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ORIGINAL PAPER

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Intact feature fusion in schizophrenic patients

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Abstract How the various features of an object are bound to a unified percept is one of the most fundamental problems the human brain has to solve. Whereas healthy observers usually do not reveal binding errors, it has been proposed that schizophrenic patients suffer from binding deficits. To elucidate such deficits, we investigated one of the most basic binding or integration paradigms: feature fusion. In feature fusion, two stimuli are presented in rapid succession. Using a vernier paradigm, we could, recently, show that the second stimulus determines feature fusion more strongly than the first one (Herzog et al. 2003). However, the first presented stimulus determines feature fusion when a grating follows the two stimuli. Reversal of dominance has occurred. In this study, we show that schizophrenic patients reveal qualitatively the same integration characteristics in feature fusion as healthy controls do. Hence, although some aspects of visual processing are strongly disturbed in schizophrenia as revealed by masking studies, feature fusion appears to be, at least qualitatively, spared. Our fusion paradigm allows one to investigate intact and deficient visual processing in schizophrenic patients with great detail and to elucidate the nature of deficits of visual processing in schizophrenia.

Key words schizophrenia · backward masking · early visual processing · binding problem · feature fusion

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Introduction

The appearance of an object can vary strongly. A square remains a square independent of its colour, texture, or spatial position. In order to cope with this large variety of appearances of an object, the brain processes a visual scene largely in parallel, i. e. the features of an object are processed in different parts of the brain simultaneously. How these separately processed features are bound to one unique perception is known as the so-called binding problem and is one of the most controversial issues in the neuro- and cognitive sciences. Even after a decade of research, it remains an enigma how healthy humans combine the various kinds of information that flexibly. However, patients with cortical lesions, e. g. in the parietal lobe, reveal disturbed binding processes suffering from so-called illusory conjunctions. For example, a red square might be perceived as a green square if a red square and green triangle are presented simultaneously (Friedmann-Hill et al. 1995; Treisman 1998; Ward et al. 2002). In recent publications, it was proposed that also schizophrenic patients suffer from impaired binding processes (Garcia-Toro et al. 2001; Green et al. 1999; Phillips and Silverstein 2003).

At least three basic types of feature integration can be differentiated: spatial object formation, feature attribution, and temporal feature fusion. Object grouping occurs when single elements are spatially bound to one object. For example, a grating is perceived as one object and not as a number of unrelated lines. In feature attribution, additional features, such as colour, are bound to the object, e. g. the grating. Feature fusion occurs when two objects are presented in rapid succession: only one object is perceived and the features of both objects are integrated. A red square followed by a green one appears as a yellow square.

Using a vernier discrimination task, we found that these binding processes strongly depend on each other. A vernier consists of two bars that are slightly displaced relative to each other (Fig. 1a). If the vernier is followed

by an anti-vernier, i. e. a vernier with its offset direction opposite to the preceding vernier, a percept of only one vernier occurs with its offset direction dominated by the anti-vernier (Fig. 1a; Herzog et al. 2003). Feature fusion has occurred. If vernier and anti-vernier are masked, in addition, by a grating of 25 elements, still only one vernier is perceived shining-through the grating (Fig. 1b; shine-through effect; Herzog and Koch 2001). In this case, the first presented vernier dominates offset direction. Perceptual dominance has reversed. We suggested that spatially binding or grouping the grating to one object, i. e. grouping the elements to a grating, causes this reversal of perceptual dominance of the verniers (Herzog et al. 2003). With this paradigm we can, therefore, study the reversal of dominance and its tentatively related integration mechanisms in great spatio-temporal detail by varying the temporal parameters of the vernier and the anti-vernier. Feature fusion is also a masking procedure. The vernier is masked by the anti-vernier and both elements in turn are backward masked by the following grating. It is well known that schizophrenic patients reveal dramatic masking deficits (Cadenhead et al. 1997; Saccuzzo et al. 1974; Rund et al. 1993; Nuechterlein et al. 1994; Green et al. 1994a, b). These deficits have been proposed to be caused by a slow processing in general (Yates 1966), slow processing in the iconic memory (Braff and Saccuzzo 1981), by interruption masking (Green et al. 1994a), or by an overactive magno-cellular pathway (e. g. Breitmeyer 1984; Cadenhead et al. 1998; Green et al. 1994b; Slaghuis and Curran 1999; however, see Keri et al. 2000, 2001; Saccuzzo et al. 1996; Slaghuis and Bakker 1995).

