Original Article

Performance strategy in the hand mental rotation task in patients with schizophrenia

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Abstract

Purpose: We compared the response times for each presented angle in a hand mental rotation task (HMRT) in patients with schizophrenia in order to investigate performance strategies adopted when patients were required to determine whether a presented picture showed a left or right hand.

Patients and Methods: Twenty-three right-handed patients with schizophrenia (15 male and 8 female, mean age 39.5 ± 11.6 years) performed the HMRT. A total of 96 pictures randomly featuring left or right hands, either palm or back of hand, rotated in six different angles (at a 60° intervals) were presented to participants. Participants were instructed to determine the left or right for each picture as fast and as accurately as possible by pressing the left or right key.

Conclusion: Response times were longer for the angles that were difficult for participants to simulate. These results indicate that participants utilize a motor imagery strategy to perform HMRTs.

Keywords: Motor imagery, Mental disorder, Cognitive dysfunction, Reaction time, Motor response generation

Introduction

Schizophrenia is one of the most important diseases in the rehabilitation of mental disorders, characterized by positive symptoms such as hallucinations and delusions, and negative symptoms such as flat affect. In addition to its characteristic mental symptoms, in recent years, the focus has been shifted to the clinical significance of cognitive dysfunction due to this disease. One of the reasons for this shift is that cognitive dysfunction is more closely associated with social outcomes than mental symptoms (Green, 1996; Green, 2000).

Cognitive functions that are impaired in patients with schizophrenia include memory (Bilder, 2000; Wilk, 2005), working memory, (Gold, 1997; Cassetta, 2016), information processing speed, (Wilk, 2005; Cassetta, 2016), attention (Harvey, 1989; Granholm, 1996), and executive function (Bilder, 2000; Vizzotto, 2016). These elements are included in evaluation items for the standardized Brief Assessment of Cognition in Schizophrenia (Keefe, 2004) and the MATRICS Consensus Cognitive Battery (Green, 2004), and are considered to be at the central core of cognitive dysfunction in patients with schizophrenia. Alternatively, it has been reported that motor imagery ability in patients with schizophrenia is also impaired (Maruff, 2003).

In the rehabilitation of patients with schizophrenia, poor gross motor function, manual clumsiness, and poor judgment of

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appropriate physical distance from people and objects are observed. It is possible that along with impairment in attention and executive function, motor imagery ability may also be affected, suggesting that the evaluation of motor imagery ability is important for patients with schizophrenia.

One of the tasks that enable evaluation of implicit motor imagery ability is the hand mental rotation task (HMRT) (Sekiyama, 1982; Takeda, 2010; Chen, 2015; Zapparoli, 2016). In the HMRT, individual pictures of the “left” or “right” hand at various angles are presented to participants. Participants are required to determine whether the presented picture features the left or right hand as fast and as accurately as possible, with accuracy and response time (RT) recorded. A previous study, utilizing this methodology, found that, when there was a 90° clockwise rotation, RT for the right hand picture was longer than that of left hand picture. Conversely, when there was a 90° counterclockwise rotation, RT for the left hand picture was longer than that of the right hand picture (Takeda, 2010). This suggests that if participants superimpose their own hand on the presented picture, RT becomes longer for pictures at angles that are difficult to simulate (Sekiyama, 1982; Saimpont, 2009; Sekiyama, 2014). Furthermore, if the position of participants’ hands (de Lange, 2006; Ionta, 2009) or the position of fingers (Blasing, 2013) are changed during the experiment, RT changes. During this task, brain activities are observed in motion-related areas (premotor cortex, parietal association cortex, etc.) (Kosslyn, 1998; de Lange, 2006), indicating that during the HMRT, participants simulate the movement with their own hands (motor imagery strategy).

In previous studies utilizing the HMRT in patients with schizophrenia, it was reported that these individuals demonstrate a high rate of error and longer RTs compared to a healthy population (de Vignemont, 2006; Chen, 2015; Mazhari, 2015). In addition, patients suffering from hallucinations had a higher rate of error (de Vignemont, 2006), and there was a correlation between the rate of correct answers and attention, information processing speed, and executive function (Mazhari, 2014). However, little report has carefully examined the relationship between the angle of presented hand pictures and RT, to determine whether patients with schizophrenia were simulating their own hand movements during the HMRT. There are reports of participants with lowered motor imagery ability not using motor imagery during the HMRT (Wilson, 2004; Craje, 2010); thus, this may be true for patients with schizophrenia as well. Therefore, in this study, we targeted patients with schizophrenia, and by comparing RT for each presented angle during the HMRT, we examined whether a motor imagery strategy was used as a task performance strategy.

We explained the objective and methods of the present study in a written form and obtained informed consent. This study was implemented with an approval from the ethical review board of Faculty of Health Sciences, Kyorin University (Approval number 26-48).

