



Language-specific Dysgraphia in Korean Patients with Right Brain Stroke: Influence of Unilateral Spatial Neglect

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The purpose of the present study was to investigate the relationship between Korean language-specific dysgraphia and unilateral spatial neglect in 31 right brain stroke patients. All patients were tested for writing errors in spontaneous writing, dictation, and copying tests. The dysgraphia was classified into visuospatial omission, visuospatial destruction, syllabic tilting, stroke omission, stroke addition, and stroke tilting. Twenty-three (77.4%) of the 31 patients made dysgraphia and 18 (58.1%) demonstrated unilateral spatial neglect. The visuospatial omission was the most common dysgraphia followed by stroke addition and omission errors. The highest number of errors was made in the copying and the least was in the spontaneous writing test. Patients with unilateral spatial neglect made a significantly higher number of dysgraphia in the copying test than those without. We identified specific dysgraphia features such as a right side space omission and a vertical stroke addition in Korean right brain stroke patients. In conclusion, unilateral spatial neglect influences copy writing system of Korean language in patients with right brain stroke.

Keywords: Perceptual Disorders; Agraphia; Stroke; Writing; Language

INTRODUCTION

Injuries to the right side of the brain often cause a non-aphasic disturbance of writing (dysgraphia) known as spatial agraphia (1, 2). For spatial agraphia, writing errors generally include stroke omission, stroke addition, stroke tilting, visuospatial destruction, misgrouping of elements, and syllabic tilting. These errors have been reported in people of various languages such as English (3), Spanish (1), French (4), Japanese (2), and Korean (5). However, dysgraphia associated with right brain injuries shows different forms depending on the specific graphemic system of a given language. For example, Japanese people showed dysgraphia of kanji (ideogram) but not of kana (phonogram) (2). In addition, those who use the Korean language did not show any transposition errors, in contrast to those who use Roman alphabetical writing systems such as English and Italian (5, 6). Although these language-specific dysgraphia is not fully understood, it may be affected by graphemic systems that require visuospatial processing, have a complex array of letters, and need an educational strategy of their alphabet (2, 5).

The Korean alphabet, Han-geul, is distinctive in its written application. Modern Han-geul includes 10 vowels and 14 consonants. For spatial construction, each Korean grapheme must be placed within a square space to form a syllable. Unlike other alphabets, each syllable always comprises an onset, which is a consonant, followed by a vowel and then an optional consonant.

Korean children are educated to keep the regular arrangements of this combination rule and to maintain the strictly defined position for each grapheme within a syllabic square. Therefore, in the Korean writing system, writing performance after a right brain injury may be particularly affected if unilateral spatial neglect also manifests. However, no study to date has examined the relationship between Korean language-specific dysgraphia and unilateral spatial neglect.

In the present study, we investigated the patterns of dysgraphia in right brain stroke patients and the relationship between Korean language-specific dysgraphia and unilateral spatial neglect.

MATERIALS AND METHODS

Subjects

In this study, patients with right brain stroke were recruited from an in-patient stroke rehabilitation unit in Korea. They were also recruited on the basis of the following criteria: 1) they had experienced subacute stroke within 3 months of stroke onset, 2) this was their first stroke, 3) they had completed more than 6 yr of grade school education, 4) they had a Mini-Mental Status Examination-Korean score of more than 20, and 5) they were right handed. The patients were excluded from the study if they had associated aphasia, a visual field defect, apraxia, or a previous history of a writing deficit. Korean-Western Aphasia Battery

was used to evaluate an aphasia (7). A total of 31 patients (24 males, 7 females) with right brain stroke participated in this study. Of these, 11 patients had suffered intracranial hemorrhage, 19 had ischemic cerebral infarction, and 1 had subdural hemorrhage. The mean age of the patients was 59.3 yr (Table 1).

Assessment of unilateral spatial neglect

All patients completed the line bisection test (8), Albert's test (9) and star cancellation test (10) under the direction of one occupational therapist. In the line bisection test, patients were asked to bisect 18 horizontal lines. The deviation between a real midpoint and one marked by the patients was determined. A deviation of more than 6 mm from the midpoint indicates unilateral spatial neglect. The Albert test is to mark a total of 40 oblique lines on an A4 paper. The patients who could not check above five lines in the left side were diagnosed as having unilateral spatial neglect. In the star cancellation test, star ratio was calculated from the ratio of stars cancelled on the left of the page to the total number of stars cancelled. Scores between 0 and 0.46 indicated unilateral spatial neglect. If a patient produced abnormal results on more than one of these tests, the patient was considered to have unilateral spatial neglect.

