Exploratory Eye Movements and Neuropsychological Tests in Schizophrenic Patients

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Abstract

Exploratory eye movements in schizophrenic and nonschizophrenic subjects were examined with an eye mark recorder while the subjects viewed geometric figures. Elementary components of eye movements and the responsive search score (RSS), a function of the number of sections on which the subjects fixated, were measured by means of an eye movement analyzer and slow motion replay. The schizophrenic group and the depressed patient group had fewer eye fixations than the normal control group and the obsessive-compulsive disorder group. The schizophrenic group had a lower RSS average than patients with depression, patients with obsessive-compulsive disorders, or subjects in the normal control group. These results in conjunction with those of our previous studies suggest that a low RSS is specific to schizophrenia.

We examined the relationship between these eye movements and neuropsychological tests and also investigated the relation between the eye movements and clinical symptoms by means of the Brief Psychiatric Rating Scale, Schedule for Affective Disorders and Schizophrenia, and the Scale for the Assessment of Negative Symptoms. The RSS correlated positively with the performance IQ and Wechsler's Maze test, but not with the Wisconsin Card Sorting Test or the verbal IQ result. The RSS also correlated negatively with negative symptoms. These results suggest that the RSS has two characteristic features: it is strongly associated with the interpersonal response and it may be connected with visuospatial and visuomotor functions including attention.

Disturbed attentional functioning is a common cognitive deficit seen in schizophrenia. Holzman and his associates found abnormal pursuit eye movements in schizophrenic subjects and their relatives indicative not only of disturbed attention but also of susceptibility to schizophrenia (Holzman et al. 1973, 1976; Holzman and Levy 1975). Considerable interest has been directed to the possibility that smooth pursuit eye tracking dysfunction may serve as a genetic marker of schizophrenia.

On the other hand, the authors have been studying eye movements in schizophrenic patients while they are freely viewing geometric figures. These eye movements are considered to reflect more voluntary attention than the pursuit eye movements (Moriya et al. 1972; Kojima et al. 1986a, 1986b, 1988, 1989, 1990; Nakajima et al. 1988). Callaway and Naghdi (1982) distinguished between two types of information processing: one consisted of automatic parallel processes, and the other used controlled serial processes. In schizophrenia, only the controlled serial system, which is a conscious and intentional process, seems disordered. According to this theory, voluntary attention must be examined more precisely. The assessment of scanning behavior by means of eye movement recording during a viewing task offers the opportunity to measure an overt constituent of voluntary and involuntary attentive behavior.

In the present study, eye movements of schizophrenic subjects were compared with those of nonschizophrenic subjects to determine

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whether the disturbance of exploratory eye movements is specific to schizophrenia. Next, the implication of disturbed eye movements in schizophrenia was investigated by examining the relationship between eye movements and the results of neuropsychological tests.

Method

Study I: Exploratory Eye Movements of Schizophrenic and Nonschizophrenic Patients

Subjects. The subjects were 25 chronic schizophrenic patients (17 males, 8 females); 25 depressed patients (13 males, 12 females); 10 patients with obsessive-compulsive disorders (6 males, 4 females); and 25 normal control subjects (13 males, 12 females). All patients were diagnosed by DSM-III-R criteria (American Psychiatric Association 1987). The mean ages and standard deviations for the schizophrenic subjects, depressed patients, patients with obsessive-compulsive disorders, and normal controls were 35.3 ± 6.1, 46.4 ± 10.1, 38.9 ± 14.4, and 35.7 ± 7.4, respectively. No statistically significant difference in age was found among the schizophrenic subjects, patients with obsessive-compulsive disorders, and normal controls. However, the mean age of depressed patients was significantly higher than that for the schizophrenic subjects and normal controls. Of the schizophrenic subjects, those with neurological disorders, hypertension, diabetes mellitus, history of head injury and/or electroconvulsive therapy, or IQ under 70 on Wechsler’s Adult Intelligence Scale (WAIS; Wechsler 1958) were excluded. All schizophrenic patients, depressed patients, and patients with obsessive-compulsive disorders were on neuroleptic medication. Average psychopathology scores on the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham 1962) were 23.2 ± 7.6 (range = 7-37) for the schizophrenic subjects and average scores on the 24-item Hamilton Rating Scale (Hamilton 1960) were 25.0 ± 6.7 (range = 15-39) for the depressed patients. Informed consent was obtained from all patients and normal subjects who took part in this study.

