Effects of Object Size on Unimanual and Bimanual Movements in Patients With Schizophrenia

Shu-Mei Wang, Li-Chieh Kuo, Wen-Chen Ouyang, Hsiao-Man Hsu, Keh-Chung Lin, Hui-Ing Ma

MeSH TERMS
- movement disorders
- schizophrenia
- size perception
- task performance and analysis

Schizophrenia affects not only mental function but also movement. We compared the movement of patients with mild schizophrenia and healthy control participants during a bimanual assembly task and examined whether changes in object size affected unimanual and bimanual movements. Fifteen patients with schizophrenia and 15 age- and gender-matched control participants were instructed to bimanually reach for and assemble objects. We manipulated the object size for the left hand (large vs. small) and measured movement time, peak velocity, and bimanual synchronization to represent movement speed, forcefulness, and bimanual coordination. Patients with schizophrenia showed slower and less forceful unimanual movements and less coordinated bimanual movements than control participants. Increasing the object size elicited faster and more forceful unimanual movements and more coordinated bimanual movements in patients. The results suggest the need for movement rehabilitation in patients with schizophrenia and the possibility of manipulating object size to optimize patients’ movements. These results benefit the practice of evidence-based therapy.


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Occupational therapists commonly treat patients with schizophrenia in mental health practice (Brown, 2011). Schizophrenia causes complicated and multifaceted impairments and interferes with patients’ ability to participate in productive occupations. Studies focused on performance skills have found problems in cognitive skills, social skills, and even motor skills in patients with schizophrenia (Arbesman & Logsdon, 2011; Bellgrove et al., 2001; Carnahan, Elliott, & Velamoor, 1996). Compared with cognitive and social skill problems, motor disorders in patients with schizophrenia have drawn less attention from occupational therapy researchers. One possible reason is that patients’ movement problems are regarded primarily as side effects of antipsychotic medications (Haddad & Mattay, 2011; MacRae, 2005). However, several recent studies have indicated that movement disorders in patients with schizophrenia are illness induced and that antipsychotic drugs modify movement expression (Koning et al., 2010; Pappa & Dazzan, 2009; Whitty, Owoeye, & Waddington, 2009). These findings indicate the need for studies analyzing movement features in patients with schizophrenia.

Occupational therapy for movement disorders involves adjusting task constraints to facilitate adaptive movements in clients (Newell & Valvano, 1998). Task constraints are boundaries of tasks that limit the number of possible movement patterns (Newell, 1986; Newell & Valvano, 1998). Object size, which is a task constraint common in rehabilitation settings, affects movement patterns in healthy people (Adam, 1992; Bingham, Hughes, & Mon-Williams, 2008; Fitts, 1954; Fowler, Duck, Mosher, & Mathieson, 1991). It is of interest to know whether object size may be used to optimize movements in patients with schizophrenia.
Functional Movements in Patients With Schizophrenia

Earlier studies used neuropsychological tests to evaluate movements in patients with schizophrenia (Bellgrove et al., 2001; Bilder et al., 2000; Flyckt et al., 1999; Fuller & Jahanshahi, 1999). Their results showed that patients performed slowly or inaccurately on pegboard tests, pronation–supination tests, and out-of-phase bimanual movements. Another study examined unimanual movements during object liftoff and indicated that patients had impaired coordination between the grasp and the lift movement components (Delevoye-Turrell, Giersch, & Danion, 2003).

Occupational therapy is concerned with the ability of clients to engage in daily or productive occupations given the influence of illness (Mahaffey & Holmqvist, 2011). In a study that examined a unimanual functional task, patients with schizophrenia picked up a glass more slowly (i.e., had longer movement times) than healthy control participants but picked up the glass as forcefully as control participants (i.e., had similar peak velocities; Carnahan et al., 1996).

