Chapter 15

Visual search performance and eye movements in schizophrenia

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Abstract

Recent evidence points to the syndrome specificity of attentional deficit in schizophrenia on various tasks, especially those of visuomotor performance (Gaebel et al., 1986, 1987; Gaebel and Ulrich, 1987). Deviations have been reported in elementary eye movement components (e.g. prolonged fixation duration in chronic schizophrenics with negative symptoms). Starting from previous eye movement studies in schizophrenia, the present study tried to elucidate some of the relationships between eye movements, search performance and psychopathology in a visual target-distractor discrimination task.

Introduction

The present study aimed at replication and extension of these findings in a visual search task. Twenty acutely admitted schizophrenic inpatients (mean age 33.5 + 11.3 years, 50% male), diagnosed according to ROC and age-matched normal controls, were instructed to search for a randomly located target letter (Z) in 10 lists of 284 distractor letters of rounded or angular shape projected on a screen (23 x 18 deg). Eye movements (EM) were recorded using infrared corneal reflection pupil-centre measurement (DEBIC 80). Search time (ST) in seconds from the onset of the display until localisation of the target was averaged for the 5 lists with rounded and distractor letters respectively. The same procedure was applied to basic EM parameters: total number of fixations (TNF); mean duration (msec) of a single fixation (MDF); mean scan path (distance) between successive fixations (MSP). Assessment took place shortly after admission (T1) and before discharge (T2).

Although the BPRS (Brief Psychiatric Rating Scale) total score decreased significantly from T1 to T2 ($p<0.0001$), the mean ST did not change over time with remission and revealed a persistent dependence on task difficulty ($F1,19=15.57$, $p<0.001$). For both paradigms TNF correlated highly with ST ($r=0.89$ to 0.97, $p<0.001$). Concerning the basic EM components, MDF and MSP were persistently negatively correlated ($r=-0.52$ to -0.74, $0.05>p<0.001$). Consequently the group was split according to opposite EM patterns: 10 individuals (G1) fell below the grand mean of MDF (331.4 ± 34.9 msec) and above the grand mean of MSP (62.3 ± 17.1) and 10 individuals behaved vice versa (G2). The EM patterns of G1 (extensive scanning) and G2 (staring) were stable over time. Only the EM pattern of G1 differed significantly from normal controls. At T1, G2 scored

higher in emotional withdrawal ($T=2.56$, $p<0.05$). Concerning ST, an interaction effect emerged between time point (T1,T2) and group (G1,G2) for rounded distractors only ($F1,19=6.16$, $p<0.05$). Accordingly, ST improved with remission particularly in G2.

Search performance in schizophrenics is heavily affected by task difficulty, which is reflected by target/distractor similarity. Since there is no change in mean ST over time, the conclusion could be drawn that search performance is independent of improvement in psychopathology. However, in accordance with previous findings, two relatively time stable trait-like EM patterns in schizophrenics can be distinguished which are differently related to psychopathology and performance measures. The relationship between staring behaviour, emotional withdrawal and search performance in the acute illness phase points to a state specific regulation of attention and negative symptoms in a clinical subgroup, which is characterized by restricted scanning. From preliminary findings of differences in saccadic velocity between G1 and G2, attention seems to be regulated by varying the width of the functional visual field.

The measurement of behavioural signs of psychiatric disorders can improve diagnostic precision and understanding of underlying brain mechanisms (Alpert, 1985). In biologically oriented schizophrenia research, the assessment of oculomotor dysfunctions as possible markers for the liability to the illness has become increasingly more important (Erlenmeyer-Kimling, 1987). However, more complex looking behaviour, as in picture viewing or visual search, has scarcely been assessed under abnormal psychic conditions.

