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Perceptual Organization in Schizophrenia: The Processing of Symmetrical Configurations

Raymond A. Knight
Brandeis University

Dara S. Manoach and David S. Elliott
Harvard Medical School

Maurice Hershenson
Brandeis University

The hypothesis that the perceptual organization dysfunction of patients with poor premorbid schizophrenia is due to a deficit in global visual sensory store processing was tested by assessing their ability to process symmetrical configurations that develop early and have strong prepotent structures. Two same–different judgment tasks in which performance varies as a function of the symmetrical organization and task demands were administered to participants with good and poor premorbid schizophrenia, those with mood disorders, and normal controls. Like the other groups, poor premorbid schizophrenics' latency and error response patterns closely paralleled the a priori model of adequate processing. The results support their competence in perceptually processing symmetrical configurations and disconfirm the hypothesis that their input deficiencies represent a general deficiency in all forms of perceptual organization. The implications for specifying their early input dysfunction are discussed.

A wealth of evidence indicates that patients with schizophrenia have deficiencies in early visual information processing (Braff & Saccuzzo, 1981; Knight, 1992, 1993; Knight & Silverstein, 1998; Nuechterlein & Dawson, 1984). A number of studies have suggested that an impairment in perceptual organization or the rapid perceptual organization of separate stimulus components into object representations constitutes an important part of the early processing deficiency in schizophrenia, especially for patients with histories of poor social functioning (Cox & Leventhal, 1978; Knight & Silverstein, 1998; Place & Gilmore, 1980; Rabinowicz, Opler, Owen, & Knight, 1996; Silverstein, Knight, et al., 1996).

Current support for the importance of the distinction between schizophrenia patients with good and poor premorbid social adjustment includes recent studies that have not only confirmed the traditional association of poor premorbidity with negative outcome but have also found it to be a better predictor of outcome than either negative or positive symptoms (Bailer, Brauer, & Rey, 1996). In addition, poor social competence has been found to be a risk factor for the development of schizophrenia (Cornblatt, Lenzenweger, Dworkin, & Erlenmeyer-Kimling, 1992; Malmberg, Lewis, David, & Allebeck, 1998) and to covary strongly with both negative symptoms (Lenzenweger & Dworkin, 1996) and genetic factors (Dworkin & Lenzenweger, 1984). Moreover, poor social functioning among schizophrenia patients has been linked to neurocognitive deficits (Addington & Addington, 1999; Temkin, Knight, Silverstein, & Schatzel, 1998).

Several hypotheses about the underlying processes responsible for schizophrenic patients' perceptual organization deficiencies have been proposed. These hypotheses can be organized within the framework of a two-stage model of early visual processing (Loftus, Hanna, & Lester, 1988; Long, 1980; W. A. Phillips, 1974; Potter, 1976). Stage 1 is a brief (approximately 100 ms) large-capacity, veridical sensory store during which global, parallel, or holistic analyses occur automatically and stimulus components are organized on the basis of gestalt principles (e.g., similarity, proximity) to form object representations. Stage 2 is a subsequent limited-capacity store, labeled short-term visual memory (STVM; W. A. Phillips, 1974), which is highly efficient for another 500 ms but can persist longer and involves the allocation of attentional and conceptual resources to the object representation that is the output of the first stage (Loftus et al., 1988). During Stage 2, serial, local, or analytic processing occurs (Cowan, 1988; Loftus et al., 1988; Long, 1980; W. A. Phillips, 1974; Potter, 1976), and the consolidation of information that takes place during this stage is considered to be a prerequisite for long-term storage and for subsequent

Raymond A. Knight and Maurice Hershenson, Department of Psychology, Brandeis University; Dara S. Manoach, Departments of Neurology and Psychiatry, Harvard Medical School; David S. Elliott, Department of Psychiatry, Harvard Medical School.

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Correspondence concerning this article should be addressed to Raymond A. Knight, Department of Psychology, Brandeis University, MS 062, Waltham, Massachusetts 02454-9110. Electronic mail may be sent to Knight2@Brandeis.edu.

judgments regarding stimulus familiarity (Potter, 1976). Recent evidence suggests that Stage 1 and Stage 2 processes operate in parallel (Heinze & Munte, 1993) and interact so that contextual information and attentive strategies may, in a top-down fashion, guide Stage 1 perceptual processes that have traditionally been considered to be automatic and preattentive.

Although deficit models implicating both stages have been proposed (see Knight, 1992, 1993, for a discussion of these), the preponderance of evidence suggests the adequacy of schizophrenic patients' Stage 1 sensory store and points to deficiencies in either allocation of attention or consolidation of information in STVM (Knight & Silverstein, 1998). The findings of several studies (Rabinowicz et al., 1996; Silverstein, Knight, et al., 1996; Silverstein, Matteson, & Knight, 1996) suggest that perceptual organization deficits in schizophrenia are not due to early perceptual processes per se (e.g., Stage 1) but to impaired feedback to Stage 1 from postperceptual processes and possibly from inadequacies in Stage 2 functioning. Knight (1993) speculated that poor premorbid schizophrenic patients were deficient in automatizing (Logan, 1988, 1990) their responses to unstructured stimuli over repeated exposures to stimuli (i.e., developing a rapid parallel processing or perceptual organization of stimulus components), because either their attentional allocation or consolidation deficiencies in STVM interfered with the development of adequate memory representations. Such top-down influences on the development of automaticity are generated on the basis of previous exposure to the organizational scheme of stimulus components (Kosslyn & Koening, 1992).

There is a wide variance both in the prepotency of perceptual structures and in the speed with which automatic responding to various stimuli is learned by adults (Logan, 1988, 1990). Thus, stimuli vary considerably in the degree to which top-down capabilities are involved in their perceptual processing. If postperceptual rather than perceptual processes are responsible for poor premorbids' perceptual organization deficiencies, a research strategy that assesses their perceptual organization capabilities over a range of stimuli that vary in the degree to which they demand top-down processing capacities could both test the hypothesis of the adequacy of their sensory store and illuminate the nature of their deficits. The present study is the first in a series of studies in which the demand that stimuli place on postperceptual processing was varied. This study focused on the processing of symmetrical stimuli, which require minimal top-down involvement.

A pattern is symmetrical when it can be reoriented and mapped onto either another part of the pattern or the whole pattern. Symmetry, which is a fundamental organizational principle (Hochberg, 1978), is prepotent (Rock, 1983; Rock & Leaman, 1963), early developing, and possibly innate (Ballesteros, Millar, & Reales, 1998; Bornstein, Ferdinandsen, & Gross, 1981; Bornstein, Gross, & Wolf, 1978; Wagemans, 1995; Yonas & Granrud, 1985). It is considered a fundamental visual primitive to which the visual system is predisposed (Biederman, 1987) and which consequently draws attention (Julesz, 1971). Symmetrical configurations are initially organized as gestalts and depend minimally on top-down influences for their structure, not requiring contact with memory representations (Peterson, 1994). In the biological world, vertical axis bilateral symmetry predominates (e.g., faces; Moller, 1992; Pensini, 1995; Sackheim, Gur, & Saucy, 1978). Its prevalence contributes to its perceptual salience, and its informational redundancy may lead to more efficient encoding (Barlow & Reeves, 1979).

If patients with schizophrenia were deficient in their perception of symmetry, it would suggest a primary deficit in global visual sensory store processing (Stage 1) that would likely have pervasive disabling effects on processing at subsequent stages. If they were found to have intact perception of symmetry, this would suggest that perceptual processing in the sensory store is adequate, at least for prepotent structures, and that their perceptual organizational deficits may reflect a failure of top-down influences.

We designed this study so that the pattern of responding for specific deficiencies could not be explained by a general information-processing deficit (Chapman & Chapman, 1978a, 1978b; Knight, 1984). We made use of data that indicated that symmetrical configurations are initially processed as gestalts and consequently inhibit judgments of elements in physical match tasks but facilitate name match task judgments (e.g., Fox, 1975; Mermelstein, Banks, & Prinzmetal, 1979). We adapted two visual matching studies of Hershenson and Ryder (1982a, 1982b) for patient samples. They demonstrated that in normal participants symmetric letter-pair configurations took longer to match than pairs that produced asymmetric configurations when the task was to decide whether the two letters were physically the same (e.g., the same letter in the same orientation). In contrast, when the task was to match on the basis of letter identity (e.g., same letter name regardless of orientation), the presence of certain types of symmetry (vertical axis bilateral [VAB] and translational [TRA]) facilitated performance. These findings were interpreted to suggest that symmetrical configurations are initially processed as a gestalt (Stage 1) that has to be broken down in STVM to compare elements for the physical match task. In the name match task, because only same-letter pairs produce symmetrical configurations, VAB and TRA symmetry can be used as a "diagnostic" for sameness and facilitate performance. Thus, symmetry inhibits a physical match of individual elements, but VAB and TRA symmetry facilitate a name match.