To our knowledge, no study has examined how patients with schizophrenia perform bimanual functional tasks. In daily life, using both hands together to execute a task is common (Carr & Shepherd, 2010) and is worthy of a thorough examination in patients with schizophrenia. In addition, given that movement control mechanisms may vary in unimanual and bimanual tasks (Kelso, Southard, & Goodman, 1979), it is inappropriate to generalize the results of unimanual tasks to represent the movement features of bimanual tasks. Therefore, our study aimed to examine the movements of patients with schizophrenia in a bimanual assembly task similar to a typical work activity.

Effects of Object Size on Movements

According to the Occupational Therapy Practice Framework: Domain and Process (2nd ed.; American Occupational Therapy Association, 2008), object properties, such as size, are major task constraints that affect movement performance. Many studies have reported significant effects of object size on unimanual and bimanual movements in healthy people (Adam, 1992; Bingham et al., 2008; Fitts, 1954; Fowler et al., 1991). For unimanual movements, researchers have found a robust relationship between the object size and movement time; that is, a smaller object induces a slower movement (Adam, 1992; Fitts, 1954). For bimanual movements that aim at separate objects, the bilateral upper limbs exhibit a natural tendency to interact with each other and move synchronously (Jackson, Jackson, & Kritikos, 1999; Kelso et al., 1979). Therefore, decreasing the object size for one hand simultaneously induces slower movements for both hands (Kelso et al., 1979). In addition, it is more difficult for both hands to keep this bimanual coordination at the end of the movement as the object sizes decrease (Bingham et al., 2008; Fowler et al., 1991).

Earlier research has shown that patients with schizophrenia respond to object properties (texture and mass) in a manner similar to that of healthy people (Delevoye-Turrell et al., 2003). Until now, no published studies have examined the effects of object size on bimanual movements in patients with schizophrenia. It is worth examining how patients respond to changes in object size because this investigation could provide rehabilitation guidelines for how to grade task demands to optimize unimanual and bimanual movements in such patients. It would also help the practice of evidence-based therapy for patients with schizophrenia.

Research Purposes and Hypotheses

The purpose of this study was to examine, in patients with mild schizophrenia, the effects of object size on unimanual and bimanual movements in a bimanual assembly task. We analyzed unimanual (movement speed and forcefulness) and bimanual (coordination) movement features. First, we hypothesized that patients would have slower and less forceful unimanual movements, as well as less coordinated bimanual movements, than healthy control participants. Second, we hypothesized that increasing the object size would induce faster and more forceful unimanual movements and more coordinated bimanual movements in patients with schizophrenia.

Method

Research Design

A counterbalanced repeated-measures design was used. Participants were randomly assigned to either the large-object condition or the small-object condition first and the other condition second. The study protocol was approved by the Human Research Ethics Committee of Jianan Mental Hospital in Taiwan. All participants signed informed consents.

Participants

We used convenience sampling to recruit patients with mild schizophrenia and healthy control participants. The two groups were matched on age and gender. Patients were recruited from the day care or chronic wards of a psychiatric teaching hospital. Healthy control participants...
were recruited from a university. The inclusion criteria for participants with mild schizophrenia were (1) diagnosis of schizophrenia or schizoaffective disorder by a psychiatrist on the basis of criteria of the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (American Psychiatric Association, 1994); (2) absence of extrapyramidal motor symptoms according to results on the Extrapyramidal Symptom Rating Scale (Chouinard & Margolese, 2005; Chouinard, Ross-Chouinard, Annable, & Jones, 1980); (3) stable psychiatric symptoms—that is, the use of the same oral or injected antipsychotics for at least the 4 wk immediately before the study began; (4) sufficient cognitive ability—that is, a score $>$24 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975; Guo et al., 1988); (5) right-handedness; (6) no substance abuse; and (7) no neurological or musculoskeletal diseases, diabetes mellitus, or other diseases that might affect manual movements. We used the Positive and Negative Symptom Scale (Cheng, Ho, Chang, Lan, & Hwu, 1996; Kay, Fiszbein, & Opler, 1987) to evaluate symptom severity in patients with schizophrenia; higher scores mean more severe symptoms. The inclusion criteria for healthy control participants were Criteria 4 through 7.

