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Anomalous visual experiences, negative symptoms, perceptual organization and the magnocellular pathway in schizophrenia: a shared construct?

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ABSTRACT

Background. Schizophrenia is associated with impaired visual information processing. The aim of this study was to investigate the relationship between anomalous perceptual experiences, positive and negative symptoms, perceptual organization, rapid categorization of natural images and magnocellular (M) and parvocellular (P) visual pathway functioning.

Method. Thirty-five unmedicated patients with schizophrenia and 20 matched healthy control volunteers participated. Anomalous perceptual experiences were assessed with the Bonn Scale for the Assessment Basic Symptoms (BSABS). General intellectual functions were evaluated with the revised version of the Wechsler Adult Intelligence Scale. The 1–9 version of the Continuous Performance Test (CPT) was used to investigate sustained attention. The following psychophysical tests were used: detection of Gabor patches with collinear and orthogonal flankers (perceptual organization), categorization of briefly presented natural scenes (rapid visual processing), low-contrast and frequency-doubling vernier threshold (M pathway functioning), isoluminant colour vernier threshold and high spatial frequency discrimination (P pathway functioning).

Results. The patients with schizophrenia were impaired on test of perceptual organization, rapid visual processing and M pathway functioning. There was a significant correlation between BSABS scores, negative symptoms, perceptual organization, rapid visual processing and M pathway functioning. Positive symptoms, IQ, CPT and P pathway measures did not correlate with these parameters. The best predictor of the BSABS score was the perceptual organization deficit.

Conclusions. These results raise the possibility that multiple facets of visual information processing deficits can be explained by M pathway dysfunctions in schizophrenia, resulting in impaired attentional modulation of perceptual organization and of natural image categorization.

INTRODUCTION

Visual perceptual dysfunction is an important aspect of the experimental psychopathology of schizophrenia. Researchers who aimed to study the psychophysical mechanisms of early-stage visual abnormalities focused on perceptual processing channels with different functional characteristics (Green *et al*. 1994; Cadenhead *et al*. 1998). The pioneering model of sustained and transient channels stimulated physiologically oriented studies investigating the magnocellular (M) and parvocellular (P) visual pathways, which originate in the retina and project to the primary visual cortex (V1). M pathways (transient channels) are sensitive for low luminance contrast, low spatial frequency (coarse resolution and large details of objects),

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rapid temporal changes (brief stimulus exposure and fast offset) and motion. P pathways (sustained channels) prefer static stimuli with medium and high spatial frequency (high resolution and small details of objects) and colours (Schiller *et al*. 1990; Van Essen & Gallant, 1994). Despite the interaction between M and P pathways even in the primary visual cortex (Sawatari & Callaway, 1996; Vidyasagar *et al*. 2002), M pathways give rich input to the cortical areas responsible for motion perception, detection of spatial location, visuo-motor and eye-movement coordination (dorsal occipito-parietal stream). P pathways project to the ventral occipito-temporal regions related to colour and object recognition and categorization (Schiller *et al*. 1990; Van Essen & Gallant, 1994). Although results on M and P pathway functioning in schizophrenia are not fully consistent (Slaghuis, 1998; Bedwell *et al*. 2003; Chen *et al*. 2004), recent data from psychophysical, electrophysiological, and functional neuroimaging studies suggest the severe impairment of the M pathway/dorsal stream system (Butler *et al*. 2001; Braus *et al*. 2002; Doniger *et al*. 2002; Kéri *et al*. 2004).

Independently of the 'channel theory', dysfunctions in perceptual organization have been demonstrated in schizophrenia and linked to formal thought disorder, as a reliable index of dysfunctions in cognitive coordination and context processing (Phillips & Silverstein, 2003; Silverstein & Uhlhaas, 2004). The cornerstone of perceptual organization is that the visual system is able to connect, group and complete small features of the environment in order to build up coherent percepts (Kovács, 1996). The Gestalt rules of proximity, collinearity, good continuation, closure and similarity facilitate grouping processes. Lateral interactions between neurons in the early visual areas (V1/V2), which code, for example, features with similar orientation, play an important role in Gestalt grouping (Kovács, 1996; Polat *et al*. 1998; Freeman *et al*. 2001) and have been shown to be impaired in schizophrenia (Must *et al*. 2004).