Material and Methods

Twenty acutely admitted schizophrenic inpatients (mean age 33.5 ± 11.3 years, 50% male), diagnosed according to RDC (Spitzer et al., 1982), and 8 normal controls (mean age 33.3 years, 6 male) were instructed to search for a randomly located target letter (Z) in 10 lists of 284 capital distractor letters, each projected on a screen (23 deg x 15 deg) for a maximum of 60 seconds. Half of the lists contained distractor letters of rounded (R) or angular shape (A) respectively, presented in random order.

Both paradigms thus differed with respect to similarity and dissimilarity of formal characteristics of target and distractor letters. While the dissimilarity paradigm ostensibly activates more automatic attentional processes, the similarity paradigm activates more focal attentional processes (Neisser, 1974). Both paradigms were chosen, to answer the question, which of both processes are disturbed in schizophrenia (Nuechterlein and Dawson, 1984)?

Search performance was defined as the search time (ST) in seconds from onset of the display until localization of the target.

All subjects had normal vision. Eye movements were recorded using infrared corneal reflection-pupil centre measurement (Young and Sheena, 1975; Gaebel et al., 1986). A single fixation was defined to represent at least 10 consecutive gaze positions (>200msec) within a predetermined window. From this, the following parameters were extracted: total number of fixations (TNF), total duration of fixations (TDF), mean duration (msec) of a single fixation (MDF), total scanpath (TSP), and mean scanpath (distance in pixels) between successive fixations (MSP).

In schizophrenics, assessment took place shortly after admission (T1) and before discharge (T2), while normal controls were assessed only once. At T1 a drug washout phase of minimum 3 days was required, at T2 all patients were on neuroleptic drugs.

Table 15.1 Pearson correlations between ST (R/A) and EM-parameters (macro-/ micropattern) in normals (N) and schizophrenics (S) at T1 and T2.

		macro			*micro*	
		TNF	TSP	TDF	MDF	MSP
Schizophrenics						
T1	ST/R	.97[d]	.84[d]	.95[d]	.63[b]	−.66[b]
	ST/A	.89[d]	.76[d]	.86[d]	.30	−.26
T2	ST/R	.94[d]	.89[d]	.95[d]	.44[a]	−.53[a]
	ST/A	.90[d]	.76[d]	.89[d]	.45[a]	−.46[a]
Normals						
	ST/R	.92c	.77[b]	.84[b]	−.20	.01
	ST/A	.97c	.89c	.97c	.02	−.51

[a] $p<.05$, [b] $p<.01$, [c] $p<.001$, [d] $p<.0001$

The psychopathological status of the schizophrenic patients was assessed with the Brief Psychiatric Rating Scale (BPRS, Overall and Gorham, 1962) at T1 and T2. From the 18 items of this scale, 5 factors were calculated (HOST = hostile suspiciousness, ACTV = activation, THOT = thought disturbance, ANER = anergia, ANDP = anxiety/depression). The first 3 factors represent positive symptoms, while ANER represents negative symptoms, which were additionally assessed in more detail with the Scale for the Assessment of Negative Symptoms (SANS, Andreasen, 1982).

Results

Search performance

The results of a 2-way-ANOVA with repeated measurement on ST revealed a highly significant main effect for paradigm (ST/A>ST/R, $F1,19=15.57$, $p<.001$), but no significant dependency on illness acuity and neuroleptic treatment. An influence on ST of the position of the randomly located target letter (left/right, centre/periphery) was also ruled out. ST in normal controls was also significantly dependent on task condition, but was not different from schizophrenics. Accordingly, since the psycho-pathological status (including negative symptoms) improved significantly from T1 to T2, visual target-distractor discrimination in schizophrenics seemed to be neither state-, nor disease-(trait-) specifically impaired. However, true differences might be obscured by group statistics, in so far as subgroups of schizophrenics may deviate from normal controls in opposite directions. Indirect evidence for this argument comes from the finding that the longitudinal stability (Pearson correlations) of search performance in schizophrenics is only weak (ST/R, T1/T2: $r=.52$, $p<.05$; ST/A, T1/T2: $r=.52$, $p<.05$), pointing to opposite developments of search performance in certain schizophrenic individuals over time, leaving the mean performance unaffected.

