Visuomotor Behavior in Schizophrenia

W. Gaebel
Department of Psychiatry of the Free University of Berlin (Head: Prof. Dr. H. Helmchen), Berlin (West), Germany

Summary

The diagnosis of "positive" schizophrenia relies heavily on reported symptoms. Behavioral signs, however, play an important role in "negative" schizophrenia. Their advantage is that they can be assessed objectively and quantitatively. Thus, their measurement can improve both the precision of the diagnostic process and the phenomenological basis of biologically oriented research. The assessment of various types of visuomotor behavior (e.g., eye fixations, saccades, smooth-pursuit eye movements) with different functions and anatomic organization, and of their trait- and state-related disturbances in schizophrenia are an example of this kind of research. Whether analyzed from an interactional or an individual perspective, visuomotor behavior is best understood within a broader neurobiological frame of reference. In combination with brain imaging techniques it is an important tool with which to explore brain behavior relationships in schizophrenia and other related psychoses.

Visuomotorisches Verhalten schizophrener Patienten

Die Diagnostik schizophrener Erkrankungen stützt sich auf Erleben und Verhalten. Deren relatives diagnostisches Gewicht variiert jedoch im Hinblick auf nosologische Unterformen, die eher durch Plus- bzw. Minus-Symptomatik gekennzeichnet sind. Die Erfassung objektiver und quantifizierbarer Verhaltensmerkmale bedeutet generell für den diagnostischen Prozeß und eine biologisch orientierte psychiatrische Forschung eine wesentliche Bereicherung. Die Untersuchung verschiedener Arten visuomotorischen Verhaltens (z. B. Fixation, Sakkaden, Augenfolgebewegungen) mit unterschiedlicher Funktion und anatomischer Organisation stellt ein Beispiel dieses Forschungsansatzes dar. Das Verständnis interaktioneller wie individueller Störungen visuomotorischen Verhaltens erschließt sich am ehesten in einem neurobiologischen Bezugsrahmen. In Kombination z. B. mit modernen bildgebenden Verfahren stellt die Analyse visuomotorischen Verhaltens eine wichtige Strategie zur Aufklärung patho- und syndromgenetischer Mechanismen der Schizophrenie und anderer Funktionspsychosen dar.

Introduction

The diagnosis of schizophrenia is based on psychopathologic signs (nonverbal behavior) and symptoms. However, the weighting of these cross-sectional elements in the diagnostic process varies from one classificatory system to the other. While, for instance, *Bleuler*'s (1911) "basic symptoms" of schizophrenia ("the 4 A's": affect, autism, ambivalence, association) pertain to observable signs, *Schneider*'s (1950) first-rank symptoms pertain to reported symptoms (e.g., delusional perceptions). Symptoms in particular have become an integral part of modern day diagnostic classification systems, e.g., DSM-III (*APA*, 1980); a development which has been criticized by *Alpert* (1985). He states that "greater emphasis could have been placed on efforts to develop objective measures in areas in which they are clinically important and technologically feasible". Most psychopathologic rating instruments, on the other hand, comprise both signs and symptoms. The former are considered extensively in the Scale for the Assessment of Negative Symptoms (*SANS*, *Andreasen*, 1982). These signs (e.g., unchanging facial expression, decreased body movements, paucity of gestures, poor eye contact, vocal inflexions, poverty of speech, latency of response) are prevalent in so-called type II (negative) schizophrenia as opposed to type I (positive) schizoprenia, which is characterized by the prevalence of self-reported symptoms (*Crow*, 1985). For both types, there is some evidence of differences in structural brain deficit, involvement of DA-mechanisms, neuroleptic response, and prognosis (e.g., *Andreasen* and *Olsen*, 1982), which underscores the clinical and theoretical value of subtyping schizophrenia according to the prevalence of signs or symptoms.

Generally, the advantage of signs is that they are "objective, observable, and at least potentially accessible to measurement… Measurement of the behavior that are the sign of the disorder will improve diagnostic precision and, potentially, understanding of their underlying processes" (*Alpert*, 1985). Thus, objectively measured behavioral signs can give access to "the neurology of schizophrenia" and its underlying brain mechanisms (*Nasrallah* and *Weinberger*, 1986).

