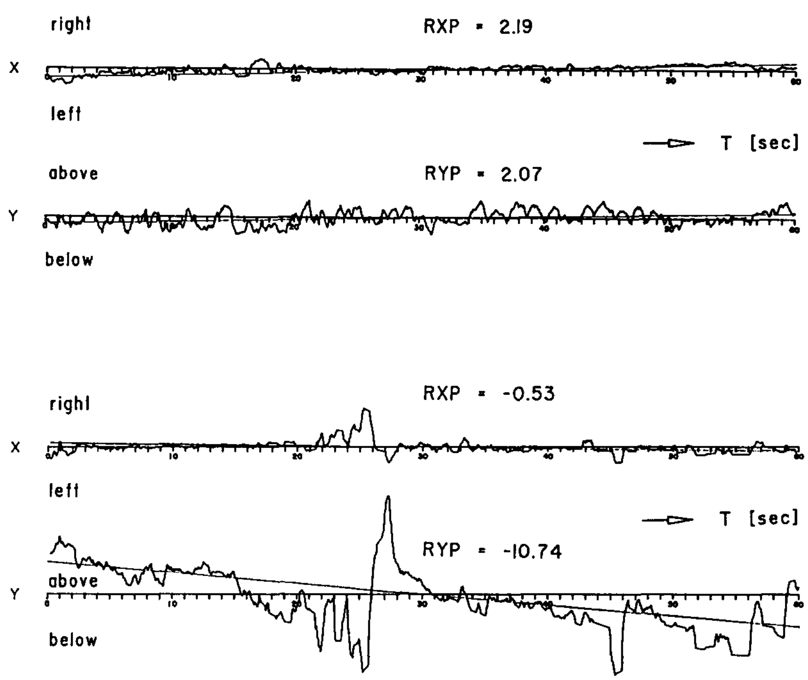


Fig. 3. Gaze drift along the orthogonal coordinates during fixation (RXP ≙ horizontal gaze drift, RYP ≙ vertical gaze drift)

a)

b)

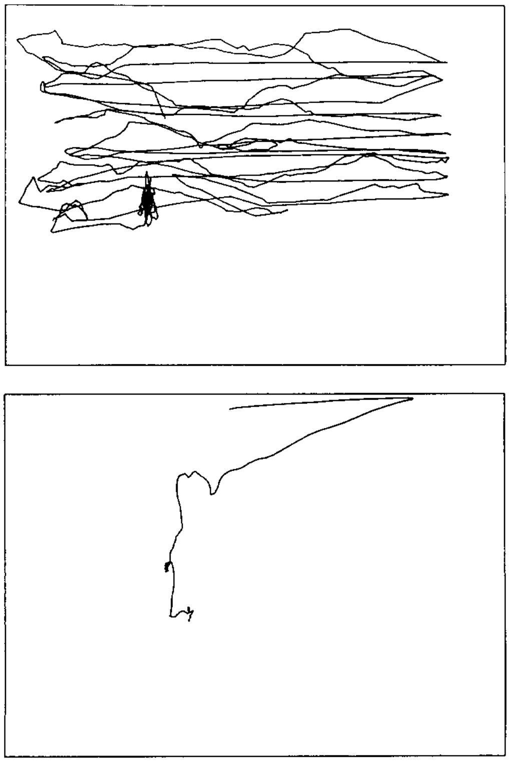


Fig. 4. Two examples of different search strategies (schizophrenics) **a** serial; **b** parallel

Table 1. Comparisons of means (± SD) of eye movement parameters of schizophrenic patients and normal controls (*t*-tests)

	Schizophrenics ($n = 20$)	Controls ($n = 20$)	*t*-test (P)
Pupil diameter (P1) (fixation)	110.8 ± 25.6	124.4 ± 19.5	0.066
Variability SD-P1	4.2 ± 2.0	4.1 ± 1.9	NS
Pupil diameter (P2) (search)	101.1 ± 25.6	109.4 ± 17.9	NS
Variability SD-P2	5.7 ± 2.1	6.6 ± 1.9	NS
Regression coefficient			
horizontal (RXP)[a]	0.05 ± 1.10	0.28 ± 0.76	NS
vertical (RYP)[b]	−0.03 ± 3.70	0.51 ± 1.73	NS
Phi (°)	88.0 ± 11.3	89.7 ± 2.8	NS
Fixation (4°)			
Frequency	64.8 ± 30.6	69.7 ± 31.4	NS
Total duration (s)	11.0 ± 6.2	12.9 ± 8.2	NS
Mean duration (ms)	162.0 ± 23.1	170.5 ± 39.9	NS
Latency (s)	3.0 ± 3.9	3.7 ± 3.9	NS
Fixation (2°)			
Frequency	6.8 ± 6.9	7.5 ± 8.0	NS
Total duration (s)	0.9 ± 0.9	1.0 ± 1.1	NS
Mean duration (ms)	116.5 ± 42.6	104.5 ± 48.1	NS
Latency (s)	13.6 ± 13.0	13.3 ± 10.7	NS
Search time (s)	26.1 ± 17.0	18.4 ± 16.6	NS
Length of search route (units)	2853.4 ± 1857.9	2142.9 ± 1846.0	NS
Search speed (u/s)	108.9 ± 36.4	116.2 ± 38.6	NS