If schizophrenic patients, and particularly poor premorbids, have a perceptual organization deficit such that they fail to perceive symmetrical configurations as a gestalt, this pattern of results should be reversed for them (see the relative superiority strategy in Knight, 1984). Symmetry should not interfere with their performance of the physical match task, and TRA and VAB symmetry should not enhance their performance in the name match task. If, however, as we hypothesized, poor premorbids have intact early perceptual processes, they should perform like controls in the physical match task. They should perceive symmetrical configurations as gestalts and be slower in responding to them. If their perceptual organization deficit is the result of their difficulty using top-down influences to process visual information efficiently, unlike control participants, they should not be able to use TRA and VAB symmetry as a diagnostic to facilitate their performance of the name match task. Thus, this paradigm provides a direct test of the adequacies of poor premorbids' Stage 1 processing of highly organized patterns and an indication of the functioning of their postperceptual processes. Although this paradigm does not directly test the adequacy of STVM, the finding of difficulty in postperceptual facilitation in the name mask condition of processing would be consistent with a deficit in STVM.

In sum, each hypothesis predicts a different pattern of results for the poor premorbid schizophrenia patients' performance: (a) Stage 1 sensory deficit would predict that symmetry would neither interfere with performance in the physical match task nor facilitate it in the name match performance; (b) their performance would be consistent with the Stage 2 explanation if symmetry were to interfere in the physical match but TRA and VAB symmetry were not to help in the name match; (c) a hypothesis of adequate early visual processing would predict that poor premorbid schizophrenia patients' performance would parallel that of control participants; and (d) the general deficit hypothesis would predict that the poor premorbid schizophrenia patients' performance deficiencies would vary with the difficulty level of the conditions.

Method

Participants

Criteria for selection of patient participants. The patients were 30 hospitalized male veterans from the psychiatric wards of Edith Nourse Rogers Memorial Veterans Hospital in Bedford, Massachusetts. We reviewed the medical records of all patients who were diagnosed as psychotic and selected patients who met the following entry criteria: (a) age between 18 and 50 years, (b) no history of any independent condition or neurological disorder that might affect brain function, (c) no history of alcohol or drug dependence, and (d) no electroconvulsive therapy within 6 months prior to testing. After obtaining permission from the treating physician, potential participants were asked to participate and were screened to determine that they met the following additional criteria: (e) at least low-average intelligence on the Shipley Institute of Living Scale (Shipley, 1940) and (f) normal or corrected-to-normal vision, tested with the Snellen Eye Chart.

Twelve male hospital maintenance and grounds staff and hospital volunteers with no history of psychiatric illness as determined by interview and who also met the age, IQ, and vision criteria served as a normal control group. Of these 12 participants, 6 performed both matching tasks, and the remaining 6 performed the physical match task only. All of the participants in the patient groups performed both matching tasks. All of the participants gave informed consent, and the Institutional Review Board at the hospital approved the experimental protocol. Participants were paid for their participation.

Diagnostic procedure. After the experimental data were collected on a preliminary pool of 41 hospital-diagnosed schizophrenic and nonschizophrenic psychotic patients, these patients were independently diagnosed according to Research Diagnostic Criteria (RDC; Spitzer, Endicott, & Robins, 1980) by a clinical psychologist and one or both of two trained research assistants, all of whom were unaware of the patients' performance on the matching tasks. Diagnoses were based on detailed medical abstracts prepared according to a procedure described elsewhere (Knight, Sherer, & Shapiro, 1977).

Eleven patients were excluded from further analyses on the basis of having the following primary diagnoses: 9 schizoaffective, 1 personality disorder, and 1 posttraumatic stress disorder. Of the remaining 30 participants, the initial diagnoses given by the two raters differed for 4, yielding an initial agreement rate of 88%. In the 4 cases of disagreement, a consensus diagnosis was reached during discussion after a second clinical psychologist also diagnosed the case.

Of the 30 patients, 20 met RDC and *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., *DSM–IV;* American Psychiatric Association, 1994) criteria for schizophrenia, and 10 met both RDC and *DSM–IV* criteria for mood disorder (bipolar disorder or major depressive disorder). The mood-disordered participants, referred to as *affectives,* formed a nonschizophrenic psychotic control group, whose members shared many characteristics with the schizophrenic group, including psychosis and hospitalization.

Premorbidity criteria. Participants were rated on Farina's (Farina, Garmezy, & Barry, 1963; Farina, Garmezy, Zalusky, & Becker, 1962) adaptation of the Phillips Scale (L. Phillips, 1953) on the basis of participants' responses to DeWolfe's (1968) General Information Questionnaire (GIQ). Two of three judges independently rated a sample of questionnaires, yielding a high interrater reliability, $r(20) = .93$. A single rater rated the remaining questionnaires. Schizophrenic patients with average Phillips scores of 14 and below were considered good premorbid ($n = 10$), and those with scores of 15 and above were considered poor premorbid ($n = 10$). The division is arbitrary and should not be interpreted as a taxonomic classification. We used the traditional dichotomy for the convenience of prediction and data analysis.

Descriptive data for the subgroups. Descriptive data for the diagnostic groups are presented in Table 1. Analyses of variance (ANOVAs) were computed to compare the groups. The changes in the degrees of freedom in these ANOVAs reflect missing data, as indicated in Table 1. The four groups did not differ in age ($F < 1$) but did differ in years of education, $F(3, 32) = 3.22, p < .05$. A Newman–Keuls multiple-range test revealed that the normal participants had more education than the other three groups ($p < .05$).

In the remaining descriptive analyses, only the patient groups were compared. The three patient groups did not differ in days of hospitalization,

Table 1
Descriptive Statistics of Schizophrenic Subgroups and of Affective and Normal Control Groups

Measure	Schizophrenics GPM (n = 10)	Schizophrenics PPM (n = 10)	Affective (n = 10)	Normal (n = 6)
Age (in years)				
M	33.00	32.00	33.40	29.67
SD	9.68	4.64	9.86	5.64
Education (in years)				
M	12.55	12.67	12.35	14.50
SD	1.75	0.94	1.63	2.26
Shipley Vocabulary score				
M	26.38 (8)[a]	25.10	31.20	
SD	5.97	5.78	3.22	
Shipley Abstract score				
M	15.75 (8)	17.00	23.60	
SD	5.90	9.58	5.56	
Shipley Total score				
M	42.12 (8)	43.10	54.80	
SD	10.82	11.80	6.37	
Phillips score (average)				
M	9.14 (9)	18.67	14.53	
SD	3.34	3.56	3.76	
Hospitalization (days)				
M	280.38 (8)	285.60	253.88 (8)	
SD	178.76	195.76	364.94	
Hospitalization (number)				
M	11.50	9.10	5.89 (9)	
SD	8.45	5.26	5.16	
Medication (chlorpromazine equivalent)				
M	1,066.67 (6)	603.75 (8)	276.25 (8)	
SD	889.76	404.15	367.93	

Note. GPM = good premorbid; PPM = poor premorbid.
[a] Means that have parentheses in the table had missing data, and the number in parentheses indicates the number of participants included in the analyses.

number of hospitalizations, or Shipley Abstract scores (all $Fs < 1$; Shipley, 1940). The groups did differ, however, in Shipley Verbal scores, $F(2, 25) = 3.96$, $p < .05$; Shipley Total scores, $F(2, 25) = 4.88$, $p < .05$; and mean Phillips scores, $F(2, 26) = 16.93$, $p < .01$. Newman–Keuls tests revealed that the affective participants had higher Shipley Verbal scores than the poor premorbid schizophrenics and higher Shipley Total scores than both schizophrenic groups ($p < .05$). The two schizophrenic groups did not differ on their Shipley scores. Newman–Keuls differences also emerged for mean Phillips premorbidity scores. As expected because of selection criteria, poor premorbid schizophrenics had higher scores (i.e., poorer premorbid social competence) than the good premorbid schizophrenics ($p < .01$). The affective participants were mixed in their premorbidity scores (range = 10.5 to 21); they had lower scores (i.e., better premorbid social competence) than the poor premorbid schizophrenics ($p < .05$) and higher scores than the good premorbid schizophrenics ($p < .05$).

Medication. We did not control for medication status. All of the patients were taking conventional antipsychotic or antidepressant medications. Hospital policy precluded instituting drug withdrawal for the present study. Withdrawing patients from antipsychotic medication before testing has been shown to create disabling sampling biases. Participant loss due to patients' refusal of medication withdrawal or relapse due to withdrawal may combine to produce a sample that is not representative of the clinical population (Spohn & Fitzpatrick, 1980). Previous work has demonstrated that medicated and unmedicated patients do not perform differently on perceptual organization tasks (Rabinowicz, Knight, Bruder, Owen, & Gorman, 1995), and the perceptual organization deficit has been demonstrated among unmedicated schizophrenic patients (Frith, Stevens, Johnstone, Owens, & Crow, 1983).

A one-way ANOVA revealed a nearly significant overall group difference, $F(2, 19) = 3.36$, $p = .056$, for chlorpromazine equivalents between patient groups. A Newman–Keuls test indicated only that good premorbid schizophrenics had higher doses than did affective participants. Correlations between chlorpromazine equivalents and 32 performance variables were computed for the entire sample, and three significant relationships emerged. For two variables, higher medication levels were associated with greater response latencies, $r(20) = .54$ and $.59$, $p < .01$. There was no apparent reason why these particular variables should have been differentially affected by medication level. Because the two schizophrenic groups, whose performance was expected to differ on the experimental tasks, did not differ in dosage levels, we concluded that there was no clear evidence that medication level was a confounding variable in this study.