Visuomotor behavior – general principles

Major areas of research in nonverbal behavior are facial action, gaze, vocal communication, gestures, and body motion (overview in *Scherer* and *Ekman*, 1982). Depend-

Pharmacopsychiat. 22 (1989) 29–34 (Supplement)

ing on the researcher's perspective, visuomotor behavior (gaze) as well as the other behavior types can be analyzed from an individual or an interactional point of view. Neither form of analysis is exclusive, but differs in the way it deals with intervening variables of the social context of the behavior. The differences in defining subunits of behavior are intimately related to these differences in perspective. While in the study of interpersonal relationships gross measures of eye contact (molar behavior) might be sufficient, the research focus of a neurophysiologist might be on such behavioral subunits (molecular behavior) as fixations and saccades (*Scherer* and *Ekman*, 1982a). Since visuomotor behavior has many functions, such as exploration of the environment, participation in body movements, and postural stabilization, communicative characteristics, such as effect on people (*Levy-Schoen*, 1981), are only part of its functions and are more determined by the receiver than by the sender's intentions (*Wagner* et al., 1981). Therefore, different aspects of visuomotor behavior have to be assessed separately under varying and standardized experimental conditions.

Types of visuomotor behavior

Socially significant visuomotor behavior, characterized by an individual's tendency to look at (into) the eyes, eye region (face), or away from his interaction partner, has been termed gaze (*Exline* and *Fehr*, 1982). Gaze, more generally defined, means the position of the eye in space, which under natural conditions is the result of the position of the eye in its orbit, and the position of the head in space (*Leigh* and *Zee*, 1983). Consequently, *Exline* and *Fehr* (1982) state that "regardless of how we label our variable, what we actually record are eye fixations, their duration, and the point or points of fixation-time and location, such are the raw materials of our measures".

Together with interspersed eye fixations, repetitive saccades, i.e., in direction, amplitude and velocity preprogrammed conjugate eye movements, form a "scanpath", which actively guides the intake of visual information. Thus, as defined above, gaze is always part of a scanpath, which varies interindividually and intraindividually under different viewing conditions (*Yarbus*, 1967; *Noton* and *Stark*, 1971).

Eye movements can be best understood by considering their functions. Vestibulo-ocular reflex and optokinetic nystagmus act to hold images of the perceived world steady on the retina. With the evolution of the fovea and frontal vision, saccadic, smooth pursuit, and vergence eye movements became necessary. These eye movements are partly under voluntary control and – working together – acquire and hold images of objects of interest on the fovea (*Leigh* and *Zee*, 1983).

Functional and anatomic organization

Time and location of eye fixations (corresponding to gaze duration and gaze direction) subserve monitoring (channel) as well as regulatory and expressive (signal) functions in social interaction (*Kendon*, 1967). Although both functions are intimately related (*Wagner* et al., 1981), their involvement differs according to the experimental situation (e.g., visual search task vs. social interaction). With respect to the monitoring fuction of gaze, an eye fixation at a particular location is a natural observable unit of behavior (*Russo*, 1978), which approximately corresponds in timing to the simultaneously occurring perceptual-cognitive process. Therefore, fixation duration varies with the computation-to-acquisition ratio, i.e., the relationship between stimulus computation time and stimulus acquisition rate of a task: the lower the computation-to-acquisition ratio, the briefer the duration, as for instance in a search task (*Russo*, 1978). On the other hand, prolonged fixation durations occur in tasks, where the computation-to-acquisition ratio is high (e.g., problem solving, decision making) or where anticipation strategies based on stored structures, completed computations, and peripheral perception are dysfunctional (*Russo*, 1978). Thus, durations of eye fixations are not related to cognitive processes per se (*Just* and *Carpenter*, 1976) but are determined by the task-specific interaction of top-down and bottom-up processes as well as by intervening variables such as attention.

In terms of the underlying anatomic structures, voluntary saccadic eye movement commands are mediated by parallel pathways from the frontal eye fields (*Brodmann's* area 8) and superior colliculus that converge in the brain stem (pontine paramedian reticular formation, PPRF). While the frontal eye fields are more concerned with shifts of gaze that voluntarily direct visual attention, the superior colliculi mediate involuntary, reflexive shifts of gaze for orientation toward visual stimuli that suddenly appear within the environment (*Zee*, 1984). The frontal eye fields are reciprocally connected with the posterior parietal cortex (area 7), which is modulated by limbic influence (*Mesulam* and *Geschwind*, 1978) and is functionally related to selective visual attention (*Lynch* et al., 1977; *Bushnell* et al., 1981; *Mountcastle* et al., 1984). The cerebellum functions in the control of saccade metrics.

