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Regular Article

Abnormalities of mental rotation of hands associated with speed of information processing and executive function in chronic schizophrenic patients

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Aim: Deficits in mental imagery ability have been reported in patients with schizophrenia. However, there is scarce evidence about the correlation between impairment in mental rotation and other cognitive deficits in the patients. The aim of this study was to assess mental rotation ability, along with other measures of cognitive function in patients with schizophrenia.

Methods: The performance of 29 patients with schizophrenia was compared with 29 healthy controls. Mental rotation was measured with the Hand Rotation Task, and cognitive functions were measured with the Brief Assessment of Cognition in Schizophrenia (BACS).

Results: On Hand Rotation Task, the patients were significantly slower and less accurate compared to controls. Moreover, mental rotation accuracy was significantly correlated with all the BACS domains except verbal memory. In multiple regression analysis, the two BACS subscales, Tower of London and Symbol Coding tasks, were significant predictors and accounted for 41% of the variance in accuracy in the patients.

Conclusion: These results support previous findings showing dysfunction of the posterior parietal cortex in schizophrenia, which is involved in general mental rotation, as well as other cognitive processes.

Key words: Brief Assessment of Cognition in Schizophrenia, hand rotation, mental imagery, mental rotation, schizophrenia.

COGNITIVE DYSFUNCTION IS a core feature of schizophrenia.[1,2] The aspects of cognition that are specifically impaired in schizophrenia are verbal memory, working memory, motor function, attention, executive functions, and verbal fluency. Recently, studies have shown impaired mental imagery ability in the patients.[3–6] However, there is lack of evidence regarding the correlation between impairment in mental rotation and other cognitive deficits in patients with schizophrenia.

Mental rotation, the ability to imagine how a misoriented object would appear if rotated away from the presented orientation, is a widely studied area of spatial cognition.[7] Mental rotation is usually studied by using Parson's hand rotation paradigm in which participants judge the laterality of pictures of left or right hands in different rotation angles.[8] Typically, reaction times and error rates increase as a function of the rotation angle of the stimulus, suggesting that participants engage in a cognitive process of mental rotation.

A few studies have found compromised mental imagery ability in patients with schizophrenia.[3–6] A study by Danckert *et al.* showed poor correlation between imagined movement duration and target size in the Visually Guided Pointing Task (VGPT) in patients.[4] The authors concluded that schizophrenic patients were unable to generate accurate internal

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images of their own movements. Maruff *et al*. found that only the patients with passivity symptoms were impaired in the VGPT task.[5] de Vignemont *et al*. reported that while patients were slower and less accurate than controls on mental rotation tasks, they showed the same decrease in speed and performance with increasing angles of rotation as controls. They suggested that lower accuracy in patients results from a general impairment of attention and visuospatial working memory in patients, although they did not examine these correlations in their study.[3] While this information suggests impaired mental rotation in schizophrenia, the lack of electrophysiological and neuropsychological data raises the question about the underlying neural and cognitive mechanisms. To our knowledge, no study has investigated the correlation between impairment in mental rotation and other cognitive deficits in schizophrenia, which is the main aim of the present study.

For mental rotation, basic processing of visual input relies on activation of the posterior parietal cortex, while frontal activation are required to integrate, manipulate, and employ visual information. Researches in cognitive processes of mental rotation have proposed the crucial role of the speed of spatial processing, executive function, and working memory.[7,8]

Considering the wide range of cognitive deficits in patients with schizophrenia, as well as evidence of impaired mental rotation, further research is required to determine the neuropsychological correlates of this impairment. The length of cognitive assessment is a factor that affects patient cooperation. Therefore, to examine the effects of domains of cognitive functions that are impaired in patients with schizophrenia, we chose a brief battery, the Brief Assessment of Cognition in Schizophrenia (BACS). The BACS is specifically designed for assessment of cognitive function in schizophrenia and has several advantages, including brief administration (approximately 35 min) and scoring time, portability, and repeatability. Studies have shown acceptable reliability and concurrent validity of the BACS with a standard cognitive battery, which takes more than 2 h to administer.[9]

The current study aimed to examine the correlation between cognitive performance, measured with the BACS, and performance on a mental imagery task, measured with the Hand Rotation Task (HRT). We hypothesized that impaired performance on task of mental hand rotation would be associated with impairment of other cognitive functions, particularly measures of working memory and executive functions.