Eye movements

There was no difference between schizophrenics and normal controls in eye movement-related (TSP, MSP) and eye fixation-related parameters (TNF, TDF, MDF), neither at

T1 nor at T2. Thus, schizophrenics in acute and remitted state resemble normals in visuomotor performance and behaviour.

In normals and in schizophrenics at T1 and T2 a very similar correlational pattern emerged between ST and visuomotor behaviour for both paradigms (Table 15.1): longer search time is highly significantly related to more global scanpath characteristics (macropattern), such as higher TNF, longer TDF and TSP. With regard to elementary characteristics (micropattern), however, longer MDF and shorter MSP are related to longer ST only in schizophrenics. Accordingly, poorer search performance in some schizophrenics is not only the result of a prolonged search process, but is also related to a deviant micropattern, characterized by longer computation time and decreased saccade size. This in turn may be related to a decrease in the visual span or width of the functional visual field (narrowed attention), leading to a more focal search process. This concept is supported by the finding that MDF and MSP are significantly negatively correlated for both paradigms at T1 and T2 (T1: R, $r = -.74$, $p<.001$; A, $r = -.61$, $p<.01$; T2: R, $r = -.52$, $p<.05$; A, $r = -.60$, $p<.01$).

Since in normals MDF and MSP were also marginally negatively correlated for both paradigms (R: $r = -.58$, A: $r = -.49$), this relationship between elements of the micropattern points to a basic principle in visual search being unaffected in schizophrenics. However, in order to assess the clinical correlates of different microbehaviour the schizophrenic group was split according to opposite micropatterns (pooled paradigms) at T1: 10 individuals (G1) fell below the grand mean of MDF (331.4 ± 34.9 msec) and above the grand mean of MSP (62.3 ± 17.1), and 10 individuals behaved vice versa (G2).

