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Deficit of theory of mind in individuals at ultra-high-risk for schizophrenia

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Abstract

Background: Although a deficit in social cognition is regarded as an early indicator of schizophrenia, few studies have investigated social cognition in ultra-high-risk (UHR) individuals.
Methods: Our investigation involved subjects at UHR for psychosis (N=33) and an age- and IQ-matched healthy control (HC) group (N=36). Two types of theory of mind (ToM) tasks and a neuropsychological test battery were measured.
Results: Compared to the HC group, the UHR group performed significantly worse for ToM tasks, with the effect size at an intermediate level (0.64–0.68). Furthermore, the UHR group showed impaired performance in the executive and working memory tests, but not verbal memory tests. These deficits for ToM tests observed in the UHR group were significantly correlated with set-shifting tasks.
Conclusions: Deficits in social cognition may be modest at the prodromal stage of schizophrenia and may be attributed to prefrontal dysfunction. To prevent or delay transition to psychosis, there is a need for specific preventive strategies targeting social functioning for the UHR group.

Keywords: Ultra-high-risk; Theory of mind; Social cognition; Schizophrenia; Neurocognition

1. Introduction

In recent years, several research groups have investigated the characteristics of 'at-risk mental states' or prodromes to warrant early intervention before the development of psychosis. In this regard, a recent study (Cornblatt et al., 2003) has suggested four domains of risk factors that appear to be particularly good targets for early intervention for schizophrenia, based on published studies: cognitive deficits, affective disturbance, social isolation, and academic failure. Previous research regarding cognitive domains in high-risk individuals has reported several areas of cognitive dysfunction, including working memory (Simon et al., 2007), verbal memory (Hawkins et al., 2004; Niendam et al., 2006; Pukrop et al., 2006), attention (Hawkins et al., 2004),

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verbal executive function (Simon et al., 2007; Hawkins et al., 2004), and speed of processing (Niendam et al., 2006). Based on these findings, researchers have described the early intervention that may prevent further cognitive damage in the treatment of high-risk individuals.

With respect to the social domain of high-risk individuals, there has been little investigation relative to the cognitive domain. Social skills required to manage social interaction effectively are encompassed by the term social cognition, and a deficit in social cognition is an important feature of schizophrenia (Pinkham et al., 2003). Furthermore, patients with schizophrenia exhibit a poor level of community functioning, even prior to the onset of the first psychotic episode (Davidson et al., 1999). A core aspect of social cognition is the ability to conceptualize other people's mental states, i.e., their beliefs and intentions; this is known as theory of mind (ToM). Several studies have investigated ToM mind-reading skills with various ToM tasks in schizophrenia and have reported a deficit in detecting deception and false belief (Brüne and Brüne-Cohrs, 2006; Corcoran et al., 1995) in schizophrenia, compared to healthy controls (HC). However, little is known regarding the ToM ability in subjects at ultra-high-risk (UHR) for schizophrenia.

One study (Janssen et al., 2003) has found evidence for reduced mentalizing capability in unaffected relatives of patients with schizophrenia and suggested that those deficits in ToM ability have been associated with IQ and neuropsychological factor, especially executive functions, but another study (Kelemen et al., 2004) has found evidence against such a phenomenon. Recently, it has been reported that ToM deficits for individuals at high genetic-risk of schizophrenia are related to the experience of clinical symptoms (Marjoram et al., 2006). Comparison of the ToM ability in high genetic-risk group with that of controls has shown that there is increased activation in the prefrontal cortex (PFC) in the unaffected relatives compared to affected relatives and controls during the performance of a ToM paradigm (Marjoram et al., 2006). Considering these findings, together with the various clinical and neurocognitive deficits in the UHR group mentioned above, social cognition deficit in schizophrenia may precede the initial stage of psychotic breakdown, and furthermore, accelerate disease progression, with a strong interaction with social environment.