Task Setup and Kinematic Measures

All task materials were placed on a height-adjustable table. A stationary pin (target) mounted on a base was centered 60.0 cm from the body midline of the participant (Figure 1). The tip of the pin was 27.0 cm above the table. Two cylindrical objects were located close to the participant’s midline near the edge of the table. The right object was 3.0 cm wide. Two sizes of the left object were used: large (7.0 cm wide) and small (3.0 cm wide). We manipulated the size of the left object because the literature (Riek, Tresilian, Mon-Williams, Coppard, & Carson, 2003; Srinivasan & Martin, 2010) suggests that a right-handed person tends to look at the left object first. The large and small objects had the same height (1.4 cm) and similar weights (21.5 g and 20.9 g). Inner diameters (4.7 cm and 2.0 cm) were two-thirds of the outer diameters (7.0 cm and 3.0 cm) for each object. For the starting position, the participant was required to place the right hand 40.0 cm away from the right object and to place the left hand 20.0 cm away from the left object. Unequal aiming distances for each hand were set to simulate an actual work situation.

Movements were recorded by an optical motion capture system (Qualisys AB, Gothenburg, Sweden) containing six cameras and a stationary measurement computer. The cameras use light-emitting diodes to generate invisible infrared flashes and illuminate reflective markers, after which they capture three-dimensional movements of the markers. Movements were recorded at 70 Hz. Six markers (0.4 cm in diameter; three on each hand) were attached to the participant to capture hand movements: on the dorsal side of the thumbnail and index fingernail and on the metacarpal base of the long finger (wrist). Three additional markers were attached to the upper side of the two objects to capture the position of the object planes. One marker was attached to the top of the target pin to capture its position. Motion capture data in the computer were tracked by Qualisys Track Manager software (Qualisys AB, Gothenburg, Sweden) and then streamed to Matlab 7.1 (Mathworks, Natick, MA) for kinematic calculation.

Procedures

Each participant sat in front of a table with the table height adjusted close to his or her elbow. The participant put each hand on the corresponding starting position. Upon receiving the starting signal, the participant moved both hands inward to grasp the objects (prehension) and then moved both hands forward to place objects on the target pin (assembly). The participant was asked to grasp the object with the thumb and index finger and to place the left object first and then the right one. In addition, the participant was required to perform the task as quickly and accurately as possible. After a short practice session, the participant did five trials in each condition with a 5-min break between conditions.

Variable Definitions

We dissected the movement sequence into prehension and assembly and identified four critical events (time points of movement onset and movement end). The definitions of critical events were (1) prehension onset, which was when the initial wrist velocity reached a speed that was 5% of the prehensile peak velocity; (2) prehension end, which was when the thumb velocity dropped to 0 mm/s and the average position of the three markers on the object did not change; (3) assembly onset, which was when the wrist velocity reached a speed that was 5% of the assembly peak velocity; and (4) assembly end (goal achievement), which was when the left object dropped to the pin for the left hand and when the right object dropped to the pin for the right hand.

To characterize unimanual movements, we calculated movement time and peak velocity to represent movement speed and forcefulness. Movement time is defined as the time interval between movement onset and movement end. A shorter movement time means a faster movement. Peak velocity is the maximal instantaneous velocity during a movement. A higher peak velocity means greater force generation (Lin, Wu, Lin, & Chang, 2008).

For bimanual coordination, we calculated the timing interval between both hands at critical events, including...
prehension onset, prehension end, assembly onset, and assembly end. A shorter interval indicates more synchronous bimanual movements and thus better bimanual coordination (Wu et al., 2009).

**Data Analysis**

We used two-way analysis of variance (ANOVA) with one between factor (Group: patients with mild schizophrenia vs. healthy control participants) and one within factor (Size: large vs. small). Significance (two-tailed) was set at .05. Effect size, $\eta^2$, was calculated to estimate the magnitude of the effects. Values for small, medium, and large effect sizes are $\eta^2 = .01$, .06, and .14, respectively (Cohen, 1988).