Smooth pursuit eye movements are controlled by the parieto-occipital association cortex and the cerebellar flocculus; the frontal eye fields are probably not directly involved with these eye movements. Intact vestibulo-ocular reflex is related to intact labyrinths, and the optokinetic nystagmus is controlled by brain stem, cerebellum, and cortex (partial field optokinetic nystagmus).

Measurement

Gaze variables such as direction, frequency, and duration are normally assessed by the receiver or an observer, either in live or recorded form (*Exline* and *Fehr*, 1982). The accuracy with which the direction of gaze can be judged seems to depend on gaze duration, head position, distance between sender and receiver, etc. (*Krüger* and *Hückstedt*, 1969). Although the reliability and validity of observer ratings in interaction research may be sufficient and can even be raised by rater training (*Exline* and *Fehr*, 1982), objective measurement is desirable for more detailed analysis of gaze variables under experimental task conditions. Since, in this kind of research, it is of interest to know the fixation point of the subject as it falls in space rather than the position of the eye with respect to the head, "point of regard measurement" can be applied, which records corneal reflection and pupil centre position by means of an external infrared light source and a video camera (*Young* and *Sheena*, 1975). This method is sufficient with respect to spatial and temporal resolution (0.5°–1°, 20 msec), and allows the additional measurement of pupil diameter as a way of assessing task-evoked processing load (*Beatty*, 1982).

Methods for measuring eye movements relative to head position are electro-oculogram and infrared reflection techniques with a head-mounted device or with the head fixed in a chin rest. Strengths and weaknesses of the different methods have to be evaluated with respect to the specific research purposes (*Young* and *Sheena*, 1975; *Meienberg*, 1987).

Visuomotor behavior in schizophrenia

Various motor abnormalities in schizophrenia, specifically related to thought disturbances, have been reported by *Manschreck* (1986). In particular, visuomotor abnormalities have been observed already in the pre-neuroleptic era. *Stevens* (1978) reports on signs of ocular disturbance, such as staring with or without gaze aversion, eye-head synkinesia, episodic unexplained lateral glances, grossly interrupted ocular pursuit movements, defective convergence, and spontaneous lateral saccades in almost 80% of 44 (minimum one month medication-free) schizophrenics. Various visuomotor abnormalities are thus a frequent finding in schizophrenics, possibly related to the underlying disease process. Systematic findings will be given in more detail in the following chapters.

Saccadic eye movements

Diefendorf and *Dodge* (1908), who were the first to report on disturbed smooth pursuit eye movements in schizophrenia, reported that saccadic eye movements were intact. More recent studies also report unimpaired saccadic latencies and velocities (*Iacono* et al., 1981; *Levin* et al., 1981, 1982; *Mather* and *Putchat*, 1982/3), which contrast with prolonged manual reaction times (*Nuechterlein*, 1977). However, *Levin* et al. (1981) found that schizophrenics' saccadic latencies increased relatively more and saccadic velocities relatively less than those of normal controls in case of stimulus displacements greater than 10° to the right periphery. Although these effects were slight and nosologically unspecific, they may shed light on asymmetrically dysfunctional cerebral mechanisms of attention.

Conjugate lateral eye movements (*CLEMs*) are interpreted as a concomitant of contralateral hemisphere activation during hemisphere-specific cognitive task performance (*Kinsbourne*, 1972). Although the paradigm for eliciting these eye movements as well as the supposed underlying brain mechanisms are a matter of debate (*Ehrlichman* and *Weinberger*, 1978), the finding that (paranoid) schizophrenics exhibit more frequently right-sided *CLEMs* has been related to left-hemisphere dysfunction and overactivation in schizophrenics with positive symptoms (*Gruzelier*, 1983). On the other hand, the findings of *Cegalis* et al. (1977) concerning the selectivity of attention in the functional visual field demonstrate that stimulus detection in the (right) periphery of the visual field is especially reduced in chronic schizophrenics. Since attention to the periphery is related to contralateral parietal cortical structures (see above), the finding of impaired saccades to the right periphery might also be related to left-hemisphere dysfunction.