Schizophrenia appears to be a heterogeneous disease with regard to psychopathological (Andreasen et al. 1995) and cognitive features (Green 1997). In some studies, cognitive performance has been found to be related to current psychopathology (Liddle 1996; Hill et al. 2002). Also early visual processing was suggested to be more strongly impaired in schizophrenic patients with negative symptoms such as avolition, blunted affect, or alogia (Braff and Saccuzzo 1985; Braff 1989; Green and Walker 1986; Slaghuis and Curran 1999; Slaghuis and Bakker 1995; Butler et al. 2002). Therefore, we assessed psychopathological symptoms in order to investigate relations between basic visual processing in early integration processes and psychopathology.

Materials and methods

General set-up

Stimuli were displayed on an Eizo monitor F563-T controlled by a PC. In the experiments, a vertical vernier preceded an anti-vernier. A vertical vernier is composed of two bars that are slightly displaced in the horizontal direction. The anti-vernier had the same spatial parameters as the preceding vernier except for opposite offset direction (see Fig. 1). In most conditions, a grating followed the vernier and the anti-vernier (Fig. 1b). The elements of these gratings were aligned verniers, i. e. verniers without horizontal offset. The horizontal distance between elements of the grating was 200″ (arc sec). Vernier or grating element segments were 600″ long and separated by a vertical gap of 60″. Hence, total vernier and grating element length was 1260″. The vernier and the central element of the grating appeared always in the middle of the screen. Gratings lasted for 300 ms.

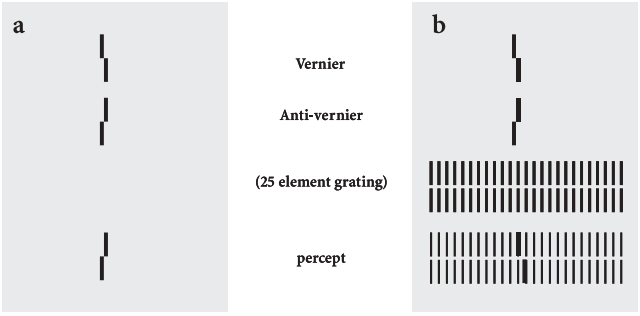

Fig. 1 Stimulus configurations as used in experiments 1 and 2. A vernier is followed by an anti-vernier (**a**). These two verniers are followed by a 25 element grating (**b**). Gratings appear immediately after the anti-vernier and last for 300 ms. The duration of vernier and anti-vernier is varied in the conditions 1 to 3 of experiment 1 (see Table 2)

Subjects observed the stimuli from a distance of 2.5 m in a room illuminated dimly by a background light (around 0.5 lx). A pixel comprised about 24″ at this distance. Stimuli were white on a black background. Luminance of stimuli was approximately 80 cd/m^2. Refresh rate was 100 Hz.

Because of short presentation times, vernier and anti-vernier were fused to one subjective percept, i. e. only one vernier was perceived. Observers had to discriminate the offset direction of the lower part of this fused vernier in relation to the upper segment by pressing one of two push buttons. No feedback was provided.

Observers

A total of 15 schizophrenic patients and 16 healthy controls participated. Their age, gender, duration of illness, education, chlorpromazine equivalents, SAPS (Scale for the assessment of positive symptoms; Andreasen 1984) and SANS (Scale for the assessment of negative symptoms; Andreasen 1983) means, d2 measures, and results of the LPS (Leistungspruefsystem) and the MWT (Mehrfachwahl-Wortschatz-Intelligenztest) are listed in Table 1.

