Why are some patients with severe neglect able to copy a cube?  
The significance of verbal intelligence  

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Abstract

Cube-copying is often used to assess constructional ability of brain-damaged patients and the influence of unilateral spatial neglect is often pointed out in patients with right hemisphere lesions. However, some patients with severe neglect perform cube-copying satisfactorily. The aim of the present study is to identify the factors that affect the performance of cube-copying in patients with left unilateral spatial neglect. Constructional performance was investigated in 100 patients with unilateral spatial neglect using a task to copy the Necker cube. The relationship of the patients' cube-copying performance to the severity of their neglect, as well as other factors (verbal intelligence, age, duration after onset of the disease, educational level, lesion site, piecemeal approach, and side of starting to copy) was analyzed. Twenty-two normal subjects also participated in this study as controls. Among many factors adopted for analysis, neglect severity and verbal intelligence were found to be primary factors affecting the cube-copying performance of the patients with unilateral spatial neglect. The effect of neglect severity on cube-copying performance was apparent in the patients whose verbal intelligence was deteriorated, but was not observed in the patients with preserved verbal intelligence. Similarly, the effect of verbal intelligence on cube-copying performance was apparent in the patients with severe neglect, but not in the patients with mild neglect. We conclude that constructional ability in the copying of a cube is determined by verbal intelligence, as well as by the severity of unilateral spatial neglect. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Unilateral spatial neglect; Cube-copying; Verbal intelligence; Neglect severity; Constructional disability

1. Introduction

Cube-copying is often used to assess the constructional ability of brain-damaged patients, since the three-dimensionality of a cube enhances their copying deficit [6]. Most studies using the cube-copying task have reported the influence of unilateral spatial neglect among patients with right hemisphere lesions [2–6,11,20,21,28]. Patients with left unilateral spatial neglect typically copy the right half of a cube and leave the left side unfinished. However, we occasionally encounter patients with severe neglect who are able to copy a cube, while some patients with mild neglect are unable to do so (Fig. 1). Factors may exist, other than neglect severity, that affect the performance of neglect patients in copying three-dimensional models. Many studies have suggested that disorders of visual perception result in the copying disability among patients with right hemisphere lesions [2,5,11,20]. While this may be true for some neglect patients, one report suggests that most neglect patients with preserved perception failed to copy the left side of the stimulus [10]. In other studies, intelligence has been shown to affect the copying performance of right and left brain-
It is important to note that severe neglect results in a poor performance on non-verbal tasks, such as the performance subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) [31] or Raven’s Coloured Progressive Matrices [22], which were used for assessment of intellectual ability in the above-mentioned studies. The aim of the present study is to examine the association between neglect severity and cube-copying performance, and to specify any other factors, independent of neglect severity, that influence the cube-copying performance of neglect patients.

2. Methods

2.1. Subjects

The subjects were 100 right-handed Japanese patients with a right hemisphere stroke, who showed left unilateral spatial neglect in at least one test of our screening battery. The screening battery included the line bisection [8,24] and line cancellation [1,9] tests, as well as the copying of a daisy with blades of grass 6 cm away on both sides [25,26]. In each test, the patient’s neglect was scored as either 0 (absent), 1 (mild), 2 (moderate) or 3 (severe) according to the scales of Levine et al. [13] and Ishiai et al. [8]. The sum of the scores of the three tests was treated as the total neglect severity, with the most severe neglect having a score of 9. The patients were divided into two neglect groups: 59 patients, whose total neglect severity was 3 or less, were classified as the mild neglect group (mean score = 2.1 ± 0.7); and 41 patients, whose score was 4 or more, were classified as the severe neglect group (mean score = 6.2 ± 1.7). All patients were assessed with the WAIS-R, Japanese edition [31]. No significant difference was observed in the verbal IQ between the mild (mean = 84.9 ± 11.1) and severe (mean = 87.2 ± 14.2) neglect groups. Fifty-seven patients had a dense left homonymous hemianopia on confrontation testing. Fourteen patients had an incomplete left homonymous hemianopia, and 24 had a left inferior quadrantanopia. The remaining five patients showed no visual field defect or left-sided extinction on double simultaneous stimulation. Computed tomographic scans or magnetic resonance images showed that all subjects had lesions that involved the right parietal lobe primarily and, to some extent, one or more of the frontal, temporal, and occipital lobes. The age of the patients varied from 35 to 84 years (mean 61.2). The length of time since the onset of the stroke ranged from 0.5 to 77 months (mean 8.0), and the years of education ranged from 6 to 19 years (mean 11.0).

