•Original Article•

Binocular rivalry in children with schizophrenia: the conscious and unconscious cognitive processing of interpersonal information

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Background: Childhood schizophrenia is a severe mental disorder that is believed to affect both conscious and unconscious cognitive functioning, but there have been few studies that have assessed this.

Objective: Develop a version of the binocular rivalry test that will assess the conscious and unconscious cognitive processing of interpersonal information and use this test to determine whether or not social cognition is impaired in children with schizophrenia.

Methods: Thirty images of three types – with no persons, with 2-3 persons and with 4+ persons – were selected for use in a binocular rivalry test that presented the images both in an interocularly suppressed (unconscious) format and an unsuppressed (conscious) format. Fifteen children under 16 years of age with schizophrenia who had prominent delusional symptoms and 15 healthy children were administered the test. Accuracy rates (in assessing the left or right orientation of a patch presented immediately after the target images) and reaction times were compared between patients and controls.

Results: For all types of pictures, the accuracy of patients was less than that of controls, though the differences were only significant in two of the twelve comparisons assessed. Compared to controls, patients showed a non-significant increase in the attention paid to images with people in them compared to images without people in them, both for conscious and unconscious presentations of the images. We did not find any relationship between the severity of psychotic symptoms in the patients and the degree of impairment in the cognitive processing of images. When asked to assess the attributes of the images, patients reported significantly higher levels of happiness depicted in images with 2-3 people than controls.

Conclusions: The non-significant increase in the attention children with schizophrenia paid to images depicting interpersonal relationships suggests, but does not prove, that the illness is associated with impairments in the cognitive processing of social information. Our use of the binocular rivalry paradigm to identify these differences was only partially successful, largely because of the wide variability in the key index from the test used to assess the amount of attention respondents pay to different types of images.

1. Introduction

Binocular rivalry refers to the phenomenon that when the right and left eye are presented with different stimuli, no stable perception can be formed so there are alternating perceptions.[1] During the binocular rivalry test, the different stimuli presented in front of the retina of each eye do not change, but the fluctuating perception of either one or the other image requires alternating suppression of the conscious perception of one of the eyes.

Childhood schizophrenia is associated with serious disturbances in cognitive processing. Abnormal processing of interpersonal information may be one of the mechanisms that leads to delusional beliefs in these children, particularly delusions of reference.[2] Most studies on cognitive functioning in childhood schizophrenia are potentially confounded by a variety of factors including the severity of the illness, educational status of the respondent, experimental environment, and medication status. One of the advantages of the binocular rivalry test is that it is much

doi: 10.3969/j.issn.1002-0829.2013.03.005

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less influenced by these factors. It is, therefore, a relatively direct way of assessing the cognitive functioning of children with schizophrenia. The current study uses the binocular rivalry test to compare the processing of social information among children with schizophrenia who have prominent delusions to that of normal children and, thus, to test the hypothesis that their conscious and unconscious processing of social information is impaired.

2. Methods

2.1 Sample

The enrollment process for the study is shown in Figure 1. Enrolled patients were children who met the diagnostic criteria for childhood schizophrenia specified in *the Chinese Classification of Mental Disorders, Third Edition* (CCMD-3)[3] who were treated in the outpatient or inpatient services of the Shanghai Mental Health Center from January to April 2010. Included patients were under 16 years of age, had delusions as their primary symptoms, were right-handed, did not have other mental or serious physical illnesses, and were able to complete the binocular rivalry test. The severity of schizophrenia at the time of the binocular rivalry test was assessed using the severity of illness subscale of the Clinical Global Impression scale (CGI-SI)[4] which rates illness severity on a 7-point Likert scale (from 1=not at all ill, to 7=extremely ill). The level of paranoia at the time of the test was also assessed by the treating clinician using a similar 7-point Likert scale that we constructed for the purpose of the current experiment.

The control group consisted of 15 students under 16 years of age nominated by their teachers from one grade 8 class and one grade 10 class in a public school in Shanghai. All of them were right-handed, did not have mental or serious physical illnesses, did not have a family history of mental illness, and were able to complete the binocular rivalry test.

All participants in this study and one parent for each participant signed informed consent forms. The study was approved by the institutional review board of the Shanghai Mental Health Center.