In chronic schizophrenics, too, prolonged saccadic latencies have been reported (*Schmidt-Burgk* et al., 1982; *Schmid-Burgk*, 1984). *Done* and *Frith* (1984) observed longer latencies in strategic (voluntary) but not in automatic (reflexive) saccades, which points to possible dysfunctions of frontal cortical command structures. *Mackert* (1988) found a positive relationship between negative symptoms and saccadic latencies. All of these results underline the necessity of paying greater attention to intervening variables, such as stimulus conditions, syndrome, and illness phase. Similarly, the influence of neuroleptic medication has to be considered, since it seems to transitorily lower saccade velocity under acute treatment conditions (*Schmid-Burgk* et al., 1982; *Schmid-Burgk*, 1984).

A relatively consistent finding in schizophrenia is an increase of dysmetric saccades, mostly undershooting the target with correcting saccades (*Levin* et al., 1981; *Schmid-Burgk* et al., 1982; *Mather* and *Putchat*, 1982/3; *Schmid-Burgk*, 1984), as well as a higher rate of nonfixation, i.e., deviation of the gaze from a stationary target (*Mialet* and *Pichot*, 1981; *Schmid-Burgk* et al., 1982; *Mather* and *Putchat*, 1982/3; *Schmid-Burgk*, 1984). Instability of fixation, which is related to certain psychopathologic symptoms such as tension (*Gaebel* et al., 1986), is considered by some authors to be a nosologically unspecific characteristic of psychiatric inpatients, whereas saccadic dysmetria is considered to be related to a schizophrenia-specific attentional deficit (*Schmid-Burgk*, 1984). *Mather* (1986) was able to show that normals without visual context information (in the dark) showed an increase in saccadic dysmetria similar to schizophrenics. She concludes that schizophrenics suffer from a general deficit of attention and information processing rather than from a pure oculomotor disturbance. Since brain stem and cerebellar mechanisms in schizophrenia seem to be intact (*Levin* et al., 1982a; *Levin*, 1983), these eye movement dysfunctions have been related to deficits in tuning of cortical (e.g., frontal and parietal) functions.

Smooth-pursuit eye movements

The early observations of disturbed smooth-pursuit eye movements in schizophrenia by *Diefendorf* and *Dodge* (1908) were confirmed by *Couch* and *Fox* (1934) and *White* (1938), but were forgotten until the late 1960s, when *Holzman* rediscovered the phenomenon (*Holzman*, 1983). Since then, disturbed smooth-pursuit eye movements in schizophrenia have been confirmed with different recording techniques (electro-oculography, infrared reflection technique) and different target characteristic and scoring methods (*Lipton* et al., 1983). Evidence supporting the suggestion that smooth-pursuit eye movement disruption is a biological marker for the liability to schizophrenia, can be summarized as follows (*Erlenmeyer-Kimling*, 1987). Smooth-pursuit eye movements have been found to be disrupted in some 50–85% of schizophrenic patients in contrast to about 8% of the general population; eye tracking performance has been shown to be stable over time in normal and psychiatric samples and to be dystunctional in remitted schizophrenics; about 40–50% of the first-degree relatives of schizophrenic patients show the dysfunction; concordance for eye tracking dysfunction in monozygotic twins who are discordant for schizophrenia is about double the concordance rate for dysfunction in dizygotic twins who are clinically discordant for schizophrenia; the dysfunction is more frequent in high-risk children of schizophrenic mothers (*Mather*, 1985); occurrence of the dysfunction in "normals" is more frequently related to schizotypal personality disorder (*Siever* et al., 1984); the occurrence of the dysfunction in 30–50% of patients with manic psychosis is related to treatment with lithium, with only about 10–13% of the first-degree relatives of patients with major affective disorders having eye tracking dysfunction. Since eye tracking dysfunctions occur in relatives of schizophrenics, who themselves do not show the dysfunction, *Matthysse* et al. (1986) have suggested that both schizophrenia and deviant eye tracking may be expressions of a "latent trait".

Since neuroleptic medication, motivational factors, and attentional factors do not play a significant role in eye tracking dysfunction (*Lipton* et al., 1983), the question arises as to "what eye tracking dysfunctions tell us about schizophrenia" (*Holzman*, 1983). *Levin* (1984), using the infrared reflection technique, suggests that distinguishable eye-tracking dysfunctions (saccadic intrusions), which cannot be suppressed by attention-enhancing procedures, are the result of frontal disinhibition of the saccade system. While lesions restricted to the frontal eye fields of trained monkeys cause only subtle changes in saccadic performance, frontal lesions in man are associated with difficulties in voluntary contralateral saccades, in voluntary visual search, and in suppression of unwanted saccades to a contralateral visual stimulus (*Leigh* and *Zee*, 1983).