Recording Method. Each subject sat in a chair 150 cm in front of a screen and had an eye mark recorder attached to his or her head. Three geometric figures were individually projected on the screen. The width of the projected figure was 90 cm; the height 75 cm; and the angle of sight was 33° horizontally and 27.5° vertically. The eye movements and fixation points during viewing of the figures were examined. The test procedure was as follows (Kojima et al. 1990):

1. Each subject was shown an original S-shaped target figure for 15 seconds (figure 1).
2. The subject was asked to draw the figure from memory immediately after viewing it.
3. Two other figures, slightly different from the original, were then shown in turn for 15 seconds each. The subject was asked to look at each figure, compare it with his or her memory of the original, and answer the question: “Are there any differences between this figure and the original?” Following this response, while still being shown the figure, the subject was then asked again, “Are there any other differences?” This question was repeated until the subject stated that there were no differences present.
4. The subject was thenreshown the original figure and told to look at it carefully in order to draw it again.
5. Finally, the subject was asked to draw the original target figure from memory a second time.

The eye mark recorder consists of a helmet with very small video cameras attached to the left and right sides and another camera attached to the top. Infrared light sources are positioned in front of each lower eyelid. The side cameras record the infrared lights reflected on the corneas. The camera on the top of the helmet records the target figure on the screen. These three recordings are formed into a composite by means of a camera controller with a 1/100 second electric timer and then recorded on a video tape. This technique makes it possible to see the eye fixation points and eye movements simultaneously on the target figure. The instrument is sensitive enough to detect movements of more than 0.3° of sight.

Measurement. The recorded data were analyzed by means of a computerized analyzing system and slow motion replay of the video tape. From his study on the relation between eye movements and visual...
cognition, Poulton (1962) concluded that it takes more than 0.2 seconds for the information processing system in the brain to deal with an image on the retina. The eye fixation points that remained focused on the same position for more than 0.2 seconds were taken as real points in this study. To eliminate eye fixation tremor and other artifacts, a movement of 2° and more of sight was taken as an eye movement. A blinking artifact was easily recognized by a vertical shift in eye movement; these shifts were ignored in scoring. The eye mark recorder was recalibrated after each figure was viewed to eliminate any helmet movement artifacts.

All scoring of eye movements was conducted by two trained investigators blind to group assignment of subjects; the scores were averaged. The reliability of the two eye movement scorers was $r = 0.96$. Statistical analysis was conducted by means of the Mann-Whitney U Test and Spearman’s Rank Correlation Test (study I and study II).

The elementary components of eye movements consist of the number of eye fixations ($N$) and mean eye scanning length ($MESL$). Eye scanning length is the distance between two eye fixation points. $MESL$ is the total eye scanning length divided by the number of eye fixations. These components were analyzed while the subjects viewed the original figure for 15 seconds.

The two partially different target figures were each divided into seven sections. The number of sections of the two different target figures on which the subjects fixed their eyes once or more were counted for 5 seconds, at which time the final question, “Are there any other differences?”, was asked. The maximum possible score was 7 for each figure.

Study II: Exploratory Eye Movements and Neuropsychological Tests

Subjects and Measurement. The subjects were the same 25 schizophrenic patients involved in study I. The subjects took three neuropsychological tests: the WAIS, the Maze test drawn from the Wechsler Intelligence Scale for Children—Revised (WISC-R; Wechsler 1974), and the New Modified Wisconsin Card Sorting Test (WCST), which was modified by Kashima et al. (1987) and is highly valid and specific for frontal lobe brain damage. Clinical symptoms were scored on BPRS, the Scale for the Assessment of Negative Symptoms (SANS; Andreasen 1983), and the Schedule for Affective Disorders and Schizophrenia (SADS; Spitzer et al. 1978). Only five of the positive symptoms were selected from SADS.

