Eur Arch Psychiatr Neurol Sci (1989) 239:23–26

European Archives of Psychiatry and Neurological Sciences

Release of Saccades in Schizophrenics: Inattention or Inefficiency?

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Summary. This paper attempts to distinguish between inattention and inefficiency as the cause of the eye movement problems of schizophrenic subjects. It focuses on their release of fast saccadic eye movements in four different situations: interrupting smooth tracking, as double-jumps in refixation, and as inadvertent departures from steady fixation or too-early prediction moves. If an attention deficit causes saccades during tracking, they should be reduced only for schizophrenic subjects in the dark, when there is no constrasting background. Instead the reduction was present for all groups. If double-jumps in saccadic refixations were caused by inattentional instability, they should increase in schizophrenic subjects when the target is a temporary flash of light. Instead, they were reduced in all groups to almost none, suggesting a perceptual processing cause for the excess double jumps. If a global attentional problem of schizophrenia caused saccade release, saccade number should be correlated across the four situations. Instead, there were significant correlations only between departures and predictions in paranoid schizophrenic subjects ($r = 0.728$) and between predictions and looking in nonparanoid schizophrenic subjects ($r = -0.855$). This lack of over-all correlations suggests that a common inattentional problem does not produce these eye movement deficiencies. Instead, the perceptual influence on tracking and looking suggests that processing inefficiency is responsible for at least part of the deficit.

Key words: Saccades – Schizophrenia – Inattention – Inefficiency

Introduction

Deficiency of slow pursuit tracking, involving production of excessive fast saccadic interruptions, is seen as the ocular motor problem of schizophrenic subjects (Holzman et al. 1976; Iacono 1982; Mather and Putchat 1983). The source of the disorder has been specified as attentional dysfunction (Inattention) (Holzman et al. 1976), or as faulty processing of perceptual information (Inefficiency) (Mather 1986). Since schizophrenics have general attentional problems (see Oltmanns and Neale 1978), it has been easy to ascribe this oculomotor control difficulty to "a disorder of non-voluntary attention" (Holzman et al. 1976; Holzman 1987), leading to excess saccade release. Proving this is difficult, though important.

A strong case for inattention as a controller of oculomotor performance in schizophrenia would build on three results. First, schizophrenic individuals should have less accurate oculomotor control; this has been abundantly proven (see Iacono 1982). Second, attentional manipulations of normal individuals should produce similar oculomotor deficiencies; results of this approach are inconclusive. Only Brezinova and Kendall (1977) found normal individuals under stress (distracted) had the deficient pursuit of schizophrenic patients. Lipton et al. (1980) and Kaufman and Abel (1986), did not find the same results with individuals distracted by noise. Third, reduction of distraction of schizophrenic subjects should increase their oculomotor performance to become equal to that of normals. Shagass et al. (1976), who used number-reading from a tracked pendulum to increase attentiveness, did not find this, and a similar manipulation by Pivik (1979) actually decreased ocular tracking accuracy in hospitalized schizophrenics. Adding a dichotic listening task to tracking did produce comparatively greater impairment in the oculomotor tracking of schizophrenic subjects than in that of normals (Pass et al. 1978). However, this result could be expected both if the situation overloaded attentional demands and if it strained an inefficient processing system. These three approaches have not made a conclusive case for inattention as a controller of oculomotor accuracy in schizophrenia.

To test for attention as a controlling factor in oculomotor performance we could look for excessive "release" of saccades not just in tracking but across all

Offprint requests to: J. A. Mather

This article was presented in part at the Symposium on Eye Movements and Psychopathology, Berlin, 23–24 June 1988

three oculomotor subsystems, as saccade departures from fixation, multiple saccadic jumps to look to a single target, and saccades interrupting pursuit tracking. Matthyse (1978) suggested a "release of saccades" model to measure an attentional cause of schizophrenic subjects' oculomotor deficits, but only in smooth pursuit tracking. He postulated that "saccadic disturbances should be more frequent at the extremes of the pendulum's motion" where attention lapsed. Mialet and Pichot (1981), Mather and Putchat (1983) and Iacono and Koenig (1983) all found that there were more saccades not at the end but at the high-velocity "catch-up" phases of target motion, which suggests a tracking efficiency and not an attentional problem. Mialet and Pichot (1981) and Matsue et al. (1986) looked at saccade production across fixation and tracking, but did not find the significant correlations across tasks which would suggest a common deficit.