METHODS

Participants

A group of 29 patients with schizophrenia (16 male) was recruited from inpatients and outpatients of a psychiatric hospital. All patients met DSM-IV criteria for a lifetime diagnosis of schizophrenia. All the patients were assessed using the Positive and Negative Syndrome Scale (PANSS) for schizophrenia.[10] At the time of testing, patients were receiving antipsychotic medication ($n = 20$ atypical, $n = 9$ on both typical and atypical antipsychotics) and were clinically stable. The mean chlorpromazine equivalent was 341.4 mg (SD = 186.5).[11]

The control group comprised 29 healthy participants (17 male) screened for a personal or family history of psychotic illnesses. Exclusion criteria for all participants included head injury, neurological disorder, and substance abuse treatment at the time of testing. All the participants were right-handed. Written informed consent was obtained from all participants. The study was approved by the Ethics Committees of Kerman University of Medical Sciences.

Assessment procedures

BACS

All the participants were tested using the Persian version of the BACS, which has been validated in a sample of schizophrenic patients speaking in Persian language.[12] The BACS is a pen-and-paper battery of neurocognitive tests, which takes approximately 30 min to administer. The BACS is specifically designed for assessment of cognitive function in schizophrenia and is as sensitive to cognitive dysfunction in schizophrenia as standard 150-min batteries.[9] The battery of tests in the BACS consists of assessments of verbal memory, verbal fluency, working memory, attention, motor speed and reasoning and problem solving.

1. Verbal memory (List Learning): Patients are presented 15 words and then asked to recall as many as possible. This procedure is repeated 5 times.
2. Verbal fluency: Patients are given 60 s to name as many words as possible within a given category

(Semantic Fluency). Also, in two separate trials, patients are given 60 s to generate as many words as possible that begin with a given letter (Letter Fluency).

3 Working memory (Digit Sequencing): Patients are presented with clusters of numbers of increasing length. They are asked to tell the examiner the numbers in order, from lowest to highest.
4 Motor speed (Token Motor Test): Patients are given 100 plastic tokens and asked to place them into a container as quickly as possible for 60 s.
5 Reasoning and Problem Solving (Tower of London): Patients look at two pictures at the same time. Each picture shows three different colored balls arranged on three pegs, with the balls in a unique arrangement in each picture. The patients are asked to provide the minimum number of times the balls in one picture would have to be moved in order to make the arrangement of balls identical to that of the other, opposing picture. There are two alternate forms.
6 Attention and Processing Speed (Symbol Coding): Patients receive a key explaining how unique symbols correspond to the individual numerals 1–9. They are asked to fill in the corresponding number beneath a series of symbols as quickly as possible for 90 s.

The composite scores of the Persian-BACS were calculated by averaging all the subscales in each instrument, after transforming them into z scores.[9]

HRT

Parson's classical hand-rotation paradigm was used.[8] In this task, participants judge the laterality of pictures, representing left or right hands in various rotation angles. The participants were seated on a chair in front of a table. The stimuli consisted of line drawings of left and right hands in back view and palm view (Fig. 1) presented in random order. The hand pictures were rotated in six different orientations (0°, 60°, 120°, 180°, 240°, and 300°). Each picture was repeated five times resulting in 120 trials ($6 \times 2 \times 2 \times 5$). The participants were asked to judge as quickly and accurately as possible if it was a picture of a left or right hand by pressing a left or right button. Response time and accuracy rate (percentage of correct response) were registered via key press. A score below 75% indicates inability to perform HRT accurately.