Stimuli

The stimuli used for both matching tasks were negative slides of Hershenson and Ryder's (1982a, 1982b) letter-pair stimuli, which consisted of combinations of the uppercase letters F, G, J, L, and R in either normal (N), reversed (R), or inverted (I) orientations. The letters in each pair were either the same or different. When a pair comprised two of the same letter, the different orientation combinations produced configurations that were symmetrical in one of the four ways described by Weyl (1952): rotational (ROT), horizontal axis bilateral (HAB), vertical axis bilateral (VAB), or translational (TRA). We henceforth refer to these configural patterns as symmetry types, which comprise both same and different letter pairs producing, respectively, both symmetrical and asymmetrical configurations. Each symmetry type is defined in reference to a preliminary element (in this study, a letter) that is reproduced to produce a two-letter stimulus in accordance with specific rules. After this manipulation is completed, the original element and its transformation combine to form, in the case of the same-letter pairs, a symmetrical unit. A spatial configuration is symmetrical with respect to a point; that is, it possesses ROT symmetry, if there exists a point in the figure about which it may be rotated by less than 360° to reproduce the figure. A configuration is symmetrical with respect to a line or plane, that is, possesses bilateral symmetry (either HAB or VAB), if it is carried into itself by reflection in the line or plane. Finally, a configuration possesses TRA symmetry if a translation carries every point of one part of the configuration into corresponding points of another part of the configuration. Corresponding different-letter pairs were considered asymmetric. These stimulus and symmetry types are illustrated in Table 2.

The physical match task required participants to judge whether a stimulus contained the same letter in the same orientation. The stimuli were 60 same-letter pairs with TRA symmetry (20 each of NN, RR, and II orientations); 10 same-letter pairs each of ROT, VAB, and HAB symmetry types; 15 different-letter pairs with TRA arrangement (5 each of the three orientations); and 5 different-letter pairs each of the ROT, VAB, and HAB arrangements. Of these 120 pairs for the physical match task, 60 required a *same* response (same-letter, same-orientation pairs), and 60 required a *different* response (same-letter, different-orientation pairs and all different-letter pairs). Because some symmetrical configurations required a *same* response and others required a *different* response, the same–different judgments were not confounded by the presence of symmetry.

The name match task required participants to judge whether the letter was the same regardless of orientation. The stimuli were 30 same-letter pairs with TRA symmetry; 10 same-letter pairs each of ROT, VAB, and HAB symmetry types; 30 different-letter pairs with the TRA arrangement; and 10 different-letter pairs each of the ROT, VAB, and HAB arrangement. Under the name match instructions, all same-letter pairs (60) required a *same* response, and all different-letter pairs (60) required a *different* response. Although all of the symmetrical configurations required a *same* response and all of the asymmetrical configurations required a *different* response, different forms of symmetry (TRA, VAB, HAB, and ROT) were predicted to yield distinct response patterns. Therefore, same–different judgments were not confounded with the expected patterns of results.

Apparatus

The stimuli were projected on the center of a rear-projection screen through one channel of a Gerbrands Model G1177 automatic three-channel slide projection tachistoscope. A second channel was used to present a negative image of two faint parallel horizontal lines, each bisected by a dot, which served as an adapting field and identified the area within which the

Table 2
Exemplars of the Letter-Orientation Combinations That Produced the Four Types of Symmetry in Same-Letter Pairs and Corresponding Asymmetric Stimuli Produced by Different-Letter Pairs

Symmetry type	Symmetric stimuli (same letter)	Corresponding stimuli (different letter)
Rotational		
Reversed–inverted	ꟻ Ⅎ	ꟻʁ
Inverted–reversed	Ⅎ ꟻ	ℲЯ
Vertical-axis bilateral		
Normal–reversed	F ꟻ	FЯ
Reversed–normal	ꟻ F	ꟻR
Horizontal-axis bilateral		
Normal–inverted	F Ⅎ	Fʁ
Inverted–normal	Ⅎ F	ℲR
Translational		
Reversed–reversed	ꟻ ꟻ	ꟻЯ
Inverted–inverted	Ⅎ Ⅎ	Ⅎ ʁ
(Normal–normal)[a]	F F	F R

[a] Normal–normal stimuli were not included in the analyses.

stimuli would appear. This field was on between all trials. The projectors were set at high intensity (247 cd/m^2). Each stimulus appeared as a light configuration against a dark background and subtended approximately 1.4° of horizontal visual angle and 0.9° of vertical visual angle. Reaction time (RT) was measured to the nearest millisecond by a Gerbrands G1270 Clock/Counter from the onset of the stimulus field until the participants' voice tripped a Gerbrands G1341 Voice Operated Relay through a microphone mounted on the table in front of the participant.

Procedure

Each patient participant was given DeWolfe's GIQ, the Shipley–Hartford test, and the two matching tasks. The first two were administered according to standard procedure (DeWolfe, 1968; Shipley, 1940).

Each participant was oriented to the apparatus and was provided a brief explanation of the function of the tachistoscope and the voice-operated relay. He was then given standard instructions for either the physical or the name match task, depending on his order condition. He was shown a 12 × 17 cm card with five *same* match exemplars and a 12 × 17 cm card with five *different* exemplars and was instructed about the judgments he was to make. If he had any questions, we answered these by restating parts of the instructions and using the examples to explain. To clarify the nature of the task and to acquaint the participants with its requirements, we preceded each experimental procedure with a practice set consisting of 30 stimuli composed of pairs of the letters A, B, K, T, and Y in the same form as in the experimental sets. A trial consisted of a 500-ms warning tone and a 100-ms stimulus that appeared 500 ms after the offset of the tone. Participants were told to fixate between the dots bisecting the lines in the fixation field when the tone sounded and to respond *same* or *different* as quickly and as accurately as possible when the stimulus appeared. Verbal support was given throughout the practice procedure, and instructions were restated, if a participant was not responding according to the instructions. All of the participants were able to perform the tasks. RTs and responses were recorded as the dependent measures.

For the experimental conditions, each set of 120 slides was divided into five equal subsets so that each subset was a proportional representation of the entire stimulus set (i.e., each subset had one fifth of the total number of each different type of letter pairs). Within each subset, the 24 slides were randomized with the constraint that no more than three stimuli with the same orientation combination would appear consecutively. At the beginning of each subset of slides were 2 slides with task-orienting stimuli, one requiring a *same* and one a *different* response. Data from these slides were not used in the analyses.

Within each task, the order of the five stimulus subsets was counterbalanced using a Latin square design, so that any particular order was repeated after every 5 participants were tested, and the order of instruction conditions (physical first vs. name first) alternated with successive participants. Detailed analyses of the task order effects for both RT and percentage correct yielded only one significant result. All other effects were not only insignificant but also had inconsequential effect sizes. In the physical match ANOVA for the percentage of errors (four-way ANOVA with two repeated measures: 4 Groups × 2 Orders [before/after name match] × Symmetrical–Asymmetrical × 4 Symmetry Types), order did interact with group, $F(3, 34) = 13.22$, $p < .001$. Whereas both normal controls and affective participants who had the physical match task second made more errors than those who had it first, both good and poor premorbid schizophrenics made fewer errors in this task when it was second. This interaction should not affect the interpretation of the results for several reasons: (a) The focus of the a priori hypotheses was RT performance for correct responses, in which order was not significant; (b) the overall error rate of all groups was low (range = 3% to 5%); (c) groups did not differ significantly from each other in their error rates (see Results); and (d) in the error rates ANOVA, order did not interact with any factors or set of factors except group. Therefore, for all physical and name match analyses, the two order groups were combined.

A break of approximately 2 min followed the presentation of each subset, and at least 10 min separated the two instruction conditions. Most participants completed the testing on 1 day during two sessions. The entire testing procedure, including the Shipley–Hartford, the GIQ, and the experimental tasks, required approximately 2.5 hr. Upon completion of the study, participants were paid for participation and given a brief explanation of the study.

Data Analysis

The TRA pairs with normal–normal orientation were excluded from analyses (as in Hershenson & Ryder's [1982a, 1982b] studies) because of the overriding effect of familiarity in responding to these stimuli. Because of instabilities typically found in the RT performances of most schizophrenics, RT analyses were calculated using the median RT of correct responses to minimize the effect of extreme responses.

Results

Physical Match

RT performance. A three-way ANOVA with repeated measures on two factors (4 Groups × Symmetrical–Asymmetrical × 4 Symmetry Types) was calculated on the median RT for the correct responses in the physical match task. As can be seen in Figure 1, the schizophrenic groups were slower than the normal controls, $F(3, 38) = 3.80$, $p < .025$ ($p < .05$ by Newman–Keuls test). The affective participants produced intermediate RTs that did not differ from either the normal or schizophrenic participants.

All groups produced the same pattern of responding to all types of symmetry. Neither the two-way interactions of group with symmetry–asymmetry, $F(3, 114) = 0.98$, and with symmetry type, $F(3, 114) = 1.15$, nor the three-way interactions of group with symmetry–asymmetry and symmetry type, $F(9, 114) = 0.89$, were significant. Participants responded more slowly to symmetrical stimuli than to asymmetrical stimuli, $F(1, 38) = 65.77$, $p < .001$, a replication of the finding of Hershenson and Ryder (1982b). Planned contrasts comparing all symmetric to all asymmetric stimuli within each group were all significant: poor premorbids, $F(1, 9) = 34.39$, $p < .001$; good premorbids, $F(1, 9) = 11.35$, $p < .01$; affectives, $F(1, 9) = 21.19$, $p < .005$; and normals, $F(1, 11) = 9.96$, $p < .01$. The predicted pattern indicating that the performance of the poor premorbids, like all other groups, was significantly affected by the presence of symmetry was therefore found. The interference of symmetry disconfirms the hypothesis that the poor premorbids do not process symmetrical structures.