Results

Study I. Figure 2 shows the eye fixation points and their sequence for a normal subject and for a chronic schizophrenic while they viewed the original figure for the first 5 seconds of the total 15-second exposure. This allows the elementary components of eye movements to be examined. The

![Figure 2. Eye fixation points and their sequences for a chronic schizophrenic and a normal subject as they viewed the original target figure](https://academic.oup.com/schizophreniabulletin/article-abstract/18/1/85/1906190)

The chronic schizophrenic had less frequent eye fixation points and a more limited area of inspection than the normal subject. $N$ = number of eye fixations, $TESL$ = total eye scanning length, $MESL$ = mean eye scanning length.
chronic schizophrenic patient had less frequent eye fixation and a more limited area of inspection than the normal subject. Figure 3 shows the actual responsive search score (RSS) for a chronic schizophrenic patient and for a normal subject. The slightly different target figures on top have a bump in the upper circle on the left side and, unlike the original target figure, no bump on the part to the left of the straight line. The bottom figures have no bumps. When each subject was asked “Are there any other differences between this figure and the original?”, the normal control subject moved his eye fixation point as if to examine the figure again and answered “No.” The eye fixation points of the normal subject were on six sections of the top figure and five sections of the bottom. The total for the sections, the RSS, was thus 11. The eye fixation points of the chronic schizophrenic patient remained on two sections of the top figure and three of the bottom. Thus, the RSS for the chronic schizophrenic patient was 5.

The elementary components of eye movements (the number of eye fixations and the mean eye scanning length) and the RSS for each group are shown in Table 1. The schizophrenic patient group had a significantly lower RSS than all other groups ($p < 0.01$). The subjects in the schizophrenic group also had shorter MESL than the depressed patients ($p < 0.01$) and the normal control group ($p < 0.01$), but no significant difference was found between the schizophrenic group and the obsessive-compulsive disorder group. The number of eye fixations for the schizophrenic patient group was fewer than those of the obsessive-compulsive patients and the normal control groups, but did not differ significantly from that of the depressed patient group. In recognition tasks, the rate of correct response for recognizing the different figures for the schizophrenic patients was 96.4 percent for recognizing the figure with different location of a bump, 100 percent for recognizing the figure with no bumps, and 96.4 percent for recognizing the original target figure. The rates of correct response for the normal controls were 100 percent, 100 percent, and 92.6 percent; for the depressed patients, 92 percent, 96 percent, and 100 percent; and for the patients with obsessive-compulsive disorders, 100 percent, 100 percent, and 100 percent, respectively. No significant differences were found in the rates of correct response between the schizophrenic patients and normal controls and between the schizophrenic subjects and the patients with obsessive-compulsive disorders.

Study II. Table 2 shows the relationship between the indicators of
Table 1. Values for number of eye fixations (n), mean eye scanning length (MESL), and the responsive search score (RSS) in the schizophrenic group and other groups

<table>
<thead>
<tr>
<th>Subjects</th>
<th>n</th>
<th>MEWL (SD)</th>
<th>RSS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schizophrenics (n = 25)</td>
<td>32.6</td>
<td>(9.1)cm</td>
<td>7.2</td>
</tr>
<tr>
<td>Depressed (n = 25)</td>
<td>34.6</td>
<td>(9.0)cm</td>
<td>10.7</td>
</tr>
<tr>
<td>Obsessive-compulsive (n = 10)</td>
<td>39.4</td>
<td>(8.8)cm</td>
<td>10.5</td>
</tr>
<tr>
<td>Normals (n = 25)</td>
<td>39.4</td>
<td>(6.2)cm</td>
<td>19.4</td>
</tr>
</tbody>
</table>