Patients as well as healthy controls participated in the tests after

Table 1 Demographic, psychopathological, and cognitive characteristics of patients and controls. For two patients and one control subject, no cognitive tests were performed. The last column displays the p-values of ANOVAs comparing patients and controls

	Schizophrenic patients	Healthy controls	p-value
N	15	16	
Gender (f/m)	5/10	8/8	
Age (years)	35.5 ± 8.5	34.1 ± 8.3	ns
Years of education	12.2 ± 2.1	14.1 ± 3.0	$p = 0.06$
Duration of illness	7.3 ± 4.9		
CPZ (mg)	583.4 ± 480.9		
SANS	11.9 ± 4.4		
SAPS	6.1 ± 2.7		
d2	48.4 ± 8.7	66.6 ± 10.5	$p \leq 0.0001$
MWT	62.5 ± 11.4	67.4 ± 9.3	ns
LPS3	51.5 ± 4.5	62.8 ± 11.5	$p = 0.003$
LPS4	49.0 ± 6.8	67.4 ± 9.3	$p = 0.001$

signing informed consent. Each observer was informed on the general purpose of the experiment. Subjects were told that they might quit the experiment at any time they wish. Some patients had previously participated in another backward masking study (Herzog et al., in revision).

Diagnosis and psychopathology

In this study, 15 patients participated from the Centre for Psychiatry and Psychotherapy at the Hospital Bremen Ost, two of whom were outpatients. Exclusion criteria were age older than 50 years, diagnosis of a neurological disease, and current substance abuse. Diagnosis was made according to DSM-IV relying on a clinical interview, the medical record, and interviews with the hospital staff. For the assessment of the psychopathological condition, the SANS and the SAPS were used. Diagnosis and psychopathological ratings were carried out by an experienced senior psychiatrist (A. B.) within the week following the day of testing. Psychopathological rating was based on the symptoms existing in the week preceding the rating. With this method, we determined symptoms with a close temporal relationship to the testing. According to the dimensional approach (Andreasen et al. 1995; Liddle 1987; Cuesta et al. 2003; Peralta et al. 2002), we computed composite scores for the psychotic (mean of delusions and hallucinations), the negative (mean of blunted affect, alogia, and avolition) and the disorganized dimension (mean of bizarre behaviour, formal thought disorder, and inadequate affect). All patients were receiving neuroleptic medication taking perphenazine, clozapine, risperidone, quetiapine, amisulprid, zuclopenthixol, haloperidol, or flupentixol. Two patients received two of these neuroleptics, another one three neuroleptics and biperiden. Two other patients received biperiden with a neuroleptic, one patient an additional antidepressant. Four patients received some kind of benzodiazepine medication (oxazepam, diazepam, or lorazepam). Chlorpromazine equivalents were calculated according to the Agency for Healthcare Research and Quality (Agency for Healthcare Research and Quality 2002).

Neuropsychological tests

We assessed sustained attention by the d2 test (Brickenkamp 1994), global cognitive performance by the subtests 3 and 4 of the Horn Leistungspruefsystem LPS (Horn 1983), and premorbid intelligence by a word recognition test (Mehrfachwahl-Wortschatz-Intelligenztest, MWT; Lehrl et al. 1991).

Procedure

First, we determined *visual acuity* of patients and healthy control subjects by standard tests using number digits as target elements. To participate in the following experiments observers had to reach at least a value of 0.8.

Second, we assessed the *critical vernier duration* for each observer individually, i. e. the duration observers need to perform vernier discrimination properly related to a certain criterion level (for details see Herzog et al. in revision).

To study *feature fusion*, we presented a vernier followed by an anti-vernier (unmasked condition, Fig. 1a). In the *masked condition*, vernier and anti-vernier were followed by a 25 element grating (see Fig. 1b). These two conditions (unmasked vs. masked) were presented with various *total* durations of the vernier and the anti-vernier (40 ms, 80 ms, 120 ms, and 140 ms (only in experiment 2)).