**Results**

**Participant Characteristics**

Fifteen patients with mild schizophrenia and 15 healthy control participants were enrolled in our study. No participants withdrew. Table 1 shows demographic and clinical characteristics of participants. The age- and gender-matched control participants had significantly higher education levels and scores on the Mini-Mental State Examination than the patients.

**Group Differences**

Two-way ANOVA showed no significant Group $\times$ Size interaction effects for any variables (Table 2). For unimanual movements, significant group effects were found for prehensile and assembly movement times and for assembly peak velocities for both hands. For bimanual movements, a significant group effect was found for the timing interval at assembly end. Compared with the control participants, the patients with schizophrenia had longer prehensile and assembly movement times, lower assembly peak velocities for both hands, and a longer timing interval between both hands at assembly end.

**Effects of Object Size**

For unimanual movements, significant size effects were found for prehensile and assembly movement times, for the assembly peak velocities for both hands, and for the prehensile peak velocity for the right hand (Table 2). For bimanual movements, significant size effects were found for the timing intervals at prehension end and assembly end. Compared with the small-object condition, the large-object condition yielded shorter prehensile and assembly movement times, higher assembly peak velocities for both hands, a higher prehensile peak velocity for the right hand, and shorter timing intervals between both hands at prehension end and assembly end.

**Discussion**

To our knowledge, this is the first study that kinematically analyzed bimanual functional movements in patients with mild schizophrenia and that showed significant effects of object size on patients’ unimanual and bimanual movements. The patients’ unimanual movements were slower and less forceful than those of the healthy control participants when they performed the bimanual assembly task, and their bimanual movements were less coordinated than those of the control participants. In addition, the patients responded to changes in object size in a manner similar to that of the healthy control participants. That is, the increase in the object size elicited faster and more forceful unimanual movements, as well as more coordinated bimanual movements, both in patients and in control participants.
Patients’ Movements in the Bimanual Assembly Task

In the bimanual assembly task, the patients had slower and less forceful unimanual movements, as well as less coordinated bimanual movements at assembly end, than the control participants. These results are consistent with those of other studies that reported movement disorders in patients with schizophrenia (Delevoye-Turrell et al., 2003; Haddad & Mattay, 2011; Henkel et al., 2004; Koning et al., 2010; MacRae, 2005; Pappa & Dazzan, 2009). Our study extends earlier reports by providing information on how the patients generated bimanual functional movements in terms of speed, forcefulness, and bimanual coordination. We quantified the patients’ movement process instead of merely showing movement outcomes. The results of movement impairments may be explained by patients’ basal ganglia dysfunction (Shenton, Dickey, Frumin, & McCarley, 2001; Torrey, 2002), which disables the internal modulation of motor programs from the cerebral cortex (Canning, 2010) and thus leads to impaired timing control over unimanual and bimanual movements (Debaere, Wenderoth, Sunaert, Van Hecke, & Swinnen, 2003; Majsk, Kaminski, Gentile, & Flanagan, 1998).

Table 1. Demographic and Clinical Characteristics of Study Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients (n = 15)</th>
<th>Control Participants (n = 15)</th>
<th>Statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>33.99 (4.93)</td>
<td>32.02 (4.98)</td>
<td>t(28) = 1.09</td>
<td>.287</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>8/7</td>
<td>8/7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education, yr</td>
<td>11.87 (1.73)</td>
<td>18.33 (3.24)</td>
<td>t(21.342) = 6.82</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Duration of illness, yr</td>
<td>12.13 (4.05)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>28.80 (0.94)</td>
<td>29.47 (0.74)</td>
<td>t(28) = 2.15</td>
<td>.040</td>
</tr>
<tr>
<td>PANSS: Positive symptoms</td>
<td>14.20 (5.06)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANSS: Negative symptoms</td>
<td>17.20 (2.65)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANSS: General psychopathology</td>
<td>32.20 (7.55)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERS: Clinical global impression severity of dyskinesia</td>
<td>0.13 (0.52)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERS: Clinical global impression severity of parkinsonism</td>
<td>1.60 (0.51)</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. ERS = Extrapyramidal Symptom Rating Scale; MMSE = Mini-Mental State Examination; NA = not applicable; PANSS = Positive and Negative Symptom Scale.

