Directional and Spatial Motor Intentional Disorders in Patients With Right Versus Left Hemisphere Strokes

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Objective: Motor intentional disorders (MIDs) are characterized by dysfunction in the preparation, initiation, maintenance, and termination of goal-oriented actions. In this study, we investigated (1) whether patients with right hemisphere strokes (RHS) and left hemisphere strokes (LHS) differ in the frequency of delayed action initiation (hypokinesia) and motor impersistence; (2) whether there is a directional or hemispatial component of hypokinesia or motor impersistence; (3) whether there is an association between the presence of hemispatial neglect and tests for MID; and (4) the location of injury associated with MID. Method: Thirty-two patients with acute unilateral stroke (21 with RHS and 11 with LHS) and 12 age-matched healthy controls participated in the study. To determine the presence and severity of directional and spatial hypokinesia and impersistence we used a new apparatus, the Directional Movement Tester (DMT). While being tested with the DMT, the participants held a static bar located either in the right or left hemispace using either their right or left hand and upon stimulus onset pushed the bar either leftward or rightward and maintained a given force for 10 sec. Results and Conclusion: The frequency of hypokinesia and impersistence was higher in the RHS group than in the LHS group, but there were no hypokinetic directional or spatial asymmetries. The RHS group did demonstrate left contralesional directional impersistence, but there were no spatial asymmetries of impersistence. Signs of hemispatial neglect were not associated with these measures of MID. Participants with frontal or subcortical lesions were significantly more likely to demonstrate hypokinesia and impersistence than those with posterior lesions.

Keywords: motor intention, hypokinesia, motor impersistence, direction, hemispatial neglect

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Motor intentional disorders (MIDs) are induced by the disruption of systems that control the planning, initiation, maintenance, and termination of purposeful actions (Heilman, 1991). Our study focused on two forms of MID, akinesia (or hypokinesia) and motor impersistence. Patients with motor initiation disorders are unable to initiate a movement (akinesia) or have delays in their ability to initiate a movement (hypokinesia) despite intact elementary sensory or motor functions. Patients with motor impersistence are impaired in sustaining an action (Heilman, 2004).

Hemispatial neglect refers to a syndrome in which patients with unilateral brain injury fail to report or respond to stimuli presented in a portion of space, primarily contralesional space (Heilman, Watson, & Valenstein, 2003). Hemispatial neglect can be divided into two major components: sensory-attentional neglect resulting from decreased awareness of, or attention to, stimuli presented contralesionally and motor-intentional neglect resulting from a failure to move the ipsilesional limb into or toward contralateral hemispace in response to contralateral stimuli even when the patient is aware of the stimuli (Heilman et al., 2003). Several studies have demonstrated the dissociation of motor-intentional neglect from sensory-attentional neglect (Chiba, Yamaguchi, & Eto, 2005; Coslett, Bowers, Fitzpatrick, Haws, & Heilman, 1990; Ghacibeh, Shenker, Winter, Triggs, & Heilman, 2007; Na et al., 1998).

In the context of motor-intentional hemispatial neglect, hypokinesia can be further subdivided into directional hypokinesia (Heilman, Bowers, Cossett, Whelan, & Watson, 1985) and spatial hypokinesia (Meador, Watson, Bowers, & Heilman, 1986). Patients with directional hypokinesia resulting from right hemisphere lesions may show delayed movement initiation when they move toward the contralesional side compared with the ipsilesional side regardless of the hemispace in which this action takes place. Patients with hemispatial hypokinesia have more delayed movement initiation when their limb movements take place in contralateral (e.g., left) rather than ipsilesional (e.g., right) hemispace regardless of the direction of movement. Likewise, motor impersistence may also be divided into spatial and directional motor impersistence (Heilman, 2004).