In the *unmasked condition*, vernier and anti-vernier had always equal duration, e. g. for a total duration of 40 ms, the vernier and the anti-vernier were presented for 20 ms each. In the masked conditions, temporal proportions of the verniers were varied. We determined performance for each total duration with three different time ratios (see Table 2): 1) vernier and anti-vernier had identical duration, i. e. each vernier had half total duration (condition 2), 2) the vernier had a duration of half total duration minus 10 ms for total durations of 40, 80, and 140 ms and minus 20 ms for a total duration of 120 ms (the anti-vernier being presented 10 ms or 20 ms longer than the half total duration) (condition 1) and 3) the vernier had a duration of half total duration plus 10 ms for total durations of 40, 80, and 140 ms and plus 20 ms for a total duration of 120 ms (condition 3). This means that in the first case both verniers were presented with equal duration, in the second case the anti-vernier was presented longer than the vernier and in the third case the vernier was presented longer than the anti-vernier. The dependent variable in both experiments was the proportion (%) by which the observers indicated the correct offset direction according to the first vernier.

In *experiment 1*, we determined in a first step the individually shortest total duration of each subject for which in the unmasked condition (see Table 3) performance was clearly below 50 %, i. e. the anti-vernier dominates. In a second step, we assessed performance for the three conditions (vernier longer, equal duration, anti-vernier longer). In the third step, we fitted regression lines to the data determining the slopes for each observer.

In *experiment 2*, subjects were tested with a total duration of 140 ms (see Table 2). The data were analysed by means of a repeated measures analysis with a within-subject factor of 3 levels (temporal proportions) and a between-subjects factor of two levels (patients vs. controls). All repeated measures analyses were corrected by the Greenhouse-Geisser formula, if necessary. In this case, degrees of freedom were truncated to integers (Bortz 1999). Regression lines were calculated and the slopes compared between both groups by an ANOVA.

Table 3 Performance (%) in the unmasked and the masked condition for the three total durations of experiment 1. Two patients needed total durations of 140 and 160 ms, respectively, and are not represented here. These two observers reveal the same qualitative characteristics as observers with shorter total durations. Vernier and anti-vernier were presented for an identical duration. This Table demonstrates the reversal of dominance for healthy controls as well as for patients, i. e. the anti-vernier dominates in the unmasked condition (performance below 50 %) whereas the vernier dominates in the masked condition (performance above 50 %) . n indicates the number of subjects for the respective durations

Total duration	Schizophrenic patients			Healthy controls		
	n	unmasked	masked	n	unmasked	masked
40 ms	3	36.3±10.00	59.2±5.90	10	37.4±11.67	55.4±5.45
80 ms	4	22.9±15.65	59.7±10.04	10	19.8±10.83	63.8±7.20
120 ms	6	24.9±16.17	52.1±4.73	10	9.8±6.35	53.7±8.09

Table 2 Temporal proportions of vernier and anti-vernier for total durations as used in experiments 1 and 2. Total durations of 40, 80, and 120 ms are used in experiment 1, 140 ms in experiment 2. Values in brackets indicate the percentage of the vernier/anti-vernier duration regarding the total duration

Total duration (ms)	Duration of vernier/anti-vernier (ms) and proportions (%)		
	Condition 1 ms (% of total duration)	Condition 2 ms (% of total duration)	Condition 3 ms (% of total duration)
40	10/30 (25/75)	20/20 (50/50)	30/10 (75/25)
80	30/50 (37.5/62.5)	40/40 (50/50)	50/30 (62.5/37.5)
120	40/80 (33.3/66.7)	60/60 (50/50)	80/40 (66.7/33.3)
140	60/80 (42.9/57.1)	70/70 (50/50)	80/60 (57.1/42.9)

Results

Neurocognitive tests

Schizophrenic patients performed substantially worse than healthy controls in all neurocognitive tests (see Table 1) except for the Mehrfachwahl-Wortschatz-Intelligenztest indicating similar premorbid intelligence.