The Symmetry Type × Symmetrical–Asymmetrical interaction approached significance, $F(3, 114) = 2.62$, $p = .054$. Participants responded more slowly to VAB configurations, $F(3, 114) = 7.68$, $p < .001$, in the symmetrical condition only ($p < .01$ by Newman–Keuls test).

Errors. A three-way ANOVA with repeated measures on two factors was calculated on the percentage of errors within each condition for the physical match task (4 Groups × Symmetrical–Asymmetrical × 4 Symmetry Types). There were no differences among the groups, $F(3, 38) = 1.76$, $p > .10$, and group did not interact with other variables. Each group had the same pattern of errors across conditions, and the overall error rate, which ranged

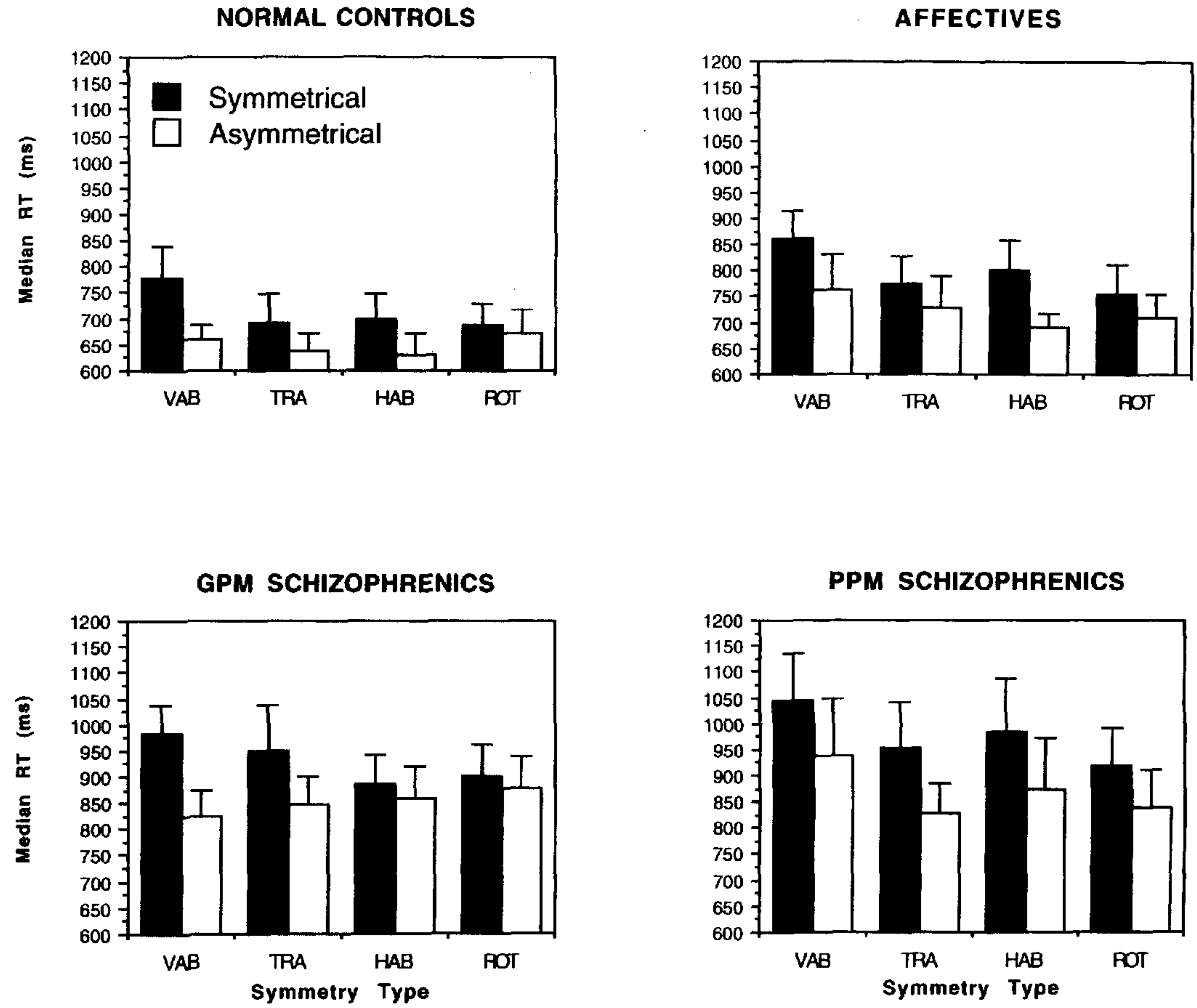

Figure 1. Median correct reaction times (RTs) and standard errors on the symmetrical and asymmetrical versions of the four symmetry types in the physical-matching task for normal controls, nonschizophrenic affectively disordered patients, and good and poor premorbid schizophrenics. VAB = vertical axis bilateral symmetry; TRA = translational symmetry; HAB = horizontal axis bilateral symmetry; ROT = rotational symmetry; GPM = good premorbid; PPM = poor premorbid.

from 3% for normals to 5% for poor premorbid schizophrenics, was acceptably low.

Participants made more errors to symmetrical than to asymmetrical stimuli, $F(1, 38) = 25.62, p < .001$. More errors were made to HAB than to ROT and TRA stimuli, $F(3, 114) = 4.22, p < .01$ ($p < .05$ by Newman–Keuls test). The number of errors to VAB stimuli was intermediate, differing from neither HAB nor ROT and TRA configurations.

There was also an interaction between symmetrical–asymmetrical and symmetry types, $F(3, 114) = 3.07, p < .05$. For the symmetrical stimuli, participants made significantly more errors in the HAB condition than in VAB, TRA, and ROT conditions, $F(3, 114) = 3.07, p < .05$ ($p < .05$ by Newman–Keuls test), which in turn did not differ from each other. Symmetry types did not differ for asymmetrical stimuli, $F(3, 123) = 0.19, p > .90$.

Name Match

RT performance. A three-way ANOVA with repeated measures on two factors (4 Groups × Symmetrical–Asymmetrical × 4 Symmetry Types) was computed on the median RTs for the correct responses in the name match task. As can be seen in Figure 2, the schizophrenic groups were slower than normal controls, $F(3, 32) = 4.43, p < .025$ ($p < .05$ by Newman–Keuls test for each group comparison). The affective participants produced intermediate RTs that were not different from those of the normal controls