Most previous studies of MID relied on bedside evaluations for assessment (Coslett & Heilman, 1989; Heilman, 2004; Kertesz, Nicholson, Cancellerie, Kassa, & Black, 1985; Sandson & Albert, 1987) and few studies have quantified these disorders (Seo et al., 2009). A prior study from our group quantified MID in patients with right hemisphere stroke (RHS) using a finger dynamometer, in which the four components of MID including initiation, development, maintenance, and termination of a force, were investigated. The results of this study showed that the use of a finger dynamometer could be a sensitive method for demonstrating MID compared with conventional bedside examinations, and that this technique was especially good for examining the maintenance phases of forces (Seo et al., 2009). Although this was the first study that quantified motor intention using a force dynamometer, the authors did not measure the directional components of MID because the subjects were asked to press a dynamometer placed on a table and therefore the direction of movement was not assessed. Therefore, we developed a new apparatus called Directional Movement Tester (DMT), which could quantify the directional and spatial components of the action initiation and action persistence components of MID. When using the DMT to quantify directional and spatial hypokinesia as well as directional and spatial motor impersistence, the participants were asked, in response to stimuli displayed on a monitor, to start pushing a static bar placed in either left or right body-centered hemispace in either a rightward or leftward direction and then to maintain a certain force for a given duration.

The goals of the present study are two-fold. First, we wanted to quantify hypokinesia and motor impersistence and compare the frequencies of these disorders in patients with right versus left hemisphere strokes. Second, we wanted to learn whether an asymmetrical directional and/or spatial motor impersistence exists in patients with left or right hemisphere strokes. Although several studies have investigated directional and spatial hypokinesia in unilateral stroke patients (Coslett & Heilman, 1989; Heilman et al., 1985; Mattingley, Bradshaw, & Phillips, 1992; Meador, Watson, Bowers, & Heilman, 1986; Valenstein & Heilman, 1981), to our knowledge there has been only one case study that examined spatial motor impersistence (Roeltgen, Roeltgen, & Heilman, 1989) and there are no reported studies of directional motor impersistence. Furthermore, in our previous study there was no hemispatial effect (right vs. left hemispace) of MID, and therefore a systematic study was needed to investigate whether the directional effects of MID are stronger than the spatial effects, or vice versa. Third, a few studies have suggested that directional or spatial MID is one of the factors responsible for the signs and symptoms associated with unilateral neglect (Bisiach, Gemini, Berti, & Rusconi, 1990; Cossett et al., 1990; Mattingley et al., 1992; Na et al., 1998). However, only one study has explored the association between conventional tests of neglect and the results of tests on directional or spatial MID (Mattingley et al., 1992). Therefore, we wanted to determine whether there are associations between the conventional tests of neglect and tests for MID (directional or spatial hypokinesia and motor impersistence). Lastly, we wanted to evaluate neuroanatomical correlates of MID by comparing left versus right hemispheric injury and anterior versus posterior intrahemispheric brain injury. Whereas the human intention system is known to be mediated primarily by right hemispheric networks that include the frontal lobe and MID can be induced by lesions of the right frontal lobe (Heilman, 2004), the lesion studies for MID have been primarily based on case reports and small series (Heilman et al., 2003; Kertesz et al., 1985; Sandson & Albert, 1987). Thus, the studies of neural correlates of directional or spatial MID have been rare and based on computed tomography (CT) findings (Coslett & Heilman, 1989; Heilman et al., 1985; Mattingley et al., 1992; Meador et al., 1986).

Materials and Methods

Participants

Patients. Between April 2010 and January 2011, a total of 107 patients were admitted to the Neurology Department at Pusan National University Hospital for first acute cerebral infarctions involving unilateral supratentorial vascular territory. All patients fulfilled the following criteria: right or left hemispheric infarction involving at least two cortical gyrus, or subcortical infarction involving subcortical white matter, basal ganglia, or thalamus. Of the 107 patients, 75 were excluded, including 11 for significant diffuse cerebral white matter changes, 1 with a history of dementia before...
the stroke, and 63 who had neurologic signs that impaired their ability to follow the directions of the experimental protocol (41/63 with impaired level of consciousness, e.g., drowsy, stupor, semicomatose, or coma according to the Glasgow coma scale, 32/63 with aphasia and impaired spontaneous speech or comprehension by bedside neurological examination, or 3/63 with left-right disorientation). None of the patients had problems with their ipsilateral arms that interfered with the experimental task.