There is extensive clinical evidence that anomalous visual perceptual experiences (unclear seeing, partial sight, photopsia, micro-macropsia, dysmegalopsia, changes in perception of others' faces and figures, skewed sight/disturbed perspective, disturbed sense of distance, disturbed rectilinearity and abnormal persistence of visual irritation) are dominant features of schizophrenia, including the pre-psychotic prodromal phase of the disorder (Matussek, 1952; Conrad, 1958; McGhie & Chapman, 1961; Venables, 1964; Phillipson & Harris, 1985; Cutting & Dunne, 1986; Bunney *et al*. 1999; Klosterkötter *et al*. 2001; Parnas *et al*. 2003). Pioneering psychopathologists Matussek (1952) and Conrad (1958) described the fundamental fragmentation and crystallization of the perceptual world of schizophrenia patients, whereas McGhie & Chapman (1961) and Venables (1964) emphasized input dysfunctions resulting in information overload and cognitive fragmentation. Controlled studies confirmed the high incidence of anomalous visual experiences (Phillipson & Harris, 1985; Cutting & Dunne, 1986; Bunney *et al*. 1999).

The aim of this study was to investigate the relationship between anomalous perceptual experiences and the models of visual information-processing dysfunctions. Besides the administration of a structured interview for visual disturbances, the patients received a natural scene categorization task in order to evaluate the capacity of the visual system to process briefly presented complex images (Thorpe *et al*. 1996; Antal *et al*. 2000). To investigate the 'channel model', different types of vernier tasks were applied for M pathways (frequency doubling and low contrast) and P pathways (colour) (McKendrick *et al*. 2002; Kéri *et al*. 2004). The discrimination of high spatial frequency patterns was included as an additional test for P pathways (O'Donnell *et al*. 2002). Finally, the flanker task was administered to assess basic mechanisms of perceptual organization. This task is suitable for the investigation of lateral interactions in the early visual cortex (Polat *et al*. 1998; Freeman *et al*. 2001).

Our hypothesis was that anomalous perceptual experiences, perceptual organization, rapid categorization of natural scenes, and M pathway functions are related to each other. This hypothesis was based on the recently proposed role of M pathways in attentional modulation (Schröeder, 1995; Vidyasagar, 1999; Schwartz *et al*. 2001). According to this hypothesis, M pathways rapidly transfer low spatial frequency information, which reaches higher-level cortical areas through fast feed-forward pathways. This fast route of information processing

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mobilizes attentional resources related to the posterior parietal cortex, which will eventually influence perceptual organization in the early visual areas and the categorization of natural images in the ventral occipito-temporal cortex. More generally, attentional processes related to the M pathway/dorsal stream system may influence perceptual grouping and object recognition taking place in the early visual cortex and ventral stream respectively (Schröeder, 1995; Vidyasagar, 1999; Schwartz *et al.* 2001). We propose that the dysfunction of this system may contribute to anomalous perceptual experiences in schizophrenia.

METHOD

Participants

Thirty-five patients with DSM-IV schizophrenia (APA, 1994) [paranoid ($n=22$), undifferentiated ($n=11$), disorganized ($n=1$), catatonic ($n=1$)] and 20 healthy control subjects participated in the study. The patients were selected from a larger sample according to the following criteria: (i) stabilized clinical state, (ii) the ability and willingness to participate and give informed consent, and (iii) no antipsychotic medication at least for 3 weeks before testing. The patients discontinued treatment for reasons of subjective well-being ($n=13$) and side-effects ($n=10$). Twelve patients never received antipsychotic medications before testing. All participants were screened with the Mini-International Neuropsychiatric Interview Plus (Sheehan *et al.* 1998) and received neurological examination, EEG, magnetic resonance imaging, and a screening blood and urine test including tests for psychoactive substances. The patients were assessed on the Scale for the Assessment of Positive Symptoms (SAPS) (Andreasen, 1984*a*) and Scale for the Assessment of Negative Symptoms (SANS) (Andreasen, 1984*b*). The diagnosis was based on the extensive longitudinal history of the patients. Similarly to the diagnosis, the SAPS and SANS scores were provided by treating clinicians who were blind to the study.