Assessment of writing

All patients completed spontaneous writing, writing to dictation, and copying tests under the direction of one speech therapist. The patients gave the tests seated in a chair in a quiet environment. The examiner sat directly in front of the patient and presented the test material. The patients were asked not to move the paper or their trunk while performing the tasks. They were required to perform each test by writing characters in block shapes within 5 × 5 cm squares on an A4-sized plain paper. They wrote their address within a 3 × 3 cm square. The patients were asked to keep each character in the center of the square and to keep the block shape as straight as possible. No time limit was

given for the tests. The spontaneous writing test required patients to write their name and address. All patients were given the same set of monosyllables for the dictation and copying tests. These consisted of 30 Korean syllables (Han-geul) which based on for configuration, length, frequency of use, ease of visualization, and regularity. For the dictation test, the target syllables were spoken to the patients by the examiner 3 times. The patients were then asked to write the target syllables from dictation after repeating the target syllable verbally to exclude any auditory impairment. For the copying test, a letter was printed in the center of an A4-sized plain paper in 300-point lettering size. The patients were requested to read each letter after copying it.

Assessments were performed by an experienced speech therapist. Only constructive (visuospatial) errors were assessed as dysgraphia, and semantic (linguistic) errors were not included. The constructive errors (Fig. 1) were classified into visuospatial omission, visuospatial destruction, syllabic tilting, stroke omission,

Table 1. General characteristics of the patients (n = 31)

Variables	
Age (yr)	59.3 (18-82)
Sex (M:F)	24:7
Mini-Mental Status Examination-Korean	24.8 (20-30)
Type of stroke	
Intracranial hemorrhage	11
Cerebral infarction	19
Subdural hemorrhage	1
Region of stroke	
Cortex	11
Sub-cortex	17
Brain stem	3
Unilateral spatial neglect	
Neglect	18
No neglect	13

Age and Mini-Mental Status Examination-Korean score are shown as mean (range). All other values represent the number of patients.

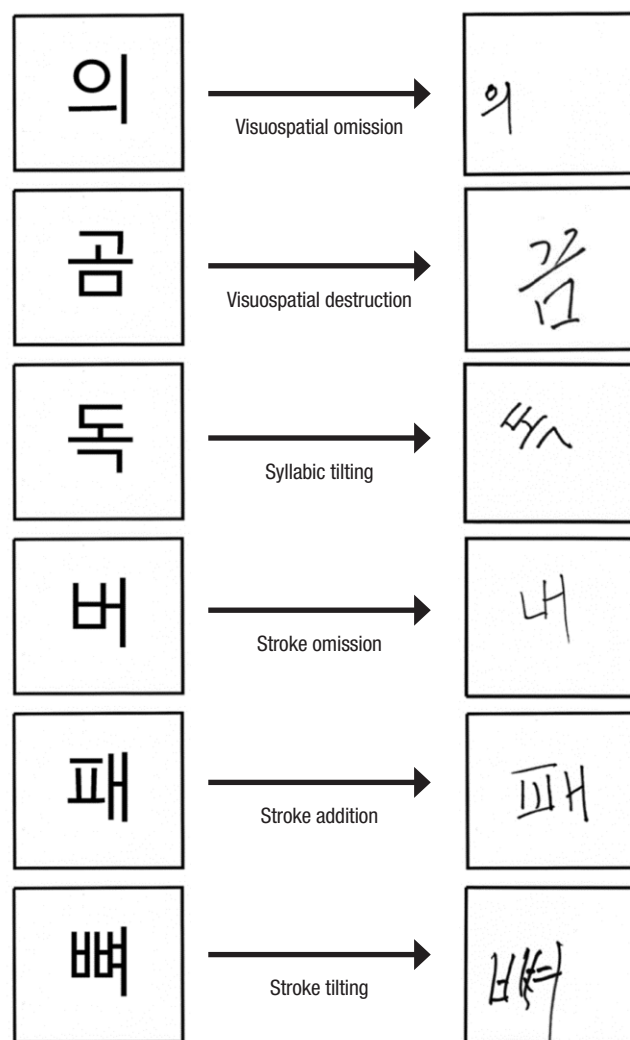


Fig. 1. The classification of dysgraphia (constructive errors of writing) in the Korean language used in this study. Left side was a target letter and right side was examples of the response of the patients.