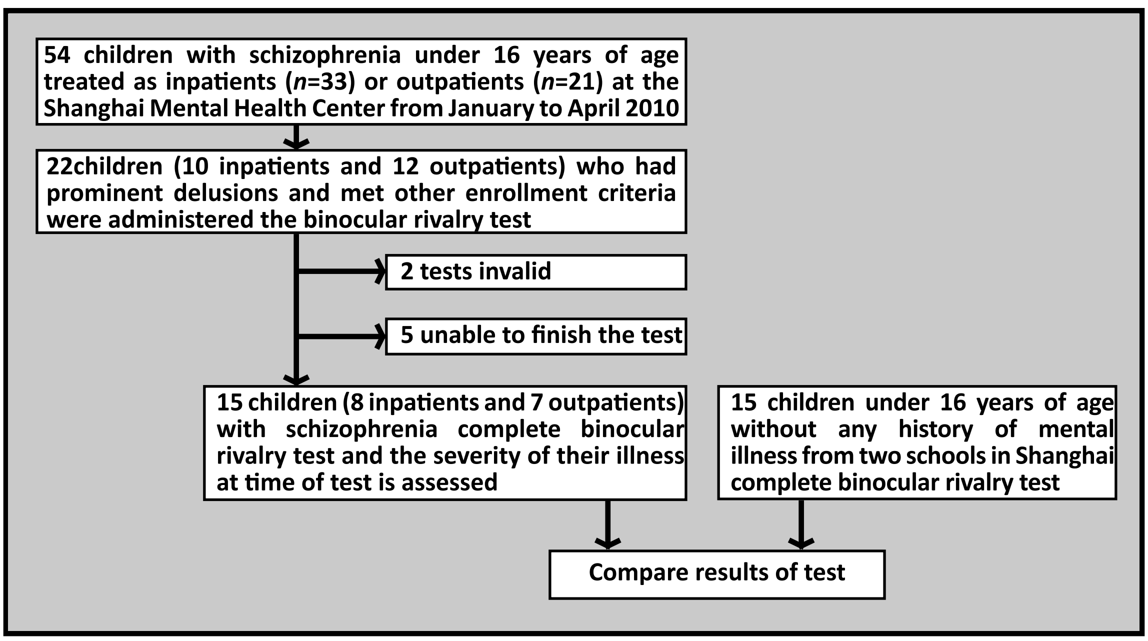
2.2 Assessment of binocular rivalry

A total of 30 images depicting different levels of interpersonal interactions were selected from a series of candidate images. Photoshop 7.0 software was used to alter the colors, brightness and sizes of these images in order to generate monochrome images that are 150 mm×112 mm in size. These images were then categorized into the following three groups (10 images in each group): images with no people, images with two to three people, and images with more than three people.

During the test each image was presented on a 17-inch monitor (brand: Lenovo Model: L193pC, 1280 *1024) using MATLAB (Matrix Laboratory) software. Participants sat behind the electric stereoscope (66 Vision- Tech Co., Ltd., Model: YT2B-2201857) and placed their chin on the supporting bracket, which was adjusted according to the sitting height of the participant to ensure that their eyes were at the same level as the cross ('+') on the monitor.

The version of the binocular rivalry test employed in this study is similar to that described elsewhere.[5] At the beginning of the test, the dominant eye of the subject was determined. During the test two pairs of images are independently presented to each eye. There are two versions of the test that were both administered to each

Figure 1. Enrollment of subject in the study



participant. In the interocularly suppressed version of the test, the dominant eye is presented with two colored mosaic patches and the non-dominant eye is simultaneously presented with a monochrome mosaic patch and a monochrome version of one of the 30 target images described above (which alternate randomly between the right and left side of the visual field of the non-dominant eye). In the unsuppressed version of the test, the images presented to the dominant and non-dominant eyes are identical: both eyes are presented with paired images of a monochrome mosaic patch and a monochrome version of one of the 30 images which alternate between the right and left sides of the visual field.

The viewing angle for all images was 4.1°×6.2°. Each set of images was shown for 800 ms followed by a 100 ms presentation of a grating (a Gabor patch) with a viewing angle of 2.5°×2.5° which was 1° skewed to either the left or the right side at random. The task of the participant was to determine the direction of the skew (left or right) and to press the right or left side of the mouse for the computer accordingly. In the suppressed version of the test there were a total of 120 trials (i.e., presentations of the images) divided into two sessions, 60 trials each session with a five-minute break between the two sessions; if the respondent reports seeing a clear image for more than 10 of the trials (i.e., the interocular suppression did not work), the test was considered invalid. In the unsuppressed version of the test there were a total of 90 trials divided into 3 sessions, 30 trials in each session with a two-minute break between sessions. The sequence of image presentation in the two versions of the test is shown in Figure 2.