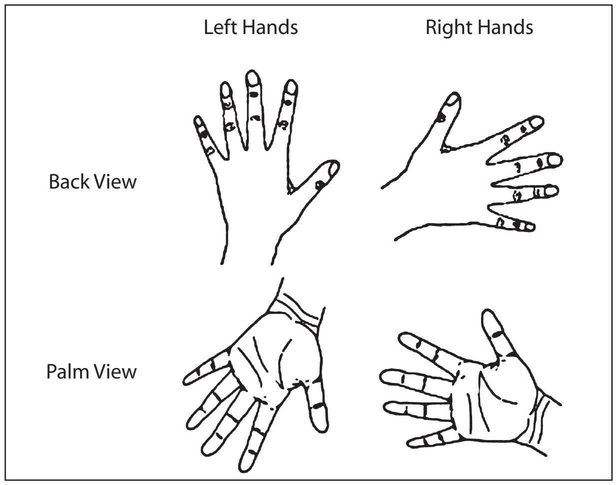

Figure 1. Examples of the line drawings of left and right hands viewed from the palm and from the back with different rotation angles (0°, 60, 120°, 180°, 240°, 300°).

Data analyses

Because our focus was the correlation between performance on hand rotation task and the cognitive domains of the BACS, we collapsed different rotations into two angles of rotation: small rotation angle (0°, 60°, and 300°), and large rotation angle (120°, 180°, and 240°). To examine response time and accuracy of HRT between groups in different angles, a repeated-measures ANOVA with group (patient, control) as between-subject and hand rotation angles as within-subject was carried out. Follow-up analyses were conducted using independent-samples *t*-test. Before conducting the ANOVA, each variable was tested for deviation from normal distribution using Shapiro–Wilk test. The magnitude of effects was expressed in terms of Cohen's d estimate. χ^2-test and *t*-tests were applied to analyze the demographic and clinical data. The correlation between the patients' characteristics and the HRT measures were examined using Pearson correlation. Multivariate regression was used to determine the predictor factors (the BACS domains) of the hand rotation (HR) results.

RESULTS

Demographic, clinical and neuropsychological characteristics of participants are displayed in Table 1. The two groups did not significantly differ in age, sex and years of education.

Table 1. Demographic and clinical characteristics of the study participants

	Patients *n* = 29	Controls *n* = 29	*P*-value
Age	41.1 (10.3)	37.9 (10.6)	NS
Education	9.9 (2.9)	11.5 (3.1)	NS
Sex *n* (% male)	16 (55.2)	17 (58.6)	NS
Edinburgh	96.9 (5.4)	91.6 (9.2)	NS
Length of illness (years)	16.3 (9.5)	NA	NA
Age at onset of illness (years)	24.8 (10.5)	NA	NA
Mean chlorpromazine equivalent (mg)	341.4 (186.5)	NA	NA
PANSS-Global	28.58 (8.39)	NA	NA
PANSS-Negative	16.1 (8.6)	NA	NA
PANSS-Positive	12.5 (5.2)	NA	NA

NA, not applicable; NS, not significant; PANSS, Positive and Negative Syndrome Scale.

HRT

Table 2 shows means and SD of the accuracy rates and response times of the study participants.

Response time

The mean response times across the two degrees of rotations were calculated. A repeated measure ANOVA for mean response time, degree of rotation (large/small) and group (schizophrenia/control) showed a significant main effect of degree of rotation ($F[1,56] = 114.91$, $P < 0.001$, $\eta2 = 0.6$), suggesting an increase in response time with increasing angle of rotation. A significant main effect of group was also found ($F[1,56] = 4.84$, $P = 0.03$, $\eta2 = 0.08$), showing that schizophrenic patients were significantly slower than the control group. Pairwise comparisons of the mean scores between the two groups for each angle of rotation showed significant group differences for the small angle of rotation ($P = 0.001$) but not for the large angle ($P = 0.3$). Moreover, there was a significant interaction effect between group and degree of rotation ($F[1,56] = 24.52$, $P < 0.001$, $\eta2 = 0.3$), indicating differential changes in the response time between patient and control groups across the two degrees of rotations (Fig. 2).