aUnless otherwise indicated, data are means (standard deviation).b n = 13 because of missing data from 2 patients’ medical records.

Table 2. Descriptive and Inferential Statistics for Unimanual and Bimanual Kinematics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Descriptive Dataa</th>
<th>Two-Way ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients (n = 15)</td>
<td>Control Participants (n = 15)</td>
</tr>
<tr>
<td></td>
<td>Large Object</td>
<td>Small Object</td>
</tr>
<tr>
<td>Prehension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT, s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand</td>
<td>0.71 (0.17)</td>
<td>0.82 (0.19)</td>
</tr>
<tr>
<td>Right hand</td>
<td>0.90 (0.22)</td>
<td>0.99 (0.22)</td>
</tr>
<tr>
<td>PV, mm/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand</td>
<td>418.94 (77.62)</td>
<td>411.76 (82.54)</td>
</tr>
<tr>
<td>Right hand</td>
<td>928.85 (153.46)</td>
<td>856.91 (197.84)</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT, s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand</td>
<td>0.66 (0.13)</td>
<td>0.83 (0.19)</td>
</tr>
<tr>
<td>Right hand</td>
<td>1.14 (0.38)</td>
<td>1.35 (0.48)</td>
</tr>
<tr>
<td>PV, mm/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand</td>
<td>833.48 (135.47)</td>
<td>783.87 (149.70)</td>
</tr>
<tr>
<td>Right hand</td>
<td>601.19 (220.86)</td>
<td>569.43 (202.84)</td>
</tr>
</tbody>
</table>

Note. ANOVA = analysis of variance; MT = movement time; PV = peak velocity.

aData are means (standard deviation).b Timing intervals between both hands at critical events.
We used the Extrapyramidal Symptom Rating Scale to ensure that we included only patients with schizophrenia who had no extrapyramidal motor symptoms. The results of our kinematic analysis showed that, compared with control participants, the patients without extrapyramidal motor symptoms still had slower, less forceful, and less coordinated movements. Our findings are consistent with previous studies that indicated that instrumental measures are more sensitive to subclinical motor impairments than observer-based ratings (Caligiuri & Lohr, 1994; Cortese et al., 2005; Pappa & Dazzan, 2009). Our findings illustrate the importance of kinematic measures in identifying patients’ movement impairments and detecting their movement responses to therapy. We suggest that occupational therapy practitioners consider movement rehabilitation for patients with mild schizophrenia.

**Effects of Object Size**

We manipulated the size of the left object and found that movements of both hands were affected. A large object induced faster and more forceful unimanual movements, as well as more coordinated bimanual movements, than did a small object in patients with mild schizophrenia and in healthy control participants. The result that patients responded to the object property in a manner similar to the healthy control participants is in accordance with earlier research (Delevoye-Turrell et al., 2003).

Moreover, the effect of object size is consistent with previous studies (Adam, 1992; Bingham et al., 2008; Fitts, 1954; Fowler et al., 1991; Kelso et al., 1979). We extend earlier findings by showing that this effect also exists in patients with schizophrenia. Rose and Christina (2006) suggested that when people reach for objects of various sizes, the visual system provides the brain with information to correct endpoint errors of the movement trajectory and thus to ensure that the movement is accurate. More time to correct movements is needed when objects are smaller (Shumway-Cook & Woollacott, 2007), which results in a longer movement time. For bimanual movements, because both upper limbs rely on visual information to correct movements, decreasing the object size makes it more difficult for the visual system to simultaneously guide both hands (Bingham et al., 2008). People need to fixate on one object first to correct endpoint errors of the movement trajectory and then fixate on the other object for the same purpose (Bingham et al., 2008; Riek et al., 2003; Srinivasan & Martin, 2010), thus leading to decreased bimanual synchronization at movement ends.