Several measures are assessed based on the results of the test. (a) the proportion of correct responses (about the orientation of the Gabor patch) when the target image and the Gabor patch are presented on the same side of the visual field (hereinafter referred to as the 'target image accuracy rate'), (b) the proportion of correct responses when the monochrome mosaic patch and Gabor patch are presented on the same side of the visual field (hereinafter referred to as the 'mosaic patch accuracy rate'), (c) the difference between the target image and mosaic patch accuracy rates, and (d) the difference in reaction times for responding when the target image is on the same side or the opposite side as the Gabor patch (when this difference score is positive it indicates that the subject pays more attention to the target image than to the monochrome mosaic patch).

After the tests, the participants rated each of the 30 images on three aspects – happiness depicted in the picture, impact on the subject, and relevance to the subject – on three nine-point Likert scales, where '1' represented extremely unhappy, no impact, or completely irrelevant and '9' represented extremely happy, huge impact, or highly relevant.

2.3 Statistical analysis

The statistical software SPSS 17.0 was used to conduct the analysis. Descriptive statistical analyses, independent sample t-test, paired t-test, analysis of variance, non-parametric tests and correlation analysis were used depending on the type of variable. When comparing the results for the three types of images, multiple comparison methods were employed to compare the three paired comparisons (i.e., images with no people v. images with 2-3 people; images with no people v. images with 4+ people; and images with 2-3 people v. images with 4+ people) if the overall assessment found that there was a statistically significant difference between groups. Statistical significance was set at p<0.05.

Figure 2. Diagram of the sequence of presentations of images in each trial for the two versions of the binocular rivalry test used in the study (see methods section for detailed description of the test)

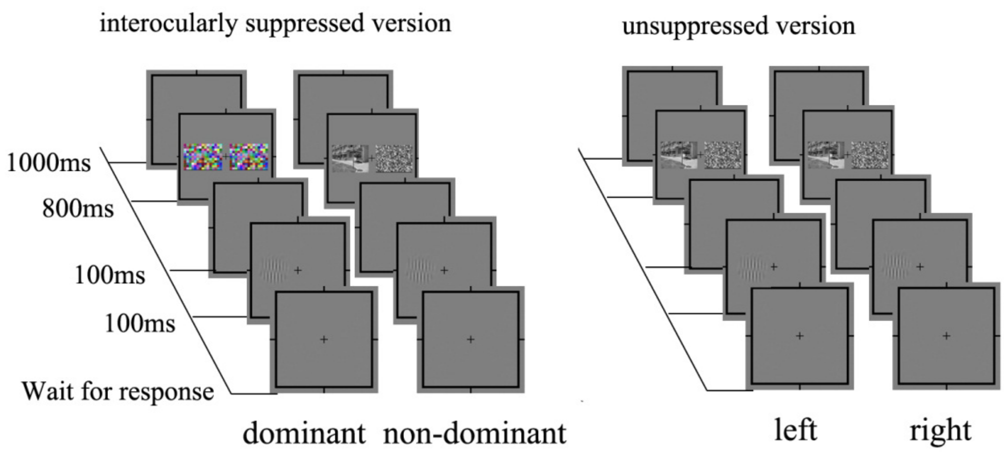


Table 1. Comparison of the mean (sd) proportion of correct responses between the 15 patients and 15 control subjectsin 120 trials when target images are only presented to the non-dominant eye ('suppressed presentation') and in 90 trials when target images are presented to both eyes ('unsuppressed presentation')