Gaze and mutual gaze

With increasing complexity of visuomotor behavior, such as, for example, in social interaction and visual exploration (scanning), the perceptual-cognitive (monitoring) function of gaze becomes more involved. During interviews, for instance, eye contact (mutual gaze) in schizophrenics has been reported to be reduced in frequency as well as in duration (*Rutter* and *Stephenson*, 1972). However, this seems to be a state-dependent phenomenon related to acute symptomatology, normalizing under neuroleptic drugs in treatment responders, but not in nonresponders (*Meya* and *Renfordt*, 1986). It is still uncertain whether this visuomotor abnormality is just part of a more general deficit in interpersonal skills, whether it is related to deficits in facial discrimination and emotional perception (*Feinberg* et al., 1986) as well as to dysfunctions in selective attention and information processing, or whether it is an adaptive strategy for coping with sensory overload or hyperarousal. Given the functional importance of the dopaminergic system in schizophrenia and possibly in visual attention (*Matthysse*, 1978), it might also be speculated that, depending on the functional state of this system (unblocked or pharmacologically blocked), the abovementioned computation-to-acquisition ratio, corresponding to the availability of anticipation strategies (e.g., peripheral vision), will be differently affected, leading to contrary changes in gaze characteristics and scanning behavior. However, these assumptions can only be tested when visual behavior is assessed under different stimulus conditions with varying attentional demands and with standardized pharmacological interventions.

The author studied the performance of schizophrenics in visual target-distractor discrimination tasks (lists of letters) using point-of-regard measurement (*Gaebel* et al., 1986; *Gaebel*, 1987). With respect to elementary scanpath characteristics (mean duration of and distance between fixations), there was evidence of two scanning types, which were labelled "minimal scanning" and "extensive scanning" respectively (following the example of *Silverman*, 1964). These types were related to different types of psychopathology and attentional performance. Minimal scanning, characterized by a significantly longer duration of fixation (prolonged computation time) and a shorter mean scanpath between fixations (restricted functional visual field), was related to more pronounced negative symptoms (emotional withdrawal), poorer search performance, and more frequent anomalous eye dominance (left-eyedness). This scanning type has been described in chronic schizophrenia (*Kojima* et al., 1986), mentally retarded children (*Reinert*, 1983), and patients with lesions of the frontal lobes (*Luria* et al., 1966). With respect to gaze direction, minimal scanners were characterized by a stronger left-sided deviation of their gaze axis during search. Since the amount of leftward gaze deviation was significantly related to negative symptoms of the SANS (unchanging facial expression, paucity of gestures, vocal inflexions, latency of response), these findings partly confirm the hypothesis that negative symptoms might be related to right-hemisphere overactivation (*Gruzelier*, 1983; *Alpert*, 1985). Behavioral abnormalities such as "gaze avoidance" might thus be primarily related to altered brain functions in psychopathologically characterized nosological subgroups.

Conclusions

Different types of visuomotor behavior are characteristically disturbed in schizophrenia. Most researchers agree that these dysfunctions have to be interpreted with reference to a more general deficit in attention and information processing. Gaze abnormalities in social interaction might thus better be conceptualized within this broader frame of reference than within the narrow concept of interpersonal skills. Concerning the question of underlying brain dysfunctions as a clue to pathogenetic mechanisms of the disorder, the answer may come from the assessment of different visuomotor behavior types and the simultaneous application of brain-imaging techniques. Using rCBF measurement, *Fox* et al. (1985), for example, have demonstrated that the frontal eye fields are involved in all kinds of voluntary saccades in normals. *Bartfai* et al. (1985) observed that eye-tracking dysfunction in schizophrenia is related to disturbances in visual search (trailmaking). Above all, the hypothesis of frontal dysfunction in schizophrenia (*Levin*, 1984a) is worth testing using visuomotor behavior as a "cortical stress test" (*Berman*, 1987). The assessment of visuomotor behavior should be regarded as an important tool with which to further explore the brain-behavior relationship in schizophrenia and other functional psychoses.