[a] +/− ≙ Rightward/leftward gaze drift
[b] +/− ≙ Upward/downward gaze drift

Table 2. Gender differences in eye movement parameters of schizophrenic patients

	Males ($n = 9$)	Females ($n = 11$)	*t*-test (P)
Pupil diameter P1	122.3	101.3	0.057
P2	116.1	88.8	0.013
Phi (°)	92.4	84.4	0.098
Fixation (2°)			
Frequency	3.2	9.7	0.024
Total duration (s)	0.4	1.3	0.039
Search speed (u/s)	123.4	97.0	0.090

Results

Comparison Between Patients and Controls

Table 1 shows the mean values of the recorded eye movement parameters for patients and controls.

One-way comparisons (*t*-tests) showed no significant differences between the two groups except for the patients' tendency to have a smaller pupil diameter during the fixation task ($P < 0.10$). Search time and search route were longer for the group of patients than among the controls, but this difference did not reach significance. In the fixation performance it was striking that both groups focused within the relatively large fixation window of 4° diameter for only approximately one-fifth of the entire fixation time.

Sex Differences in Some of the Eye Movement Parameters

Sex differences in the eye movement parameters remarkably only arose for the group of patients (Table 2).

Men had a greater mean pupil diameter both during the fixation and during the search task. This difference may be explained in part by the higher age of the women, since, as is generally known, pupil diameter decreases with increased age. The schizophrenic women exhibited significantly better results with regard to the 2° window in the fixation performance.

Comparison of the Mean Values of Some Eye Movement Parameters and Clinical Variables for Diagnostic Subgroups

Statistical comparisons were not made due to the small number of patients in the individual schizophrenic subgroups.

That the group of catatonic schizophrenics (ICD 295.2) exhibited the best fixation and search performances is worthy of special attention. This group also differed the most from all others in the extent of pupillary variability (SD 9.4) during the search task as well as in the intensity of leftward gaze deviation (phi 96.2°). This group also occupied a special position with regard to clinical findings having the lowest mean age (31.7 years), lowest neuroleptic dosage (37.7 mg CPZ), and best psychosocial adjustment (GAS score 68.3; best possible score = 100).

Table 3. Means of selected eye movement parameters and clinical data for schizophrenic subgroups (ICD-9)

		295.2 ($n = 3$)	295.3 ($n = 9$)	295.6 ($n = 4$)	295.7 ($n = 3$)	297.0 ($n = 1$)
Pupil diameter	P1	124.8	114.5	100.4	105.5	92.8
	SD-P1	6.1	3.3	5.6	3.3	4.1
Pupil diameter	P2	99.0	108.5	95.5	92.4	88.7
	SD-P2	9.4	4.7	5.1	6.0	4.0
Phi (°)		96.2	86.4	91.2	87.8	65.2
Fixation (2°)						
Frequency		11.3	5.7	6.0	7.0	6.0
Total duration (s)		1.6	0.7	0.8	0.9	0.7
Mean duration (ms)		136.7	103.3	120.0	133.3	110.0
Latency (s)		13.2	11.2	12.3	20.4	22.0
Search time (s)		8.2	31.1	22.4	22.7	60.0
Length of search route (units)		811.8	3786.3	1953.8	2583.8	4989.2
Search speed (u/s)		68.9	123.5	109.9	112.3	83.4
Age (years)		31.7	35.1	46.0	34.7	40.0
Neuroleptic dose (mg CPZ/day)		37.7	225.2	211.3	133.3	400.0
GAS		68.3	60.3	45.5	60.0	55.0
BPRS total		23.7	29.8	42.5	28.0	22.0
FBF total		3.0	28.1	26.5	2.7	20.0

GAS: Global Assessment Scale, Score 0–100 (Best score)
BPRS total: Brief Psychiatric Rating Scale, 18 (Best score) – 126
FBF Total: Frankfurter Beschwerde-Fragebogen, 0 (Best score) – 103

Table 4. Pearson correlations between eye movement parameters and clinical variables

	RYP	RXP	Phi	FFP1	P1	SDP1	P2	SDP2	MLZ	LLZ
BPRS total	−0.47[b]									
BPRS factors										
Withdrawal/retardation	−0.57[c]					0.46[b]			−0.41[a]	
Activation		0.50[b]								
Hostile-suspiciousness	−0.38[a]									
BPRS items										
Somatic concern					−0.46[b]					
Emotional withdrawal			0.45[b]			0.45[b]			−0.57[b]	−0.44[b]
Conceptual disorganization				0.48[b]						
Tension				0.63[d]						
Mannerisms/posturing										−0.43[a]
Hostility	−0.45[b]									
Motor retardation	−0.69[e]					0.44[b]				
Blunted affect	−0.47[b]									
Excitement		0.54[c]								
Neuroleptic dose (mg CPZ/day)	−0.54[c]							−0.39[a]		
Side effects (CGI)	−0.54[b]									
Age (years)	−0.45[b]		−0.49[b]		−0.65[d]		−0.56[c]	−0.54[c]	0.43[a]	

[a] $P < 0.10$; [b] $P < 0.05$; [c] $P < 0.01$; [d] < 0.005; [e] $P < 0.001$
RYP: Vertical regression coefficient (see Text)
RXP: Horizontal regression coefficient (see Text)
Phi: Main direction of visual axis
FFP1: Fixation latency of 2° window (s)
P1, SDP1: Pupil diameter and variability during fixation
P2, SDP2: Pupil diameter and variability during search
MLZ: Search time (s)
LLZ: Length of search route (units)

Correlation Between Clinical Variables and Eye Movement Parameters

Table 4 shows the Pearson correlations between clinical and eye movement parameters for the group of patients.