1p < 0.01 vs. schizophrenic patients (Mann-Whitney U test).
2p < 0.05 vs. schizophrenic patient (Mann-Whitney U test).
3p < 0.05 vs. depressed patients (Mann-Whitney U test).

eye movements and the neuropsychological tests employed (WAIS, Maze test, and WCST). The RSS correlated positively with performance IQ on the WAIS (r = 0.74, p < 0.01) and with subcategories of performance IQ on the WAIS such as picture completion (r = 0.42, p < 0.05); block design (r = 0.67, p < 0.01); picture arrangement (r = 0.43, p < 0.05); and object assembly (r = 0.76, p < 0.01). The RSS correlated negatively with total time for Maze 2 (r = -0.55, p < 0.01). There was no significant correlation between RSS and the WCST. The MESL correlated with block design on the WAIS (r = 0.58, p < 0.01), and the number of eye fixations correlated with total time for Maze 1 (r = -0.42, p < 0.05). On the other hand, although the following results are not shown in this table, the total time for Maze test 2 correlated with performance IQ on the WAIS (r = -0.52, p < 0.01), while the WCST correlated with verbal IQ on the WAIS (r = -0.49, p < 0.05). No other correlations with neuropsychological tests were significant.

The relationships between clinical symptoms and the three indicators of eye movements were examined (table 3). The RSS correlated with emotional withdrawal (r = -0.52, p < 0.01) and blunted affect (r = -0.57, p < 0.01) on the BPRS. The RSS correlated negatively with affective flattening or blunting (r = -0.50, p < 0.01), avolition-apathy (r = -0.64, p < 0.01), and inattentiveness (r = -0.62, p < 0.01) on the SANS. Thus, there was a negative correlation between the RSS and the negative symptoms.

The relationships between clinical symptoms and the results of neuropsychological tests were also examined. The performance IQ correlated negatively with blunted affect (r = -0.48, p < 0.05) and avolition-apathy (r = -0.42, p < 0.05). With regard to subtests, significant correlations were found between picture completion and blunted affect (r = -0.55, p < 0.01), between block design and avolition-apathy (r = -0.69, p < 0.01), and between block design and inattentiveness (r = -0.48, p < 0.05). The verbal IQ correlated negatively with conceptual disorganization (r = -0.51, p < 0.01). The results of the WCST correlated negatively with mannerisms and posturing (bizarre behavior) (maximum classification score: r = -0.65, p < 0.05; perseverative errors: r = -0.48, p < 0.05). The Maze test 2 correlated negatively with emotional withdrawal (r = -0.52, p < 0.01) and blunted affect (r = -0.57, p < 0.01) on the BPRS.

Table 2. Correlations between eye movements and neuropsychological tests

<table>
<thead>
<tr>
<th>Scale</th>
<th>n</th>
<th>MEWL</th>
<th>RSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td>0.74¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture completion</td>
<td>0.42²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block design</td>
<td>0.58¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture arrangement</td>
<td>0.43²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object assembly</td>
<td>0.76¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maze test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maze 1 total time</td>
<td>-0.42²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maze 2 total time</td>
<td>-0.55¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note.—n = number of eye fixations; — = no significant correlation; MEWL = mean eye scanning length; RSS = responsive search score; WAIS = Wechsler Adult Intelligence Scale (Wechsler 1974); WCST = Wisconsin Card Sorting Test-modified version (Kashima et al. 1987).

¹p < 0.01 (Spearman).
²p < 0.05 (Spearman).
Table 3. Correlations between eye movements and clinical symptoms

<table>
<thead>
<tr>
<th>Scale</th>
<th>n</th>
<th>MESL</th>
<th>RSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somatic concern</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excitement</td>
<td></td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>Emotional withdrawal</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunted affect</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affective flattening or blunting</td>
<td>-0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avolition-apathy</td>
<td>-0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inattentiveness</td>
<td>-0.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SANS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pSADS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. — n = number of eye fixations; — = no significant correlation; MESL = mean eye scanning length; RSS = responsive search score; BPRS = Brief Psychiatric Rating Scale (Overall and Gorham 1962); SANS = Scale for the Assessment of Negative Symptoms (Andreasen 1983); pSADS = Positive Symptoms from the Schedule for Affective Disorders and Schizophrenia (Spitzer et al. 1978).