Perceptual disorder was evaluated with 10 items from the Bonn Scale for the Assessment of Basic Symptoms (BSABS), including unclear seeing, partial sight, photopsia, micromacropsia, dysmegalopsia, changes in perception of others' faces and figures, skewed sight/disturbed perspective, disturbed sense of distance, disturbed rectilinearity, and abnormal persistence of visual irritation (Klosterkötter *et al.* 2001; Parnas *et al.* 2003). We used a categorical approach. If the patient did not experience perceptual disorder for any BSABS item, a score of 0 was given ($n=11$). If the patient experienced perceptual disorder for at least one BSABS item, but the experience was only doubtfully present, a score of 1 was given ($n=12$). If the patient experienced perceptual disorder for at least one BSABS item and the experience was definitely present, a score of 2 was given ($n=12$). None of the control participants reported anomalous perceptual experiences. The assessor of perceptual disorder (I.K.) was blind to the psychophysical and clinical data. The kappa reliability coefficients for single BSABS items were above 0·6 between the interviewer (I.K.) and a consensus rating by two clinicians who did not participate in the study. History of neurological disorders, head injury, substance abuse and electroconvulsive therapy were the exclusion criteria. All participants had normal or corrected-to-normal visual acuity. After a complete description of the study, written informed consent was obtained.

General intellectual functions and sustained attention

General intellectual functions were evaluated with the revised version of the Wechsler Adult Intelligence Scale (WAIS-R; Wechsler, 1981). Sustained attention was measured with a computer-administered version of the 1–9 Continuous Performance Test (CPT; Finkelstein *et al.* 1997). During this test, participants were asked to press a button when a number 1 was followed by number 9 in the sequence. The maintenance of numerical information during the CPT is related to working memory. The stimulus duration was 200 ms and the interstimulus-interval was 800 ms. Three hundred trials were presented with 30 targets. The sensitivity index (d') was calculated from the hit rate and false-alarm rate (Finkelstein *et al.* 1997).

Vernier threshold

The stimuli were presented on a gamma-corrected ViewSonic PF815 monitor (resolution: 800×600 pixels; refresh rate: 100 Hz; VSG graphic card, version 5·02, Cambridge Research

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System Ltd, Rochester, UK). The monitor was controlled by an IBM-compatible PC. There were three types of vernier threshold measurements: (1) blue-on-yellow (colour), (2) frequency-doubling, and (3) achromatic low-luminance contrast. In the colour condition, two blue dots were presented against a yellow background. The stimulus chromaticity was defined according to a three-dimensional cone contrast space. There was no luminance contrast between the dots and the background (isoluminant condition). To achieve the isoluminant condition, a heterochromatic flicker-photometry procedure was carried out. In the low-contrast condition, two dark dots were presented against a white background. Luminance contrast (5%) was defined according to the Michelson formula (the absolute difference between the luminance of the stimulus and the background divided by their sum). Before the administration of the low-contrast vernier task, participants underwent a contrast threshold measurement in order to ensure that they perceived the low-contrast dots. In the frequency-doubling condition, stimuli were two sinusoidal luminance-contrast gratings (contrast 90%). The spatial frequency was 1 cycle/degree. The adjacent bars with minimal and maximal luminance changed places several times during a second (counterphase modulation). The grating was counterphase modulated at 25 Hz. The spatial phase of the upper grating was random and the lower grating was horizontally displaced from the upper grating. The maximum displacement was 0·5 cycle of the grating (Fig. 1).

The vernier acuity thresholds were determined in each condition using a two-alternative forced-choice method. The location of the upper stimulus (dot or grating) was constant, whereas the lower stimulus was displaced either to the left or to the right of the upper stimulus (spatial offset). The participants were asked to indicate the direction of the spatial offset by pressing different buttons on the keyboard. The initial displacement was 400 sec arc. The displacement was decreased by 10% after three consecutive correct responses and was increased by 10% after one incorrect response. The staircase was terminated after four reversals. The final vernier threshold was the average value obtained from two separate staircase procedures. For a detailed description, see McKendrick *et al.* (2002) and Kéri *et al.* (2004).