Response accuracy

The analyses were repeated for response accuracies across the two angles of rotation (Fig. 2). The results revealed a significant main effect of angle of rotation ($F[1,56] = 52$, $P < 0.001$, $\eta2 = 0.5$), suggesting a decrease in accuracy with increasing angle of rotation. The main effect of group was also significant ($F[1,56] = 96.30$, $P < 0.001$, $\eta2 = 0.5$), showing that the performance of patients was less accurate than

Table 2. Means and SD of the accuracy rate and response time of performance on HR task in the participants

	Patients *n* = 29	Controls *n* = 29	*P*-value
HR response time (total)	1888.3 ± 264.7	1738.8 ± 252.5	0.03
Small	1835.9 ± 272.3	1596.5 ± 267.6	0.31
Large	1940.7 ± 275.4	1881.4 ± 255.2	<0.001
HR accuracy (total)	41.1 ± 17.2	80.1 ± 12.8	<0.001
Small	44.1 ± 19.2	86.8 ± 10.9	<0.001
Large	38.2 ± 16.5	73.5 ± 16.2	<0.001

HR, hand rotation.

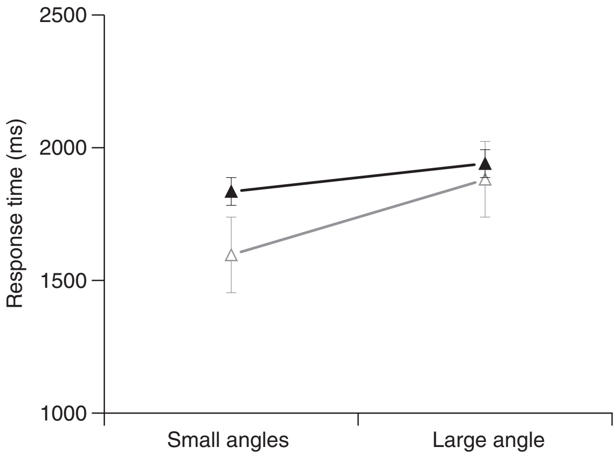

Figure 2. Mean response time (with SEM) of performance on hand rotation task in the (—▲—) patients with schizophrenia and (—△—) controls.

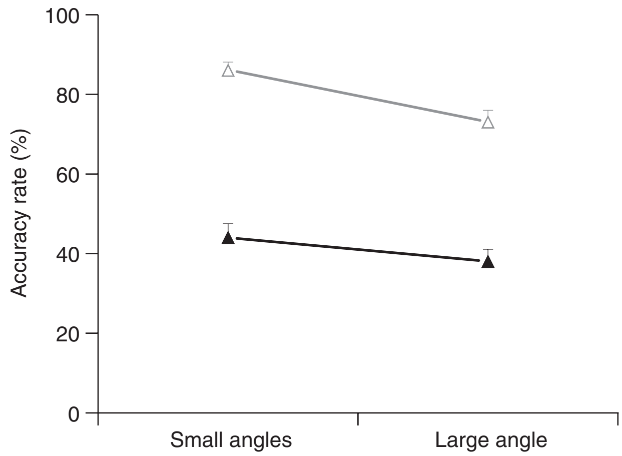

Figure 3. Mean accuracy rate (with SEM) of performance on hand rotation task in the (—▲—) patients with schizophrenia and (—△—) controls.

that of controls. Pairwise comparisons of the accuracy rates between the two groups at each angle of rotation showed significant group differences for both small and large angles (all $P = 0.001$). There was also a significant interaction effect between degree of rotation and group ($F[1,56] = 7.9$, $P < 0.007$, $\eta 2 = 0.1$), indicating differential changes in response accuracy between groups across angles (Fig. 3).