Critical vernier duration

The critical vernier duration was significantly longer for the patients than for controls (40.0 ± 25.1 and 20.0 ± 5.4, respectively; $F[1,29] = 9.1$, $p = 0.005$).

Experiment 1

A total of 15 patients and 10 control subjects participated in experiment 1. For three patients 40 ms, for four patients 80 ms, and for six patients 120 ms were the shortest minimal durations yielding clear dominance of the anti-vernier. Two patients needed longer total durations. Both schizophrenic patients and healthy controls show a clear dominance of the anti-vernier in the unmasked condition, i. e. without a following grating (Table 3). If a 25 element grating follows, dominance reverses, i. e. performance is above 50 % if the vernier and the anti-vernier have the same duration, i. e. in the 20/20, 40/40, or 60/60 ms conditions (Table 3).

If the anti-vernier is presented longer than the vernier, the anti-vernier clearly dominates performance and vice versa (see Fig. 2, conditions 1 and 3, respectively). To quantify the data, we computed regression lines for each observer. Slopes of patients are in the mean 3.2 ± 0.7 (for 40 ms total duration), 1.5 ± 0.4 (for a total duration of 80 ms) and 1.2 ± 0.5 (for a total duration of 120 ms). For the healthy controls, who were tested for all total durations, slopes are in the mean 3.6 ± 0.7 (for 40 ms total duration), 2.6 ± 0.5 (for a total duration of 80 ms) and 1.9 ± 0.3 (for a total duration of 120 ms). A one sample t-test reveals that slopes are significantly different from zero ($p \leq 0.0001$) for patients as well as for controls. Therefore, patients and controls reveal both a clear reversal of dominance. Moreover, verniers and anti-verniers contribute to performance proportional to their durations.

Experiment 2

Experiment 1 demonstrates the fundamental capability of schizophrenic patients to perform feature fusion. Patients performed qualitatively like controls. Dominance depends mainly on the ratio of durations of the vernier and the anti-vernier respectively. Does this result also hold for longer total durations? To test this, we displayed the vernier and the anti-vernier for a total duration of 140 ms and used ratios of vernier/anti-vernier duration of 60/80, 70/70, and 80/60 ms. All 10 patients of experiment 2 had participated in experiment 1 previously. Five healthy subjects of experiment 1 and 5 new control subjects participated in experiment 2.

Patients scored with a percentage of 26.5 % in the 60/80 ms condition and attained 51.5 % in the 80/60 condition, whereas controls scored at a lower percentage of 10.9 % and achieved a mean of 44.1 % in the 80/60 condition (see Fig. 3). In all three conditions, the values of the controls were below those of the patients (significant group effect ($F[1,18] = 5.8$, $p = 0.027$). There was no significant interaction of condition by group but a highly significant condition effect ($F[1,24] = 43.1$, $p \leq 0.0001$). As in experiment 1, we fitted regression lines to the data. For both groups, slopes are significantly different from zero ($p \leq 0.0001$) with 1.3 ± 0.7 for patients and 1.7 ± 1.1 for controls and do not differ statistically between both groups ($p = 0.33$).