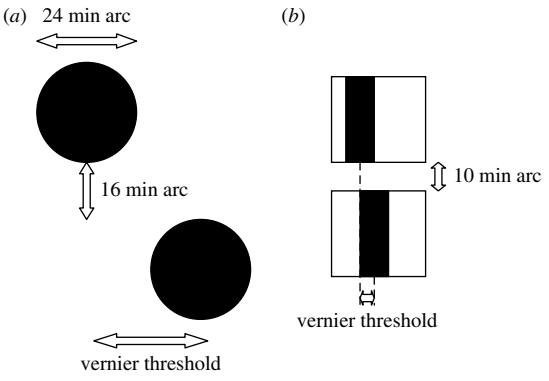


FIG. 1. Vernier tasks. (*a*) In the achromatic low-contrast condition, two dark dots were presented against a white background. In the blue-on-yellow condition, blue dots were presented against a yellow background. (*b*) In the frequency-doubling condition, counterphase modulated gratings were used (only two vertically displaced dark bars are shown). The task was to decide whether the lower dot/grating was to the left or to the right in relation to the upper dot/grating. Vernier threshold was the minimal displacement indispensable for the detection of spatial offset.

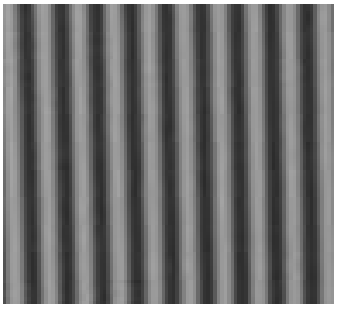


FIG. 2. An example of sinusoidal luminance-contrast gratings used for spatial frequency discrimination. During the test two gratings appeared side by side on the screen. The task was to decide whether the two gratings had the same spatial frequency (the number of bars on the stimulus surface) or not.

Spatial frequency discrimination

The stimuli consisted of two squares (4° of visual angle), localized side by side on the screen. The squares contained vertical sinusoidal gratings with a Michelson contrast of 80% and an average luminance of 30 cd/m² (Fig. 2). The spatial frequency of the standard gratings was 8·3 cycles/degree. On each trial, one standard high spatial frequency grating was compared with a second grating. Angular disparity (AD) was used to measure the mismatch between the

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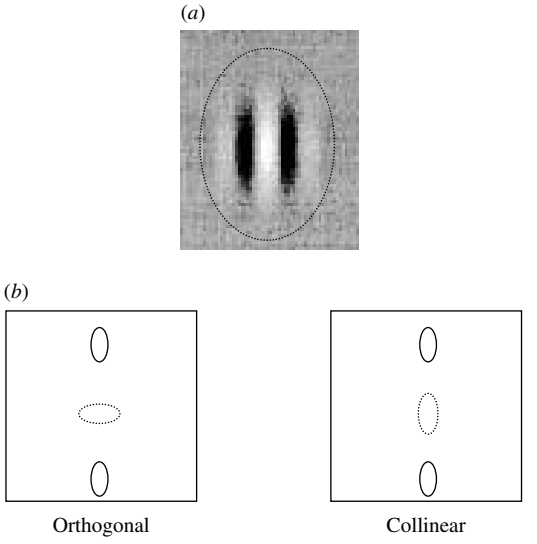


FIG. 3. (*a*) Gabor patch. (*b*) Configuration of the target Gabor patch (dotted line) and the lateral flankers. The task was to detect the target Gabor patch. The collinear flankers facilitated target detection, resulting in lower contrast threshold for the target compared with that in the orthogonal condition.

spatial frequency of the two gratings (G1 and G2): AD = (G1 – G2)/(G1 + G2). The average disparity was 0·12.

At the beginning of each trial, a fixation cross of 500 ms was presented. After the fixation cross, the stimulus display with the two gratings were presented. The exposure time of the stimulus display was 1500 ms. The participant gave the discrimination response (match or non-match) by pressing a button on the computer keyboard. Altogether 100 trials (50 same and 50 different gratings) were included. The phase of the gratings was randomly varied by 180°. The blocks and the trials were randomized across subjects. The dependent measure was the percentage of correct discriminations. For a detailed description, see O'Donnell *et al.* (2002).

The flanker task

The stimuli were Gabor patches, which were small oriented features defined by luminance contrast (Fig. 3). The luminance contrast profile of Gabor patches is formed by the multiplication of a sinusoidal waveform with a Gaussian envelope. Gabor patches are ideal stimuli for neurons in the early visual cortex (V1/V2). Gabor patches had a wavelength (λ) and Gaussian distribution equal to 0·15° of visual angle. The spatial frequency was 6·7 cycles/degree.