What first attracts attention when considering the overall extent of psychopathology (BPRS total; a higher score means more psychopathology) is that it correlated negatively only with the vertical regression coefficient RYP. More pronounced psychopathology accordingly occurred together with a downward gaze drift during the fixation task. If one looks at this relationship from a more differentiated perspective in light of the BPRS factors constituting the total score, the factor "withdrawal retardation" was essentially responsible for the correlation mentioned above. This factor in turn consisted of separate items such as "blunted affect" and "motor retardation" among others. In particular a high degree of motor retardation correlated with downward gaze drift during the fixation tasks to a high level of significance (-0.69, $P < 0.001$). There were further relationships to the vertical regression coefficient as well. Higher age, higher neuroleptic dosage and greater extent of experienced neuroleptic side-effects also correlated with downward gaze drift.

Horizontal gaze drifts during the fixation task (RXP) correlated with the extent of "activation" or rather with the psychopathological item constituting this factor, "excitement" (0.54, $P < 0.014$). A higher degree of excitement correlated with rightward gaze drift.

Additional notable connections between psychopathology and fixation performance were also observed. Consequently, a greater degree of "emotional withdrawal" was more apt to appear together with leftward gaze deviation (phi $> 90°$). Further relationships were found between increased prominence of items typical for schizophrenia such as "conceptual disorganization" as well as "tension" and correspondingly longer 2° fixation latency (FFP 1). A greater degree of "withdrawal/retardation" appeared together with greater pupillary variability during the fixation task (SDP 1).

There were relationships to the measurement parameters of the search task such that more "emotional withdrawal" correlated with shorter search time (MLZ) and shorter search route (LLZ).

Finally, a number of age correlations were found, only in the group of patients. Higher age correlated with smaller pupil diameter during the fixation task (P1) and the search task (P2), with less pupillary variability during the search task (SDP2), with greater rightward gaze deviation (phi $< 90°$), with downward gaze drift (RYP) and lastly with longer search time. On the basis of the absent age correlation in the control group, one can conjecture that these relationships with age actually reflected the relationship with chronicity of the illness process.

Table 5 represents the relationship between factors in the FBF and some eye movement parameters.

The closest correlations were between the factor "motor interference" and the 2° fixation latency (FFP1), and between the factor "visual disturbances" and the mean fixation duration of this window (FMP1): the more visual disturbances stated, the shorter the mean duration of an individual fixation.

The individual items of the questionnaire which made up this factor "visual disturbances" are: "Sometimes I have to focus my eyes very hard on one point or else everything becomes blurred." "At times everything shimmers before my eyes." "I usually have a feeling of pressure above my eyes." "Sometimes everything looks blurred even though I'm not dizzy."

There were additional tendencies towards a number of relationships particularly between pupillary variability during the search task (SDP 2) and the majority of the FBF factors.

Table 5. Pearson correlations between FBF factors and eye movement parameters

	P2	SDP2	FMP1	FFP1	Phi
FBF factors					
Disturbance of language functions		-0.42^a			
Perceptual disturbance		-0.43^a			-0.43^a
Loss of automatic functions		-0.43^a			
Motor interference				0.48^b	
Thought interference	-0.38^a				
Visual disturbance			-0.62^c		
Delusional mood		-0.39^a			
FBF total		-0.44^b			

[a] $P < 0.10$; [b] $P < 0.05$; [c] $P < 0.005$
FMP1: Mean duration of 2° fixation (ms)
P2, SDP2, FFP1, Phi: see Table 4

Table 6. Pearson correlations between search parameters and both phi and pupil variability (SD-P2) for schizophrenic patients and normal controls

	Schizophrenics ($n = 20$)		Controls ($n = 20$)	
	Phi	SD-P2	Phi	SD-P2
Search time	-0.58^a	-0.58^a	NS	NS
Length of search route	-0.59^a	-0.58^a	NS	NS
Search speed	NS	NS	NS	NS

[a] $P < 0.01$

Intercorrelations of Certain Eye Movement Parameters

Table 6 shows the relationships between main direction of visual axis (phi), pupillary variability during the search task (SDP2), and search parameters for the patient and control group.

Whereas no significant correlations whatsoever emerged for the control group, a highly significant negative correlation appeared in the group of patients between search time or respectively search route and the angle phi and with pupillary variability (SDP2). Accordingly, a long search time and a long search route (both correlated highly with one another. $r = 0.89$, $P = 0.0001$) correlated with rightward gaze deviation (phi $< 90°$) and low pupillary variability during the search task.