Twenty-two healthy controls, matched with the experimental patients in age (mean = 61.2 years, range = 45–72) and educational level (mean = 11.5 years, range = 7–16), also participated in the study. All control subjects were right-handed, and had no clinical signs or history of brain disease. They were tested with our screening battery and showed no evidence of unilateral spatial neglect.

All patients and control subjects used their right hand in each test. All subjects gave informed consent to participate in this study.

Fig. 1. Examples of perfect and imperfect copies of a cube. A: Models. B: Copies for a patient with severe neglect whose total neglect severity (for the explanation, see the text) is 8. C: Copies for a patient with mild neglect whose total neglect severity is 2.

Fig. 2. The model to be copied (Necker cube). Vertices A, B, C, and D represent those located on the left side of a cube, and vertices a, b, c, and d represent those located on the right side of a cube.
2.2. Cube-copying

All subjects were presented with a perspective drawing of a cube, which is often called the Necker cube ([18], Fig. 2). The drawing was placed on the desktop directly above a blank sheet of B5 paper (182 × 257 mm) on which the patient made his copy. Both the stimulus and the response sheets were centered in the sagittal midplane of the subject’s trunk. The subject was permitted to perform the task in free vision, but the stimulus and response sheets were fixed by the examiner. The subject was instructed to copy the model as accurately as possible. No time limits were imposed. The whole copying process was recorded with a video tape recorder (VTR) for all subjects, except five patients. The copying performance was evaluated in terms of the numbers of correctly drawn vertices, which is the intersection of three lines with a proper angle. Accordingly, the maximum number of correct vertices in one examination was eight. The performance for the left and right sides of a cube was analyzed separately, if necessary. The following aspects of the cube-copying performance were also assessed with the help of the VTR recordings.

1. The presence or absence of a ‘closing-in’ phenomenon [16] and a ‘piecemeal approach’ [4,17,19]. The closing-in phenomenon was defined as a tendency to overlap the model with the copy, which is often reported among the patients with the left hemisphere lesions. The piecemeal approach is a tendency to copy the design in a fragmentary way, lacking general structure, which is indicated as the drawing feature for the right hemisphere damaged patients [17,19]. The piecemeal approach was regarded as present when six or more lines were drawn to complete the first plane.

2. The side from which a subject started to copy a cube.

3. The total number of lines drawn by each subject [4,12,17,29].

2.3. Statistical analysis

Either Spearman’s rank correlation coefficient or Pearson’s product-moment correlation was used to assess relations among variables. Results between the left and right sides of a cube were compared using paired t-test. A comparison of means between the two groups was performed using either the Student’s t-test or the Mann–Whitney U-test. Statistical significance was defined as a P value of 0.01 or less. Data were expressed as means ± SDs.

3. Results

3.1. Relationship between neglect severity and the number of correct vertices

All but one of the 22 control subjects showed perfect performance in copying the Necker cube. The remaining subject failed in copying one of the four right-sided vertices, but the other portions of the cube were well constructed. On the contrary, the neglect patients showed deficient performance. The number of correct vertices copied by the patients was 4.8 ± 2.5 for the entire cube. The patients displayed more difficulty in copying the left side of a cube than in copying the right side (1.8 ± 1.6 and 3.0 ± 1.3, respectively; P < 0.0001). The total neglect severity score of the patients, as measured by our screening battery, correlated with the total number of correct vertices (r = −0.40, P < 0.0001). The total neglect severity score also correlated with the number of correct vertices for the left side of a cube (r = −0.44, P < 0.0001), but did not correlate with the number of correct vertices for the right side of a cube.