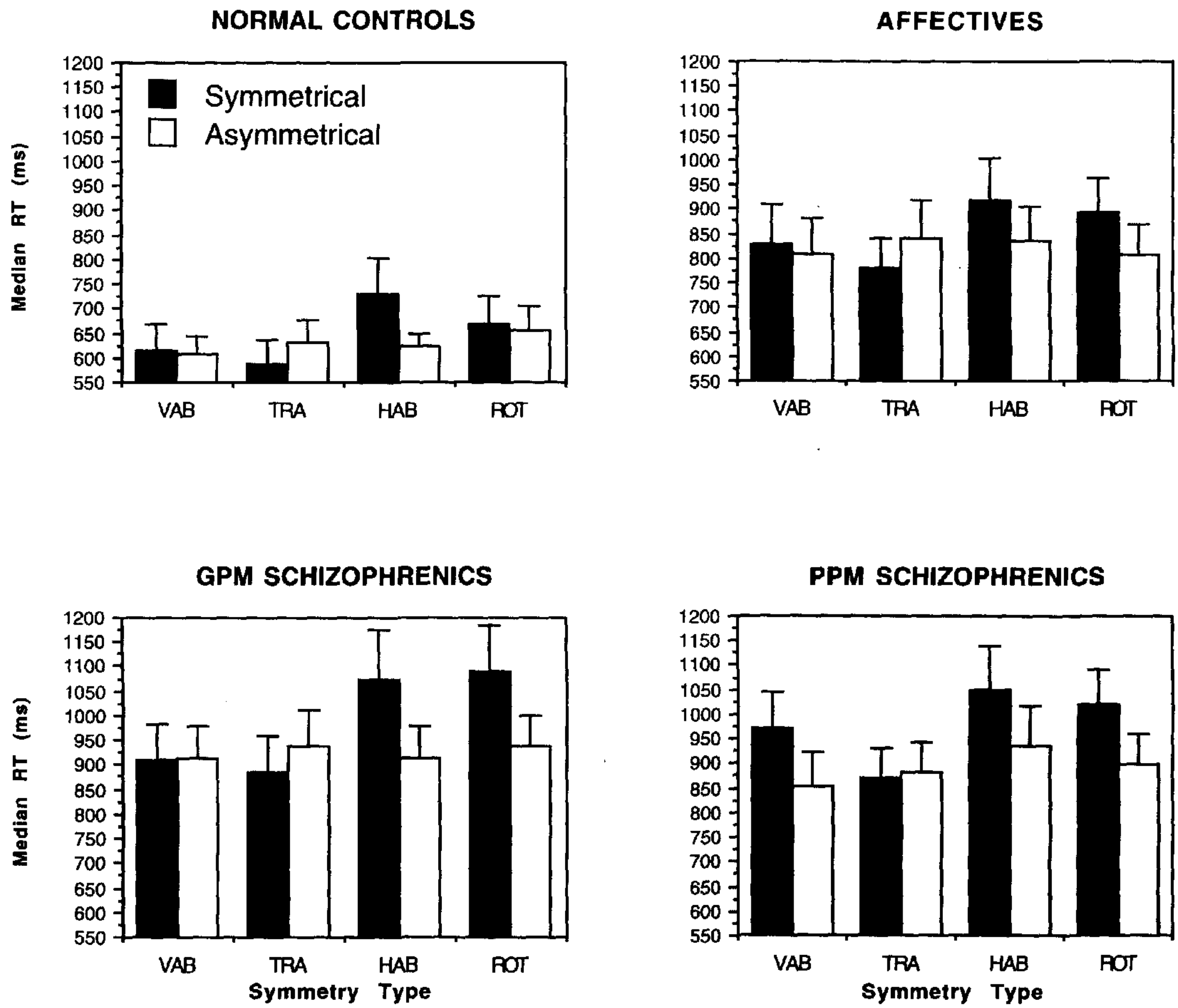

Figure 2. Median correct reaction times (RTs) and standard errors on the symmetrical and asymmetrical versions of the four symmetry types in the name-matching task for normal controls, nonschizophrenic affectively disordered patients, and good and poor premorbid schizophrenics. VAB = vertical axis bilateral symmetry; TRA = translational symmetry; HAB = horizontal axis bilateral symmetry; ROT = rotational symmetry; GPM = good premorbid; PPM = poor premorbid.

or the schizophrenic participants. None of the interactions with groups were significant (all *F*s < 1).

As in Hershenson and Ryder's (1982a) study, HAB and ROT stimuli produced longer latencies than VAB and TRA stimuli, $F(3, 96) = 14.27$, $p < .001$ ($p < .01$ by Newman-Keuls test for each individual comparison). Although the average response latency to symmetrical configurations was longer than to asymmetrical configurations in both studies, it reached significance only in the present data, $F(1, 32) = 9.43$, $p < .005$. The relative latency for symmetrical and asymmetrical configurations varied as a function of symmetry type, $F(3, 96) = 10.82$, $p < .001$, in a pattern that paralleled those found by Hershenson and Ryder (1982a). Symmetrical configurations produced longer latencies only in response to HAB and ROT stimuli, $F(1, 32) = 16.87$, $p < .001$ and $F(1, 32) = 8.42$, $p < .01$, respectively. Responses to VAB stimuli did not differ in latency, $F(1, 32) = 3.99$, $p > .05$. Symmetrical configurations elicited shorter latencies than asymmetrical configurations in response to TRA stimuli, $F(1, 32) = 5.61$, $p < .025$.

Because the a priori hypotheses for the name match task focused on the VAB and TRA conditions, in which symmetry either did not interfere with or facilitated the match, separate two-way ANOVAs with repeated measures on one factor were calculated on each of these symmetry types (4 Groups × Symmetrical–Asymmetrical). We calculated a priori contrasts (Rosenthal & Rosnow, 1985) on each symmetry type separately, testing the hypothesis that poor premorbids in contrast to all other groups were not able use VAB and TRA symmetry as diagnostics of sameness (i.e., that latencies to symmetrical stimuli were faster than those to asymmetrical stimuli for all groups but the poor premorbids). The critical contrast was significant for VAB stimuli, $F(1, 32) = 9.59, p < .005$, but not for TRA stimuli, $F(1, 32) = .83, p > .50$. An examination of the VAB symmetrical–asymmetrical latencies for the four groups (see Figure 2) reveals that symmetrical stimuli elicited longer latencies than asymmetrical stimuli only for poor premorbid schizophrenics, $F(1, 9) = 19.87, p < .005$ (all other Fs < 1). For the TRA symmetrical–asymmetrical latencies, all groups were faster on the symmetrical than the asymmetrical stimuli, but the difference between these conditions reached significance only for the normal controls and the affective patients, $F(1, 5) = 14.95, p < .025$ and $F(1, 9) = 9.44, p < .025$, respectively.

Errors. A three-way ANOVA with repeated measures on two factors was calculated on the percentage of errors within each condition for the name match task (4 Groups × Symmetrical–Asymmetrical × 4 Symmetry Types). Good premorbid schizophrenics made more errors (10%) than normals (3%), $F(3, 32) = 2.95, p < .05$ ($p < .05$ by Newman–Keuls test). Poor premorbid schizophrenics (6%) and affectives (6%) made a moderate number of errors, differing neither from good premorbids nor from normals. The error rate for good premorbids was, however, different only for the symmetrical stimuli, $F(3, 31) = 4.23, p < .025$, in which they differed from all other groups ($p < .05$ by Newman–Keuls tests). Their accuracy on asymmetrical stimuli was equivalent to that of other groups, $F(3, 31) = 0.71, p > .50$. Thus, the interaction of group and symmetrical–asymmetrical approached significance, $F(3, 32) = 2.72, p < .07$. There was neither an interaction between group and symmetry type, $F(9, 96) = 0.83, p > .50$, nor an interaction among group, symmetrical–asymmetrical, and symmetry type, $F(9, 96) = 0.54, p > .80$.

Participants made more errors on symmetrical than asymmetrical patterns, $F(1, 32) = 29.79, p < .001$. They also made fewer errors on both VAB and TRA stimuli than on both HAB and ROT stimuli, $F(3, 96) = 20.15, p < .001$ ($p < .01$ by Newman–Keuls test), and they made more errors on HAB than ROT stimuli ($p < .05$ by Newman–Keuls test). Moreover, they responded differently to the various symmetry types, depending on whether they were symmetrically or asymmetrically configured, $F(3, 96) = 10.56, p < .001$. They showed the overall pattern of symmetry type errors described above only to symmetrical stimuli, $F(3, 105) = 21.45, p < .001$, and not to asymmetrical stimuli, $F(3, 105) = 1.52, p > .20$.

When we examined the error rates for the VAB and TRA symmetry conditions, using two-way ANOVAs with repeated measures on the second factor (4 Groups × Symmetrical–Asymmetrical), the only significant effect to emerge was from the VAB stimuli analyses, in which all participants made more errors to symmetrical stimuli, $F(1, 32) = 5.11, p < .05$.

Post hoc analysis of order effects. Although no factors interacted significantly with group in the name match order analyses for the RTs, examination of the data revealed a different pattern of RT findings for VAB stimuli in poor premorbid schizophrenics (see Figure 3). For normal controls, the relative performance on the symmetrical and asymmetrical versions of VAB did not vary as a function of order of presentation (either the name or physical match task first). For the affective and good premorbid schizophrenic participants, VAB symmetrical configurations elicited longer response latencies than asymmetrical configurations when the name match task was first. When the name match task was presented after the physical match task, the reverse occurred: VAB symmetrical stimuli yielded slightly, but not significantly, faster RTs than their asymmetrical counterparts. For poor premorbid schizophrenics, the VAB symmetrical configurations elicited longer latencies, regardless of task order. Indeed, poor premorbid schizophrenics were the only group that had significantly longer latencies on the VAB symmetrical configuration, when the physical task was presented first, $F(1, 4) = 16.80, p < .025$. In contrast, in parallel analyses of the TRA name match order effects, all groups showed faster RTs for symmetrical stimuli, regardless of the order of task presentation. This suggests that the use of TRA symmetry as a diagnostic for the same name was rapidly learned by all groups during the first session.

Discussion

In a pair of tasks in which performance has been found to vary as a function of the symmetrical organization of the stimuli, poor premorbid patients with schizophrenia showed overall response patterns in both RTs and error rates that closely paralleled those of normal controls, affective participants, and good premorbid schizophrenics. These findings demonstrate that poor premorbids' perception of symmetrical configurations as gestalts during early visual processing is intact and that they do not have a general deficiency in all types of perceptual organization. The only performance difference manifested by the poor premorbids was in their ability to take advantage of VAB symmetry as a diagnostic of sameness in the name match task. This suggests some inefficiencies in the top-down influences on their perceptual processes. Because all of the participants were male, the generalizability of these findings to women must be established.

Physical Match

In the physical match task, the pattern of the results was very clear and consistent with the findings of Hershenson and Ryder (1982b). For all groups, all forms of symmetry inhibited physical matching performance, as indicated by the longer latencies to and greater number of errors on symmetrical than on asymmetrical configurations. VAB symmetrical patterns, the configuration rated by normals as most symmetrical (Hershenson & Ryder, 1982b) and the symmetry type that we have suggested has the greatest ecological validity (McBeath, Sciano, & Tversky, 1997; Moller, 1992; Pensini, 1995; Sackheim et al., 1978), had the greatest effect on RTs for all groups. These findings support the hypothesis that all groups processed symmetrical stimuli as gestalts that had to be broken down so that element comparison could proceed. It is important to emphasize that the inferences of congruity of responding across groups and of the adequacy of poor premorbids' processing of symmetrical configurations in the physical match are not based solely on the failure of groups to interact with any experimental condition, which might conceivably be attributed to a failure of sufficient power to detect differences. Rather, this conclusion is based on the significant rejection for the poor premorbid patients of the null hypothesis of no differences between critical conditions that parallel the performance of all control groups.