Based on these criteria, the participants in this study consisted of 32 patients (23 men and 9 women, age 59.3 ± 11.9 years, Mini-Mental State Examination [MMSE] scores 21.5 ± 6.4). They were divided into 21 RHS patients (13 men and 8 women, age 60.4 ± 11.1 year, MMSE score 23.3 ± 4.3) and 11 LHS patients (10 men and 1 woman, age 57.2 ± 13.5 years, MMSE score 18.5 ± 8.3). Eighteen out of 21 patients with RHS and all 11 patients with LHS were right-handed. All patients had undergone brain magnetic resonance imaging (MRI), and 30 out of 32 completed neglect tests. The mean time intervals from acute stroke onset to neglect testing and experimental testing were 6.5 ± 6.3 and 8.0 ± 6.1 days, respectively. The RHS and LHS patients did not differ in age, t(17) = −0.68, p = .508, MMSE score, t(13) = −1.75, p = .103, and the interval between stroke and experiment testing (RHS: 8.2 ± 7.3 days; LHS: 7.6 ± 2.9 days; t(28) = −0.38, p = .706) except for gender ratio (z = 2.12, p = .034) (see Table 1).

**Controls.** Twelve right-handed individuals matched to patients by age and sex (six men and six women, mean age 61.4 ± 5.7 years, mean MMSE score 28.8 ± 1.3) with no history of neurologic or psychiatric illnesses participated in the experiment. Informed consent was obtained from all participants and the study was approved by the institutional review board of Pusan National University Hospital.

**Apparatus**

The DMT (Figure 1A) was constructed to measure reaction times and an ability to maintain a force for each hand. It was placed on a table at a distance of 40 cm from the participant’s body, oriented horizontally (width 145 cm × vertical 18 cm × height 10 cm) parallel to the subjects’ coronal plane, and with the center of the apparatus aligned with the midsagittal plane of the subject’s body. In the center of the DMT there was a 100 cm rail but, in the experiment the bar was set 20 cm to the right or left of the subject’s body. In the center of the DMT there was a 100 cm rail but, in the experiment the bar was set 20 cm to the right or left of the subject’s midsagittal plane using a step motor (4S56Q-02154S; step angle 0.8 degree, motor length 54 mm; Saehan Electronics Co. Ltd., Ichon, South Korea). Forces applied to the subject were recorded at a sampling rate of 200 Hz and ME was calculated using exerted forces by the subject at the designated force, respectively. In each trial the time taken to initiate a designated force, respectively. In each trial the time taken to initiate a movement (reaction time, RT), and the error in maintaining the designated force level (maintenance error, ME) were measured. Forces exerted by the subject were recorded at a sampling rate of 200 Hz and ME was calculated using exerted forces by the subject below the target force as follows: ME = \sum_{i=1}^{n} (19.8 - fi)h, i =
number of measurements, $f_i = i$th force measurement (N), and $n =$ total number of measurements of which the subject’s force $< 19.8$ N. If subjects reached the target force and maintained it for 10 sec, the trial automatically ended. Even if they reached the target force but could not maintain this force, the trial still ended 10 sec after the time of reaching the target force. Only patients’ ipsilesional hands were tested and controls performed the experiment using their right and left hands. Therefore, we performed a total of 24 trials for patients (six trials with four conditions) and 48 trials for controls (six trials with eight conditions) divided into two blocks of 24 trials with a 20-min rest between the blocks.