Our primary objective was to investigate social cognition capacity in a UHR group compared to that in an HC group, using two types of ToM tasks. Considering the possible influence of other components of cognitive function such as memory, language, and executive function on ToM tasks, a neuropsychological test battery was administered to both the UHR and HC groups. Our secondary objective was to delineate the relationship between deficits in social cognition, indexed by ToM tasks, and other cognitive dysfunction observed in the UHR group. Based on previous reports, we hypothesized that ToM task performance in the UHR group would be worse than that in the HC group, and that a subset of cognitive dysfunctions, especially a deficit in executive function, would be correlated with ToM ability.

2. Methods

2.1. Recruitment strategy

The Seoul Youth Clinic (SYC), which is a prospective, longitudinal project for the investigation of people at high-risk for schizophrenia, was established in 2004. Subjects made initial contact by telephone or via the website (http://neuroimage.snu.ac.kr/youth/index.html), having heard about the project from various sources, including a mental health education program for early psychosis, referral from health care providers, and hospitals. For subjects who were considered to be at UHR after a brief telephone interview, a screening interview was completed by two experienced psychiatrists (SYY and DHK).

2.2. Participants

Sixty-nine age- and IQ-matched subjects were recruited from the SYC in the Seoul metropolitan area between November 2004 and April 2007, and consisted of 36 HC and 33 UHR individuals. All subjects were aged 16–29 years.

The UHR group was recruited according to the Comprehensive Assessment of At-Risk Mental States (CAARMS) criteria (Yung et al., 2005); the participants met the criteria for at least one of three groups at intake, as determined by specific state and/or trait risk factors for psychosis. The three groups were those with: (1) trait plus state risk factors; (2) attenuated symptoms; and (3) brief, limited intermittent psychotic symptoms. The criteria met by the subjects were as follows: attenuated symptoms, 31; brief, limited intermittent psychotic symptoms, 0; trait plus state and attenuated symptoms, 6. Four of the latter subjects were included in two criteria because they had attenuated symptoms and trait plus state and attenuated symptoms. A total of 13 subjects in the UHR group (39%) received low-dose treatment with atypical antipsychotics or antidepressants at baseline.

The HC group consisted of 36 subjects who were recruited from an Internet advertisement and via the social networks of hospital staff members. Participants in the control group were screened with an additional exclusion criterion of any first- or second-degree biological relatives with a lifetime history of a psychotic disorder.

Subjects were excluded if they had any lifetime diagnosis of psychotic illness, substance dependence, or neurological disease; a history of head injury or medical illness with documented cognitive sequelae; sensory impairment; current use of psychotropic medication; or a full-scale IQ estimate of <70. Subjects aged ≥ 18 years gave informed consent, whereas subjects <18 years of age gave assent in conjunction with informed consent provided by a parent. All procedures were carried out in accordance with the current version of the Declaration of Helsinki. The study was approved by the Institutional Review Board at Seoul National University Hospital.

2.3. Clinical interviews and assessments

At intake, to measure psychotic symptoms, the CAARMS and a modified 24-item version of the Brief Psychiatric Rating Scale (BPRS; Lukoff et al., 1986) rating items from 1 to 7 were assessed by two experienced psychiatrists. The Structured Clinical Interview for DSM-IV Axis I Disorder (SCID) was administered to ascertain exclusion criteria disorders. To monitor the development of psychotic features and other symptoms that could be precursors of psychotic disorders, e.g., mood and anxiety symptoms, subjects were assessed using the following: Global Assessment of Functioning (GAF), parental socioeconomic status with the Hollingshead scale, Hamilton Depression Rating Scale (HAM-D; Hamilton, 1967), Hamilton Anxiety Rating Scale (HAM-A; Hamilton, 1959), and Yale-Brown Obsessive Compulsive Scale (Y-BOCS; Goodman et al., 1989). The family interview for genetic studies (Gershon and Guroff, 1984) was used to document a family history of psychotic disorders.