The difference between the micropattern of G1 (termed "extensive scanning") and

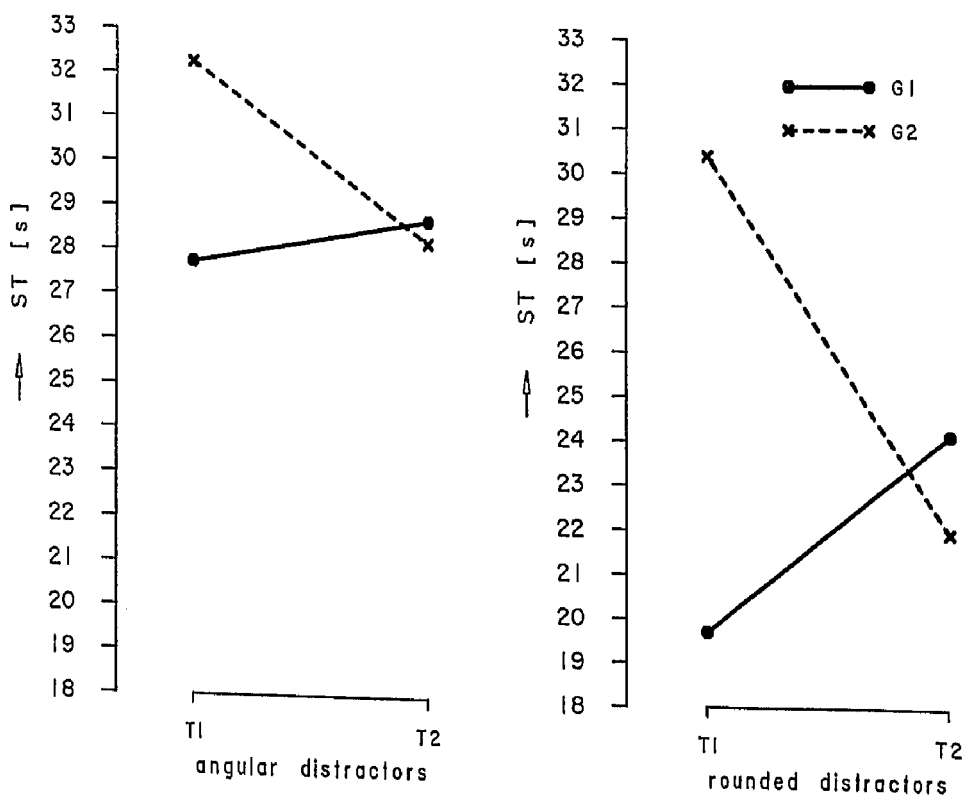

Figure 15.1 Search performance (ST) under 2 task conditions (angular and rounded distractor letters) in 2 schizophrenic subgroups (G1, G2) at T1 and T2.

Table 15.2 Factor pattern[+] of 2 separate Principal Component Analyses including ST and psychopathology[++] in schizophrenics at T1 and T2.

	T1		*T2*	
	F1	F2	F1	F2
ST/A	−.75	.50	.74	−.35
ST/R	−.72	.52	.75	−.22
SANS	.01	.52	.71	.43
ANER	.21	.58	.61	.38
ANDP	−.13	.45	.55	.40
THOT	.65	.42	.48	.67
ACTV	.55	.49	.02	.80
HOST	.14	.64	.30	.74
Explained variance:	35%	31%	37%	31%

[+] F1,F2 correspond to the first 2 of 4 extracted factors (eigenvalue = 1), which explain 70% of the variance

[++] 4 originally included EEG variables were deleted from the table.

G2 (termed "minimal scanning") was stable over time, pointing to trait-like visuomotor characteristics of 2 schizophrenic subgroups. However, only the micropattern of G1 differed slightly to significantly from normal controls (shorter MDF and longer MSP). The difference in MDF can especially be traced back to shorter fixation durations of G1 under dissimilar target/distractor conditions.

With regard to ST, there was no difference between G1 and G2 under similar target/distractor conditions. However, for the dissimilarity paradigm an interaction effect emerged between time point and group ($F1,19=6.16$, $p<.05$). Accordingly, ST improved with remission particularly in G2 (Figure 15.1). However, at T1 ST under dissimilar target/distractor conditions was only slightly longer in G2 compared to G1 ($T=1.91$, $p<.10$) and normals ($T=1.88$, $p<.10$).

Clinical and psychopathological correlates

Univariate analysis of the relationship between search permance and psychopathology did not yield significant results. To analyse the complex interrelationship between search performance and psychopathology more adequately, principal component analysis was applied to the data. Table 15.2 gives the factorial structure of this analysis at T1 and T2.

Taking into account only factor loadings of >.50, at T1 the first factor represents a negative relationship between positive symptoms and search time, while the second factor independently represents a positive relationship between negative symptoms and search time. At T2, the relative position of these 2 factors is reversed, but their meaning is similar to T1. Consequently, positive and negative symptoms retain their opposite relationship to search performance, underscoring the syndrome specificity of search performance.

Concerning G1 and G2, there was no difference in age, sex, and duration of inpatient

treatment. However, at T1 G2 scored significantly higher in emotional withdrawal (BPRS: T=2.56, p<.05) and restricted affect (SANS: T=2.20, p<.05). However, this difference disappeared at T2. From these results it may be concluded that emotional withdrawal and poorer search performance in G2 at T1 are related phenomena, which are possibly regulated by the same underlying brain mechanisms.

Discussion

The results of this exploratory study concerning search performance (search time) demonstrate that schizophrenics' overall ability to extract information from visual displays is neither significantly affected by illness acuity and neuroleptic drugs (T2) nor is it significantly different from the performance of normal controls. The latter result corresponds to previous findings in schizophrenic outpatients (Gaebel et al., 1986). Russell and Knight (1977) and Russell et al. (1980) report on comparable results in process schizophrenics, whose performance was not affected by the paranoid/non-paranoid dichotomy either. From the present findings, however, it is clear that search performance deteriorates with increasing negative symptoms, and improves with increasing positive symptoms, irrespective of illness phase (acute or remitted). Thus, the results partly confirm the syndrome specificity of attentional deficits, especially in visuomotor performance (Cornblatt et al., 1985; Green and Walker, 1985; Gaebel and Ulrich, 1987).