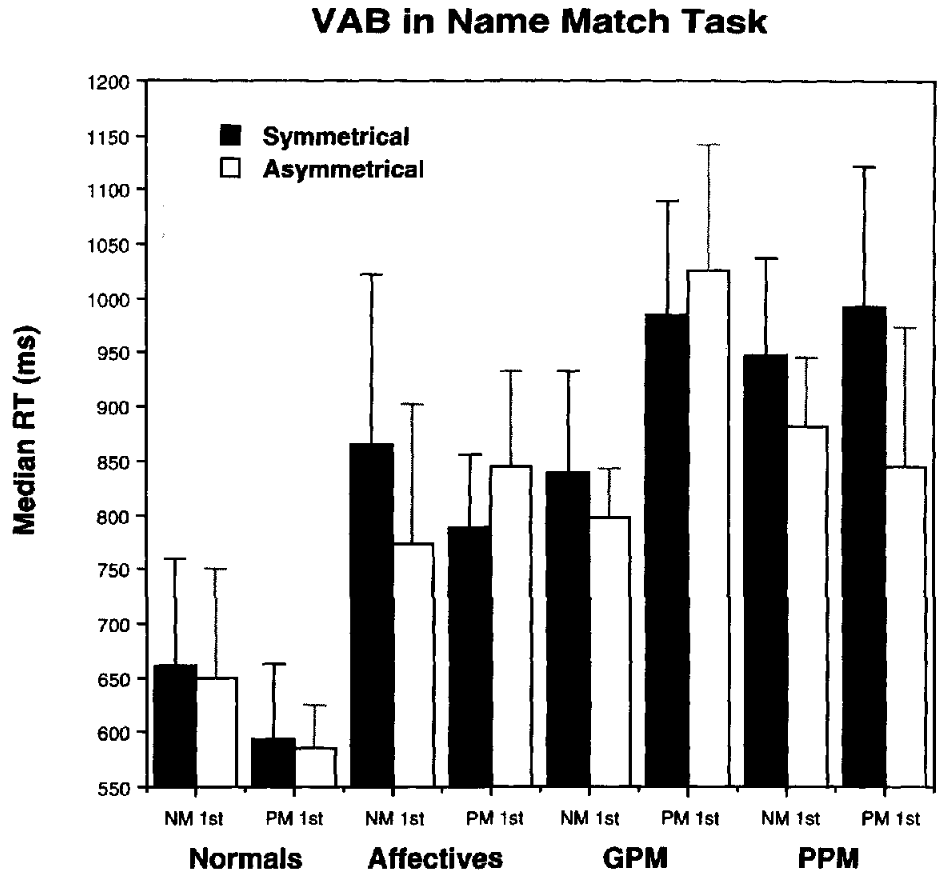

Figure 3. Median correct reaction times (RTs) and standard errors on the name-matching-task-first and physical-matching-task-first order conditions for the symmetrical and asymmetrical stimuli of the VAB symmetry type in the name-matching task for normal controls, nonschizophrenic affectively disordered patients, and good and poor premorbid schizophrenics. VAB = vertical axis bilateral symmetry; NM 1st = name-matching task presented first, PM 1st = physical-matching task presented first; GPM = good premorbid; PPM = poor premorbid.

Three alternative explanations for this pattern of results must be considered. First, an exhaustive search explanation would argue that *same* responses require an exhaustive search, whereas *different* responses terminate when the first difference is encountered (Proctor, 1981). Although this explanation could account for performance in the TRA condition, in which *same* and *different* judgments were confounded with symmetry conditions, both symmetrical and asymmetrical VAB, HAB, and ROT stimuli required *different* responses. Thus, the longer latencies to symmetrical configurations for these symmetry types could not be accounted for by positing that *same* responses require an exhaustive search.

Second, an inhibition deficit explanation (e.g., Frith, 1979; McGhie & Chapman, 1961) might posit that poor premorbids' slowness to symmetrical stimuli in the physical match task may not be due to their ability to process and be affected by symmetry, but rather to their being overly influenced by and unable to inhibit the sameness of the name in the symmetrical VAB, HAB, and ROT conditions. Such an explanation cannot account either for poor premorbids' increased RT to symmetrical versus asymmetrical stimuli in the TRA condition or for their larger symmetrical–asymmetrical difference for TRA than for the other symmetry types.

The third alternative explanation for the pattern of results stems from the work of Royer and his associates (Royer, 1966, 1971a, 1971b; Royer & Friedman, 1973; Royer & Janowitch, 1973), who found that pairs of elements that are equivalent through rotation and reflection operations are more difficult for participants to discriminate and remember. Consequently, one may hypothesize that the longer latencies to the symmetrical stimuli for all participants may be due to the greater difficulty in discriminating among elements in an equivalent set (same letters) than among the elements from different sets (different letters), and not from the processing of symmetrical configurations as gestalts. This confusability explanation cannot account for the finding that across all participant groups within the symmetry (same-letter) condition stronger forms of symmetry (VAB and TRA—those with greater developmental prepotency and higher organization ratings) were found to interfere more with performance (i.e., produced longer latencies) than weaker forms of symmetry (ROT and HAB; $p < .001$). In contrast, there was no effect of strong versus weak forms of configuration ($p = .49$) for the asymmetrical (different-letter) condition. Although these results suggest that it was not simply the effect of having the same letter or an equivalent set by virtue of reflection or rotation that increased RT, but it was the degree of symmetry of the stimulus, they do not completely rule out the hypothesis that "confusability" was having some effect. Consequently, a separate study directly testing this alternative hypothesis was carried out. Using the same letter stimuli as the present study, Farkas (1999) demonstrated that breaking the perceptual gestalt by increasing the spatial separation between the letter-pair stimuli reduced or eliminated the slowing of RT attributed to symmetry. Because this spatial manipulation should break the potency of the symmetrical configurations (Tyler, Hardage, & Miller, 1995) but leave intact same-letter confusability, this study corroborates the hypothesis that symmetry rather than confusability is the operative factor in the present experiment.

Name Match

In the name match task, the pattern of responses to TRA, HAB, and ROT configurations was similar for all groups. As in Hershenson and Ryder's (1982a) study, HAB and ROT symmetrical stimuli inhibited the name match. Apparently, these symmetrical configurations were processed as whole perceptual units, but symmetry was not used as a diagnostic of sameness. Thus, the gestalt had to be broken into component parts, which were rotated and compared. Such rotation increased both RT and error rates in these conditions (Corballis, Zbrodoff, Shetzer, & Butler, 1978a, 1978b; White, 1980). In contrast, participants appeared to be able to take advantage of TRA symmetry as a diagnostic (Fox, 1975) for sameness and bypass the subsequent gestalt breaking, rotation, and comparison steps, thereby decreasing their RTs.

The only group difference in the pattern of performance in the name match task was to the VAB configurations. Here, as in Hershenson and Ryder's (1982a) study of normal participants, the symmetry of the configuration appears to have acted neither as a facilitator nor as an inhibitor of performance for the normal, the affective, and the good premorbid schizophrenic participants. For the poor premorbid schizophrenic patients, the VAB symmetrical patterns inhibited their performance. Interestingly, when affective and good premorbid schizophrenic control participants were presented the name match condition first, VAB symmetrical stimuli slowed their latencies. In contrast, when the physical match condition preceded the name match task, their relative latencies on the symmetrical and asymmetrical versions of VAB stimuli switched. Thus, greater familiarity with the stimuli appears to have enhanced their ability to use the presence of this type of symmetry as a diagnostic. Poor premorbid schizophrenic patients had slower latencies on the VAB symmetrical configurations as compared with the asymmetrical stimuli regardless of the order of task presentation, suggesting that, in contrast to the other patient groups, they failed to learn to use this response strategy.

This singular variation in the response pattern of the poor premorbids does not suggest a problem with the wholistic perceptual processing of symmetrical configurations. Rather, it implicates their implementation of top-down response strategies. This deficit may be a matter of degree rather than kind. The ability of both affectives and good premorbids to use VAB symmetry as a diagnostic seems to have depended on familiarity with the stimuli (i.e., they were more able to use symmetry when the physical match was first). Poor premorbid schizophrenic patients may require more experience before they can implement such a strategy. In the TRA condition, in which all groups were apparently able to use this form of symmetry as a diagnostic quickly, with little practice, poor premorbids did not differ in the pattern of their performance.

It is important to be clear about the status of the data supporting inferences about the differences in poor premorbid schizophrenics' performance. Poor premorbids' unique inability to use VAB symmetry as a diagnostic in the name match was predicted a priori and was significant. In contrast, the order effects analysis for this symmetry type was post hoc. Even though the pattern of results in this analysis was consistent with the proposed model of deficiencies in top-down influences on perceptual processes in poor premorbid schizophrenics, such results have substantially less weight than a corroborated a priori prediction. Also, predictions that were not realized necessarily qualify conclusions. We predicted, but did not find for poor premorbids a similar difficulty with TRA symmetry in the name match task. Finally, in contrast with the affective and the good premorbid participants, the normal control participants did not show the increased use of symmetry as a diagnostic in the VAB condition as a function of increased stimulus familiarity and practice. From the beginning, they responded equally quickly to symmetrical and asymmetrical VAB configurations but never showed the symmetry advantage manifested by the affectives and good premorbids.