3.2. Patient characteristics and the number of correct vertices

The assessed verbal IQ of the patients correlated with the number of correct vertices, but age, months after onset of the disease, and years of education did not (Table 1). Among the six WAIS-R verbal subtests, scaled scores of Vocabulary and Similarities correlated with the number of vertices for the whole cube (r = 0.39, P < 0.001 and r = 0.35, P < 0.01), as well as for the left (r = 0.29, P < 0.01 and r = 0.30, P < 0.01) and right (r = 0.40, P < 0.001 and r = 0.31, P < 0.01) sides of a cube. A tendency was observed for the patients whose lesion involved the frontal, temporal, and occipital lobes, in addition to the parietal lobe, to perform significantly poorer than those without such lesion extension in copying the whole cube (4.1 ± 2.6 and 5.2 ± 2.4, respectively; P = 0.03), and in copying the left side of a cube (1.4 ± 1.5 and 2.1 ± 1.5, respectively; P = 0.02). The former group of patients tended

<p>| Table 1 |
|---|---|---|</p>
<table>
<thead>
<tr>
<th></th>
<th>Whole cube</th>
<th>Left side</th>
<th>Right side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>0.33**</td>
<td>0.27*</td>
<td>0.34**</td>
</tr>
<tr>
<td>Age</td>
<td>−0.24</td>
<td>−0.25</td>
<td>−0.14</td>
</tr>
<tr>
<td>Months postonset</td>
<td>0.05</td>
<td>0.16</td>
<td>−0.12</td>
</tr>
<tr>
<td>Years of education</td>
<td>0.19</td>
<td>0.14</td>
<td>0.18</td>
</tr>
</tbody>
</table>

* Note: *P < 0.01; **P < 0.01.
to show more severe neglect than the latter group of patients (4.4 ± 2.6 and 3.4 ± 2.2, respectively; \( P = 0.03 \)).

### 3.3. Other aspects of cube-copying and the number of correct vertices

None of either our patients or the control subjects showed the closing-in phenomenon. In addition, none of the control subjects used the piecemeal approach. Among the 100 patients, 41 patients who drew with six lines or more to complete the first plane were identified as using the piecemeal approach. Patients who used the piecemeal approach performed significantly worse than those who did not use it in copying the whole cube, as well as the left and right sides of the cube (Table 2). Verbal IQ was also significantly lower for the patients using the piecemeal approach than for those who did not. However, the neglect severity scores were not significantly different between the two groups of patients.

All control subjects began their copy of the cube from the left side. A total of 19 control subjects copied the left line of the upper horizontal plane first, while the remaining three constructed the left vertical plane initially. Among the 95 patients whose VTR recording was available, data for three patients with severe neglect were excluded from the analysis, due to indecision for the starting side. Eighteen patients, who started from the right side of a cube, performed significantly worse than the 74 patients, who started from the left side, in copying the whole cube, as well as the left and right sides of the cube. In addition, patients who started from the right side of the cube showed significantly more severe neglect than those who started from the left side.

The figure of the Necker cube is constructed using 12 lines. The total number of lines drawn to copy the cube was 12 for all control subjects and for 23 of the patients, who performed perfectly. On the other hand, the number of lines varied from four to 20 (12.3 ± 3.4) for the remaining 77 patients, who showed imperfect performances. As seen in Fig. 3, the mean number of lines drawn by the patients with imperfect performance did not change significantly with the number of correct vertices. This result suggests that patients with poor performance tended to draw many lines that did not contribute to constructing correct vertices. Accordingly, the number of lines, which were invalid in constructing correct vertices, was examined for each patient. There was a negative correlation between the number of invalid lines and the number of correct vertices (\( r = -0.57, P < 0.0001 \)), but the number of invalid

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### Table 2

A comparison of patient groups (those with or without a piecemeal approach and those with a left or right start) on various factors and performance

<table>
<thead>
<tr>
<th></th>
<th>Piecemeal approach</th>
<th>Starting side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present (n = 41)</td>
<td>Right (n = 18)</td>
</tr>
<tr>
<td></td>
<td>Absent (n = 54)</td>
<td>Left (n = 74)</td>
</tr>
<tr>
<td>Whole cube (^b)</td>
<td>3.6 ± 2.3</td>
<td>3.3 ± 2.5</td>
</tr>
<tr>
<td>Left side (^b)</td>
<td>1.1 ± 1.5</td>
<td>1.0 ± 1.4</td>
</tr>
<tr>
<td>Right side (^b)</td>
<td>2.5 ± 1.3</td>
<td>2.3 ± 1.4</td>
</tr>
<tr>
<td>Neglect severity (^b)</td>
<td>3.5 ± 2.1</td>
<td>5.1 ± 2.7</td>
</tr>
<tr>
<td>Verbal IQ (^c)</td>
<td>81.4 ± 8.5</td>
<td>88.1 ± 11.9</td>
</tr>
<tr>
<td>Age, years (^c)</td>
<td>62.0 ± 9.7</td>
<td>64.6 ± 10.1</td>
</tr>
<tr>
<td>Months postonset (^c)</td>
<td>8.2 ± 8.8</td>
<td>8.6 ± 9.6</td>
</tr>
<tr>
<td>Education, years (^b)</td>
<td>10.3 ± 2.3</td>
<td>11.2 ± 3.5</td>
</tr>
<tr>
<td>Number of invalid lines in copying the whole cube (^b,d)</td>
<td>6.8 ± 4.9 (41)</td>
<td>6.4 ± 6.1 (17)</td>
</tr>
</tbody>
</table>