At the beginning of a trial, the participants were asked to press the space button on the computer keyboard. After this, a fixation display of 300 ms appeared, which contained a central cross and two peripheral bars (length 0·3° of visual angle; eccentricity 1·4° of visual angle). The central cross indicated the location of the subsequent target Gabor patch for which contrast threshold (the minimal contrast necessary for detection) was measured. The orientation of the target was either 45° or 135°. The peripheral bars indicated the location of two subsequent peripheral Gabor patches (flankers with a contrast of 40%). The orientation of the flankers was either collinear or orthogonal to that of the target (Fig. 3). The centre-to-centre distance between the target and the flankers was 4λ. The participants were asked to fixate on the central cross. The experimenter observed the participants throughout the whole experiment to ensure fixation. After the fixation display, a brief interval of 80 ms occurred during which the Gabor patches were presented. The participants were asked to indicate if they detected the target by pressing separate buttons on the keyboard ('1' = yes, '9' = no). The next trial was not initiated without a response. The responses with reaction times exceeding 2000 ms were eliminated. In the case of three consecutive correct responses (hits), the contrast was decreased by 0·1 log unit, whereas in the case of one incorrect response (miss), the contrast was increased by 0·1 log unit. A decrease or an increase of the contrast was considered a reversal. One block of trials terminated after eight reversals. The contrast threshold was the average of the last six reversals. Measurements with collinear and orthogonal flankers were performed in separate blocks, which were counterbalanced across the participants.

Perceptual organization was indexed by the subtraction of the contrast threshold obtained in the orthogonal condition from that obtained in the collinear condition. In healthy controls, contrast threshold is lower in the collinear condition than in the orthogonal condition, because collinear flankers facilitate target detection. Therefore, lower perceptual organization values indicate stronger facilitation by collinear flankers

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and hence more efficient perceptual organization. For a detailed description, see Freeman *et al*. (2001) and Must *et al*. (2004).

Natural scene categorization

The stimuli were 100 photographs of real-world images. The target images contained an animal (birds, mammals, reptiles, sea creatures, insects), while the non-target images contained no animals (buildings, flowers, fruits, forests, fields, mountains, urban scenes with people and vehicles). The stimuli subtended 8° by 5° of visual angle from a viewing distance of 100 cm. The mean luminance of the stimulus area was 85 cd/m², the background luminance was 9 cd/m².

Each trial was initiated by the participant by pressing one of the response buttons on the computer keyboard. First, a fixation point of 0·1° of visual angle was presented for 300–700 ms. After this, one image was presented for 30 ms. The third part of the trial was a response period, during which participants decided whether the image contained an animal or not by pressing the category-associated buttons on the computer keyboard ('1' for animal and '9' for non animal). After the response, the fixation point was presented again and a new trial began. The probability of target and non-target images was the same (50%). Altogether 100 trials were included. The dependent measure was the percentage of correct category decisions. Previous studies demonstrated that healthy participants show a surprisingly high capacity to categorize briefly presented natural images, performing above 90% on this task (Thorpe *et al*. 1996; Antal *et al*. 2000). Category-specific information processing takes places within 150 ms after stimulus onset. For detailed descriptions, see Thorpe *et al*. (1996) and Antal *et al*. (2000).

Data analysis

The STATISTICA 6·0 software (StatSoft, Inc., Tulsa, OK, USA) was used for data analysis. Kolmogorov–Smirnov tests were applied in order to ensure that the data were normally distributed. The vernier threshold and the perceptual organization data were logarithmically transformed. Student's *t* tests (two-tailed) were used for the comparison of the demographical and the test data from the patients and the controls. The vernier data were analysed with a repeated-measures analysis of variance (ANOVA), with group as the between-subject factor and vernier task type as the within-subject factors. The Tukey HSD test was used for *post-hoc* comparisons. Forward stepwise linear regression analysis was used to determine factors that predicted perceptual dysfunctions. In this analysis, the dependent variable was BSABS perceptual disorder and the independent variables were perceptual organization, vernier thresholds, spatial frequency discrimination, and natural scene categorization performances. Spearman rank order correlations (R_s) were calculated between the measures of interest. True-score variances (a product of reliability and variance) were calculated using the reliability and item analysis panel of the STATISTICA package. The level of significance was $\alpha < 0{\cdot}05$.