Mean Values of Clinical Variables as a Function of phi $<$ and $> 90°$ Respectively

The sample of patients was divided in half at the median (90°) with regard to the angle phi, and the two groups were compared with one another regarding eye movement parameters and clinical variables (Table 7).

Table 7. Comparisons of means of eye movement parameters and clinical variables (*t*-Tests) of schizophrenic patients with rightward (phi < 90°) and leftward (phi > 90°) gaze deviation

	< 90° ($n = 10$)	> 90° ($n = 10$)	*t-Test* (*P*)
Pupil diameter P1	98.6	123.0	0.028
P2	88.9	113.2	0.029
Fixation latency (2°)	11.8	15.4	NS
Search time	30.8	21.4	NS
Length of search route	3448.4	2258.4	NS
BPRS total	26.9	34.6	0.033
BPRS factors			
Withdrawal retardation	7.1	9.3	0.032
Thinking disturbance	5.1	7.4	0.029
Hostile suspiciousness	3.5	5.4	0.038
BPRS items			
Emotional withdrawal	2.1	3.0	0.042
Suspiciousness	1.3	2.4	0.051
Unusual thought content	1.3	2.5	0.004
Blunted affect	2.3	3.2	0.033
FBF factors			
Perceptual disturbance	2.2	0.5	0.041
Gender			
Males	2	7	Fisher-test
Females	8	3	$P = 0.05$

Table 8. Comparisons of means (± SD) of search time of controls and both schizophrenic patients with leftward (phi > 90°) and rightward (phi < 90°) gaze deviation

	Schizophrenics: phi > 90° ($n = 10$)	Controls ($n = 20$)	*t*-Test (*P*)
Search time (s)	21.3 ± 17.0	18.4 ± 16.6	NS
	Schizophrenics: phi < 90° ($n = 10$)	Controls ($n = 20$)	*t*-Test (*P*)
Search time (s)	30.8 ± 16.6	18.4 ± 16.6	0.06

No significant group differences were found for the eye movement parameters, although the search time (MLZ) and the search route (LLZ) tended to be longer for the group with rightward gaze deviation (phi < 90°). Significant differences were only found concerning pupil diameter during the fixation and search tasks. The group with leftward gaze deviation (phi > 90°) had a greater mean pupil diameter in each case. This group of patients was characterized by a significantly higher BPRS total score with regard to psychopathology. At the factorial level this was due to factors typical for schizophrenia, "thinking disturbance" and "hostile suspiciousness" as well as the nonspecific factor "withdrawal/retardation". On the level of BPRS individual items the group with leftward gaze deviation was characterized by a greater degree of "emotional withdrawal", "suspiciousness", "unusual thought content" and

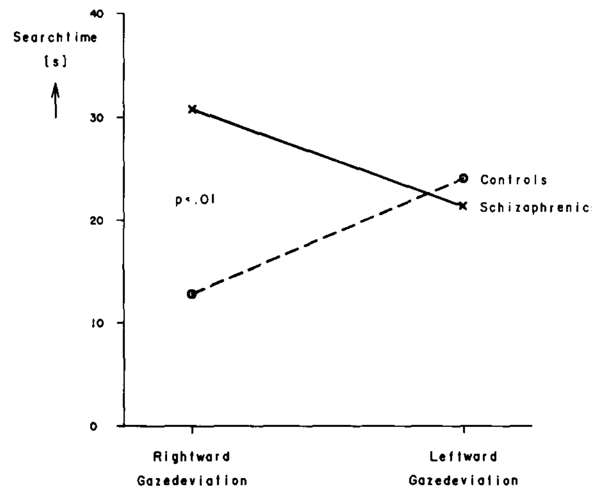


Fig. 5. Comparison of search time of schizophrenics and controls with rightward and leftward gaze deviation (*t*-test)

"blunted affect". In contrast, this group attained significantly lower values for the factor "perceptual disturbance" of the FBF. Incidentally, regarding sex distribution there were more men in this group ($P < 0.05$).