Assessment of Hemispatial Neglect

A psychometrician who was unaware of the clinical data and imaging results administered a series of neglect tests. These tests included line bisection, cancellation, and figure copying, which have been demonstrated to be reliable and valid tests of spatial
has been described previously (Lee et al., 2004). Briefly, the solid central character was multiplied by 5.5 mm. Positive and negative deviations from the true midpoint were approximately aligned with the center of the character lines. The score for each subject was calculated by subtracting the true midpoint from the subject's midpoint. For each test, the score of all tests has been described previously (Lee et al., 2004). Briefly, the solid central character was multiplied by 5.5 mm. Positive and negative deviations from the true midpoint were measured to the closest millimeter in solid-line bisection test. For order between subjects. Deviation from the true midpoint was measured to the closest millimeter in solid-line bisection test. For character-line bisection test, the number of intercharacter spaces between the true central character and the subject's choice of central character was multiplied by 5.5 mm. Positive and negative values denoted rightward and leftward deviation, respectively. To convert to a 10-point scale ranged from 10 to 10, each mean deviation error divided by 121 was multiplied by 10. Seven points were assigned to the two figure copying tasks. There are four objects (left pine tree, fence, house, and right tree) in the modified Ogden Scene. For each object, we scored 1 for failure to reproduce objects on the left side of the patient’s drawing (i.e., left scene-based neglect), 0.5 for objects that have missing elements from the left side of the object (i.e., left object-centered neglect), and 0 for a complete figure. Conversely, subjects scored −0.5 for right-sided object-centered neglect and −1 for right scene-based omission. Because the fence in the Ogden Scene is symmetric, the score of 0.5 or −0.5 was not applied; instead we scored this part as either 0 (complete drawing), 1 (complete omission of the left side of the fence), or −1 (complete omission of the right side of the fence). Similarly, we considered three objects within the Two Daisy Figure Test (left daisy, right daisy, and pot) and applied the scoring method described for the Ogden Scene to each object. The final score was obtained by summing scores of the two drawings, yielding scores that ranged from −7 to 7. Thus, when summing the scores of all tests, a final score ranged from +57 to −57. This score was again modified to a 100-point scale score such that the possible scores can range from −100 to 100. A positive score indicated rightward bias and a negative score leftward bias. A patient was classified as having hemispatial neglect if his or her total neglect score was at least 2 SD poorer than that of the normal control group. In this study, 13 (10 with RHS and 3 with LHS) of 30 patients revealed contralesional hemispatial neglect (see Table 2).

### Lesion Analysis

A neurologist who was unaware of the clinical findings reviewed the diffusion-weighed MRI scans and coded the lesion locations as anterior (A group: frontal lobe, frontotemporal, subcortical areas), posterior (P group: parietal and occipital lobes), and subcortical (S group: subcortical gray matters such as basal ganglia and thalamus, subcortical white matters at frontoparietal junction such as the centrum semiovale). The 18 RHS patients were classified by lesion location as follows: six in A group, three in P group, and nine in S group. The 11 LHS patients were similarly grouped: three in A group, four in P group, and four in S group. Three patients with RHS who had lesions located over two or more locations were excluded from the lesion analysis. The lesion location did not differ between RHS and LHS patients (χ2(2) = 1.46, p = .482).

The lesions identified by diffusion-weighed MRI scans were manually traced on the standard T1-weighted MRI templates provided by MRicro (http://www.mricro.com) by a neurologist who was blinded to the patients’ clinical information. The standard templates used for our study were 12 axial slices (−32, −24, −16, −8, 0, 8, 16, 24, 32, 40, 50, and 60 on Talairach z coordinate). The neurologist overlapped lesions of patients in each group (A, P, and S groups). All left-sided lesions were flipped to the right side before the overlap. The number of overlaps in each pixel was color coded, ranging from violet (n = 1) to red (n = maximum number in the respective group) (see Figure 2).