Patients and Methods

1 Participants (Table 1)
Participants were 15 males and 8 females, all right-handed, with a mean age of 39.5 ± 11.6 (*Mean ± Standard Deviation*) years, who were diagnosed with schizophrenia based on the ICD-10 classification of mental and behavioral disorders (World Health Organization, 1992). The age ranged from 20s to 50s, and the education level was high school or higher. To confirm the dominant hand, we obtained Laterality Quotient with a simplified version of

the Edinburgh Handedness Inventory (Oldfield, 1971) by Sakano et al. (1985).

Table 1: Demographic and clinical characteristics of patients

	n = 23 (Male 15, Female 8)
Age (years)	39.5 ± 11.6
Education (years)	13.3 ± 1.7
Laterality Quotient	98.3 ± 5.8
Disease duration (years)	14.1 ± 9.0
Chlorpromazine equivalent (mg)	653.2 ± 437.9

Mean ± Standard Deviation

2 Experimental procedure

Before the HMRT, patients completed a left-right selection task (30 images) in which an image of an arrow pointing to the left or right was displayed. Participants then practiced the HMRT using six hand images prior to engaging in the experimental task in the actual HMRT (96 images). For stimulated presentation, accuracy of response, and measurement of RT, as assessed by E-prime 2.0 (Psychology Software Tools, Inc., Pittsburgh, PA, USA), were used. Images used for stimulation and measurement protocols are shown. These are almost identical to those used in a previous study of the HMRT with stroke patients (Harada, 2016).

1) Experimental setup

All experiments were conducted in a quiet setting with no distracting sounds. A laptop computer (Latitude 15, 3000 series, 15.6 model, Dell-Japan Corp., Kawasaki, Japan) was placed on the desk in front of the participants. The keyboard was masked with an acrylic plate with two openings over the F and J keys. Participants gently placed their left index finger on the F key, and right index finger on the J key. During the HMRT, a cover was placed to prevent participants from seeing their hands.

2) Left-right arrow task (Figure 1a)

An image of an arrow pointing to the left or right was used. Following the presentation of a fixation point for 1.5 seconds, participants were presented with an image of a left or right arrow in a random order, at which point they were required to indicate whether the arrow pointed to the left or right. They were instructed to press the F key for left arrow and J key for the right arrow as fast and accurately as possible. Accuracy and RT were recorded for 15 trials each for left and right arrows.

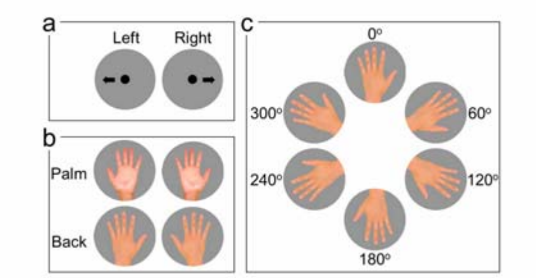

Figure 1: (a) Fixation point and arrow. (b) Hand pictures. (c) Six orientations for the hand mental rotation task. We used the same figures in our previous study (Harada, 2016).

3) HMRT (Figures 1b and 1c)

We used pictures of hands in which the middle finger pointing upward was defined as an angle of 0°, and clockwise rotation that occurred in increments of 60° (0°, 60°, 120°, 180°, 240°, and 300°). The total of images used was left or right hand (2) × palm or back of hand (2) × presented angle (6) × repetition (4), totaling 96 images, which were presented randomly. Participants were instructed to press the F key and J key for left and right hand pictures, respectively, as fast as possible. RT and accuracy were recorded.

3 ΔRT

Although there was no difference in mean RT (RT_{mean}) between right and left arrows, we subtracted the RT_{mean} of the left arrow from the RT_{mean} of the left hand picture, and RT_{mean} of the right arrow from the RT_{mean} of the right hand picture (ΔRT). This was to reduce the difference between left and right hands from when deciding which key to press (decision making), and to actually press the key (motor response generation), in order to compare the time required for mental rotation in the cognitive process in the HMRT (Zapparoli, 2016; Harada 2016). For ΔRT, we performed a repeated measure ANOVA, with left and right hand, and presented angle, as the within-subjects factors.

With 5% as the significance level, we used SPSS Statistics (Ver.24.0, IBM Corporation, Armonk, USA). Subsequently, multiple comparisons made in the test were corrected with the Bonferroni method. In addition, we examined sphericity prior to ANOVA, and when sphericity was not assumed, we obtained ε_{GG} with the Greenhouse-Geisser method to correct the degrees of freedom.

Results

Regarding ΔRT (Figure 2), there was significant interaction between left-right hand pictures and presented angles, $F(5, 110) = 8.54$, $\varepsilon_{GG} = 0.61$, $p < 0.001$. At 0°, compared to ΔRT for the right hand picture (1.02 ± 0.12 s) (*M* ± *SEM*), ΔRT for the left hand picture (1.18 ± 0.12 s) was significantly longer ($p < .05$). At 120°, compared to ΔRT for the left hand picture (1.34 ± 0.16 s), ΔRT for the right hand picture (1.75 ± 0.22 s) was significantly longer ($p < .01$). At 240°, compared to ΔRT for the right hand picture (1.08 ± 0.11 s), ΔRT for the left hand picture (1.76 ± 0.22 s) was significantly longer (p < .01). Similarly, at 300°, compared to ΔRT for the right hand picture (0.95 ± 0.11 s), ΔRT for the left hand picture (1.33 ± 0.15 s) was significantly longer ($p < .05$).