We also compared the performance in the unmasked

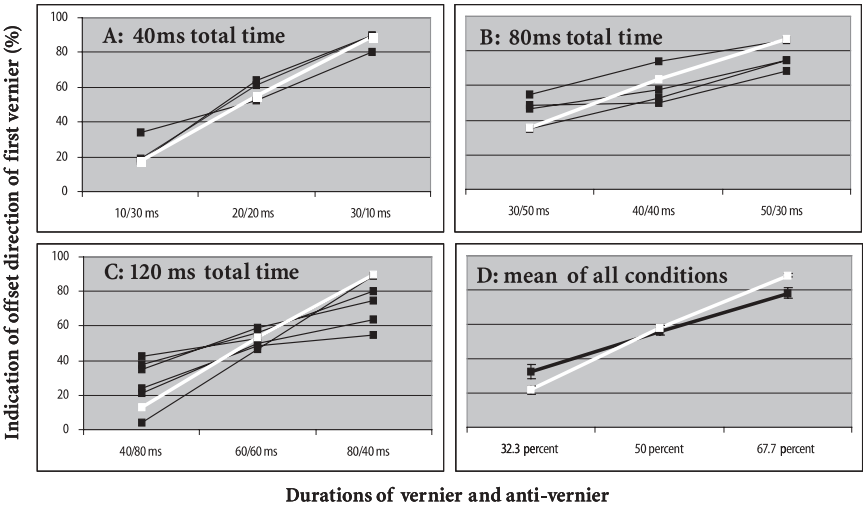

Fig. 2 Performance of individual schizophrenic patients (black lines) and mean performance of healthy controls (single white lines). **A-D** In each panel, the total duration of vernier and anti-vernier is indicated in the upper left corner. Performance is assessed as the percentage of correct responses regarding the preceding vernier, i. e. performance above 50 % indicates perceptual dominance of the vernier, below 50 % denotes dominance of the anti-vernier, and 50 % no dominance. Each patient contributes to only one panel. Healthy controls were tested for all total durations. **A** 40 ms total duration, **B** 80 ms total duration, **C** 120 ms total duration, **D** means of patients and controls. Proportions are indicated as percent of the first vernier in relation to the total duration and are calculated as weighted means of proportions of the three total durations. Displayed are means and standard errors. Standard errors of controls are smaller than symbol size

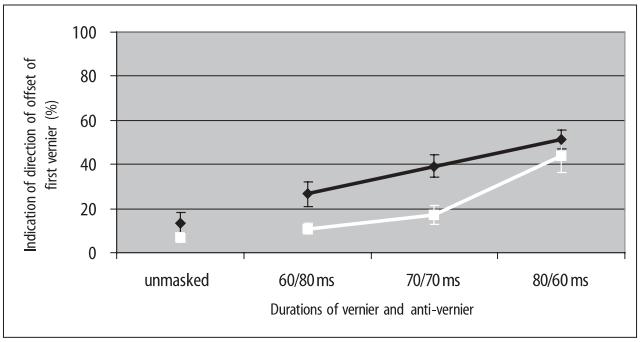

Fig. 3 Means of performance of patients (black) and controls (white) for a total duration of 140 ms. Subjects were tested with two conditions: unmasked with a temporal proportion of 70/70 ms (black and white dots) and masked with three different temporal proportions of vernier and anti-vernier (black and white lines). On the ordinate, the percentage of correct offset discrimination regarding the preceding vernier is shown. For one patient, there was no unmasked result. Displayed are means and standard errors. Standard errors of controls are sometimes smaller than symbol size

and the masked condition (temporal proportion 70/70 ms masked and unmasked) for both groups. Healthy subjects increased their performance from 6.8 ± 6.1 % in the unmasked condition to 17.1 ± 12.7 % in the masked condition, patients from 13.6 ± 13.9 % to 39.2 ± 16.8 % (see Fig. 3). A repeated measures analysis with the factors condition (unmasked vs. masked) and group revealed a highly significant condition effect ($F[1,17] = 26.0$, $p \leq 0.0001$), a weak interaction ($F[1,17] = 4.5$, $p = 0.049$), and a significant group effect ($F[1,17] = 8.5$, $p = 0.01$).

Psychopathological dimensions

In experiment 2, we correlated the slope of the patients with psychopathological dimensions (psychotic, negative and disorganized). We did not find a significant correlation between these dimensions and the slope of regression lines.

In experiment 1, patients in the 40 ms total time showed predominantly psychotic symptoms (2.7 psychotic, 1.0 negative, 1.0 disorganized), whereas patients who needed longer total durations revealed more negative symptoms (the four patients with a positive slope with 80 ms: 2.3 psychotic, 2.9 negative, 1.1 disorganized; the six patients with a positive slope with 120 ms: 1.8 psychotic, 2.6 negative, 1.2 disorganized). However, groups are too small to perform a statistical analysis.