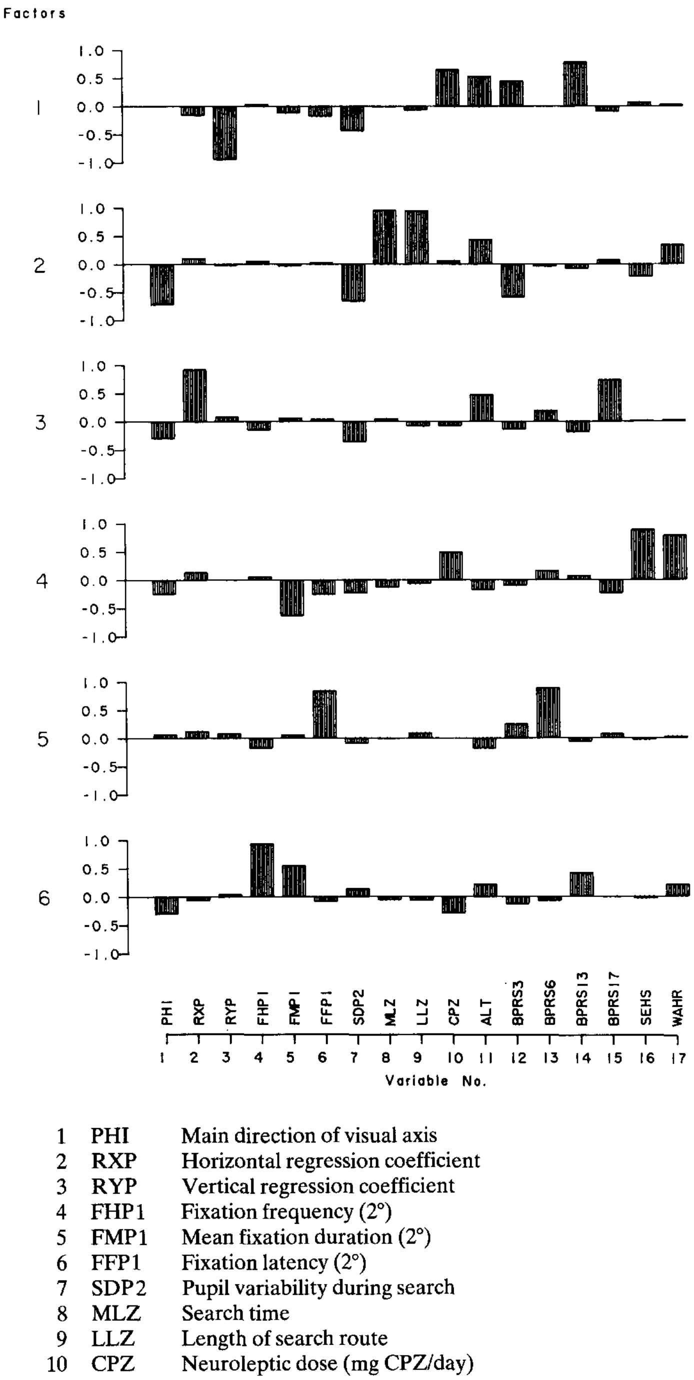
On the basis of the previously described relationships between search time and direction of gaze deviation, we additionally compared the two groups of patients with phi > 90° and respectively < 90° with the controls (Table 8).

Here the surprising finding emerged that the group with leftward gaze deviation (phi > 90°), therefore, those with more pronounced clinical symptoms, did not differ significantly from the controls. In contrast, the group with rightward gaze deviation (phi < 90°), accordingly those with rather less pronounced clinical symptoms (but a higher FBF factor score for "perceptual disturbances") tended to have longer search times than the controls ($P = 0.06$).

Figure 5 depicts these relationships graphically for the group of patients phi >/< 90° in comparison to the control group phi >/< 90°. Statistically (*t*-test) it becames apparent that the patients with rightward gaze deviation had highly significantly longer search times than the controls with rightward gaze deviation, whereas the subjects with leftward gaze deviation in the two groups showed no important differences. This finding suggested a different interpretational basis for rightward gaze deviation among the controls, on the one hand, and the schizophrenic patients on the other.

Factor Pattern of Clinical Data and Eye Movement Parameters

Clinical data and eye movement parameters for the group of patients were subjected to a joint factor analysis with subsequent varimax rotation. Here we limited ourselves to those clinical variables of the BPRS, which showed the closest connections to the movement parameters from the perspective of the one-way comparisons (Table 4) (emotional withdrawal, tension, motor retardation, and excitement). Also included were the neuroleptic equivalent dosage and age, and the factors "visual disturbances" and "perceptual disturbances" from the FBF. In the solution with 6 factors (Eigenwert > 1), which explained 83% of the total variance, the factor pattern represented in Fig. 6 emerged (only factor loadings > 0.50 were considered).



1	PHI	Main direction of visual axis
2	RXP	Horizontal regression coefficient
3	RYP	Vertical regression coefficient
4	FHP1	Fixation frequency (2°)
5	FMP1	Mean fixation duration (2°)
6	FFP1	Fixation latency (2°)
7	SDP2	Pupil variability during search
8	MLZ	Search time
9	LLZ	Length of search route
10	CPZ	Neuroleptic dose (mg CPZ/day)
11	ALT	Age
12	BPRS3	Emotional withdrawal (BPRS)
13	BPRS6	Tension (BPRS)
14	BPRS13	Motor retardation (BPRS)
15	BPRS17	Excitement (BPRS)
16	SEHS	Visual disturbance (FBF)
17	WAHR	Perceptual disturbance (FBF)

Fig. 6. Factor pattern of selected eye movement parameters and clinical variables of schizophrenic patients

The loadings on factor 1 were: the vertical regression coefficient RYP (0.94), the BPRS item "motor retardation" (0.78), the neuroleptic equivalent dosage (0.65) and age (0.53). This factor could be interpreted as a factor of *psychomotor reactivity*.

The loadings on factor 2 were: search time MLZ (0.95), search route LLZ (0.94), the angle phi (−0.72), pupillary variability during the search task SDP2 (−0.66) and the BPRS item "emotional withdrawal" (−0.59). This factor, which reflected relationships between visual processing performance, preferred direction of visual axis, autonomic reactivity, and emotional contact behavior, might be interpreted as a factor of *adaptive flexibility* (both cognitively and emotionally).