In the left hand pictures , ΔRT at 180° was significantly longer than at 0° ($p < .001$), 60° ($p < .01$), 120° ($p < .001$), and 300° ($p < .05$). In the right hand pictures , ΔRT at 180° was significantly longer than at 0° ($p < .01$), 60° ($p < .05$), 240°, ($p < .01$), and 300° ($p < .01$).

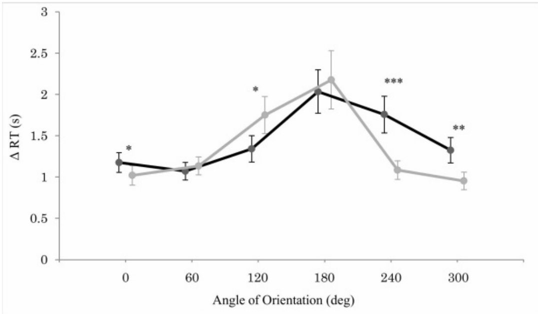

Figure 2: ΔRT (*M* ± *SEM*) plotted against the orientations (0°, 60°, 120°, 180°, 240°, and 300°) for left hand (black) and right hand (grey) pictures. Asterisks indicate a significant difference between left- and right- pictures in each orientation; *$p < .05$, **$p < .01$, and ***$p < .001$. In left hand picture recognition, there were Bonferroni-corrected significant differences between six pairs (0° and 180°, $p < .001$; 0° and 240°, $p < .05$; 60° and 180°, $p < .01$; 60° and 240°, $p < .05$; 120° and 180°, $p < .001$; 180° and 300°, $p < .05$). In right hand picture recognition, there were Bonferroni-corrected significant differences between eight pairs (0° and 120°, $p < .01$; 0° and 180°, $p < .01$; 60° and 120°, $p < .01$; 60° and 180°, $p < .05$; 120° and 240°, $p < .01$; 120° and 300°, $p < .01$; 180° and 240°, $p < .01$; 180° and 300°, $p < .01$) .

Discussion

This study targeted patients with schizophrenia to conduct the HMRT, and by comparing ΔRT for each presented angle, we examined whether a motor imagery strategy is used as a task performance strategy.

At 0° where mental rotation is not required, compared to ΔRT for the right hand picture, that of the left hand was longer. It indicated that in the HMRT, participants may be simulating the movement of their dominant hand (right hand) (Nico, 2004; Ionta, 2009). If participants of the present study were simulating the movement of the dominant hand (right hand), with the right hand pictures, participants actually press the key with their right hand while simulating the movement. With left hand pictures, participants press the key with the left hand instead of the right hand that simulates the movements, and that adds extra time. Therefore, results at 0° where mental rotation is not required suggest that participants are using motor imagery strategy as task performance strategy.

At 120°, ΔRT for the right hand pictures was significantly longer when compared to the left hand pictures. At 240° and 300°, compared to ΔRT for the right hand pictures, that of the left hand pictures was significantly longer. Angles of 120° for the right hand picture, and of 240°/300° for the left hand picture, all have fingertips facing the lateral sides of the body for both right and left hands, and are difficult to simulate compared to the angles that have fingertips facing the center of the body. Therefore, at these three angles (120°, 240°, and 300°), ΔRT was found to be long for pictures that were difficult for the participants to simulate with their own hands. Based on the idea that the time actual movement takes equals the time the movement will take in motor imagery as well (Decety, 1989), many previous HMRT studies with healthy adults as the subjects have proposed that if RT is longer with angles that are difficult to simulate, participants are using a motor imagery strategy (Sekiyama, 1982; Saimpont, 2009; Takeda, 2010; ter Horst, 2010; Conson, 2013; Zapparoli, 2016). The similar results obtained in the present study indicate that patients with schizophrenia, who may have impaired cognitive functions, such as memory, working memory, processing speed of visual information, executive function, and motor imagery ability, also use a motor imagery strategy for HMRT task performance, in a manner similar to healthy individuals. In the future, by comparing results of HMRT with healthy individuals, matching gender and age, we will examine differences in motor imagery ability, and examine any connection between results of HMRT and mental symptoms, cognitive dysfunction, and social function. In this manner, we hope to understand and support behavioral characteristics in rehabilitation.

In the present study, with the HMRT that is already clinically applied (Polli, 2016), and by comparing RT for different presentation angle, it was shown that patients with schizophrenia also use a motor imagery strategy as a performance strategy, similar to healthy individuals and stroke patients shown in our previous study (Harada, 2016).

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