A neurologist blinded to each patient’s clinical status measured lesion volume. In each section, the lesion’s boundary on MR

### Table 2: Demographical Data of the Patients With Neglect

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex (M:F)</th>
<th>K-MMSE</th>
<th>Lesion volume (cm³)</th>
<th>Lesion side and location</th>
<th>Neglect score</th>
<th>MIDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>58</td>
<td>M</td>
<td>20</td>
<td>Right, A</td>
<td>6.956</td>
<td>—</td>
</tr>
<tr>
<td>P2</td>
<td>71</td>
<td>F</td>
<td>18</td>
<td>Right, S</td>
<td>3.485</td>
<td>RT (+), ME (+)</td>
</tr>
<tr>
<td>P3</td>
<td>70</td>
<td>M</td>
<td>22</td>
<td>Right, P</td>
<td>3.215</td>
<td>—</td>
</tr>
<tr>
<td>P4</td>
<td>56</td>
<td>M</td>
<td>27</td>
<td>Right, Mix</td>
<td>3.839</td>
<td>—</td>
</tr>
<tr>
<td>P5</td>
<td>61</td>
<td>F</td>
<td>29</td>
<td>Right, P</td>
<td>5.423</td>
<td>—</td>
</tr>
<tr>
<td>P6</td>
<td>65</td>
<td>F</td>
<td>27</td>
<td>Right, S</td>
<td>4.244</td>
<td>ME (+)</td>
</tr>
<tr>
<td>P7</td>
<td>62</td>
<td>M</td>
<td>27</td>
<td>Right, Mix</td>
<td>6.462</td>
<td>ME (+)</td>
</tr>
<tr>
<td>P8</td>
<td>59</td>
<td>F</td>
<td>11</td>
<td>Right, A</td>
<td>−1.576</td>
<td>—</td>
</tr>
<tr>
<td>P9</td>
<td>59</td>
<td>M</td>
<td>20</td>
<td>Left, A</td>
<td>−1.751</td>
<td>ME (+)</td>
</tr>
<tr>
<td>P10</td>
<td>71</td>
<td>M</td>
<td>27</td>
<td>Left, P</td>
<td>13.407</td>
<td>—</td>
</tr>
<tr>
<td>P11</td>
<td>48</td>
<td>M</td>
<td>16</td>
<td>Right, S</td>
<td>2.565</td>
<td>ME (+)</td>
</tr>
<tr>
<td>P12</td>
<td>69</td>
<td>M</td>
<td>16</td>
<td>Right, S</td>
<td>4.666</td>
<td>RT (+), ME (+)</td>
</tr>
<tr>
<td>P13</td>
<td>49</td>
<td>M*</td>
<td>5</td>
<td>Left, P</td>
<td>−13.751</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: K-MMSE = Korean version of Mini-Mental State Examination; A = anterior group; S = subcortical group; P = posterior group; MID = Motor Intentional Disorders; RT = Reaction time; ME = Maintenance Error.

* Even though the K-MMSE score of P13 was too low, there were no difficulties in performing the experimental tasks.
diffusion-weighted images was outlined using a manual pixel-wise method with the aid of a PACS workstation (Infinitt Health Care, Seoul, Korea). The lesion volume was computed in cubic centimeter by multiplying the area of lesions in consecutive MRI slices by the slice thickness plus the interslice gap distance. Overall, the mean lesion volume of all patients was 13.6 ± 13.4 cm³ (range: 1.6–53.7 cm³) and the lesion volume did not differ significantly between RHS (13.1 ± 13.5 cm³) and LHS (14.5 ± 14.0 cm³) patients, t(19) = 0.27, p = .788.

**Statistical Testing Methods**

Four-factor mixed-subjects ANOVA (between-subjects factors: group and neglect; within-subjects factors: space and direction) was conducted to examine the effects of group (RHS group and LHS group), space (right hemispace and left hemispace), direction (rightward and leftward), and neglect (neglect-positive and neglect-negative) to RT and ME. One-way ANOVA was performed to test the effect of lesion location on mean RT and ME in each of the RHS and LHS groups. As post hoc analysis, we applied t test for two groups with unequal sample sizes and unequal sample variances and Tukey–Kramer test for three or more groups to test the mean differences in RT and ME. Statistical testing was conducted using Minitab v. 14 with a significance level of .05.