	suppressed presentation of images to non-dominant eye				unsuppressed presentation of images to both eyes			
	patients	controls	*t*	*p*	patients	controls	*t*	*p*
Images with no people								
Target image accuracy[a]	0.70 (0.14)	0.80 (0.15)	-1.75	0.091	0.58(0.15)	0.63 (0.14)	-0.88	0.385
Mosaic patchaccuracy[a]	**0.69 (0.13)**	**0.80 (0.14)**	**-2.12**	**0.043**	0.58(0.14)	0.65 (0.12)	-1.53	0.137
Difference	0.01 (0.10)	-0.00 (0.09)	-	0.667	0.00(0.19)	-0.02 (0.14)	-	0.675
Images with 2-3 people								
Target image accuracy[a]	0.68 (0.13)	0.78 (0.17)	-1.78	0.085	0.57 (0.10)	0.63 (0.12)	-1.41	0.169
Mosaic patchaccuracy[a]	0.70 (0.13)	0.79 (0.17)	-1.52	0.141	0.57 (0.14)	0.63 (0.11)	-1.41	0.170
Difference	-0.03 (0.10)	-0.01 (0.08)	-	0.333	0.00 (0.11)	-0.01 (0.09)	-	0.950
Images with 4+ people								
Target image accuracy[a]	0.69 (0.11)	0.79 (0.16)	-2.00	0.058	0.57 (0.09)	0.60 (0.09)	-1.06	0.299
Mosaic patchaccuracy[a]	**0.67 (0.13)**	**0.78 (0.17)**	**-2.05**	**0.050**	0.58 (0.13)	0.61 (0.12)	-0.82	0.419
Difference	0.02 (0.09)	0.01 (0.08)	-	0.333	-0.01 (0.10)	0.02 (0.06)	-	0.219

[a] See methods section for definition of 'target image accuracy' and 'mosaic patch accuracy'

3. Results

3.1 Demographic data on the subjects

There were 3 males and 12 females in the patient group and 7 males and 8 females in the control group (Fisher's exact test *p*=0.245). The range of ages was 14-16 years in the patient group and 13-16 years in the control group. The mean (sd) ages in the patient and control groups were 14.2 (2.0) years and 14.0 (1.1) years, respectively. The mean years of education among patients and controls were 7.1 (1.7) years and 7.0 (1.1) years, respectively. There were no statistically significant differences in age or years of education between the two groups. The mean duration of illness of the patients was 17.9 (6.7) months. All of the patients were taking antipsychotic medications.

3.2 Results of the binocular rivalry tests

As shown in Table 1, lower accuracy rates were observed for all three types of images in the patient group compared to the control group in both versions of the test, but these differences were only statistically significant in two of the twelve outcome measures for the test. The accuracy among patients was significantly poorer than that for controls for the interocularly suppressed version of the test when the mosaic patch and Gabor patches were on the same side of the visual field and when the target images were those with no people or with four or more people. There were, moreover, no significant differences between patients and controls in the differences in target image versus mosaic patch accuracy.

The difference in mean reaction times (i.e., mean reaction time when target images were presented on the same side of the visual field as the Gabor patch minus the mean reaction time when target images were presented on the opposite side of the visual field of the Gabor patch) are not normally distributed so these results are presented as medians and interquartile ranges and rank tests were used to compare results for different groups of subjects (Table 2). There were no significant differences in the mean ranks of these difference scores between patients and controls for any of the three images in the suppressed or unsuppressed versions of test (using six separate Mann-Whitney tests). There were also no significant differences in difference scores for the suppressed versus unsuppressed presentation of each of the three images either for patients or for controls (using six separate Wilcoxon signed-rank tests).

For patients, the larger (i.e., more positive) median values for the difference scores for the two types of pictures with people compared to pictures without people (shown in Table 2) indicate that patients attended longer to images with persons in them than to images without persons; but these differences were not statistically significant. The opposite was true in controls who attended to pictures without people in them longer than to pictures with people in them. This difference in controls was statistically significant in the suppressed version of the test where the mean ranks of difference scores for reaction times for images with no persons, images with 2-3 persons, and images with 4+ persons were 2.43, 2.03 and 1.53, respectively (Chi-square for Friedman test=6.20, *df*=2, *p*=0.045) -- indicating that during uncon-

Table 2. Median (interquartile range) difference inreaction times (in seconds) when the target image is presented on the same side or the opposite side of the visual field as the Gabor patch in the patient and control groups

	suppressed presentation of images to non-dominant eye		unsuppressed presentation of images to both eyes	
	patient group	control group	patient group	control group
Images with no persons	-0.018 (-0.049~0.013)	0.002 (0.000~0.022)	0.006 (-0.159~0.104)	0.004 (-0.139~0.070)
Images with 2-3 persons	-0.006 (-0.099~0.029)	-0.001 (-0.014~0.014)	0.018 (-0.050~0.573)	-0.032 (-0.068~0.031)
Images with 4+ persons	0.000 (-0.029~0.021)	-0.007 (-0.022~0.005)	0.013 (-0.042~0.272)	-0.001 (-0.098~0.026)