References

Alpert, M.: The signs and symptoms of schizophrenia. Comprehensive Psychiatry 26 (1985) 103–112

American Psychiatric Association: Diagnostic and statistical manual of mental disorders, DSM-III. American Psychiatric Association, Washington 1981

Andreasen, N. C.: Negative symptoms in schizophrenia. Definition and reliability. Arch. Gen. Psychiat. 39 (1982) 784–788

Andreasen, N. C., S. Olsen: Negative and positive schizophrenia: Definition and validation. Arch. Gen. Psychiatry 39 (1982) 789–794

Bartfai, A., S. E. Levander, H. Nybäck, B. M. Berggren, D. Schalling: Smooth pursuit eye tracking, neuropsychological test performance, and computed tomography in schizophrenia. Psychiat. Res. 15 (1984) 49–62

Beatty, J.: Task-evoked responses, processing load, and the structure of processing resources. Psychol. Bull. 91 (1982) 276–292

Berman, K. F.: Cortical "stress tests" in schizophrenia: Regional cerebral blood flow studies. Biol. Psychiatry 22 (1987) 1304–1326

Bleuler, E.: Dementia praecox oder Gruppe der Schizophrenien. In: Aschaffenburg, G. (ed.) Handbuch der Psychiatrie. Deuticke, Leipzig 1911

Bushnell, M. C., M. E. Goldberg, D. L. Robinson: Behavioral enhancement of visual responses in monkey cerebral cortex. I. Modulation in posterior parietal cortex related to selective visual attention. J. Neurophysiology 46 (1981) 755–772

Cegalis, J. A., D. Leen, E. J. Solomon: Attention in schizophrenia: An analysis of selectivity in the functional visual field. J. Abnorm. Psychol. 86 (1977) 470–482

Crow, T. J.: The two-syndrome concept: Origins and current status. Schizophren. Bull. 11 (1985) 471–485

Diefendorf, A. R., R. Dodge: An experimental study of the ocular reactions of the insane from photographic records. Brain 31 (1908) 451–489

Done, D. J., C. D. Frith: Automatic and strategic control of eye movements in schizophrenia. In: Gale, A. G., F. Johnson (eds.) Theoretical and applied aspects of eye movement research. Elsevier Science Publ. BV (North Holland) 1984

Ehrlichman, H., A. Weinberger: Lateral eye movements and hemispheric asymmetry: A critical review. Psychol. Bull. 85 (1978) 1080–1101

Erlenmeyer-Kimling, L.: Biological markers for the liability to schizophrenia. In: Helmchen, H., F. A. Henn (eds.) Biological perspectives of schizophrenia. John Wiley, Chichester – New York – Brisbane – Toronto – Singapore 1987

Exline, R. V., B. J. Fehr: The assessment of gaze and mutual gaze. In: Scherer, K. R., P. Ekman (eds.) Handbook of methods in nonverbal behavior research. Cambridge Univ. Press, London 1982

Feinberg, T. E., A. Rifkin, C. Schaffer, E. Walker: Facial discrimination and emotional recognition in schizophrenia and affective disorders. Arch. Gen. Psychiatry 43 (1986) 276–279

Fox, P., J. M. Fox, M. E. Raichle, R. M. Burde: The role of cerebral cortex in the generation of voluntary saccades: A positron emission tomography study. J. Neurophysiol. 54 (1985) 348–369

Gaebel, W., G. Ulrich, K. Frick: Eye movement research with schizophrenic patients and normal controls using corneal reflection pupil center measurement. Eur. Arch. Psychiatr. Neurol. Sci. 235 (1986) 243–254

Gaebel, W.: Visual search performance and psychopathology in acute and remitted schizophrenics. In: Lüer, G., U. Lass (eds.) Fourth European Conference on Eye Movements, Vol. 1. Hogrefe, Toronto – Lewiston – Göttingen – Zürich 1987

Gruzelier, J. H.: A critical assessment and integration of lateral asymmetries in schizophrenia. In: Myslobodsky, M. S. (ed.) Hemisyndromes. Academic Press, New York 1983

Holzman, P. S.: Smooth pursuit eye movements in psychopathology. Schizophren. Bull. 9 (1983) 33–36

Iacono, W. G., V. B. Tuason, R. A. Johnson: Dissocation of smooth-pursuit and saccadic eye tracking in remitted schizophrenics. Arch. Gen. Psychiat. 38 (1981) 991–996

Just, M. A., P. A. Carpenter: Eye fixation and cognitive processes. Cognitive Psychology 8 (1976) 441–480

Kendon, A.: Some functions of gaze-direction in social interaction. Acta Psychologica 26 (1967) 22–63