**Results**

**Frequency of MID**

Tukey–Kramer test showed that overall mean RT of the RHS group (770 ± 202 ms), but not that of the LHS group (606 ± 143 ms), was significantly longer than that of the normal control (NC) group (607 ± 138 ms) at α = .05 (Figure 3A). Tukey–Kramer test also identified a significantly different ME between the groups at α = .05. The mean ME of the RHS (277 ± 143 mN) and LHS (189 ± 136 mN) groups was 2.1- and 1.5-fold greater, respectively, than that of the NC group (130 ± 50 mN) (Figure 3B).

If a patient’s performance in each condition (the mean value of six trials) was below 2 SD of the NC group when using the same hand, the patient was considered to exhibit MID. Independent of...
space and direction, the number of patients with MID in the RHS group was greater than the number of patients with MID in the LHS group in terms of both RT (RHS: 3/21, LHS: 1/11) and ME (RHS: 13/21, LHS: 3/11), and the difference in the frequency between the two patient groups was larger for ME than RT, such that the ME-based frequency of MID in the RHS group (62%) was 2.3-fold greater than that of the LHS group (27%) (z = 2.02, p = .043), while the RT-based frequency of MID in the RHS group (14%) appeared to be higher than that of the LHS group (9%), although this difference did not reach statistical significance (z = 0.45, p = .653).

Effects of Group, Space, Direction, and Neglect on RT and ME

Four-factor mixed-subjects ANOVA showed that the main effect of group was significant for both RT and ME. The RHS group showed a significantly longer mean RT and larger mean ME than the LHS group (RT: F(1, 29) = 7.92, p = .009; ME: F(1, 29) = 4.23, p = .049) (Figure 3A, B). The interaction between group and direction was significant for ME (F(1, 29) = 5.31, p = .029). As displayed in Figure 4, the RHS group showed a significantly larger mean ME when their movement was directed toward the left side and the LHS group showed a significantly larger mean ME when their movement was directed toward the right side. Otherwise, none of the main effects or interactions were significant for either RT or ME.

Associations Between Hemispatial Neglect and MID

In the LHS group, there was no association between hemispatial neglect and MID. The mean difference (MD) in RT and ME between neglect-positive patients and neglect-negative patients in the LHS group was not significantly different (RT: MD = 36 ms, t(16) = 0.67, p = .514; ME: MD = 82 ms, t(18) = −1.73, p = .101) (Figure 5A, B). In the RHS group, no association was observed between hemispatial neglect and RT (MD = 25 ms, t(65) = −0.55, p = .581). However, the ME of neglect patients (243 ± 123 ms) were lower than those without neglect (308 ± 155 ms) (MD = 65 ms, t(78) = 2.10, p = .039). To examine whether task specificity of neglect affected ME and RT, we compared ME and RT between the group with neglect on the line bisection and the group with neglect on the cancellation test. There was no significant difference in RT (t(14) = 0.23, p = .820) or ME (t(13) = −0.62, p = .546) between the group with neglect on the line bisection test (RT: 781 ± 212 ms, ME: 256 ± 105 mN) and those with neglect on the cancellation test (RT: 756 ± 219 ms, ME: 291 ± 167 mN).

Effects of Lesion Location on RT and ME

No significant differences in RT were observed among the three in both RHS (A: 771 ± 172 ms, S: 801 ± 255 ms, P: 728 ± 130 ms) [F(2, 73) = 0.69, p = .507] and LHS groups (A: 601 ± 137 ms, S: 667 ± 144 ms, P: 566 ± 140 ms) [F(2, 41) = 1.81, p = .176] (Figure 6A). In terms of ME, the Tukey–Kramer test showed that the ME of 5 groups in both the RHS and LHS patients (RHS: 334 ± 138 mN, LHS: 264 ± 157 mN) was significantly larger than those of A (RHS: 302 ± 154 mN, LHS: 183 ± 140 mN) and P (RHS: 150 ± 45 mN, LHS: 134 ± 84 mN) groups, and the ME of the A group in the RHS was significantly larger than that of the P group [RHS: F(2, 71) = 11.37, p < .001; LHS: F(2, 40) = 3.45, p = .042] (Figure 6B).