The present study evaluates the "release of saccades due to inattention" hypothesis, and the alternate hypothesis that the cause of excess saccade production is processing inefficiency. Saccade production was measured during three oculomotor tasks: smooth pursuit tracking, both in normal room illumination and in the dark; looking to a continuous and flashed target; and fixation, by the number of departures from steady gaze and the number of predictive departures before the target moved (Mather and Putchat 1983). The perceptual manipulation of room background should remove the group differences if the problem is attentional, or stimulate parallel changes if the problem is efficiency. Reducing target duration (to a flash) should reduce corrective saccades in looking if the problem is visual processing, and increase them if the problem is attentional stability. Correlations of subjects' mean scores on all four measures would demonstrate a common, possibly attentional, cause for excess saccade release.

Materials and Methods

Subjects. Control subjects for this study were 16 college students (9 male, 7 female), mean age 25.5 years, with no known defects of vision. Fifteen paranoid (7 male, 8 female) and 9 nonparanoid (5 male, 4 female) schizophrenic and ten nonschizophrenic depressed subjects (3 male, 7 female) were selected from the inpatient population of the London Psychiatric Hospital, London, Ontario. Hospitalized subjects were between 18 and 45 years of age and had a minimum of Grade 8 education, a Weschler Adult Intelligence Scale I.Q. of 80 or greater, and no indications of prior drug dependency or alcoholism. Their cumulative hospitalization did not exceed 3.5 years, and they had no histories of brain pathology and electroconvulsive therapy within 6 months prior to testing. All patients had a clinical diagnosis of active schizophrenia or depressive disorder according to Research Diagnostic Criteria (RDC); those with a diagnosis of schizoaffective disorder were not included.

Procedure. Subjects were given a standard set of tests of oculomotor function in a one-hour session (see Mather 1985, for details). They produced smooth pursuit tracking in response to target lights moving at slow but constant velocities (11°, 22°, 33°, 44°, 55° and 66°/s) over a 30° arc in the dark or light, and saccadic jumps following constantly illuminated or flashed target lights moving quickly over the same range. Eye movements were measured by DC electro-oculography. During pursuit tracking, the number of all saccades was recorded as (1) Tracking Saccades, regardless of their direction. In the looking tests, the number of saccades produced per target move was recorded and averaged over 12 moves per condition, and as (2) Looking Saccades. In the Fixation intervals, between looking, the number of departures $> 2°$ from fixation during a 10 s sample just before the saccade task began was recorded as (3) Departure Saccades. In addition, the number of saccadic moves (of 16) which departed too soon (before the target light moved or < 160 ms after) were recorded as false moves, or (4) Predictive Saccades.

Data from these four measures of saccade production were then submitted to statistical tests. Analyses of variance on Tracking Saccades used the variables Target Velocity, Room Illumination, and Subject Group, and for Looking Saccades, Target Illumination and Subject Group. One way ANOVAs were performed on Departures and Predictions, across Subject Groups. Correlations between the four measures of saccade production were taken separately for each group.

Results

Tracking Saccades

Group affected saccade number, $F(3,46) = 3.30$, $P = 0.028$. As expected if saccades are the result of poor tracking, patients produced more, and paranoid schizophrenics produced the most saccades (Table 1). Illumination also affected saccade number, $F(1,46) = 35.11$, $P < 0.001$. There were more saccades for all groups in the light. However, there was no Group by Illumination interaction, as would be expected if darkness differentially affected schizophrenic subjects' saccade production by removing the distraction of a background.

Looking Saccades

Data for some individuals (two normal controls, five paranoids, three nonparanoids, and one depressive)

Table 1. Number of Saccades Produced by Student Controls, Paranoid Schizophrenics, Non-Paranoid Schizophrenics, and Depressives. Saccades in Tracking are Averaged Across all 30° Moves (48), in Looking are to Continuous Targets (12), in Departures are During 10 Seconds of Fixation, and in Predictions are Out of a Possible 16

Condition	Controls	Paranoids	Non-paranoids	Depressives
Tracking	2.25	2.88	2.55	2.60
Looking	1.24	1.43	1.37	1.39
Departures	1.9	2.2	3.1	1.9
Anticipitation	1.1	2.6	3.4	3.2

Table 2. Correlations Amongst Four Measures of Saccade Production (Tracking, Looking, Departures and Predictions) for Four Subject Groups (Controls, Paranoid and Nonparanoid Schizophrenics, and Depressives)