RESULTS

The results are summarized in Tables 1 and 2. Five patients did not participate in the low-contrast vernier task because their contrast threshold was higher than 5%. The patients showed spared IQ, spatial frequency discrimination and colour vernier performances, whereas they performed poorly on the CPT, perceptual organization, frequency-doubling vernier, low-contrast vernier and natural scene categorization tasks (Table 1). The ANOVA conducted on the vernier threshold data revealed a significant main effect of group [$F(1, 48) = 15{\cdot}06$, $p < 0{\cdot}001$] and a significant interaction between group and vernier task type [$F(2, 96) = 4{\cdot}94$, $p < 0{\cdot}01$]. Tukey HSD tests indicated significantly higher vernier threshold in patients compared to controls in the frequency-doubling and low-contrast conditions ($p < 0{\cdot}05$) (Table 1).

The linear regression analysis revealed that perceptual organization was the only significant predictive factor of the BSABS perceptual disorder ($\beta = 0{\cdot}75$, $p = 0{\cdot}001$). The correlation matrix from the patient group is shown in Table 2. Similar comparisons were performed in the control group with the exception of SAPS, SANS and BSABS perceptual disorder. In the control group, there were significant correlations between perceptual organization and frequency-doubling ($R = 0{\cdot}64$, $p < 0{\cdot}05$) and low-contrast vernier ($R = 0{\cdot}63$, $p < 0{\cdot}05$), as well as between

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Table 1. *Clinical, demographical and test results from the patients with schizophrenia and healthy controls*

	Schizophrenia ($n=35$)	Controls ($n=20$)	t	True-score variance
Age (years)	34·1 (10·5)	32·9 (9·8)	0·41	—
Male/female	23/12	12/8	—	—
Duration of illness (years)	8·2 (5·3)	—	—	—
Hollingshead index	3	3	—	—
IQ	104·3 (10·9)	109·6 (12·4)	−1·65	—
SAPS	8·8 (3·8)	—	—	—
SANS	7·7 (3·5)	—	—	—
CPT d'	4·1 (0·9)	4·8 (0·7)	−3·16**	1140·8
Contrast threshold, orthogonal (%)	7·6 (2·2)	6·9 (1·4)	−0·85	1169·6
Contrast threshold, collinear (%)	7·1 (1·9)	5·1 (1·4)	3·87***	1120·0
Collinear-orthogonal	−0·07 (0·18)	−0·31 (0·17)	5·21***	1169·0
Spatial frequency discrimination (% correct)	76·9 (7·3)	79·8 (6·5)	−1·46	1152·6
Colour vernier (sec arc)	100·6 (40·3)	91·1 (28·3)	−0·65	1573·2
Frequency-doubling vernier (sec arc)	137·0 (70·1)	75·6 (28·6)	−4·32***	649·2
Low-contrast vernier (sec arc)$^{+}$	127·1 (69·6)	72·2 (24·5)	−3·66**	650·9
Natural scene categorization (% correct)	91·4 (4·8)	94·4 (3·2)	−2·45*	1316·0

Data are mean (standard deviation) with the exception of gender and the Hollingshead index, showing the parental median socioeconomic status. Group means were compared with t tests (df = 53, $^{+}$df = 48). IQ, Wechsler's IQ; SAPS, Scale for the Assessment of Positive Symptoms; SANS, Scale for the Assessment of Negative Symptoms; CPT, Continuous Performance Test d', 1–9 vigilance version.
* $p<0·05$, ** $p<0·01$, *** $p<0·001$.

Table 2. *Correlation matrix from the patients with schizophrenia* ($n=35$)

	Col-Ort	CPT	IQ	SAPS	SANS	BSABS	Spatial freq.	Colour	Frequency doubling	Low contrast	Scene categorization
Col-Ort	—	−0·02	0·19	−0·10	0·50*	0·68*	0·17	−0·20	0·61*	0·67*	−0·52*
CPT	−0·02	—	0·20	0·18	−0·10	−0·27	−0·15	0·10	0·06	0·02	0·15
IQ	0·19	0·20	—	0·18	0·17	0·12	0·07	0·21	0·26	0·28	−0·10
SAPS	−0·10	0·18	0·18	—	0·20	−0·08	−0·10	0·17	0·00	0·03	0·05
SANS	0·50*	−0·10	0·17	0·20	—	0·70*	0·10	0·00	0·39*	0·51*	−0·31
BSABS	0·68*	−0·27	0·12	−0·08	0·70*	—	0·02	0·04	0·53*	0·65*	−0·43*
Spatial frequency	0·17	−0·16	0·07	−0·10	0·10	0·02	—	−0·41*	−0·15	−0·10	0·04
Colour	−0·20	0·11	0·21	0·17	0·00	0·04	−0·41*	—	−0·18	−0·10	0·00
Frequency doubling	0·61*	0·06	0·26	0·00	0·39*	0·53*	−0·15	−0·18	—	0·90*	−0·69*
Low contrast	0·67*	0·02	0·28	0·03	0·51*	0·65*	−0·09	−0·07	0·90*	—	−0·72*
Scene categorization	−0·52*	0·15	−0·10	0·05	−0·31	−0·43*	0·04	0·00	−0·69*	−0·72*	—