\(^a\) Values are mean ± SD.

\(^b\) Mann–Whitney U-test.

\(^c\) Student’s t-test.

\(^d\) Since the analyses were executed for the patients with incomplete performance, number of subjects are provided in the parentheses.

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Fig. 3. Total number of lines drawn (mean ± SD) with regards to the number of correct vertices. Filled bars represent the mean numbers of invalid lines.
lines did not correlate with neglect severity ($r = 0.05$, $P = 0.64$). In addition, a negative correlation was found between the number of invalid lines and verbal IQ ($r = -0.33$, $P < 0.01$). As expected, the patients using a piecemeal approach drew a cube with significantly more invalid lines than those who did not.

3.4. Effects of neglect severity and verbal intelligence on cube-copying

No correlation was observed between neglect severity and verbal IQ ($r = 0.002$, $P = 0.88$). Therefore, we conducted a Kruskal–Wallis test on the cube-copying data of the four groups of patients divided by neglect severity (mild and severe) and verbal IQ (fair and poor). The patients with verbal IQ of 81 or more were classified as the fair verbal IQ group, while those with verbal IQ of 80 or less were classified as the poor verbal IQ group. Fig. 4 presents the cube-copying performance for each group. The number of correct vertices was significantly different among the four groups of patients ($H = 21.4$, $P < 0.0001$). Post hoc analyses revealed that the severe neglect patients with poor verbal IQ performed significantly worse than any of the other three groups of patients ($P < 0.001$) in copying the whole cube, as well as the left and right sides of a cube. No significant difference was found in any other analyses. Fig. 5 shows examples of copies for each group of patients.

3.5. Cube-copying performances in the acute and chronic stages

Our patients were divided into two groups according to the length of time post-stroke. Twenty patients, who were studied within the first 2 months ($1.5 \pm 0.1$ months), were classified as the acute stage group, and 80 patients, whose post-onset period was 2.1 months or more ($9.7 \pm 1.2$ months), were classified as the chronic stage group. No significant differences were found between the two groups of patients in regards to the total number of correct vertices (acute stage group: $5.4 \pm 1.9$; chronic stage group: $4.6 \pm 2.7$), total neglect severity (acute stage group: $3.6 \pm 2.1$; chronic stage group: $3.9 \pm 2.5$), and verbal IQ (acute stage group: $87.0 \pm 13.6$; chronic stage group: $85.6 \pm 12.2$). In the chronic stage group, the number of correct vertices was significantly correlated with the total neglect severity (left side: $r = -0.38$, $P < 0.0001$; whole cube: $r = -0.34$, $P < 0.001$) and verbal IQ (left side: $r = 0.35$, $P < 0.01$; whole cube: $r = 0.4$, $P < 0.01$). By contrast, the total neglect severity and verbal IQ did not correlate with the number of correct vertices in the acute stage group. Age and years of education did not correlate with the number of correct vertices in either groups.

4. Discussion

We analyzed the copying performance of a perspective drawing of a cube, which is often called the Necker cube in 100 patients with left unilateral spatial
neglect and in 22 age-matched control subjects. The control subjects demonstrated a perfect or nearly perfect performance in copying the three-dimensional Necker cube. On the other hand, our patients unilateral spatial neglect showed a significantly worse cube-copying performance than the control subjects. They showed a deficient performance on both sides of a cube, with the left side being more impaired. Therefore, we suggest that the figure is a useful model in the detection of a copying deficit among brain-damaged patients, as proposed previously by Griffiths and Cook [6].