Relationship	Controls	Paranoid Schizophrenics	Nonparanoid Schizophrenics	Depressives
1 Looking-Tracking	0.147	0.469	0.702	0.669
2 Departures-Tracking	0.020	0.167	0.277	−0.440
3 Predictions-Tracking	0.118	−0.176	−0.137	−0.642
4 Departures-Looking	0.189	0.069	0.112	−0.538
5 Predictions-Looking	0.011	−0.223	*−0.885	−0.637
6 Departures-Predictions	0.517	*0.728	0.620	0.234

*Significant at $P < 0.01$

were omitted owing to poor performance on the Flash subtask. Nevertheless, there was a significant effect of Group, $F(3,35) = 3.37$, $P = 0.029$, on saccade number; schizophrenics were more likely to make two saccadic moves before reaching the target. There was also a major effect of Illumination $F(1,35) = 192.3$, $P < 0.001$, and an interaction of Group and Illumination, $F(3,35) = 4.95$, $P = 0.006$. Despite their higher number of saccades when the light was continuous, and as predicted by an efficiency of processing model, all schizophrenics as well as controls reduced extra saccades to near zero during Flash.

Departures and Predictive Saccades

There were no significant differences across groups either in number of saccades which were Departures from steady fixation or in numbers of too-early Predictive moves. Nonparanoid schizophrenics produced more in both cases, but these differences were swamped by the large variability (see Table 1).

Correlations

There were few significant correlations amongst these four measures of saccade occurrence, using a conservative level of $P < 0.01$. Departures and predictions correlated significantly amongst paranoid schizophrenic subjects ($r = 0.728$), and predictions and looking amongst nonparanoids ($r = -0.884$). All the hospitalized groups had high correlations between looking and tracking saccade numbers, which were nonsignificant because of small group size. The depressive subjects had high (> 0.5) correlations amongst their scores on most measures (see Table 2).

Discussion

The data presented above argue against attention dysfunction as the single cause for oculomotor problems in schizophrenia, if it is measured as the inadvertent release of too many saccades. There may instead have been two causes – an Efficiency problem affecting Tracking and Looking, and a Stability problem affecting Departures (gaze-holding) and Predictions (timing of switching gaze).

Inefficient information processing problems may have been general across the saccadic and pursuit subsystems. Schizophrenic and depressive subjects were worse in both tasks than normals (also see Mather and Putchat 1983), and their performance in them was correlated (see Tables 1 and 2). The eye movement stability problems may, in contrast, be attentional. The related decrements in gaze holding and too-early moving in nonparanoid patients resembled schizophrenic patients' problems with other "attentional" tasks. This difficulty was similar to that of subjects with frontal cortex lesions, who had problems restraining an inappropriate eye movement (Guitton et al. 1981). Nevertheless, these "attentional" deficits were variable in our and other schizophrenic subjects, more likely to occur if they were not undergoing drug treatment (see Oltmann et al. 1978), and not present under all environmental conditions. Mialet and Pichot (1981) found schizophrenic individuals produced more saccades while attempting fixation than normals; Matsue et al. (1986) and Mather and Putchat (1983) did not, although the latter found schizophrenics had significantly more Prediction errors. Yet all researchers found these departures from fixation were always more frequent in schizophrenic subjects than controls, but not significantly so because of variability. Some cause of this variability, perhaps drugs, duration of illness, or a "state" effect of mood swings, may be masking true differences between groups.

What of the perceptual manipulations? Reducing room illumination could change Attentional demand as well as perceptual input, since turning off the room lights removes both the visual room background and a source of distraction. In this study, however, the featured background had a parallel and not an interactive effect on saccade production. In contrast, Pivik et al. (1987) found a significant interaction, a reduction of

tracking error in darkness in schizophrenic subjects, but only by one of their two measures, the Velocity Arrest. Since the combination of pursuit velocity and saccade number can be adjusted by normal individuals so that comparable tracking accuracy is maintained despite changes in stimulus character (Collewijn and Tamminga 1984), it is not surprising that Pivik et al.'s (1987) measure of pursuit error did not pick up the dynamic system adjustment which was found in saccade number by the present study.