1p < 0.05 (Spearman).
2p < 0.01 (Spearman).

negatively with avolition-apathy ($r = -0.42, p < 0.05$). Thus, there were negative correlations found between negative symptoms, the performance IQ, and the Maze test, and between positive symptoms, the verbal IQ, and the WCST.

The respective relationships between the chlorpromazine-equivalent dose of neuroleptics, the indicators of eye movements, the results of neuropsychological tests, and the clinical symptoms were examined. No significant correlation was found between the dose of neuroleptics and the indicators of eye movements (N: $r = 0.11$, MESL: $r = -0.25$, RSS: $r = 0.03$), between the neuroleptics and the results of neuropsychological tests (verbal IQ: $r = 0.15$, performance IQ: $r = 0.06$, Maze 1: $r = -0.09$, Maze 2: $r = 0.02$), and between the neuroleptics and the clinical symptoms (BPRS/emotional withdrawal: $r = 0.08$, blunted affect: $r = -0.02$, total score: $r = 0.07$, SANS/affective flattening: $r = -0.17$, avolition-apathy: $r = -0.04$, attention: $r = -0.22$).

Discussion

Exploratory Eye Movements of the Schizophrenic and the Nonschizophrenic Subjects. Several eye fixation studies on normal subjects (Mackworth and Morandi 1967; Noton and Stark 1971; Rayner 1978) have indicated that the choice of visual fixation is influenced by unusual aspects of the target and peripheral visual stimuli such that the fixations reflect cognitive processes. Loftus (1972) suggested that each new fixation was capable of adding new information and aiding the process of integration from successive fixations. Gaebel et al. (1987) reported visuomotor performance of schizophrenic patients in a picture-viewing task using an eye mark recorder and observed two types of eye movement patterns: staring scanning and extensive scanning. The staring scanning observed by Gaebel and colleagues in schizophrenic patients is similar to that seen in the present study where the schizophrenic subject group has less frequent eye movements (fixation points) and a more limited area of inspection than the normal group. No extensive scanning was observed in our study, although in our previous study (Kojima et al. 1990) remitted schizophrenic subjects showed more frequent eye movements than chronic schizophrenic subjects. This may be due to differences between Gaebel's viewing task and ours.

Neisser (1976) presented a theory of a perceptual cycle. According to his theory, at each moment the viewer has expectations of certain kinds of information, which are readily accepted if they are made available. It is postulated that the subject must often and actively explore the visual field by moving the eyes or head to make the information in the field available. These explorations are directed by the anticipatory schemata. Thus, according to Neisser, the result of there being fewer eye fixations and shorter eye scanning length in the group of schizophrenic subjects seems to indicate a dysfunction of the anticipatory schemata. The anticipatory schemata are considered to be associated with mental attitude—the desire to get more information from the figure and active attention, whether voluntary or involuntary.

With regard to subject motivation, the schizophrenic subjects displayed a moderate degree of motivation because they showed a high rate of correct response in the recognition task. (It seems that the disturbance for schizophrenia mentioned above is different from a simple disturbance of motivation.) These findings also may reflect the fact that schizo-
phrenic patients use the automatic parallel system of processing proposed by Callaway and Naghdi (1982) as being the cognitive process system in schizophrenia.