BACS

Table 3 shows the scores of the BACS subscales. The performance of patients significantly differed from controls (all $P < 0.001$). Table 4 represents the Pearson correlations between response times of HRT with the BACS domain scores in patients with schizophrenia. While the HR accuracy rate was significantly correlated to the BACS scores except verbal memory, HR response time was only correlated to the BACS digit sequencing.

Multiple regression analysis

Finally, stepwise multiple linear regression analyses were used to investigate the independent contribution of the BACS domain scores to the prediction of the HR accuracy rate in the patient group. All the significant BACS domains correlates of HR accuracy entered as predictor variables. The overall result was significant ($F[2, 28] = 10.9$, $P < 0.001$), with the two BACS domains, Tower of London and Symbol Coding tasks, found to be significant predictors of HR

Table 3. Means and SD of the Persian-BACS subscales of the participants

BACS domains	Patients $n = 29$	Controls $n = 29$	P-value
Verbal memory	31.9 ± 6.6	46.4 ± 8.9	<0.001
Digit sequencing	10.9 ± 4.9	15.9 ± 2.2	<0.001
Token motor	53.2 ± 12.4	79.9 ± 14.1	<0.001
Verbal fluency	30.7 ± 11.3	42.3 ± 10.7	<0.001
Symbol coding	16.1 ± 9.9	41.7 ± 10.5	<0.001
Tower of London	4.3 ± 5.2	12.1 ± 4.7	<0.001
Composite score	−0.53 ± 0.51	0.65 ± 0.43	<0.001

BACS, Brief Assessment of Cognition in Schizophrenia.

Table 4. Correlations of the BACS domain scores with HR response times and with accuracy rate in the patients

	HR response times		
BACS domains	HR response time total	HR response time for small angles	HR response time for large angles
Verbal memory	−0.17	−0.18	−0.15
Digit sequencing	−0.41*	−0.34	−0.43*
Token motor	−0.19	−0.26	−0.11
Verbal fluency	0.09	0.06	0.13
Symbol coding	0.19	0.16	0.21
Tower of London	0.22	0.15	0.28
Composite score	0.17	0.10	0.21

	HR accuracy rate		
BACS domain scores	HR accuracy total	HR accuracy for small angles	HR accuracy for large angles
Verbal memory	0.19	0.16	0.20
Digit sequencing	0.43*	0.50**	0.32
Token motor	0.43*	0.37*	0.47*
Verbal fluency	0.51**	0.50**	0.48**
Symbol coding	0.54**	0.56**	0.48**
Tower of London	0.59**	0.62**	0.52**
Composite score	0.65**	0.66**	0.59**

*$P < 0.05$; **$P < 0.001$. BACS, Brief Assessment of Cognition in Schizophrenia; HR, hand rotation.

accuracy (Table 5). Overall the model accounted for 41% of the variance in total HR accuracy rate. However, the results revealed no significant association between the BACS domain scores and HR accuracy rates in the control group.

Effects of psychotropic medications

To examine the effects of patient characteristics on their performances on HRT, correlation coefficients (Pearson's r) were calculated between HR accuracy and HR response time with chlorpromazine equivalent dose, duration of disease, and PANSS scores. The results showed that the measures of performance on the HRT were not associated with the chlorpromazine equivalent dose and disease characteristics (all $P > 0.6$). Moreover, there were no significant differences between patients taking atypical antipsychotic and patients taking both typical and atypical antipsychotic drugs on the measures of HRT and BACS composite scores. Finally, the correlations between the BACS composite scores and clinical characteristics of the patients were not significant (all $P > 0.1$).

Table 5. Multiple regression analysis on response accuracy of performance on the hand rotation task in the patients

Variables	B	SEB	Beta	*P*-value
Tower of London	1.43	0.52	0.44	0.01
Symbol coding	0.62	0.28	0.36	0.03

$R^2 = 0.45$; adjusted $R^2 = 0.41$; $F = 10.72$.