Despite these qualifications, this pattern of results across groups does suggest a way to integrate the findings of the present experiment with previous research on schizophrenics' perceptual organization. In the physical match task, symmetry automatically imposed a perceptual structure that had to be broken to complete the task. In the VAB and TRA symmetrical stimulus conditions in the name match task, participants accustomed to processing stimuli wholistically could turn this disadvantage into a processing advantage. In contrast, poor premorbids, who have deficiencies in processing wholistically, may only be passively overwhelmed by a prepotent structure, as is evident in the physical match task, but may not actively make strategic use of such information. Their deficiencies in processing wholistically may lead to a propensity to process the elements of stimuli sequentially. They may not, as other groups, have used TRA symmetry in the name match task as a diagnostic, but they may have benefited from an RT advantage for the sequential processing of the physical sameness (i.e., same letter in the same orientation). If they were processing these letters sequentially, the first letter could serve as a facilitating prime for processing the second (Proctor, 1981), and thereby could have reduced their response latency (Kwapil, Hegley, Chapman, & Chapman, 1990). Their apparent inability to use such a priming advantage in the physical match TRA symmetry condition weakens this interpretation, but their failure to benefit from priming in this condition might also have reflected the greater inhibitory effect of organization in a physical match task (Mermelstein et al., 1979).

Overview

Our findings indicate that poor premorbids adequately perceive symmetry, which is a prepotent, early developing form of organization that requires little experience to be perceived automatically as a perceptual whole. They appear to have deficits in the less potent, less automatic, later developing forms of perceptual organization that depend more on learning and prior "cognitive" decisions (Rock, 1983). These latter forms of organization have been the focus of the previous studies that have found deficiencies in poor premorbids' perceptual organizational capacities (Cox & Leventhal, 1978; Frith et al., 1983; Orlowski, Kietzman, Dornbush, & Winnick, 1985; Place & Gilmore, 1980; Wells & Leventhal, 1984).

Put in terms of Phillips and Singer's (1997) neurophysiological model, these data would suggest the poor premorbids are adequate in their system of feed-forward connections between basic feature detectors that yield neurons that are maximally responsive to correlated activity, such as that involved in the processing of parallelism, collinearity, and other gestalt properties (Hochberg, 1978). They show deficiencies, however, in the subsequent system of linkages of these correlated activity-specific neurons into dynamic, functionally coherent cell assemblies that can represent the wide range of feature combinations corresponding to real-world objects. The system of feed-forward connections is susceptible to experience-based modification during development (Miller, Keller, & Stryker, 1989; Rauschecker & Singer, 1979), but later becomes fixed (Crair & Malenka, 1995). In contrast, new cortico-cortical connections between functionally coherent cell assemblies, based on experience and context, are capable of being formed during adulthood (Singer, 1995). The present study indicates that all schizophrenic patients are sensitive to strongly configural patterns, such as symmetry, and suggests a relatively normal development of the feed-forward system. Other data (see Knight & Silverstein, 1998) suggest that the ability to dynamically form coherent cell assemblies based on experience and context is impaired in poor premorbid schizophrenic patients (Silverstein, Bakshi, Chapman, & Nowlis, 1998). Although the data from this study do not test directly the viability of STVM and automatization hypotheses, the pattern of findings is certainly consistent with a model that proposes that poor premorbid schizophrenics' perceptual organizational difficulties arise only with stimuli that tax their ability to automatize input (Knight, 1993).

This and previous studies demonstrate the usefulness of a process-oriented approach for delineating the early processing impairments of poor premorbid schizophrenic patients. The process-oriented strategy (Knight, 1984; Knight & Silverstein, in press) makes use of well-established models from cognitive psychology to predict specific theory-driven patterns of performance within and across tasks that would occur under conditions of adequate and inadequate functioning of specific stages of processing. It is the pattern of performance and not the performance on any one condition or task that is important. This approach treats the "general deficit" (Chapman & Chapman, 1978a, 1978b) as an alternative model and uses paradigms in which, like the present one, specific deficit and general deficit models predict distinguishable, unconfounded patterns of results. It is clear that the specific patterns yielded in the present study covaried with a priori hypotheses for a specific deficit and were inconsistent with the general deficit model's prediction of covariation of group discrimination with the difficulty level of conditions.

References

Addington, J., & Addington, D. (1999). Neurocognitive and social functioning in schizophrenia. *Schizophrenia Bulletin, 25,* 173–182.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Bailer, J., Brauer W., & Rey, E. R. (1996). Premorbid adjustment as predictor of outcome in schizophrenia: Results of a prospective study. *Acta Psychiatrica Scandinavica, 93,* 368–377.

Ballesteros, S., Millar, S., & Reales, J. (1998). Symmetry in haptic and in visual shape perception. *Perception & Psychophysics, 60,* 389–404.

Barlow, H. B., & Reeves, B. C. (1979). The versatility and absolute efficiency of detecting mirror symmetry in random dot displays. *Vision Research, 19,* 783–793.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review, 94,* 115–147.

Bornstein, M. H., Ferdinandsen, K., & Gross, C. G. (1981). Perception of symmetry in infancy. *Developmental Psychology, 17,* 82–86.

Bornstein, M. H., Gross, C. G., & Wolf, J. Z. (1978). Perceptual similarity of mirror images in infancy. *Cognition, 6,* 89–116.

Braff, D. L., & Saccuzzo, D. P. (1981). Information processing dysfunction in paranoid schizophrenia: A two-factor deficit. *American Journal of Psychiatry, 138,* 1051–1056.

Chapman, L. J., & Chapman, J. P. (1978a). *Disordered thought in schizophrenia.* New York: Appleton-Century-Crofts.

Chapman, L. J., & Chapman, J. P. (1978b). The measurement of differential deficit. *Journal of Psychiatric Research, 14,* 303–311.

Corballis, M. C., Zbrodoff, N. J., Shetzer, L. I., & Butler, P. B. (1978a). Decisions about identity and orientation of rotated letters and digits. *Memory & Cognition, 6,* 98–107.

Corballis, M. C., Zbrodoff, N. J., Shetzer, L. I., & Butler, P. B. (1978b). Latency to categorize disoriented alphanumeric characters as letters or digits. *Canadian Journal of Psychology, 32,* 186–188.

Cornblatt, B. A., Lenzenweger, M. F., Dworkin, R. H., & Erlenmeyer-Kimling, L. (1992). Childhood attentional dysfunctions predict social deficits in unaffected adults at risk for schizophrenia. *British Journal of Psychiatry, 161,* 59–64.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention and their mutual constraints within the human information processing system. *Psychological Bulletin, 104,* 163–191.

Cox, M. D., & Leventhal, D. B. (1978). A multivariate analysis and modification of a preattentive, perceptual dysfunction in schizophrenia. *Journal of Nervous and Mental Disease, 166,* 709–718.

Crair, M. C., & Malenka, R. C. (1995). A critical period for long-term potentiation at thalamocortical synapses. *Nature, 375,* 325–328.

DeWolfe, A. S. (1968). Self-reports and case histories of schizophrenic patients: Reliability of Phillips Scale ratings. *Journal of Clinical Psychology, 24,* 415–418.

Dworkin, R. H., & Lenzenweger, M. F. (1984). Symptoms and the genetics of schizophrenia: Implications for diagnosis. *American Journal of Psychiatry, 141,* 1541–1546.

Farina, A., Garmezy, N., & Barry, H., III. (1963). Relationship of marital status to incidence and prognosis of schizophrenia. *Journal of Abnormal and Social Psychology, 67,* 624–630.

Farina, A., Garmezy, N., Zalusky, M., & Becker, J. (1962). Premorbid behavior and prognosis in female schizophrenic patients. *Journal of Consulting Psychology, 26,* 56–60.

Farkas, M. (1999). *The role of the configuration produced by symmetry in "same–different" visual matching tasks.* Unpublished honor's thesis, Brandeis University, Waltham, Massachusetts.

Fox, J. (1975). The use of structural diagnostics in recognition. *Journal of Experimental Psychology: Human Perception and Performance, 1,* 57–67.

Frith, C. D. (1979). Consciousness, information processing, and schizophrenia. *British Journal of Psychiatry, 134,* 225–235.

Frith, C. D., Stevens, M., Johnstone, E. C., Owens, D. G. C., & Crow, T. J. (1983). Integration of schematic faces and other complex objects in schizophrenia. *Journal of Nervous and Mental Disease, 171,* 34–39.

Heinze, H. -J., & Munte, T. F. (1993). Electrophysiological correlates of hierarchical stimulus processing: Dissociation between onset and later stages of global and local target processing. *Neuropsychologia, 31,* 841-852.

Hershenson, M., & Ryder, J. (1982a). Perceived symmetry and name matching. *Bulletin of the Psychonomic Society, 19,* 19-22.

Hershenson, M., & Ryder, J. (1982b). Perceived symmetry and visual matching. *American Journal of Psychology, 95,* 669-680.

Hochberg, J. E. (1978). *Perception.* Englewood Cliffs, NJ: Prentice Hall.

Julesz, B. (1971). *Foundations of cyclopean perception.* Chicago: University of Chicago Press.

Knight, R. A. (1984). Converging models of cognitive deficit in schizophrenia. In W. D. Spaulding & J. K. Cole (Eds.), *Nebraska symposium on motivation, 1983: Theories of schizophrenia and psychosis* (pp. 93-156). Lincoln: University of Nebraska Press.