sion, stroke addition, and stroke tilting in accordance with criteria determined by Yoon et al. (5). In brief, “Stroke omission” errors delete 1 part of the grapheme and “Stroke additions” add redundant strokes. “Visuospatial destruction” errors create a nonexistent form. “Visuospatial omission” errors ignore more than 50% of space in the square.

Assessments of writing and unilateral spatial neglect were conducted on the same day.

Statistical analysis

SPSS for Windows, version 18.0 (SPSS, Chicago, IL, USA) was used for statistical analyses. Dysgraphia made by patients with and without unilateral spatial neglect was compared using Fisher’s exact test. Statistical significance was defined as $P < 0.05$.

Ethics statement

This study was approved by the institutional research review

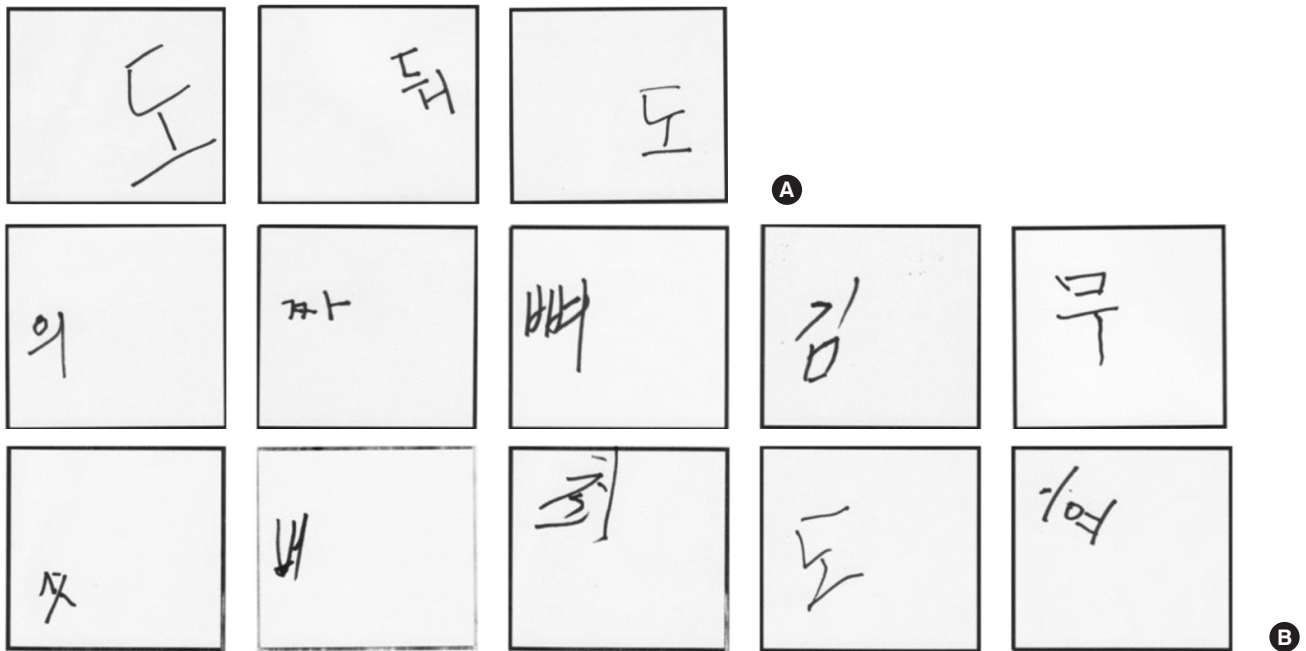


Fig. 2. Written examples of visuospatial left space omission (A) and right space omission (B).