2.4. ToM tasks

ToM was assessed by two verbal tasks, i.e., the False Belief (FB) task and the Strange Story task, and the nonverbal Cartoon task. All tasks were translated into Korean under the direction of clinical psychologists and psychiatrists, taking into consideration relevant cultural differences. The FB task is composed of first-order (Wimmer and Perner, 1983) and second-order tasks (Perner and Wimmer, 1985) including two questions. First-order FB tasks measure the recognition of a story character's false belief about the world, whereas second-order FB tasks assess the subject's cognitive capacity to infer a third character's mental state. As a measure of comprehension, subjects were asked a first question about the reality of the situation. The second question could only be answered with knowledge of the mental state of one of the characters (justification question), and reflected that character's FB about the situation. The score was rated as 1 if subjects answered the reality question correctly and 2 if they passed the justification question. The maximum sum score of the first-order and second-order FB tasks was 12 points.

The Strange Story task (Happé et al., 1999) was composed of 16 short passages, each followed by a test question. These materials were an advanced ToM task for adults, adapted from a study of ToM in autism (Happé, 1994). The story passages were of two types: a ToM and a Physical Story. The ToM stories concerned double bluff, mistakes, persuasion, and white lies. These stories were followed by questions requiring an inference about the characters' thoughts and feelings, and in most cases, an inference about the speakers'/actors' intentions. As a non-ToM task, the Physical Story, which was eight short stories, also involved people, and the subsequent test questions also required inferences to be made, but not inferences about the mental state of the characters.

The Cartoon task (Oh et al., 2005) was a nonverbal ToM task consisting of a total of 30 randomly ordered comic strips. This task was reconstructed and computerized based on Sarfati's Intention Inference Task (Sarfati et al., 1997), which takes into consideration cultural differences. To reduce the possibility for subjects to guess the answer, this task included an inquiring question. At this point, if subjects gave an incorrect answer, the response was regarded as a random response and excluded from the total score.

2.5. Neuropsychological tests

For all subjects ($n=69$), the Vocabulary, Arithmetic, Block Design, and Picture Arrangement, which are subtests of the Korean version of the Wechsler Adult Intelligence Scale (K-WAIS; Kim and Lee, 1995), were administered to provide an IQ estimate. Measures of executive function included the Wisconsin Card Sort Test, calculating the number of correct and perseverative response (WCST; Heaton, 1981), the Controlled Oral Word Association Test (COWA; Stuss and Benson, 1986), Trail-Making Tests, B (time to completion) (Reitan and Wolfson, 1985), Color-Word (Stroop C-W; Stroop, 1935) and its ratio with Stroop C (Stroop C-W/C).

A measure of visual memory was provided by the Rey–Osterrieth Complex Figure Test (ROCF; Lezak, 2004), calculating the copy, immediate and delayed scores. The Korean-California Verbal Learning Test (K-CVLT; Kang and Kim, 1997) as a function of verbal memory and learning provided measures for immediate recall and delayed recall.

Measures of working memory included K-WAIS, Digit Span and Spatial Location, a subtest of the Kaplan Baycrest Neurocognitive Assessment (Leach et al., 2000).

The processing speed tests were the Stroop Color (Stroop C) and Trail-Making Tests, A (TMT-A; Reitan and Wolfson, 1985).

2.6. Statistical analysis

Continuously distributed demographic variables, including the level of education and parental socioeconomic status, were compared between the UHR and HC groups using an independent *t*-test, whereas categorical demographic variables, including gender and handedness, were compared between the groups using a chi-square test. Neuropsychological test and ToM task scores were respectively combined into neurocognitive and social cognition domains and analyzed by multivariate analyses of variance. Subsequent ANOVAs compared individual neuropsychological and ToM tasks scores. Effect size estimates were calculated with Cohen's *d*. Pearson's correlation (*r*) was performed between the ToM task and neuropsychological test scores for the UHR and HC groups.