Knight, R. A. (1992). Specifying cognitive deficiencies in poor premorbid schizophrenics. In E. F. Walker, R. Dworkin, & B. Cornblatt (Eds.), *Progress in experimental psychology and psychopathology research* (pp. 252-289). New York: Springer.

Knight, R. A. (1993). Comparing cognitive models of schizophrenics' input dysfunction. In R. L. Cromwell & C. R. Snyder (Eds.), *Schizophrenia: Origins, processes, treatment and outcome* (pp. 151-175). Oxford, England: Oxford University Press.

Knight, R. A., Sherer, M., & Shapiro, J. (1977). Iconic imagery in overinclusive and nonoverinclusive schizophrenics. *Journal of Abnormal Psychology, 86,* 242-255.

Knight, R. A., & Silverstein, S. M. (1998). The role of cognitive psychology in guiding research on cognitive deficits in schizophrenia: A process oriented approach. In M. F. Lenzenweger & R. H. Dworkin (Eds.), *Origins and development of schizophrenia: Advances in experimental psychopathology* (pp. 247-295). Washington, DC: American Psychological Association.

Knight, R. A., & Silverstein, S. M. (in press). A strategy for averting confounds resulting from general performance deficiencies in schizophrenia: A process-oriented approach. *Journal of Abnormal Psychology.*

Kosslyn, S. M., & Koening, O. (1992). *Wet mind: The new cognitive neuroscience.* New York: Free Press.

Kwapil, T. R., Hegley, D. C., Chapman, L. J., & Chapman, J. P. (1990). Facilitation of word recognition by semantic priming in schizophrenia. *Journal of Abnormal Psychology, 99,* 215-221.

Lenzenweger, M. F., & Dworkin, R. H. (1996). The dimensions of schizophrenia phenomenology: Not one or two, at least three, perhaps four. *British Journal of Psychiatry, 168,* 432-440.

Loftus, G. R., Hanna, A. M., & Lester, L. (1988). Conceptual masking: How one picture captures attention from another picture. *Cognitive Psychology, 20,* 237-282.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95,* 492-527.

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology, 22,* 1-35.

Long, G. M. (1980). Iconic memory: A review and critique of the study of short-term visual storage. *Psychological Bulletin, 88,* 785-820.

Malmberg, A., Lewis, G., David, A., & Allebeck, P. (1998). Premorbid adjustment and personality in people with schizophrenia. *British Journal of Psychiatry, 172,* 308-313.

McBeath, M. K., Sciano, D. J., & Tversky, B. (1997). Three-dimensional bilateral symmetry bias in judgments of figural identity and orientation. *Psychological Science, 8,* 217-223.

McGhie, A., & Chapman, J. S. (1961). Disorders of attention and perception in early schizophrenia. *British Journal of Medical Psychology, 34,* 103-116.

Mermelstein, R., Banks, W., & Prinzmetal, W. (1979). Figural goodness effects in perception and memory. *Perception & Psychophysics, 26,* 472-480.

Miller, K. D., Keller, J. B., & Stryker, M. P. (1989, August 11). Ocular dominance column development: Analysis and simulation. *Science, 245,* 605-615.

Moller, A. P. (1992). Female swallow preference for symmetrical male sexual ornaments. *Nature, 357,* 238-240.

Nuechterlein, K. H., & Dawson, M. E. (1984). Information processing and attentional functioning in the developmental course of schizophrenic disorders. *Schizophrenia Bulletin, 10,* 160-203.

Orlowski, B. K., Kietzman, M. L., Dornbush, R. L., & Winnick, W. W. (1985, August). *Perceptual disorganization in schizophrenia.* Paper presented at the 93rd Annual Convention of the American Psychological Association, Los Angeles, CA.

Pensini, E. (1995). Not simple symmetry: Does it really matter if the right ear is bigger than the left? *Science News, 147,* 46-47.

Peterson, M. (1994). Object recognition processes can and do operate before figure-ground organization. *Current Directions in Psychological Science, 3,* 105-111.

Phillips, L. (1953). Case history data and prognosis in schizophrenia. *Journal of Nervous and Mental Disease, 117,* 515-525.

Phillips, W. A. (1974). On the distinction between sensory storage and short-term visual memory. *Perception & Psychophysics, 16,* 283-290.

Phillips, W. A., & Singer, W. (1997). In search of common foundations for cortical computation. *Behavioral and Brain Sciences, 20,* 657-683.

Place, E. J. S., & Gilmore, G. C. (1980). Perceptual organization in schizophrenia. *Journal of Abnormal Psychology, 89,* 409-418.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 509-522.

Proctor, R. W. (1981). A unified theory for matching-task phenomena. *Psychological Review, 88,* 291-326.

Rabinowicz, E. F., Knight, R. A., Bruder, G., Owen, D. R., & Gorman, J. (1995, October). *Short-term visual memory deficits in schizophrenia: Medication effects and electrophysiological correlates.* Poster presented at the meeting of the Society for Research in Psychopathology, Iowa City, IA.

Rabinowicz, E. F., Opler, L. A., Owen, D. R., & Knight, R. A. (1996). Dot enumeration perceptual organization task (DEPOT): Evidence for a short-term visual memory deficit in schizophrenia. *Journal of Abnormal Psychology, 105,* 336-348.

Rauschecker, J. P., & Singer, W. (1979). Changes in the circuitry of the kitten visual cortex are gated by post-synaptic activity. *Nature, 280,* 58-60.

Rock, I. (1983). *The logic of perception.* Cambridge, MA: MIT Press.

Rock, I., & Leaman, R. (1963). An experimental analysis of visual symmetry. *Acta Psychologica, 21,* 171-183.

Rosenthal, R., & Rosnow, R. L. (1985). *Contrast analysis: Focused comparisons in the analysis of variance.* Cambridge, England: Cambridge University Press.

Royer, F. L. (1966). Figural goodness and internal structure in perceptual discrimination. *Perception & Psychophysics, 1,* 311-314.

Royer, F. L. (1971a). Information processing of visual figures in digit symbol substitution task. *Journal of Experimental Psychology, 87,* 335-342.

Royer, F. L. (1971b). Spatial orientation and figural information in free recall of visual figures. *Journal of Experimental Psychology, 91,* 326-332.

Royer, F. L., & Friedman, S. (1973). Scanning time of schizophrenics and normals for visual designs. *Journal of Abnormal Psychology, 82,* 212-219.

Royer, F. L., & Janowitch, L. (1973). Performance of process and reactive schizophrenics on a symbol-digit substitution task. *Perceptual and Motor Skills, 37,* 63-70.

Sackheim, H. A., Gur, R. C., & Saucy, M. D. (1978). Emotions are expressed more intensely on the left side of the face. *Science, 202,* 434-436.

Shipley, W. C. (1940). A self-administering scale for measuring intellectual impairment and deterioration. *Journal of Psychology, 9,* 371–377.

Silverstein, S. M., Bakshi, S., Chapman, R. M., & Nowlis, G. (1998). Perceptual organization of configural and nonconfigural visual patterns in schizophrenia: Effects of repeated exposure. *Cognitive Neuropsychiatry, 3,* 209–223.

Silverstein, S. M., Knight, R. A., Schwarzkopf, S. B., West, L. L., Osborn, L. M., & Kamin, D. (1996). Configural and context effects in perceptual organization in schizophrenia. *Journal of Abnormal Psychology, 105,* 410–420.

Silverstein, S. M., Matteson, S., & Knight, R. A. (1996). Reduced top-down influence in auditory perceptual organization. *Journal of Abnormal Psychology, 105,* 663–667.

Singer, W. (1995, November 3). Development and plasticity of cortical processing architectures. *Science, 270,* 758–764.

Spitzer, R. L., Endicott, J., & Robins, E. (1980). *Research diagnostic criteria.* (Available from Biometrics Research, New York State Psychiatric Institute, 722 West 168th Street, New York, NY 10032).

Spohn, H. E., & Fitzpatrick, T. (1980). Informed consent and bias in samples of schizophrenic subjects at risk for drug withdrawal. *Journal of Abnormal Psychology, 89,* 79–92.

Temkin, J., Knight, R. A., Silverstein, S. M., & Schatzel, E. (1998, November). *The relation of cognitive disorganization to cognitive and neuromotor functioning in schizophrenia.* Poster presented at the 13th Annual Meeting of the Society for Research in Psychopathology, Cambridge, Massachusetts.

Tyler, C., Hardage, L., & Miller, R. (1995). Multiple mechanisms for the detection of mirror symmetry. *Spatial Vision, 9,* 79–100.

Wagemans, J. (1995). Detection of visual symmetries. *Spatial Vision, 9,* 9–32.

Wells, D. S., & Leventhal, D. (1984). Perceptual grouping in schizophrenia: Replication of Place and Gilmore. *Journal of Abnormal Psychology, 93,* 231–234.

Weyl, H. (1952). *Symmetry.* Princeton, NJ: Princeton University Press.

White, M. J. (1980). Naming and categorization of tilted alphanumeric characters do not require mental rotation. *Bulletin of the Psychonomic Society, 15,* 153–156.

Yonas, A., & Granrud, C. E. (1985). Development of visual space perception in young infants. In J. Mehler & R. Fox (Eds.), *Neonate cognition: Beyond the blooming buzzing confusion* (pp. 45–67). Hillsdale, NJ: Erlbaum.

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