Kinsbourne, M.: Eye and head turning indicates cerebral lateralization. Science 176 (1972) 539–541

Kojima, T., E. Matshushima, H. Moriya, K. Ando, R. Takahashi, Y. Shimazono, M. Kharazmi, J. Herrera, S. Potkin: Eye movements in remitting and non-remitting schizophrenia. Clin. Neuropharmacol. 9 (1986) 277–279

Krüger, K., B. Hückstedt: Die Beurteilung von Blickrichtungen. Zeitschr. f. exper. u. angewandte Psychologie 16 (1969) 452–472

Leigh, R. J., D. S. Zee: The neurology of eye movement. F. A. Davis Company, Philadelphia 1983

Levin, S., P. S. Holzman, S. J. Rothenberg, R. B. Lipton: Saccadic eye movements in psychotic patients. Psychiat. Res. 5 (1981) 47–58

Levin, S., A. Jones, L. Stark, E. L. Merrin, P. S. Holzman: Saccadic eye movements of schizophrenic patients measured by reflected light technique. Biol. Psychiat. 17 (1982) 1277–1286

Levin, S., A. Jones, L. Stark, E. L. Merrin, P. S. Holzman: Identification of abnormal patterns in eye movements of schizophrenic atients. Arch. Gen. Psychiatry 39 (1982a) 1125–1130

Levin, S.: Smooth pursuit impairment in schizophrenia – What does it mean? Schizophren. Bull. 9 (1983) 37–44

Levin, S.: Frontal lobe dysfunctions in schizophrenia. I. Eye movement impairments. J. Psychiat. Res. 18 (1984) 27–35

Levin, S.: Frontal lobe dysfunctions in schizophrenia. II. Impairments of psychological and brain functions. J. Psychiat. Res. 18 (1984a) 57–72

Levy-Schoen, A.: Flexible and/or rigid control of oculomotor scanning behavior. In: Fisher, D. F., R. A. Monty, J. W. Senders (eds.) Eye movements: Cognition and visual perception. Lawrence Erlbaum Associates, Publ., Hillsdale/New Jersey 1981

Lipton, R. B., D. L. Levy, P. S. Holzman, S. Levin: Eye movement dysfunctions in psychiatric patients: A review. Schizophren. Bull. 9 (1983) 13–32

Luria, A. R., B. A. Karpov, A. L. Yarbus: Disturbances of active visual perception with lesions of the frontal lobes. Cortex 2 (1966) 202–212

Lynch, J. C., V. B. Mountcastle, W. H. Talbot, T. C. T. Yin: Parietal lobe mechanisms for directed visual attention. J. Neurophysiology 40 (1977) 362–389

Mackert, A.: Increase of hypometric saccades in schizophrenics. 18th Annual Meeting: Society for Neuroscience, Toronto/Ontario, Canada 1988

Manschreck, T. C.: Motor abnormalities in schizophrenia. In: Nasrallah, H. A., D. R. Weinberger (eds.) Handbook of schizophrenia. Vol. 1: The neurology of schizophrenia. Elsevier, Amsterdam – New York – Oxford 1986

Mather, J. A., C. Putchat: Motor control of schizophrenics – I. Oculomotor control of schizophrenics: A deficit in sensory processing, not strictly in motor control. J. Psychiat. Res. 17 (1982/83) 343–360

Mather, J. A.: Eye movements of teenage children of schizophrenics: A possible inherited marker of susceptibility to the disease. J. Psychiat. Res. 19 (1985) 523–432

Mather, J. A.: Saccadic eye movements to seen and unseen targets: Oculomotor errors in normal subjects resembling those of schizophrenics. J. Psychiat. Res. 20 (1986) 1–8

Matthysse, S.: A theory of the relation between dopamine and attention. J. Psychiat. Res. 14 (1978) 241–248

Matthysse, S., P. S. Holzman, K. Lange: The genetic transmission of schizophrenia: Application of mendelian latent structure analysis to eye tracking dysfunctions in schizophrenia and affective disorder. J. Psychiat. Res. 20 (1986) 57–67

Meienberg, O.: Die Infrarot-Reflexionsmethode zur Registrierung horizontaler Augenbewegungen. Eine verbesserte, für diagnostische Routineuntersuchungen geeignete Version. Fortschr. Neurol. Psychiat. 55 (1987) 158–163