With regard to the relationship between search performance and visuomotor macrobehaviour, the present findings in schizophrenics and healthy controls are in accordance with results from eye movement research in normals. Search performance (ST) is always related to TNF (Gould and Dill, 1969), however, this relationship is strongly affected by task complexity, i.e. target/distractor similarity (Gould and Schaffer, 1965a; Gould, 1967; Gordon, 1969; Gould and Carn, 1973). With regard to the relationship between ST and visuomotor microbehaviour (especially MDF), research findings are less clear. No systematic relationship emerged in the present study for normals, similar to what has been found by Gould and Schaffer (1965a), Gordon (1969) and Luria and Strauss (1975). Gould and Dill (1969), however, report on shorter MDF in fast scanners. In the present study, a similar positive relationship between ST and MDF resulted for schizophrenics, irrespective of task complexity, especially under remitted illness conditions.

Most of the studies in normals report that higher task complexity and visual noise lead to longer fixation duration (Gould, 1967, 1973; Gould and Schaffer, 1965b; Jacobs, 1987), whereas only few studies do not find a significant relationship (Gordon, 1969; Gould and Carn, 1973). In the present study, although in the normal range (Gordon, 1969), schizophrenics do not exhibit longer MDF with increasing task complexity, neither at T1 nor at T2, whereas normals' MDF increases by 30 msec (not significant). One might conclude that the schizophrenics' micropattern is not modulated by local feature characteristics, leaving their visuomotor behaviour partly unadapted to the visual environment. In other words, automatic and focal attentional processes are not well-tuned to task demands.

If fixation duration is conceptualized with regard to the computation-to-acquisition ratio of a task (i.e. the relationship between computational demands and ongoing information intake), the need for anticipation strategies based on peripheral perception is greatest when the ratio is low (i.e. when the computation time per stimulus is

relatively brief) and a continual input of new information is necessary as in visual search (Russo, 1978). The "useful field of view", however, constricts with increasing visual noise (Mackworth, 1965). Moreover, peripheral vision seems to be reduced in chronic schizophrenics compared with acute schizophrenics and normals (Cegalis et al., 1977). Thus, task-related and illness-related factors both may act on the useful field of view, affecting the visuomotor micropattern in visual search of schizophrenics. However, it has been reported that temporal (MDF) and spatial (MSP) eye movement characteristics are independently controlled (Jacobs, 1987). The negative relationship between MDF and MSP in schizophrenics and normals thus seems to be in contradiction to these findings.

With respect to the visuomotor micropattern, there was evidence of two scanning types in schizophrenics, which were labelled "minimal scanning" and "extensive scanning", respectively (following the terms of Silverman, 1964). Both types were differently related to psychopathology and attentional performance. Minimal scanning, characterized by significantly longer fixation durations (prolonged computation time?) and shorter mean scanpath between fixations (restricted functional visual field?), was related to more pronounced negative symptoms (emotional withdrawal), poorer search performance (R-condition), and more frequent vertical scanning. This scanning type has been described in (chronic) schizophrenia (Kojima et al., 1986; Gaebel et al., 1987), mentally retarded children (Reinert, 1983), and patients with lesions of the frontal lobes (Luria et al., 1966). The relationship between staring behaviour, emotional withdrawal and poorer search performance only in the acute illness phase points to a state-specific regulation of negative symptoms and attention in a clinical subgroup, which is characterized by restricted scanning. Because of the stability of this eye movement pattern, attention seems to be regulated by varying the width of the functional visual field. This, however, may be an adaptive strategy for dealing with sensory overload in the acute illness phase.

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