Discussion

If a vernier is followed by an anti-vernier, only one vernier is subjectively perceived. Feature fusion has occurred. For total display times of the vernier and the anti-vernier of 40, 80, 120 ms, and 140 ms, the anti-vernier clearly dominates in the unmasked condition in both groups (Figs. 2 and 3; see also Herzog et al. 2003). If a grating follows the verniers, patients and healthy controls show a clear reversal in dominance when vernier and anti-vernier are presented for the same duration each. Hence, schizophrenic patients reveal qualitatively identical complex integration characteristics as healthy subjects in our feature fusion paradigm.

Dominance can be manipulated by changing the ratio of the durations of vernier and anti-vernier while keeping the overall duration constant in the masked case. The longer the first displayed vernier is presented the stronger is its dominance and analogously for the anti-vernier. Therefore, only the duration of the vernier and the anti-vernier matters, not the order of presentation, i. e. vernier first and anti-vernier second. Schizophrenic patients follow these results in an almost identical manner as healthy controls. Hence, schizophrenic patients are qualitatively as sensitive to the specific temporal arrangement of elements as healthy controls. These results hold for long and short total durations of the verniers (experiments 1 and 2). It seems that feature fusion is intact in schizophrenic patients for the entire epoch of early visual information processing.

However, the slopes of regression lines of the controls are somewhat steeper than those of the patients indicating possibly a more efficient target processing in the controls. Whereas qualitative results are comparable between patients and controls, quantitative differences might exist.

For long total vernier durations of 140 ms, dominance of the anti-vernier is prevalent even if the vernier is presented 10 ms longer. Feature fusion seems to take the later presented elements stronger into account. These characteristics occur in patients as well as in controls.

In Herzog et al. (in revision), we showed that perceptual grouping is intact in the schizophrenic patient in the shine-through effect. In Herzog et al. (2003), we argued that binding the grating to one object, i. e. perceptual grouping, determines integration over time, i. e. feature fusion. Hence, our results in this contribution, moreover, indicate not only intact feature fusion but also an intact interplay of the various integration mechanisms in schizophrenic patients. Since perceptual grouping and feature fusion are intact in schizophrenic patients, it seems that the strong masking effects occurring otherwise in shine-through are caused by other mechanisms. In most patients longer vernier/anti-vernier durations are required to show clear dominance of the anti-vernier. It may be that processing of the vernier target itself is deteriorated, reflected in the prolonged CSD (critical stimulus duration).

Doniger et al. (2001) reported that schizophrenic patients have deficits recognizing fragmented images compared to healthy controls. Reporting whether or not there is a temporal difference of two subsequently displayed identical elements is also deficient in schizophrenic patients (Schwartz and Winstead 1982; Schwartz et al. 1988). These results suggest evidence for a deficient icon formation, i. e. the temporal singling out

of an element in the steady stream of elements – while combining information in the stream is intact as feature fusion shows.

It was suggested that deficits of schizophrenic patients occur because of neurophysiological binding deficits (Green et al. 1999; Garcia-Toro et al. 2001; Phillips and Silverstein 2003). To cope with the various appearances of the same object, versatile codes were proposed based on temporal properties such as neural oscillations or synchronisation (e. g. Singer 1999; Gray 1999; v. d. Malsburg 1995; Roskies 1999). Indeed, Green et al. (1999) showed that healthy subjects show oscillating masking functions that might correspond to neural oscillations. Schizophrenic patients, in contrast, did not show these oscillating functions. We do not find evidence for a deficient binding in feature fusion. In fact, oscillations are not very likely to be involved since feature fusion can occur with total durations of vernier and anti-vernier as short as 40 ms – too short for pronounced oscillations. Therefore, different kinds of binding might require different neural mechanisms some of which are deficient in schizophrenic patients while others are not.