No piece of evidence pointed more clearly to perceptual processing as a cause of the increased saccade production in schizophrenia than the differences in saccade number across the conditions in Looking. Normal individuals made a second "corrective" saccade only to the continuous visual target, when visual feedback assisted programming for the corrective move (Becker 1972). These double saccades were also more frequent during looking in the dark, when subjects had less certainty of target position (Mather 1986). Double saccade production of schizophrenic subjects was higher than that of normals during continuous target illumination in the present study, as in Mather and Putchat (1983) and Mather (1985). When looking to the Flash, however, they stopped making double saccades. If their problem with eye movements was gaze stability, schizophrenic subjects would make more corrections with reduced visual target information. That they made almost none suggests strongly that the difference was due to perceptual processing. Thus all the evidence of this study has not linked attention and motor control. Since there seems to have been no single cause of "saccade release", there appears no single decrement. Despite the "well-known" attentional problems of schizophrenics, their deficits are variable (see Oltmann et al. 1978). Schizophrenia probably causes both processing inefficiency and inattention; the first is a factor in the control of looking and tracking, and the second in holding fixation. Thus, separating inefficiency from inattention in oculomotor control of schizophrenics is possible, but neither deficiency by itself predicts all their problems with eye movements.

This research was supported by NSERC grant T109A1 to the first author and MRC grant MA 5028 to the second. We thank Sue Zimmerman, Donna McLaughlin and Suzy Lister for assistance with testing subjects.

References

Becker W (1972) The control of eye movement in the saccadic system. Bibl Opthalmol 82:233–243

Brezinova V, Kendall RE (1977) Smooth pursuit eye movements in schizophrenics and normal people under stress. Br J Psychiatry 30:59–63

Collewijn H, Tamminga E P (1984) Human smooth and saccadic eye movements during voluntary pursuit of different target motions on different backgrounds. J Physiol (Lond) 351:217–250

Guitton D, Buchtel HA, Douglas RM (1981) Disturbances of voluntary saccadic eye movement mechanisms following discrete unilateral frontal lobe removal. In: Lennerstrand G, Zee D, Keller EL (eds) Functional bases of ocular motility disorders. Pergamon, New York, pp 497–524

Holzman PS (1987) Recent studies of psychophysiology in schizophrenia. Schizophrenia Bull 13:49–75

Holzman PS, Levy DL, Proctor LR (1976) Smooth-pursuit eye movements, attention, and schizophrenia. Arch Gen Psychiatry 33:1415–1420

Iacono WG (1982) The genetics of psychopathology as a tool for understanding the brain: the search for a genetic marker of schizophrenia. In: Lieblich I (ed) Genetics of the brain. Elsevier, Amsterdam, pp 62–91

Iacono W, Koenig WGR (1983) Features that distinguish the smooth-pursuit eye-tracking performance of schizophrenic, affective-disorder and normal individuals. J Abnorm Psychol 92:29–41

Kaufmann SR, Abel LA (1986) The effects of distraction on smooth pursuit in normal subjects. Acta Otolaryngol (Stockh) 102:57–64

Lipton RB, Frost LA, Holzman PS (1980) Smooth pursuit eye movements, schizophrenia and distraction. Percept Mot Skills 50:159–167

Mather JA (1985) Eye movements of teenage children of schizophrenics: a possible inherited marker of susceptibility to the disease. J Psychiatric Res 19:523–532

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

Mather JA, Putchat C (1983) Motor control of schizophrenics. I. Oculomotor control of schizophrenics: a deficit in sensory processing, not strictly in motor control. J Psychiatric Res 17:343–360

Matsue Y, Okuna T, Saito H, Aneha S, Ueno T, Chiba H, Matsuoka H (1986) Saccadic eye movements in tracking, fixation and rest in schizophrenic and normal subjects. Biol Psychiatry 21:382–389

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

Mialet JP, Pichot P (1981) Eye-tracking patterns in schizophrenia: an analysis based on the incidence of saccades. Arch Gen Psychiatry 38:183–186

Oltmanns TF, Neale JM (1978) Distractibility in relation to other aspects of schizophrenic disorder. In: Schwartz S (ed) Language and cognition in schizophrenia. Erlbaum, Hillsdale, pp 117–143

Oltmanns TF, Ohayon J, Neale JM (1978) The effect of antipsychotic medication and diagnostic criteria on distractibility in schizophrenia. J Psychiatr Res 14:81–91

Pass HL, Salzman LF, Klorman R, Klaskey GB, Klein RH (1978) The effect of distraction on acute schizophrenics' visual tracking. Biol Psychiatry 13:587–593

Pivik RT (1979) Smooth pursuit eye movements and attention in psychiatric patients. Biol Psychiatry 14:859–879

Pivik RT, Bylsma FW, Cooper P (1987) The effect of dark adaptation on pursuit tracking dysfunction in psychotics with impaired vestibular suppression. Prog Neuro-Psychopharmacol Biol Psychiatry 11:259–265

Shagass C, Roemer RA, Amadeo M (1976) Eye-tracking performance and engagement of attention. Arch Gen Psychiatry 33:121–125

Received October 27, 1988