We found that increasing the object size induced higher peak velocities in assembly movements. A few studies on the effect of object size on peak velocities reported contradictory results (Adam, 1992; Bingham et al., 2008; Jackson et al., 1999). One possible reason is that different studies had different movement requirements. Our study and others (Adam, 1992; Jackson et al., 1999) that used pointing or prehensile movements reported that increasing the object size elicited higher peak velocities. However, Bingham et al. (2008), who not only required prehensile movement but also required fingers to contact designated parts of the object, found no effects of object size on peak velocities. We hypothesize that complex movements weaken the impact of object size on peak velocities; this hypothesis needs additional examination.

**Limitations and Future Research**

Our study has some limitations. First, we enrolled only patients with mild schizophrenia who had good cognition and no extrapyramidal motor symptoms. Patients with tremor or rigidity may have different movement responses to changes in object size; therefore, we are cautious about generalizing our results. Second, we did not categorize patients with different symptom severities or medication histories; therefore, we are unable to know whether these differences would yield different movement results. Third, the education levels of the patients and control participants were not matched. However, we do not consider educational level a confounding factor because of a negligible correlation between education and movements (Berman et al., 1997; Keefe et al., 2006).

Some issues need further investigation. First, it is worth investigating whether changes in object size would induce movement adjustments in patients with extrapyramidal motor symptoms or in patients with different symptom severities and medication histories. Second, future research is needed to design bimanual movement training that incorporates the manipulation of object size and to examine its long-term effect in patients. Finally, comparing effects between object size and other task constraints, such as movement complexity, may help clarify their differential influences on movements in patients.

**Implications for Occupational Therapy Practice**

Our findings have the following implications for occupational therapy practice:

- When performing a bimanual assembly task, patients with mild schizophrenia may execute movements more slowly, less forcefully, and with less bimanual coordination at movement end than healthy control participants.
• When patients with mild schizophrenia perform a bimanual assembly task, increasing the object size may elicit faster and more forceful unimanual movements and more coordinated bimanual movements at movement end.

• Occupational therapy practitioners should keep in mind that patients with schizophrenia may have impaired motor skills; movement rehabilitation for patients with schizophrenia is important.

• Manipulating the object size to grade task demands should be considered in bimanual movement training for patients with mild schizophrenia.

Conclusion

The two main contributions of this study to occupational therapy are that it (1) identifies specific movement impairments during a bimanual function task in patients with mild schizophrenia and (2) examines the effects of changing the object size on patients’ unimanual and bimanual movements. We found that patients with mild schizophrenia performed the bimanual assembly task more slowly, less forcefully, and with less bimanual coordination at assembly end than healthy control participants. Increasing the object size for the task elicited faster and more forceful unimanual movements and more coordinated bimanual movements at movement end in patients with mild schizophrenia.

These results provide insights into the movement features of patients with mild schizophrenia during the bimanual functional task and also provide clear rehabilitation guidelines for grading task demands to optimize patients’ movements. These results contribute to the practice of evidence-based occupational therapy for patients with mild schizophrenia. Future studies need to examine the effects of object size on movements in patients with different symptom severities and in those taking different types of medications. ▲

Acknowledgments

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References


By Catana Brown, PhD, OTR, FAOTA

This new AOTA Practice Guideline outlines the process of occupational therapy for serious mental illness, the leading cause of disability in the United States.

Applying the *Occupational Therapy Practice Framework* evidence-based perspective and key concepts, the guideline details interventions and explains the contribution of the profession in mental health in areas such as education, work, community-living, health and wellness, and cognition. Evidence-tables in each area are included, as well as examples of diagnostic and billing coding.

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