Spearman rank-order correlations between clinical parameters (SAPS, Scale for the Assessment of Positive Symptoms; SANS, Scale for the Assessment of Negative Symptoms); Wechsler's IQ, perceptual organization (Col-Ort, collinear-orthogonal contrast threshold); CPT (Continuous Performance Test d', 1–9 vigilance version); BSABS (Bonn Scale for the Assessment of Basic Symptoms) perceptual disorder, spatial frequency discrimination, vernier tasks and natural scene categorization (* $p<0·05$).

frequency-doubling and low-contrast vernier measures ($R=0·90$, $p<0·05$). All other correlations remained non-significant ($R<0·40$).

DISCUSSION

The main finding of this study was that the severity of anomalous visual perceptual experiences specifically correlated with perceptual organization and M pathway dysfunctions in patients with schizophrenia. Perceptual organization was the only significant predictor of anomalous visual experiences, which is consistent with the classic theories of Matussek (1952) and Conrad (1958). Interestingly, perceptual organization and M pathway functions were also related, which may provide a link between the 'channel' and the Gestalt theories. The deficits of these basic mechanisms may lead to the inability of schizophrenia patients to process rapidly changing natural images and to experience anomalous visual percepts. While bearing in mind that correlation does not necessarily mean causation, a plausible explanation for these relationships may come from the recently proposed role of M pathways in attentional

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modulation (Schröeder, 1995; Vidyasagar, 1999; Schwartz *et al*. 2001).

It is important to exclude the possibility that the differential impairment in certain visual tests is a psychometric artefact. It should be taken into consideration that increased difficulty and higher true-score variance (a product of reliability and variance) on certain tasks may produce differences between schizophrenia patients and healthy controls (Chapman & Chapman, 1978; Miller *et al*. 1995). The pattern of results is against this possibility. In Table 1 it can be seen that differences between patients and controls were detected even in less difficult tasks with lower true-score variance. Table 2 shows that the visual psychophysical data did not correlate with CPT values, which is against the possibility that our results are pure consequences of fluctuating vigilance.

The perceptual organization task used in this study investigates low-level processes related to the interactions of neurons in the primary visual cortex (Kovács, 1996; Polat *et al*. 1998; Freeman *et al*. 2001). However, attention is important in enhancing target-flanker interactions (Freeman *et al*. 2001). The correlation between M pathway tasks and perceptual organization may be explained by the role of M pathways in attentional modulation (Schröeder, 1995; Vidyasagar, 1999; Schwartz *et al*. 2001).

Our findings are consistent with previous studies demonstrating impaired M pathway functioning in schizophrenia (Butler *et al*. 2001; Braus *et al*. 2002; Doniger *et al*. 2002; Kéri *et al*. 2004). The hypothesis on the role of the M pathway/dorsal stream system in the regulation of ventral visual areas was also addressed by Doniger *et al*. (2002) who investigated the significance of perceptual closure (a Gestalt factor) in object recognition in 16 patients with schizophrenia. Fragmented line-drawing images of animate and inanimate objects were presented during high-density event-related potential recording, which included the measurement of the P1 component generated in the occipito-parietal dorsal stream, the N1 component generated in the occipito-temporal ventral stream and the N(cl) (closure negativity), a specific component related to the perception of fragmented images. The main finding was that the patients with schizophrenia showed significant impairments in the recognition of fragmented images, together with an impaired generation of the N(cl) component. This is in parallel with our data demonstrating the impaired processing of collinear Gabor patches. Doniger *et al*. (2002) also found that the amplitude of the P1 potential was significantly reduced over dorsal stream sites, whereas the generation of the ventral N1 was intact. The authors concluded that the selective impairment in dorsal stream P1 suggests deficient M pathway processing. Furthermore, intact ventral N1 generation shows that the initial stage of ventral stream processing is preserved and that deficient M pathway/dorsal stream functioning may lead to secondary dysregulation of ventral stream object recognition processes. In our study, impaired M pathway vernier performances were related to perceptual organization and natural scene categorization deficits, which lends further support for the assumption that impaired M pathway/dorsal stream functioning may result in the secondary dysregulation of the ventral object recognition areas. Both hyperactive and hypoactive M pathways may also disrupt attentional filter mechanisms, which may lead to heightened perceptual sensitivity, reduced signal-to-noise ratio and information overload (McGhie & Chapman, 1961; Venables, 1964).