Table 3. Mean (sd) scores of patients and control subjects (on a 1-9 point scale) on three perceived attributes of each type of image used in the binocular rivalry test

	patient group (*n*=15)			control group (*n*=15)			patient group v. control group	
	mean (sd)	*F*	*p*	mean (sd)	*F*	*p*	*t*	*p*
Happiness depicted in picture								
Images with no persons	5.3(1.1)			6.1(0.8)			**-3.53**	**0.003**
Images with 2-3 persons	5.0(1.0)	0.46	0.634	4.3(0.5)	**24.16**[a]	**<0.001**	**2.27**	**0.040**
Images with 4+ persons	4.9(1.1)			4.7(0.9)			0.51	0.621
Impact on the subject								
Images with no persons	4.4(1.5)			5.1(1.8)			-1.34	0.201
Images with 2-3 persons	4.2(1.5)	0.14	0.868	4.1(1.3)	1.88	0.165	0.19	0.855
Images with 4+ persons	4.2(1.5)			4.2(1.5)			-0.10	0.924
Relevance to the subject								
Images with no persons	3.6(1.8)			5.5(1.3)			**-3.35**	**0.005**
Images with 2-3 persons	3.4(1.8)	0.36	0.702	3.5(1.9)	**7.63**[a]	**0.001**	-0.03	0.974
Images with 4+ persons	3.1(1.4)			3.5(1.7)			-0.68	0.509

[a] Multiple comparison tests (Tukey)found that the score for the images with no persons was significantly higher than the scores for the images with 2-3 persons and the images with 4+ persons

scious presentation of images, controls paid significantly more attention to the images with no persons than to images with people.

3.3 Attributional rating of images used in the binocular rivalry test

The perceived attributes of the three types of images as assessed by the patients and controls is shown in Table 3. Among patients there were no significant differences between the three types of pictures in the perceived happiness depicted in the pictures, in the perceived impact of the pictures on the individual, or in the perceived relevance of the pictures to the individual. However, among control subjects the perceived happiness depicted in the pictures and the perceived relevance of the pictures to the individuals was greater for images without persons than for images with persons. Compared to controls, patients reported significantly lower levels of happiness depicted in pictures with no persons and higher levels of happiness depicted in pictures with 2-3 persons; patients also reported a significantly lower relevance to themselves of pictures with no persons.

3.4 Correlation of disease severity with patients' results on the binocular rivalry test and with their attributional ratings of the images used in the test

In the patient group, the mean disease severity score at the time the binocular rivalry test was conducted (on the 1- 7-point CGI-SI scale) was 4.2 (1.4), and the mean paranoia severity score was 3.4 (1.1). There were no statistically significant correlations between disease severity or severity of paranoia with the reaction time and accuracy of the suppressed or unsuppressed versions of the binocular rivalry test. Disease severity was also unrelated to patient's attributional ratings of the 30 images employed in the tests (all p>0.05).

4. Discussion

4.1 Main findings

Previous studies have used the binocular rivalry paradigm to assess conscious and unconscious cognitive functioning in patients with mental disorders including schizophrenia,[6,7] but to our knowledge this is the first such study in children with schizophrenia. Given the clinical observation that interpersonal relationships are fertile ground for generating delusional beliefs (particularly delusions of reference) in patients with schizophrenia, we posited that these patients would have abnormal cognitive processing of images that involve social communication between individuals and that these cognitive abnormalities would be present during both conscious and unconscious information processing.

Comparison of the results of the binocular rivalry test between patients and controls did not confirm our initial hypothesis but they did provide some support for the hypothesis. For all types of pictures in both the interocularly suppressed (i.e., unconscious) and unsuppressed (i.e., conscious) versions of the test, the accuracy of patients was less than that of controls, though the differences were only significant in two of the twelve comparisons assessed. Compared to controls, patients also show a non-significant increase in the attention paid to images with people in them compared to images without people in them, both for the conscious and unconscious presentation of the images. This suggests that patient with schizophrenia require more attentional input to process interpersonal information. We did not find any relationship between the severity of psychotic symptoms and the degree of impairment in the cognitive processing of images. An interesting ancillary finding that may be relevant to cognitive processing of images is that the reported happiness depicted in the images without people and the reported relevance to the respondent of pictures without people was significantly lower in patients than in controls; conversely the reported happiness depicted in images with 2-3 people in them was significantly higher in patients than in controls.