Factor 3 was marked by the horizontal regression coefficient RXP (0.92) and the BPRS item "excitement" (0.74). Accordingly, a greater degree of excitement appeared together with rightward gaze drift during the fixation task.

Factor 4 reflected relationships between experienced complaints (FBF) such as "visual disturbances" (0.89) or "perceptual disturbances" (0.79) and the mean fixation duration FMP 1 (−0.63). This relationship might indicate that an objective disturbance in gaze control also reflects itself in subjective perception.

Factor 5 characterized a relationship between the BPRS item "tension" (0.89) and the 2° fixation latency FFP1 (0.84). The more tense a patient was the more time he needed before fixating this window for the first time.

Factor 6 reflected a connection between fixation frequency FHP1 (0.93) and mean fixation duration FMP1 (0.55). Patients, who fixated in the 2° window frequently, also stopped longer there per fixation.

In summary, these results showed:

1. Vertical and horizontal gaze deviations during the fixation task showed independently from one another, relationships with various psychopathological dimensions. Factor 1 reflects relationships between decrease in psychomotor reagibility (possibly a neuroleptic-induced hypovigilance) and downward vertical gaze drift. Factor 3 reflects relationships between increased reactivity and rightward horizontal gaze drift.
2. Phasic fixation parameters are related with certain psychopathological characteristics. Factor 4 makes it probable that experienced perceptual disturbances, particularly "visual disturbances" (FBF) can be validated by means of a reduced mean fixation duration. Factor 5, in contrast, illustrates that with increased tension, focusing the gaze on the fixation point is delayed.
3. The parameters of the search task form a relationship of their own. Contrary to expectation factor 2 shows that increased emotional withdrawal evidently appears together with a better general view while searching (shorter search route and shorter search time). This in turn occurs together with increased autonomic reactivity (pupillary variability) and leftward gaze deviation (phi >90°).

Separate factor analysis for the patients and controls using only eye movement parameters showed that search time and length of search route loaded on factor 1 in both groups. In contrast to the group of patients, however, both pupillary variability and the angle phi (with positive poling) loaded only slightly on this factor (−0.72 in the group of patients, +0.46 in the control group). These connections correspond to the representation in Fig. 5, that controls with leftward gaze deviation (phi > 90°) produced relatively poorer search performances in comparison to those with rightward deviation (phi < 90°), whereas exactly the opposite was the case for the group of patients.

Discussion

Task Performance of Schizophrenics and Normal Controls

The results showed no significant differences in the group means between patients and controls as far as main visuomotor behavioral factors are concerned. Nevertheless, there was a tendency towards poorer performance in the group of patients. These relatively unobtrusive results might be ascribed to the fact that a largely remitted outpatient population was involved. Analogously, Schmid-Burgk et al. (1982) showed that outpatient schizophrenics did not exhibit frequent nonfixation in contrast to inpatients.

If, however, one looks at the performance level of individual diagnostic subgroups, considerable variance in performance becomes apparent. In particular, catatonic schizophrenics, who generally have a favorable clinical prognosis, exhibited better mean performance behavior than the controls. In contrast, the schizophrenic men with a chronic unremitting course, showed poor fixation performances. They also predominated in the group with leftward gaze deviation (phi $> 90°$), which in turn was characterized by more pronounced symptoms typical for schizophrenia. If one considers that – according to much of the research in outcome epidemiology – schizophrenic men are more apt to have the poorer premorbid social adjustment and outcome prognosis (Salokangas 1983), the question could be asked whether the visuomotor parameters measured here would be a trait marker for this subgroup, as suggested by Mather and Putchat (1982/83). Only patients with poor premorbid social adjustment differed from normal controls in fixation performance, but not those with good adjustement. The findings by Manschreck and Ames (1984) of motor disturbances in schizophrenic men also belong in this context. Whether the visuomotor performance level defines a process indicator, with which a prognostically unfavorable type of illness course could be recorded, can only be decided in a longitudinal study involving various stages of the illness process.

Relationships Between Psychopathology and Eye Movement Parameters

As the factor analysis illustrated, various relationships between clinical variables and eye movement parameters appear independent from one another, e.g., the vertical and horizontal gaze drifts during fixation, which emerged in the regression analysis of the time-dependent gaze positions. That such gaze drifts appeared at all in the macroarea measured here (in contrast to the known microdrifts; Ditchburn 1973) has not been previously reported. As the extent and direction of these directional gaze drifts also appeared in the controls this was not something specific to patients.

The question arises as to what extent these findings can be explained on the basis of the special stimulus conditions. It seems obvious to consider the phenomenon of autokinesis as an explanation (subjective apparent movements appearing when fixating on a small point of light in the darkness). Whereas eye movements were ruled out as the basis for this phenomenon by earlier authors (e.g., Exner 1986; Guilford and Dallenbach 1928), more recent and methodologically better research indicates, at least in part, just the opposite (Matin and Mackinnon 1964). As we did not investigate this phenomenon from its subjective point of view, the decision about the correctness of this attempted explanation must remain open. From a neurophysiological view one assumes that the horizontal "vectors" of conjugate eye movements (Bender 1980) can be attributed to an interhemispheric disequilibration, whereas vertical vectors are usually generated by bilateral hemispheric activation.