Holzman et al. (1976) reported that dysfunction of smooth pursuit eye movements (SPEM) was found in 75 percent of schizophrenic patients and in 45 percent of their first-degree relatives. However, there were no correlations between the dysfunction of SPEM and clinical symptoms except a disturbance of thinking, and the eye movements were remarkably affected by drugs such as barbiturates (Holzman et al. 1975) and lithium carbonate (Levy et al. 1985). Holzman (1987) also reported that a number of schizophrenic patients with unimpaired pursuit movements had parents with eye tracking abnormalities. Also, there were five pairs of dizygotic twins in which the schizophrenic twin had good eye tracking, but the unaffected twin had impaired eye tracking. Thus, it appears that the pursuit eye movements for schizophrenic patients are more important as genetic markers than as diagnostic tools for schizophrenia.

In the present study, the schizophrenic subject group had lower RSS than all other groups. Also, the schizophrenic subject group had shorter MESL than the depressed patients and normal controls, but this difference may have been influenced by the significant mean age difference that existed between the schizophrenic patients and the depressed patients. To confirm this finding, younger depressed patients should be examined. However, younger depressed patients are assumed to have a higher RSS and a longer MESL than older patients and thus the difference between schizophrenic patients and depressed patients in eye movements may increase.

In our previous study (Kojima et al. 1990), there was no difference in the MESL of acute schizophrenic patients, schizophrenic patients in remission, and normal controls. Therefore, the shortening of MESL does not seem to be specific to schizophrenia. On the other hand, we have not yet found any patient group with psychiatric or organic diseases in which the RSS is statistically similar to that of the group of schizophrenic patients (Kojima et al. 1986a, 1987, 1988, 1990; Nakajima et al. 1988; Ohta et al. 1988). Not only chronic and acute schizophrenic subjects, but also those in remission, can be distinguished from subjects with methamphetamine psychosis (RSS: 9.9 ± 1.7), temporal lobe epileptic subjects (10.7 ± 1.9), and normal control subjects by using the RSS (Kojima et al. 1990). In another study a group of schizophrenic patients was discriminated from various non-schizophrenic groups by using the two indicators of RSS and the number of eye fixations with 73–77 percent sensitivity and with 77–82 percent specificity (Ohta et al. 1988).

The effect of neuroleptic drugs on RSS was examined and no difference was found for those on and off medication (Kojima et al. 1989). The relationship between eye movement parameters and the chlorpromazine-equivalent dose of neuroleptics was examined in the schizophrenic patients and no correlation was found between them. Moreover, there was a significant correlation between low RSS and negative symptoms such as blunted affect and emotional withdrawal. Previous work and the present study seem to indicate that the RSS in exploratory eye movements may be specific to schizophrenia and that it may be possible to use it as a clinical diagnostic tool.

Eye movements occurring in response to the final question “Are there any other differences?” were examined to elucidate the RSS. However, there was an opportunity for questions to be asked by the examiner and several answers to be made by the subjects concerning the differences between the figures just before the final question being asked. Thus, this final part was actually a repetition of what had been discussed previously. With the final question, the normal controls and non-schizophrenic subjects explored the figure again, although they seemed to discover no differences, and, moreover, searched for differences after they said there were no differences. The RSS may reflect the visual behavior of a subject who wants to check or confirm his response as part of the interaction between the subject and the examiner, and therefore the RSS may be an indicator of an interpersonal response.

Tatetsu et al. (1956) reported differences in clinical features between schizophrenic subjects and those with methamphetamine psychosis. The latter showed much better response to other persons than the former in spite of their hallucinations and/or delusions. The combination of such clinical findings and the fact that methamphetamine psychotics have higher RSS scores (Kojima et al. 1986a) also suggests that the RSS may be associated with interpersonal response.