Among the various factors adopted for the analyses, verbal IQ correlated with the number of correct vertices, while patient age, time after onset of the disease, and years of education did not. Patients whose lesion involved the frontal, temporal, and occipital lobes, in addition to the parietal lobe, performed significantly worse than those with smaller lesions. This difference was attributable to neglect severity, since large lesions frequently result in more severe neglect [13]. It is unlikely that the cube-copying disability resulted from apraxia, since all our patients had unilateral right hemisphere lesions, and they were never observed to have ideomotor apraxia in their rehabilitation activities. The piecemeal approach and the starting side were related to the cube-copying performance, but these factors were dependent upon either verbal intelligence or neglect severity. From these results, we suggest that neglect severity and verbal intelligence are independent factors that affect the cube-copying performance of neglect patients. Several reports have suggested a correlation between intellectual deterioration and copying disability [3,7,12,15,28–30]. None of these studies, however, have clarified the effect of verbal intelligence on the performance of copying a three-dimensional model among the patients with left unilateral spatial neglect.

Neglect patients usually fail to reproduce the left parts of a figure when copying, and their performance varies according to their neglect severity and the model employed for copying [25]. Our results reveal that the performance of our neglect patients in copying the Necker cube was not determined by their neglect severity alone (Figs. 4 and 5). Although performance was worse for the patients with severe neglect than for those with mild neglect, this effect of neglect severity on the cube-copying performance was observed in the patients with deteriorated verbal intelligence, but not in the patients with preserved verbal intelligence. Moreover, in the severe neglect patients, performance was worse for those with deteriorated verbal intelligence than for preserved verbal intelligence. This difference was not observed in the patients with mild neglect. Therefore, from these results, we conclude that verbal intelligence of patients with left unilateral spatial neglect plays an important role in the patients' cube-copying performance, and that verbal intelligence interacts with neglect severity.

The above findings were true for patients in the chronic stages but not for those in the acute stages. In other words, preserved intellectual ability of patients compensated for severe neglect in the chronic stages. All patients received physical and occupational therapies designed to improve unilateral spatial neglect, but never received treatments focused on their constructional deficit. The improvement of their cube-copying performance may not be a direct outcome of rehabilitation. Interventions, e.g. feedback of neglect errors, may have failed to improve performance of severe neglect patients in most spatial tasks, while it probably induced their use of verbal knowledge to compensate for the neglect-related difficulty of cube-copying. These observations are supported by the finding that performance on Vocabulary and Similarities subtests of the WAIS-R was associated with the cube-copying performance, which are described as good indicators of premorbid intellectual ability [14,27].

None of our neglect patients with the right hemisphere lesions showed the closing-in phenomenon. Piecemeal approach was used in more than 40% of our neglect patients. Unilateral spatial neglect might result in use of the piecemeal approach, as Gainotti and Tiacci [4] have discussed previously. However, we did not observe an association between using the piecemeal approach and neglect severity. Nevertheless, an association was observed between using the piecemeal approach and a deterioration of verbal intelligence. Thus, it is likely that the patients who used the piecemeal approach exhibited a generalized intellectual deterioration.

Using an increased number of lines is another controversial drawing feature for the right hemisphere damaged patients [4,17,29,30]. Our results suggest that using the piecemeal approach and an increased number of lines were associated more with deteriorated verbal intelligence than with severe neglect.

Many studies have suggested that disorders of visual perception result in a copying disability among patients with right hemisphere lesions [2,5,11,20]. As for neglect patients, Ishii et al. [10] reported that most of their neglect patients failed to copy the left side of the stimulus, although their perception of the model was well preserved. In the present study, seven of the 11 patients with very severe neglect were asked to identify the figure of a Necker cube prior to copying. The total neglect severity of these patients was seven or more, and they correctly constructed three vertices or less on the right side of a cube. Six patients described the model as a cube or a dice, admitting the three dimensional construction of the figure. The remaining patient mistook the stimulus as a vertically
located rectangle, and drew it as he mentioned. Accordingly, preserved visual perception of the model did not help the six very severe neglect patients in copying a cube. Four patients started copying from the right side, leaving the left side unfinished. The remaining two patients drew a horizontal line rightward, but the subsequent drawings converged on the right side. We suggest that the failure to copy the left side of the model derived from the strong engagement of their attention to the right side. Although these patients recognized the model prior to copying, the action of copying, which started from the right side, may result in a defective shift of attention to the left side of drawings [23].

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