Based upon the factorial structure we have interpreted vertical gaze drift as an indicator of the psychomotor reactivity of schizophrenic patients. Patients with motor retardation and blunted affect exhibited a particularly marked downwards vertical gaze drift (the metrological method rules out a confusion of eye and head movements!). The simultaneous relationships with neuroleptic dosage and age apparently reflected a complicated interplay between chronicity, deficit-related withdrawal/retardation and neuroleptic-induced hypovigilance.

Independent of these findings the relationship between horizontal gaze drift and the BPRS factor typical for schizophrenia, "activation" appeared. An increased degree of activation occurred together with rightward gaze drift. Here the question arises to what extent this finding is an expression of a functional hemispheric asymmetry in schizophrenic patients. The customary experimental paradigm, with which conjugate lateral eye movements are assessed as indicators of a hemispheric asymmetry, is however completely different from ours. Based upon the methodological criticism of Ehrlichman and Weinberger (1978), the gaze drifts established with our method seem to be a rather valid measurement of an interhemispheric disequilibration.

The customary experimental paradigm is based on the method of recording the lateral eye movements, which emerge in response to questions with "verbal" or "visuospatial" contents, for their horizontal component. Depending on certain conditions of the experimental setting, the right or left movements which then appear are interpreted as an expression of a contralateral hemispheric activation. Here a task-specific hemispheric activation (state) is differentiated from an individual hemispheric preference (trait; "hemisphericity").

Gur (1978) and Schweitzer et al. (1978) concurrently showed that schizophrenic patients exhibit more right lateral eye movements with the method stated. Whereas Gur interpreted her findings as an expression of left hemisphere overactivation, Schweitzer et al. acknowledged the possibility of a left hemispheric disinhibition brought about by loss of right hemispheric inhibition. Our findings cannot be directly compared with those above due to the different experimental procedure. If lateral eye movements are an expression of an interhemispheric disequilibration, then in our case the rightward gaze drift emerging with increasing activation may be an expression of left hemispheric overactivation or right hemispheric deactivation.

Phasic fixation parameters are likewise related with particular psychopathological characteristics. Thus the capacity for exact fixation is lost with increasing degrees of conceptual disorganization and tension. Similar relationships between motor disturbances and thought disturbances in schizophrenics were also reported by Manschreck and Ames (1984).

Lastly, an objective behavioral-physiological validation of individual factors of the FBF can be derived from the relationships between the complaint factors of the FBF and the capacity for exact fixation. Particularly the specific relationships between "visual disturbances" and mean fixation duration as well as the extent of experienced "motor interference" and longer first fixation latency support such an interpretation.

Moreover in spite of psychopathologically better remission the patients with rightward gaze deviation, who tend to produce poorer search performances, show more "perceptual disturbances". Consequently, the importance of the FBF for recording "susceptibility to experienced cognitive disturbances" (Teusch 1985) is proven despite its apparently absent schizophrenic specificity (e.g., Rösler et al. 1985).

Lateral Gaze Deviation and Search Performance

On the basis of Gur's findings (1978) it was to be expected that in the search task used here, which requires predominantly the use of preattentive processes attributed more to the right hemisphere of the brain, better performances were attained by the patients who "activate" their right hemisphere than those who activate the left half of their brain (deficient according to the hypothesis). As the graphic representations show, patients and controls differed considerably in search strategy and thus in the effectivity as measured by the reaction time. Togami (1984) showed that the effectiveness of visual search increased with slower search speed, thus indicating the importance of a sufficient duration of fixation for adequate central processing. Such relationships were apparent in the group of catatonic schizophrenics, who exhibited the shortest search time, the shortest search route, and also the slowest search speed in comparison to all other diagnostic subgroups.

The correlation analysis showed that search time as well as search route correlated to a high level of significance with a lateralization measure, although not for the control group. If one interprets these relationships along the lines of the above hypothesis, the result is as postulated; left hemispheric activation (accordingly, rightward gaze deviation, phi $< 90°$) occurs together with poorer search performance. Expressed in another way this would mean that patients with right hemisphere functional preponderance sooner use preattentive strategies and are capable of better performances (Fig. 4b). In contrast, patients who "activate" their left hemisphere (in the sense of a fixed process asymmetry "deficient", Gruzelier 1984) use more focal strategies in the sense of "tunnel vision" usually with longer search route, greater search speeds and also longer search time (Fig. 4a). That no such relationships emerged for the controls could be interpreted as implying that even if the left (functional) hemisphere is activated more, it is capable of greater performance than is true for the schizophrenic patients. The results of the factor analysis showed, an apparently independent relationship is involved here, which has a clinically psychopathological reference. We interpreted these relationships as expressing the "adaptive flexibility" of schizophrenic patients and subsumed under this both the cognitive and the emotional performance level of the patients. Surprisingly, the patients with leftward gaze deviation (right hemisphere functional preponderance) and better search performance exhibited relatively more pronounced psychopathology both with regard to nonspecific negative symptoms (emotional withdrawal, blunted affect) as well as regarding schizophrenia-specific positive symptoms (paranoid and other delusional thought content). Furthermore, the men again predominated in this psychopathologically "more ill" group. The finding that this more florid group tends to produce better search performances conforms to the hypothesis formulated by Venables (1964), in which acute schizophrenic patients are the ones with "broadened attention", which Cegalis et al. (1977) were able to confirm for visual attention tasks. On the other hand, it is conceivable that the more pronounced emotional-withdrawal behavior in this group represents a protection against distractors and thereby guarantees a greater search efficiciency.