Lesion Analysis Based on the MID

To find neural correlates of MID, we divided the patients into two groups according to the presence of MID and then overlapped their lesions manually traced on the standard T1-weighted MRI templates provided by MRIcro (http://www.mricro.com) in each group.

Figure 7 demonstrates that the areas of patients with MID were mainly basal ganglia, superior, middle- and medial frontal-subcortical areas, and thalamus. In contrast, the areas of patients without MID were diffusely involving dorsolateral frontal, temporo-parietal cortex, and parts of basal ganglia. When all voxels that were damaged more often in patients with MID than those without MID were identified at α level p < .005, no lesion related to MID was found.

Discussion

We quantified the presence and severity of hypokinesia and motor impersistence in patients with LHS and RHS. Our results demonstrate that these two signs of MID were more commonly detected in participants with RHS than in those with LHS, even though the two groups were matched in terms of demographics and lesion volume. Our results are consistent with earlier reports indicating that hypokinesia and motor impersistence are more often associated with right than left hemispheric injury (Heilman, 2004; Heilman et al., 1985; Howes & Boller, 1975; Kertesz et al., 1985).

The hemispheric asymmetry observed for these MIDs is consistent with the action-intention dominance theory. Based on be-
behavioral studies in normal subjects and patients with strokes, it has
been suggested that the right hemisphere is dominant for motor
activation or intention (Coslett & Heilman, 1989; Heilman et al.,
According to this intentional dominance theory, the right hemi-
sphere mediates the preparation for initiation of goal-oriented
actions in and toward both right and left hemispace, while the left
hemisphere mediates action preparation and execution only in and
toward right hemispace (Heilman et al., 1985). Therefore, based on
this hypothesis, it is likely that MID would be more frequently
induced by right hemispheric lesions than by left lesions (Meador
et al., 1986).
We investigated the presence of directional and spatial hypoki-
sesia in patients with RHS or LHS. Directional or spatial hypoki-
sies has been reported in several previous studies (Heilman et al.,
1985; Mattingley et al., 1992; Meador et al., 1986). Heilman et al.
(Heilman et al., 1985) showed that patients with contralosional
neglect caused by right hemisphere lesions initiate responses to-
ward left hemispace more slowly than toward right hemispace.
Similarly, in a study by Mattingley et al. (Mattingley et al., 1992),
directional hypokinesia was found to be associated with both left and
right hemisphere damages, but only in the context of contralosional
neglect. Although we did find that the RHS groups were hypokinetic compared with the LHS group, we did not detect
directional or spatial hypokinesia in either our RHS or LHS group.
It is not clear why prior studies demonstrated this deficit and our
results did not.

Regarding motor impersistence, we found no evidence of the
spatial subtype of motor impersistence, even though the presence
of a spatial motor impersistence was reported by Roeltgen et al.
(Roeltgen et al., 1989) in a patient with the right caudate infarction
who was able to maintain motor activity (e.g., continuous tapping
for 60s) in right hemispace, but not in left hemispace. In contrast,
regarding directional motor impersistence our study showed that
the subjects with RHS and LHS did demonstrate directional motor
impersistence. Although Heilman (Heilman, 2004) introduced a
way to test directional motor impersistence of eye or head using
bedside examinations in which each patient was requested to gaze
or turn their head either to the left or right for 20 sec, it has never
been investigated in a group of patients. Therefore, to our knowl-
edge, the present study is the first to quantify directional motor
impersistence of the upper limb in patients with unilateral hemi-
spheric lesions. The reason for the discrepancy between spatial and
directional motor impersistence remains to be elucidated, but in a
previous study we also demonstrated that no significant spatial
effects exist in motor impersistence (Seo et al., 2009). The defi-
nition of motor impersistence, however, needs to be further clar-
ified. Motor impersistence can be defined as impairment in a
person’s ability to sustain or maintain an action or force. There-
fore, any alterations in force (either a decrease or increase) could
be considered impersistence. However, in most clinical studies in
which patients are asked to perform a task that requires maintain-
ing a certain degree of force, as in our study, motor impersistence
is considered to be “premature giving up” (a reduction of force that