3. Results

3.1. Demographic characteristics and clinical symptoms

Table 1 provides information on the basic demographic and clinical characteristics of the two groups. There were no significant group differences in gender or parental socioeconomic status. However, the groups differed in the level of education and handedness ($\chi^2=6.02$, $p<0.05$). The level of education in the UHR group was significantly lower than that in the HC group ($t=3.07$, $df=56$, $p<0.001$). On the GAF scale, the UHR group scored significantly lower than did the HC group ($t=15.50$, $df=37$, $p<0.001$).

3.2. Social cognition: ToM capacity difference between groups

A MANOVA performed on FB task, Strange Story and Cartoon task. As Physical Story, non-ToM task was used as control task, the comparison of Physical Story between two groups was made by independent *t*-test.

There was an overall group effect in the ToM tasks ($F=2.55$, $df=5$, 63, $p=0.03$). An examination of included variables indicated significant differences between the groups for the 2nd-order FB task

Table 1
Demographic characteristics and clinical symptoms in the ultra-high-risk and healthy control group

	Healthy control ($N=36$)	Ultra-high-risk[a] ($N=33$)	Analysis[b]		
			T or χ^2	df	p
Male/female (number)	20/16	19/14	0.03	1	0.86
Right/left handed	30/0	27/6	6.02	1	0.01**
Parental SES[c]	2.78 (0.72)	2.88 (1.13)	−0.43	53.28	0.67
Education (years)	14.42 (1.4)	13.12 (2.01)	3.07	56.56	0.00**
GAF[c]	83.86 (2.69)	59.18 (8.77)	15.50	37.52	0.00**
Age (years)	21.97 (2.5)	20.88 (3.18)			
IQ[c]	110.56 (9.04)	109.47 (15.29)			
BPRS[c]		40.37 (8.56)			
CAARMS[c]		30.42 (14.88)			
HAM-D[c]		13.88 (7.65)			
HAM-A[c]		11.29 (7.05)			
Y-BOCS[c]		1.43 (4.21)			

$^{**}p<0.01$.
[a]Assessment of ultra-high-risk was based on state plus trait risk factors, attenuated symptoms, and/or brief, limited intermittent psychotic symptoms.
[b]Independent *t*-test or Welch's *t*-test if the two groups had heterogeneous variances and chi-square analysis for categorical data.
[c]Abbreviations: SES = Hollingshead socioeconomic status (highest = 1, lowest = 5); IQ = Intelligence Quotient; GAF = Global Assessment of Functioning; BPRS = Brief Psychiatric Rating Scale; CAARMS = Comprehensive Assessment of At-Risk Mental States; HAM-D = Hamilton Depression Rating Scale; HAM-A = Hamilton Anxiety Rating Scale; Y-BOCS = Yale-Brown Obsessive Compulsive Scale.

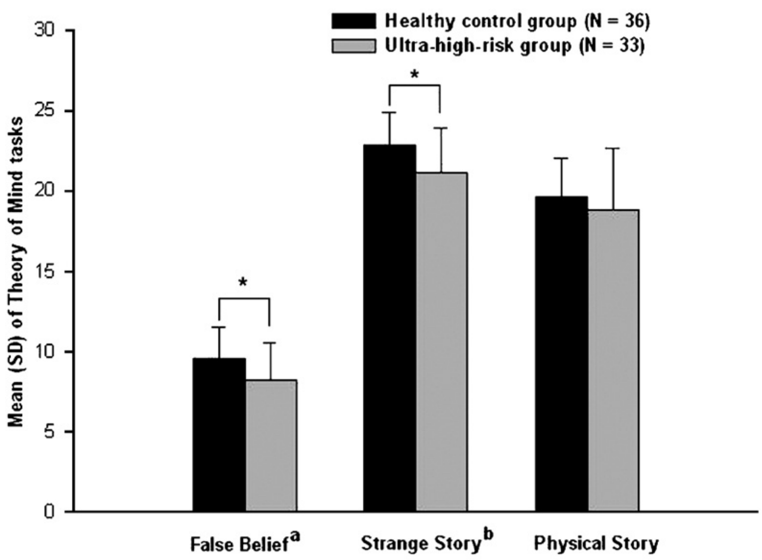

Fig. 1. Theory of mind tasks: between-group differences. [a]Significant difference on False Belief task between two groups (F=6.90, df=1, 69, p=0.01). [b]Significant difference on Strange Story task between two groups (F=7.86, df=1, 69, p=0.00).