M pathway dysfunction seems to be a sensitive marker for disorders with neurodevelopmental and genetic origin. Developmental and clinical studies indicated that M pathways are more plastic than P pathways even after childhood (Armstrong *et al*. 2002; Benedek *et al*. 2003), and M pathway dysfunctions have been described in autism (Spencer *et al*. 2000), in Williams' syndrome (Atkinson *et al*. 1997) and in children with hemiplegic cerebral palsy (Gunn *et al*. 2002). Kogan *et al*. (2004) found that in fragile X syndrome, which is characterized by the pathology of a single gene (*FMR1*) related to neurodevelopment and synaptic plasticity, a selective reduction of M cells could be detected in the lateral geniculate nucleus. Consistent with these findings, patients with fragile X syndrome had reduced sensitivity for stimuli that probe the M pathway but not for those that probe the P pathway. Therefore, M pathway tests are good candidates to investigate the behavioural aspects of neurodevelopmental and neuroplastic alterations in schizophrenia (Lewis & Levitt, 2002).

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Javitt (2003) envisioned that perceptual organization deficits may arise as a consequence of an impaired M pathway input to the dorsal stream, resulting in an abnormal recurrent processing within the ventral object recognition areas. He also stressed the role of the *N*-methyl-D-aspartate (NMDA) glutamate receptors in M pathway functioning, as a crucial factor in contrast gain mechanisms, which enable M pathways to amplify very low contrast. NMDA receptors also play an important role in the genesis of high-frequency gamma oscillations, which is a sensitive electrophysiological marker of perceptual organization. Spencer *et al*. (2004) demonstrated reduced frequency of cortical gamma oscillations in schizophrenia during a Gestalt task, which may point to the abnormality of neuronal assembly regulated by NMDA receptors. These indirect but converging evidences provide further support for the NMDA receptor and glutamate mechanisms of schizophrenia (Javitt, 2003). This speculative hypothesis between M pathway functioning, perceptual organization and NMDA receptors awaits further confirmation.

In the occipital cortex, the abnormality of gamma oscillations correlated with visual hallucinations and thought disorder, whereas in the parietal cortex, it correlated with negative symptoms (Spencer *et al*. 2004). This is in parallel with our psychophysical observations, because perceptual anomalies and visual hallucinations may have a common neurophysiological background in the occipital cortex. Second, we also observed a significant correlation between perceptual organization deficits and negative symptoms, confirming earlier findings of Doniger *et al*. (2001). In the Spencer *et al*. (2004) study, this latter correlation was specifically apparent for the parietal cortex, a main target of the M pathway. However, we did not notice correlations between thought disorder and perceptual organization deficit, which is a common finding in previous studies (Phillips & Silverstein, 2003; Silverstein & Uhlhaas, 2004). The most likely explanation may be that the intensity of thought disorder and disorganization symptoms was very low in our sample. However, anomalous perceptual experiences together with the exacerbation of negative symptoms may be progenitors of evolving positive symptoms and psychotic disorganization (Klosterkötter *et al*. 2001; Schultze-Lutter, 2004; Ventura *et al*. 2004). It is possible that a considerable proportion of our unmedicated patients was characterized by such a pattern of symptoms in the initial stage of the psychosis. Our sample, which included relatively well functioning and unmedicated patients, is not entirely representative for schizophrenia. Evidence suggests that chronic medicated patients with more severe symptoms show generalized deficits on visual tests (Kéri *et al*. unpublished observations). In this case, the generalized deficit may mask specific impairments. Further longitudinal studies are warranted to investigate the possibility that psychophysical measures of visual perceptual anomalies are useful predictors of incipient psychotic episodes.

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DECLARATION OF INTEREST

None.

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