Mesulam, M. M., N. Geschwind: On the possible role of neocortex and its limbic connections in the process of attention and schizophrenia: Clinical cases of inattention in man and experimental anatomy in monkey. J. Psychiat. Res. 14 (1978) 249–259

Meya, U., E. Renfordt: Can changes in eye-contacts predict therapeutic outcome in schizophrenic patients undergoing neuroleptic treatment? Pharmacopsychiat. 19 (1986) 429–433

Mialet, J. P., P. Pichot: Eye-tracking patterns in schizophrenia. Arch. Gen. Psychiatry 38 (1981) 183–186

Mountcastle, V. B., B. C. Motter, M. A. Steinmetz, C. J. Duffy: Looking and seeing: The visual functions of the parietal lobe. In: Edelman, G. M., W. E. Gall, M. W. Cowan (eds.) Dynamic aspects of neocortical function. John Wiley & Sons, New York – Chichester – Brisbane – Toronto – Singapore (1984) 159–193

Nasrallah, H. A., D. R. Weinberger: The neurology of schizophrenia, Vol. 1. In: Nasrallah, H. A. (ed.) Handbook of schizophrenia. Elsevier, Amsterdam – New York – Oxford 1986

Noton, D., L. Stark: Eye movements and visual perception. Sci. Amer. 224 (1971) 34–43

Nuechterlein, K. M.: Reaction time and attention in schizophrenia: A critical evaluation of the data and theories. Schizophren. Bull. 3 (1977) 373

Reinert, G.: Augenbewegungen bei geistig behinderten Kindern. Psychologisches Institut der Ruhr-Universität Bochum, Arbeitseinheit Kognitionspsychologie 1983

Russo, J. E.: Adaptation of cognitive processes to the eye movement system. In: Senders, J. W., D. F. Fisher, R. A. Monty (eds.) Eye movements and the higher psychological functions. Lawrence Erlbaum Associates, Publishers. Hillsdale, New Jersey 1978

Rutter, D. R., G. M. Stephenson: Visual interaction in a group of schizophrenic and depressed patients. Brit. J. Soc. Clin. Psychol. 11 (1972) 57–62

Scherer, K. R., P. Ekman: Handbook of methods in nonverbal behavior research. Cambridge Univ. Press. London 1982

Scherer, K. R., P. Ekman: Methodological issues in studying nonverbal behavior. In: Scherer, K. R., P. Ekman (eds.) Handbook of methods in nonverbal behavior research. Cambridge Univ. Press, London 1982a

Schneider, K.: Klinische Psychopathologie. 3. Aufl. Thieme, Stuttgart 1950

Siever, L. J., R. D. Coursey, I. S. Alterman, M. S. Buchsbaum, D. L. Murphy: Impaired smooth pursuit eye movement: Vulnerability marker for schizotypal personality disorder in a normal volunteer population. Am. J. Psychiatry 141 (1984) 1560–1566

Silverman, J.: The problem of attention in research and theory in schizophrenia. Psychol. Rev. 71 (1964) 352–379

Schmid-Burgk, W., W. Becker, V. Diekmann, R. Jürgens, H. H. Kornhuber: Disturbed smooth pursuit and saccadic eye movements in schizophrenia. Arch. Psychiat. Nervenkr. 232 (1982) 381–389

Schmid-Burgk, W.: Sakkadische Augenbewegungen und endogene Psychosen. Fortschr. Neurol. Psychiat. 52 (1984) 67–71

Stevens, J. R.: Eye blink and schizophrenia: Psychosis or tardive dyskinesia? Am. J. Psychiatry 135 (1978) 223–226

Wagner, H., J. H. Ellring, A. Clarke: Analyse des Blickverhaltens in sozialen Situationen. In: Winkler, P. (ed.) Methoden der Analyse von Face-to-Face-Situationen. Metzler, Stuttgart 1981

Yarbus, A. L.: Eye movements and vision. Plenum Press, New York 1967

Young, L. R., D. Sheena: Methods and designs – survey of eye movement recording methods. Behav. Res. Ther. 7 (1975) 397–429

Zee, D. S.: Ocular motor control: The cerebral control of saccadic eye movements. In: Lessell, S., J. T. W. van Oalan (eds.) Neuroophtalmology, Vol. 3. Excerpta Medica, Amsterdam 1984

Dr. med. W. Gaebel

Psychiatrische Klinik und Poliklinik
der Freien Universität Berlin
Eschenallee 3
D-1000 Berlin 19 (West)
Germany