Several studies have reported that the processing of interpersonal information, which is considered a component of social cognition,[8,9] is impaired in patients with schizophrenia. A meta-analysis on cognitive functioning in patients with schizophrenia by Savla and colleagues[10] reported impairments in many aspects of social cognition compared to normal controls. Some studies report that dysfunctional social cognition in schizophrenia is related to the severity of symptoms,[11,12,13] but other studies find no direct link between the negative symptoms of schizophrenia and social cognitive impairment.[14,15] Studies on the relationship between social cognition and the positive symptoms of schizophrenia (such as delusions) are rare,[16] and to our knowledge there has never previously been a study focused on this topic among children with schizophrenia.

4.2 Limitations

This study was an exploratory study to assess the usefulness of the binocular rivalry test as an instrument to assess the cognitive processing of social information in children with schizophrenia. The main problems with this study were that the sample size was small, the reliability and validity of responses to the images selected had not been pre-tested, and the study included both inpatients with relatively acute symptoms and outpatients in remission, all of whom were taking antipsychotic medication. The primary measure used to test the hypothesized impairment in patients' ability to process interpersonal information (i.e., the mean difference in reaction times to target images when presented on the same side or the opposite side of the visual field as the test images) proved to be quite variable both in patients and controls; this made it impossible to provide a definite conclusion about the hypothesis. Studies with larger samples, preferably with narrower entry criteria, that preliminarily assess the ability of different types of images to illicit 'cognitive processing of social information' are needed to determine whether or not the binocular rivalry test is an effective method of assessing cognitive processing in patients with schizophrenia.

4.3 Significance

The non-significant increase in the conscious and unconscious attention children with schizophrenia paid to images depicting interpersonal relationships (compared to healthy children of similar ages) suggests, but does not prove, that the illness is associated with impairments in the cognitive processing of social information. Further study with larger samples is needed to determine whether or not impairments in social cognition is independent of the overall cognitive dysfunction seen in patients with schizophrenia and to identify the symptomatic and other factors that are most closely associated with impaired social cognition in schizophrenia. Our use of the binocular rivalry paradigm to identify these differences was only partially successful, largely because of the wide variability in the key index from the test used to assess the amount of attention respondents pay to different types of images. Further refinements in the binocular rivalry test are needed to determine whether or not it can be used to compare cognitive functioning of social information between different types of subjects and within subjects over time.

Conflict of interest

The authors report no conflict of interest related to this manuscript.

Funding

This study was supported by the Key National Basic Research Development Plan (2007CB512306) and the National Science Foundation (81171267).

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(received: 2012-11-30; accepted:2013-01-10)

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Shanghai Archives of Psychiatry, 2013, Vol. 25, No. 3

•论著•

儿童期精神分裂症患者的双眼竞争: 意识和潜意识状态下对人际交往信息的认知加工过程

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摘要

背景: 儿童期精神分裂是一种严重的精神障碍，有理论认为其认知功能无论是意识水平还是潜意识水平都存在异常。但目前尚无针对儿童期精神分裂的潜意识认知功能研究。

目的: 开发新的双眼竞争测验版本，用于评估个体在意识和潜意识状态下对人际交往信息的认知加工过程，并依此判断儿童期精神分裂症患者的社会认知功能是否受损。

方法: 选取3种不同类型的图片（图片中无人物、有2~3个人物、有4个及以上的人物）共30张，这些图片在双眼竞争测验不可见模式（存在双眼竞争性抑制，反映潜意识状态下认知加工）和可见模式（无双眼竞争性抑制，反映意识状态下）中展示。对15名年龄≤16岁、以妄想为主要症状的精神分裂症患者及15名健康儿童进行双眼竞争测验，通过对目标图片出现后立即在其左侧或右侧出现光栅的方向的判别来比较两组儿童的正确率，并比较两组间的反应时间。

结果: 患者组对所有类型图片中光栅方向判断的正确率均低于对照组，但是12对比较中仅2对的差异有统计学意义。与对照组相比，无论是在可见模式还是非可见模式下，患者对人物图片的注意要比对无人图片的注意有所增加，但无显著性意义。我们并未发现精神病性症状的严重程度与对图像认知加工的受损程度之间存在任何关联。当要求被试对三组图片进行评分时，患者组对存在2~3个人物的图片报告的高兴程度明显高于对照组的评分，差异有统计学意义。

结论: 儿童期精神分裂症患者对描绘人际关系的图片注意一定程度的增加，提示该病与社会信息的认知处理过程受损相关，但目前结果尚不能证实这一关系。我们将双眼竞争范式应用于认知功能差异的研究，只是取得部分的成功，其主要原因是该测验中对不同类型图片的反应注意量的关键指标存在较大的变异。