(F=5.12, df=1, 69, p=0.02) and Strange Story (F=7.86, df=1, 69, p=0.00; Fig. 1). Whereas there were no significant differences between the groups for the first-order FB task (F=3.79, df=1, 69, p = 0.06) and Cartoon task (F=1.621, df=1, 69, p=0.20). Two groups didn't differ the performances on Physical Story task (t=1.045, df=52.96, p=0.30). The total scores in the UHR group for the Strange Story task (21.18±2.76) were lower than those in the HC group (22.83±2.10).

3.3. Neuropsychological functioning differences between groups

Regarding executive function, a MANOVA did not reveal significant group differences (F=2.02, df=6, 61, p=0.07). Although not interpretable in light of the non-significant overall MANOVA, an examination of included variables indicated a significant difference between two groups only for Stroop C-W (F=9.02, df=1, 68, p=0.00) and TMT-B (F=5.25, df=1, 68, p=0.02).

Exploration of the Spatial Location and Digit span as a function of working memory revealed a significant group effect (F=4.09, df=2, 63, p=0.02). While significant impairment in Spatial Location in the UHR group compared to the HC group was observed (F=7.35, df=1, 66, p=0.00), the performances of Digit Span didn't differ between two groups.

Verbal and visual memory as measured by the K-CVLT and ROCF were examined by MANOVA, revealing no significant group effects (F=2.13, df=5, 62, p=0.07). Although not interpretable in light of the non-significant overall MANOVA, an examination of included variables indicated a significant difference between two groups for the immediate recall scores of ROCF (F=4.43, df=1, 68, p=0.03). However, the UHR group did not differ from the HC group on the performances of the K-CVLT.

Speed of processing as measured by TMT-A and Stroop C did not reveal significant group differences (F=0.54, df=2, 65, p=0.58) (see Table 2).

3.4. Effect size measures

The effect sizes were calculated to measure the magnitude of group effects, thereby explaining performance deficits in the UHR group compared to the HC group (see Table 3). The effect sizes of neuropsychological tests ranged from 0.52 (ROCF) to 0.72 (Stroop C-W). The UHR group demonstrated performance deficits of ToM tasks compared to the HC group at moderate level.

3.5. Relations between ToM performances and neurocognition

To investigate the relationship between the ToM ability and neurocognition, Pearson's correlations were performed for the UHR and HC groups. The HC group showed a positive correlation only between verbal IQ and second-order FB task (r=0.34, p<0.05). No other significant correlations occurred between IQ and the Strange Story task (r=0.17, p>0.05).

Whereas the UHR group showed a negative correlation between TMT-B (time in seconds) and the FB task

Table 2
The performance of neuropsychological tests of healthy control and ultra-high-risk group

Measures [a]	HC [b] (N=36)	UHR [b] (N=33)	Analysis		
	Mean (SD)	Mean (SD)	F	df	p
Executive function					
WCST, no. correct	69.53 (14.61)	70.67 (12.88)	0.13	1, 68	0.73
perseverative response	10.19 (8.95)	12.50 (7.62)	1.28	1, 68	0.26
TMT-B (sec)	58.28 (11.15)	69.97 (28.23)	5.25	1, 68	0.02*
Stroop C-W (sec)	98.83 (14.01)	114.18 (27.52)	9.02	1, 68	0.00**
C-W/C (sec)	1.78 (0.36)	1.95 (0.48)	2.73	1, 68	0.10
COWA	39.67 (7.99)	37.76 (10.29)	0.91	1, 68	0.34
Working memory					
K-WAIS, Digit Span	13.31 (2.48)	12.22 (2.29)	2.41	1, 66	0.12
Spatial Location	45.47 (1.10)	44.33 (2.27)	7.35	1,66	0.00**
Memory/learning					
ROCF, Copy (score)	32.28 (2.41)	31.81 (3.07)	0.48	1, 68	0.48
Immediate recall (score)	22.61 (4.85)	19.48 (7.27)	4.43	1, 68	0.03*
Delayed recall (score)	21.33 (4.60)	19.64 (6.69)	1.50	1, 68	0.22
K-CVLT, Immediate recall	13.19 (2.06)	12.47 (2.36)	1.82	1, 68	0.18
Delayed recall	13.33 (1.92)	13.31 (2.13)	0.00	1, 68	0.96
Processing speed					
Stroop C (sec)	56.75 (10.15)	58.82 (9.44)	1.05	1, 68	0.30
TMT-A (sec)	30.92 (10.38)	31.28 (15.62)	0.01	1, 68	0.91