Exploratory Eye Movements and Neuropsychological Tests. In the present study, only the RSS in the eye movement parameters correlated with neuropsychological tests and clinical symptoms. The RSS correlated with the performance IQ, the subtests of which (mentioned above) are believed to reflect the function of
the posterior part of the right hemisphere (Wechsler 1958), and with the Maze test, which may also reflect the functions of the right frontal lobe (Corkin 1965; Milner 1971; Kojima et al. 1987). However, there was no correlation between the RSS and the WCST, a test that is concerned with the dorsolateral prefrontal cortex (Weinberger et al. 1986). During the experiments conducted to determine the RSS, the subjects rechecked the figure on display as they made their responses. In this context, the RSS in the present paradigm represents a type of visuospatial and visuomotor behavior in an interpersonal situation. A correlation exists between the performance IQ and the Maze test and both also test visuospatial and visuomotor behavior. This common feature may be a factor in the correlation found between the RSS, the performance IQ, and the Maze test. On the other hand, the WCST seems to have less visuospatial and visuomotor components than the RSS and the two tests just mentioned. The fact that there is a correlation between the WCST and the verbal IQ but not the performance IQ is consistent with this. These relationships may explain why the RSS does not correlate with the WCST or the verbal IQ. In addition, these results suggest that the RSS is associated with the right frontal lobe and the posterior right hemisphere, areas which may mediate visuospatial function.

Cutting (1990) reviewed the results of WAIS in schizophrenic patients and pointed out that there is some evidence that the subtests, for example, block design, object assembly, and picture arrangement, which best reflect right hemisphere function, are carried out less effectively than those, for example, dealing with similarities, which best reflect left hemisphere function. This report supports the present results.

The RSS correlates inversely with negative symptoms. The negative symptoms also correlate inversely with the performance IQ and the Maze test. The positive symptoms correlate inversely with the verbal IQ and results of the WCST. Mayer and colleagues (1985) evaluated flat affect (a negative symptom) in schizophrenic patients using neuropsychological tests and found that it is suggestive of right hemisphere dysfunction. Green and Walker (1985) examined neuropsychological performance and positive and negative symptoms in schizophrenic subjects. They reported that negative symptoms are inversely associated with deficits in visuomotor and visuospatial tests, whereas positive symptoms are associated with poor performance in verbal memory tests. These reports are consistent with the present results and can explain why the RSS correlates with negative symptoms and the performance IQ.

Studies of regional cerebral blood flow (rCBF) during the performance of spatial tasks have been reported. Berman et al. (1988) measured rCBF in medication-free schizophrenic patients and normal control subjects during the performance of an active baseline control task and in solving Raven's Progressive Matrices (RPM; Anastasi 1976), the solution of which appears to be mediated by posterior cortical areas. They reported that normal subjects activate a diffuse posterior cortical area over the baseline value and that schizophrenic subjects do not show any significant flow increase. Gur et al. (1985) measured the rCBF in unmedicated schizophrenic patients and matched controls at rest and during the performance of a verbal and a spatial task. They reported that the control subjects had a greater increase in flow for spatial tasks than for verbal tasks in the anterior and posterior regions and that schizophrenic subjects showed the reverse pattern. They also reported that the control subjects displayed a flow increase during spatial tasks in both hemispheres, not only in the right hemisphere. They believe that the greater bilateral increase in rCBF for the spatial task in normal control subjects is linked to right hemisphere involvement in attention and arousal, suggesting that stimulation of the right hemisphere generates more arousal of the entire brain.

Recently Buchsbaum et al. (1990) reported on the glucose metabolic rate in normal controls and schizophrenic subjects during a continuous performance test assessed by positron emission tomography. They found that task performance in normal controls is associated with increased metabolism of glucose in the right frontal and right temporoparietal regions. They also observed reduced metabolic rates in the frontal cortex and in the temporoparietal regions in patients with schizophrenia. In addition, Sava et al. (1988) reported that the right hemisphere was dominant in programming eye movements using simple reaction time experiments. The various reports presented here support the results of the current research, that is, that there may be a lack of right hemisphere involvement in spatial tasks in schizophrenic patients and that the RSS may thus be indicative of right brain function.

Studies I and II have shown that schizophrenic subjects display rather characteristic eye movements, which are particularly evident when expressed as the RSS. The RSS reflects interpersonal responses and visuospatial and visuomotor func-
tions, suggesting that it is correlated with right brain function.

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