![Figure 5. Association of hemispatial neglect with RT (A) and force
maintenance error (B) (mean ± SE). LHS = left hemisphere stroke,
RHS = right hemisphere stroke. (+) = groups with neglect, (-) = groups
without neglect.](image)

![Figure 6. Effects of lesion location on RT (A) and force maintenance
error (B) (mean ± SE). LHS = left hemisphere stroke, RHS = right
hemisphere stroke, A = anterior group, S = subcortical group, P =
posterior group.](image)
is below the target force) or “premature termination” of exerting a force (Seo et al., 2007). In our study, we defined motor impersistence as reduction of force below the target force. However, there is no definition of the degree of premature force reduction (e.g., 50 or 75% of target force) required to diagnose the presence of motor impersistence. Furthermore, motor impersistence in the previously reported cases may be “endo-evoked,” such that this deficit is primarily observed in the absence of external feedback. However, in our study we provided visual feedback to quantify premature giving up. Therefore, it is possible that the motor impersistence we identified might be a different form of motor impersistence from that observed in the absence of external feedback as reported in previous studies.

We hypothesized that patients with hemispatial neglect (+N) would show greater spatial or directional hypokinesia or impersistence than those without neglect (−N), but there was no significant relationship between hemispatial neglect and RT in either RHS or LHS group. Furthermore, contrary to our hypothesis, the ME in the RHS (+N) group was significantly less severe than that of the RHS (−N) group. Based on an earlier study showing that deficits in the cancellation test were associated with fronto temporal lesions and deficits in line bisection with posterior lesions (Binder, Marshall, Lazar, Benjamin, & Mohr, 1992), we investigated the relationship between the RT and ME in performance on the cancellation versus line bisection tasks. Based on this cancellation-frontal versus line bisection-parietal dichotomy, we expected that MID would be more closely associated with deficits in the cancellation test than those in the line bisection test. There was, however, no significant difference in the association between MID and deficits in these tests of neglect. The reason for our failure to find a significant association between neglect and MID is unclear. One possible explanation is that the conventional neglect tasks including line bisection, cancellation test, and copying used in this study may be more sensitive for detecting sensory-attentional and representation neglect than for detecting motor-intentional neglect and our DMT apparatus may be more sensitive for detecting motor-intentional than sensory-attentional neglect or representation neglect. This explanation may be consistent with the results of previous studies that looked at neural correlates of conventional neglect tests and found that the temporo-occipital junction was a critical area associated with hemispatial neglect as assessed with conventional neglect tests (Lee et al., 2010; Rorden, Fruhmann Berger, & Karnath, 2006; Vossel, Eschenbeck, Weiss, & Fink, 2010).

Lastly, as we expected, patients in either the RHS or LHS groups with anterior or subcortical lesions were more likely to demonstrate MID than patients with posterior lesions. Even though a few previous studies showed that directional hypokinesia could be attributed to a posterior cortical lesion including the inferior parietal lobule (Husain, Mattingley, Rorden, Kennard, & Driver, 2000; Mattingley et al., 1992; Mattingley, Husain, Rorden, Kennard, & Driver, 1998), most previous studies showed that MIDs are associated with frontal subcortical circuits including medial thalamus, cingulate gyrus, dorsolateral frontal lobe, basal ganglia, posterior limb of the internal capsule, and ventral lateral thalamus (Damasio, Damasio, & Chui, 1980; Ferro & Kertesz, 1984; Heilman & Valenstein, 1981; Velasco & Velasco, 1979; Watson & Heilman, 1979; Sapir, Kaplan, He, & Corbetta, 2007; Rossit et al., 2009; Vossel et al., 2010). These results further support the postulate noted above that conventional tests of neglect may assess perceptual-attention deficits and biases induced by temporoparietal dysfunction, whereas MID deficits detected using DMT may be more likely to be associated with motor-intentional neglect induced by anterior lesions.

References


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DIRECTIONAL MOTOR INTENTION IN STROKE


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