Backward masking deficits of schizophrenic patients are often attributed to an overactive transient magnocellular visual system that disturbs processing of the sustained parvo-cellular system (e. g. Breitmeyer 1984; Cadenhead et al. 1998; Green et al. 1994a, b; Slaghuis and Curran 1999; however, see Keri et al. 2000, 2001; Saccuzzo et al. 1996; Slaghuis and Bakker 1995). Transient responses occur after stimulus onset lasting for 10–50 ms. It might be that a deteriorated vernier processing, related to the longer durations of the vernier and the anti-vernier, are caused by the overactive magno-cellular system in the patient. On the other hand, this overactive system must disturb information processing in an unspecific way since dominance reverses for the same ratios of vernier and anti-vernier duration as for healthy subjects. That means, overactive transients must affect information processing of the vernier and the anti-vernier equally – even if these elements are displayed at different onsets.

The slope of performance in the 140 ms condition is not related to any of the psychopathological dimensions (psychotic, negative or disorganized) which is not surprising since patients and controls do not differ with respect to this variable. It appears, however, that the processing time needed for complete feature fusion is related to psychopathology. Patients who need longer total vernier/antivernier durations reveal more negative symptoms, whereas the three patients in the 40 ms total duration conditions show predominantly psychotic symptoms. Hence, the longer total durations or the "slowness" might be related to negative symptoms (see Slaghuis and Bakker 1995; Slaghuis and Curran 1999; Butler et al. 2002). But these results are preliminary and have to be replicated with a larger patient group. It has to be noted, moreover, that we assessed psychopathological symptoms within a narrow time window (1 week) whereas most researchers rate symptoms in a much wider time window (e. g. Slaghuis and Bishop 2001; Andreasen and Olsen 1982).

We used a rather small ensemble of patients that might limit our conclusions even though the qualitative effects are rather strong in all observers reflected in the strong slopes of regression lines (Fig. 2). Meanwhile, we conducted more experiments with a comparable paradigm. Also, in these studies, all observers show a clear reversal of dominance–independent of neuroleptic medication and gender (that were not perfectly matched in the above experiments). We, moreover, computed the slopes for the male and female patients in experiment 2 separately and did not find a significant difference (p-value: 0.46).

The conclusions of this study, as the ones of many other studies in schizophrenia research, are also weakened by the different neuroleptic medications of patients. Schizophrenia is a heterogeneous disorder, and results often depend on the characteristics of the sample. There is, however, no substantial heterogeneity of performance in the patient group: the standard deviation of the patients in the 140 ms condition, for example, is even smaller than for the controls. There is, moreover, no significant correlation between the chlorpromazine equivalents and the slopes of regression lines, nor are there differences between "fast" and "slow" patients with regard to CPZ equivalents or treatment with typical or atypical medication. We found a difference of slopes of patients taking benzodiazepines compared to patients not taking benzodiazepines (1.66 vs. 0.97), but without significance (p-value: 0.13; only four patients were medicated with benzodiazepines). It cannot be ruled out that the quantitative performance differences might be influenced by benzodiazepines that may yield performance more comparable to controls. However, there is no difference in the qualitative behavior between controls, patients with and patients without benzodiazepines.

The shine-through paradigm allows to investigate intact and deficient processing in schizophrenic patients with great detail. In Herzog et al. (in revision), we showed that perceptual grouping and figure-ground-segmentation are intact whereas masking itself can tremendously deteriorate performance up to a factor of ten. In the present study, we found evidence for qualitatively intact feature fusion in schizophrenic patients but a prolonged target duration. An extended analysis of intact and deficient visual functions might allow us to dissociate the affected from the unaffected visual pathways in the near future and how these pathways affect high order functions in the patient. This approach might help to improve diagnosis and isolate the deficient pathways since much is known about the neurophysiology of the early steps of visual information processing. This knowledge might contribute to explain cognitive deficits of schizophrenic patients and even might help to understand the genesis of psychopathological dimensions.

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