Pupillary Findings and Attentional Processing Load

Only in the fixation task did the group of patients tend to have a smaller pupil diameter than the controls, and this originated from the significantly smaller pupil diameter of the schizophrenic women in comparison to the men. Due to the greater age of the schizophrenic women it was obvious to consider these as age-dependent differences. However, it became apparent that highly significant negative correlations between age and pupil diameter only existed in the group of patients (pupil during the fixation task -0.65, $P = 0.002$; pupil during the search task -0.56, $P = 0.009$), whereas such relationships were not found in the control group. This could be an indication that it is not a question of purely age-correlated connections in these findings. Possibly the pupil diameter rather reflects a relationship with chronicity, approximately along the lines of a process indicator.

Pupillary anomalies in schizophrenic patients have been known for a long time (Bumke 1911). This author had observed pupils with relatively greater mean diameters among persons with dementia praecox than was the norm. However, Hakerem et al. (1964) reported that in acute schizophrenic patients (first admissions) the scotopic pupil had a smaller diameter than in normal controls, but in chronic schizophrenic patients (hospitalization for at least 5 years) it did not differ from normals. In contrast, Rubin and Barry (1972) found that both acute and remitted schizophrenic patients exhibited a scotopic pupil of smaller diameter than normal controls.

A final question was aimed at the relationship between pupillary findings and the processing load imposed on the selective attentional system during the search task. The highly significant relationships between fast search time (short search route) and increased pupillary variability only in the group of patients and only during the search task indicated that these are specific connections concerning the search performance.

The methodological objection that the pupillary play during the search task can be explained exclusively by the changing light conditions during visual search can be refuted in two respects. Firstly, these connections would then also have to be found in the controls. Secondly, one would have expected a positive connection between search time and pupillary play (the longer the search route and the search time, the more frequent the change in gaze direction and possibly with it changed incidence of light). In contrast, a negative correlation was found.

Whereas the mean pupil diameter tends to come under relatively enduring emotional influence as a measure of equilibration, the phasic component expressed in pupillary variability is brought into connection with short-term cognitive loads (Beatty 1982). In this sense the group of patients with leftward gaze deviation (right hemisphere functional preponderance) could be regarded as a group with greater autonomic arousal corresponding to their greater initial pupil diameter (see Patterson, 1976, regarding the covariation of pupillometric and electrodermal reactivity as arousal indicators). Task-evoked pupillary reactions, however, which Bumke (1911) referred to as "psychic reflexes", were interpreted by Beatty (1982) as an expression of the respective processing load of the attentional system.

Dynamic interactions between the cerebral cortex and the reticular activating system of the brain stem are considered to be the anatomical basis of such connections. Task-evoked pupillary dilations would accordingly reflect the cortical modulation of the reticular formation during cognitive activity. Concerning anatomic feedback relationships between reticular formation and forebrain, particularly the modulating influence of the frontal processes can be gathered from the autonomic pupillary indicator.

If one takes these considerations as the basis of interpretation for our findings, one can conclude that the use of preattentive (right hemisphere) processes in schizophrenic patients leads to a greater load upon the processing capacities (detectable from the greater pupillary variability). On the other hand, the load upon these capacities becomes less when predominantly serial (left hemisphere) processes are employed. That these relationships did not emerge for the control group could indicate that for them the search task is located at a level below their full attentional capacity. Beatty (1982) was, in fact, able to show that visual detection tasks are among those imposing minimal processing loads on normal controls.

As Nuechterlein and Dawson (1984) determined, it is still not clear in which area the reduction of the available processing capacities is located: whether wrong allocation occurs despite a normal pool of processing capacity, whether more processing capacity is devoted to distractor stimuli, whether there is deautomatization and hence the capacity demanding serial processing, or whether the total pool of processing capacity is smaller. Our results in the suggested interpretation could indicate a smaller total pool of processing capactiy, which would be sought mainly in the left hemisphere, but whose effects only become apparent on the basis of individual processing preferences. The schizophrenic with right hemisphere activation performs as normal controls but imposes a maximal load on his attentional system (pronounced pupillary variability), whereas the schizophrenic with left hemisphere activation has poorer performances than the controls because he cannot make use of the processing capacity available in the right hemisphere and thus "underemploys" his system. Why a number of the patients "prefer" the latter and others the former strategy of hemisphere activation is not known. One might think that premorbid cognitive "styles" are involved (in the sense of "hemisphericity"), but a change in lateralization dependent on the process stages could also be involved (in the sense of "dynamic" process asymmetries, namely that florid patients with greater emotional withdrawal sooner "activate" their right hemisphere and remitted patients sooner "activate" their left deficient hemisphere (Gruzelier 1984). Answering this question would only be possible in the context of a longitudinal study including sufficiently precise clinical operationalization of the activity of the illness process.

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