*$p<0.05$. **$p<0.01$.
[a] Abbreviations: Stroop C = Stroop Color; Stroop C-W = Stroop Color-Word; TMT-A = Trail-Making Test, Part A; TMT-B = Trail-Making Test, Part B; WCST = Wisconsin Card Sorting Test; WAIS-Digit Span = Wechsler Adult Intelligence Scale-Digit Span; COWA = Controlled Oral Word Association Test; ROCF = Rey–Osterrieth Complex Figure Test; K-CVLT = Korean-California Verbal Learning Test.
[b] Abbreviations: HC = healthy control group; UHR = ultra-high-risk group.

(r=−0.43, p<0.05) and Strange Story task (r=−0.39, p<0.05), this was not the case in the HC group (r=−0.25, p>0.05; r=−0.30, p>0.05, respectively). There was also a negative correlation between the WCST, perseverative response and the second-order FB task (r=−0.42, p<0.05). Verbal IQ and general IQ for the UHR group were positively correlated with the Strange Story task (r=0.43, p<0.05; r=0.49, p<0.01, respectively).

Table 3
Effect sizes (Cohen's d) for significant mean differences in neuropsychological tests scores and theory of mind task scores between groups

Measures [a]	HC [b] vs UHR [b]
Neuropsychological tests	
Stroop C-W (sec)	0.72
TMT-B (sec)	0.56
Spatial Location	0.65
ROCF, Immediate recall	0.52
Theory of mind tasks	
FB total	0.64
Strange Story	0.68

Effect size based on difference in raw means divided by pooled post test standard deviation.
[a] Abbreviations: Stroop C-W = Stroop Color-Word; TMT-B = Trail-Making Test, Part B; ROCF = Rey–Osterrieth Complex Figure Test; FB = False Belief task.
[b] Abbreviations: UHR = ultra-high-risk group; HC = healthy control group.

4. Discussion

To the best of our knowledge, this is the first investigation of ToM competence in a group at ultra-high-risk for schizophrenia. More importantly, previous high-risk studies examined ToM competence with comparison groups unmatched for IQ; it is noteworthy that our comparison groups were matched for IQ.

As we hypothesized, the UHR group showed impairment on ToM tasks requiring the inference of other people's beliefs compared with the HC group, while performing normally for the Physical story. Given that ToM task performance in the UHR group was correlated with set-shifting tasks and IQ, it seems that ToM ability is related to some cognitive domains. In support of this, previous ToM studies suggest that ToM ability seems to be in part mediated by general IQ (Harrington et al., 2005; Janssen et al., 2003). However, given that IQ of the two groups in the current study did not differ, impairment of ToM performance in the UHR group cannot be fully accounted for by general IQ. These results suggest that ToM deficit in the UHR group can be "basic symptoms" at the prodromal stage of psychosis. In addition, ToM ability seems to be especially related to set-shifting task performance. A recent study reported that ToM task performance in schizophrenia was correlated with TMT-B (Bora et al., 2006). Future studies are needed to reveal the nature of the relationship between ToM task performance and other cognitive domains such as working memory.