DISCUSSION

While evidence has shown that individuals with schizophrenia exhibit impairment on tasks of mental rotation, the cognitive processes that underlie have remained unclear. The primary aim of the current study was to examine the correlation between mental rotation ability and other domains of cognitive functions, assessed by the hand rotation task and the BACS, respectively. The main results can be presented into two parts. First, on hand rotation task: (i) schizophrenia patients displayed the same pattern of performance as the control group; and (ii) they performed significantly more slowly and less accurately compared to the control group. Second, impaired accuracy in mental rotation was associated with speed of information processing and executive dysfunction in the patient group.

Consistent with previous studies, our findings revealed that in general the pattern of performance of patients was comparable to the controls (same effects of angle of rotation), and their ability to mentally rotate stimuli was preserved. However, we should emphasize that there was an impairment in mental rotation, as the patients showed slower response time and higher error rate compared to controls, similar to findings reported by de Vignemont *et al*.[3] These results suggest patients with schizophrenia have difficulties in accurately manipulating mental representation of hands.

The results showed the individual domains of cognitive function were moderately correlated with error rates of hand rotation task, with correlations ranging between 0.43 and 0.59. Moreover, the results of regression analysis revealed that cognitive domains of speed of information processing, reasoning and problem solving were the best predictor of accuracy rate on the hand rotation task in patients.

Our results indicated that processing speed is an important parameter for performing mental rotation tasks in patients, and its dysfunction could be considered as the fundamental underlying the observed mental rotation deficits. A recent meta-analysis demonstrated that patients with schizophrenia show significant deficits in speed of processing compared to other neurocognitive domains.[13] Our finding supports previous studies and provides further evidence for the crucial role of deficient speed of processing on performance in cognitive tasks in patients with schizophrenia.[14]

The present study showed that hand rotation accuracy was associated with worse performance on measure of executive function. Executive functioning involves multiple components, such as attention, inhibition, planning and monitoring.[15] It is not easily clear to what extent any single specific task involves each of the different aspects of executive functioning. The Tower of London task, which was applied in the present study, is a widely used test to examine planning ability.[16,17] In fact, the planning ability consists of several cognitive processes, including strategy information, coordination and holding information online, which are also important factors to perform a mental rotation task.[18] This finding supports the proposal that suggests executive functioning deficits might contribute to many of the other cognitive deficits observed in schizophrenia.[19,20]

It should be noted that the importance of these cognitive domains for mental rotation has been proposed in previous studies.[21] Weber *et al*. found associations between hand rotation error rates and measures of executive functioning and working memory in individuals with HIV infection.[22] Crucian *et al*. found the correlation between hand rotation accuracy and mental processing and psychomotor speed in patients with Parkinson's disease.[23] As mentioned in the Introduction, de Vignemont *et al*. proposed the correlation between impaired mental imagery and visuospatial working memory in patients, which was not assessed in our study.[3] Future studies are needed to examine the impairment of the spatial working memory and its relation to mental rotation in patients with schizophrenia. Moreover, future research should examine the association between mental rotation and its cognitive mechanisms, using positron emission tomography.

We did not find significant correlations between measures of hand rotation task and chlorpromazine equivalent dose, duration of disease, or PANSS scores, indicating that impairment on the hand rotation task is not simply related to the level of psychopathology and dose of medication.

A limitation of this study is that the numbers of patients and controls were relatively small. A possible confounding factor that might have affected performances of patients on cognitive tasks was the use of antipsychotic medications. However, no correlation was found between chlorpromazine equivalent dose and either measures of hand rotation or the BACS. Also, anticholinergic drugs have adverse effects on memory; therefore, future studies are required to examine the association between mental rotation and its cognitive mechanisms across a group of drug-naïve patients as well as in different subtypes of schizophrenia.

In conclusion, these results increase our knowledge regarding associations between neuropsychological and mental rotation deficits in patients with schizophrenia. The most robust finding is that impaired accuracy on hand rotation task is correlated with speed of information processing and executive dysfunctions in patients.

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