Recent functional imaging studies using ToM tasks have reported that medial prefrontal cortex is one of the key areas to mediate mentalizing capability (Gallagher et al., 2000). Prefrontal cortex hypofunction may represent a vulnerability marker for the development of psychotic disorders, and decreased activation of prefrontal regions was observed in the UHR group (Morey et al., 2005). Taken together, our findings suggest that social cognition ability in the UHR group begins to decline before the onset of psychotic illness and that the social cognition deficit observed in the UHR group is mediated by prefrontal cortex dysfunction.

For the nonverbal ToM task, there were no significant differences between the UHR and HC groups. Representing another person's belief requires knowledge of the syntax and semantics of the situation (Malle, 2002). The syntax of the nonverbal ToM task that we used may not match that of the verbal ToM task. Previous studies have used nonverbal ToM tasks depicting the same contents as in verbal ToM tasks (Kobayashi et al., 2007). In addition, we cannot exclude the possibility that our nonverbal and verbal tasks were not equated for difficulty and may have differed in the level of ToM activity (UHR, mean 28.11; HC, mean 27.67). This task has only been used in one study of schizophrenia, and its usefulness as a measure of ToM in adults therefore requires further investigation (Harrington et al., 2005).

Regarding neuropsychological performance, the overall pattern of impairment for the various tasks used was consistent with the results of previous studies in high-risk subjects, except for verbal memory. We used the K-CVLT to assess verbal learning and memory. Retaining material after an initial presentation and retrieving it in the K-CVLT has been attributed to the medial temporal memory system (Ventura et al., 2000). Recent magnetic resonance imaging of hippocampal volume according to psychosis stage has shown that medial temporal structural changes are not observed until the onset of psychotic illness (Velakoulis et al., 2006). In support of this, it has been suggested that pathology of the prefrontal cortex might in turn affect the hippocampus, ultimately resulting in the expression of psychotic symptoms (Grace, 2004). A level of dysfunction in the prefrontal cortex is suggested by the reduced performance in neuropsychological tasks that reflect prefrontal functioning. In addition, we cannot exclude the possibility that the poor performance in verbal memory tests in the UHR group was compensated by the high average IQ (mean, 109.47). Considering these results, a consistent picture is emerging for the pathophysiology of psychosis; frontal cortex dysfunction occurs at the prodromal stage of psychosis, which may cause a deficit in social cognition, which is important for social interaction. Eventually, continuous stress and social maladaptation, caused by deficits in social cognition, will lead to the development of psychosis.

In summary, this study suggests that individuals at UHR for psychosis have impairments of ToM ability as well as working memory function at the baseline. However, these "basic symptoms" at the prodromal stage may well be followed by psychosis, or may not (Yung et al., 2003). Among 33 UHR subjects, 17 participants have been followed up over 1 year and 2 participants developed the onset of psychosis of whom one was paranoid schizophrenia and the other was undifferentiated schizophrenia diagnosed by SCID-IV and the transition rate is 11.76%. In fact, 15 of 17 participants have received low-dose atypical antipsychotics or antidepressants treatment during follow-up. Considering that the SYC has provided psychosocial education and medication, if necessary, this transition rate (11.76%) is similar to that reported by recent studies (Morrison et al., 2007; Yung et al., 2006). The future course of the UHR group needs to be evaluated longitudinally to confirm specific risk factors for psychosis.

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The Ministry of Science and Technology of the Republic of Korea and Seoul National University Hospital had no further role in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

Contributors

Yu Sun Chung wrote the draft of the manuscript and administered a neuropsychological test battery and theory of mind tasks to the subjects who participated in this study.

So Young Yoo and Do-Hyung Kang completed a screening interview for the subjects of this study.

Na Young Shin administered a neuropsychological test battery and theory of mind tasks to the subjects who participated in this study.

Do-Hyung Kang edited the manuscript.

Jun Soo Kwon undertook the study design and managed the whole procedure of this study.

All authors contributed to and have approved the final manuscript.

Conflict of interest

None of the authors have any conflict of interests to this study.

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