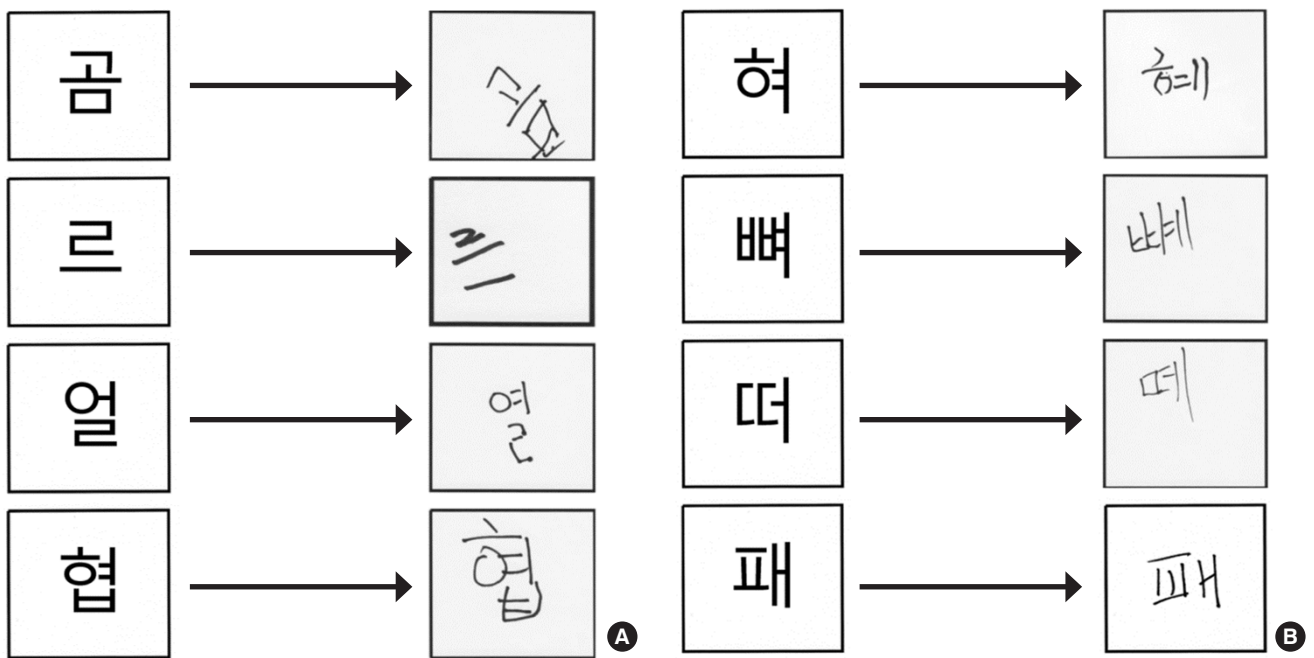


Fig. 3. Written examples of stroke addition from top to bottom (A) and from left to right (B). Left side was a target letter and right side was examples of the response of the patients.

Table 2. Number of patients with dysgraphia in the spontaneous writing, dictation, and copying tests (n = 31)

Tests	Visuospatial omission	Visuospatial destruction	Syllabic tilting	Stroke omission	Stroke addition	Stroke tilting
Spontaneous writing	8	0	2	1	4	1
Writing to dictation	8	1	3	5	5	1
Copying	10	3	2	12	12	1

All values represent the number of patients.

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RESULTS

The line bisection test, the Albert, the star cancellation test showed unilateral spatial neglect in 15, 13, and 13 patients, respectively. The patients who showed abnormal results on more than one of these tests were 18 patients (Table 1).

For the different subtypes of dysgraphia, visuospatial omission (examples shown in Fig. 2) was the most common error followed by stroke addition (examples shown in Fig. 3) and omission. As shown Fig. 2A and B, 10 patients showed right side space omission, and three patients had left side omission. The highest number of errors was made in the copying and the least was in the spontaneous writing test (Table 2).

The number of patients with and without dysgraphia was compared to those of with and without unilateral spatial neglect (Table 3). For the copying test, the number of patients with unilateral spatial neglect was significantly related to those with dysgraphia (14 patients vs. 4 patients). However, no significant differences were observed between the patients with dysgraphia and unilateral spatial neglect in the spontaneous writing or dictation tests.

DISCUSSION

We assessed dysgraphia of writing in Korean patients with right brain stroke. Twenty-three (77.4%) of the 31 patients made dysgraphia and 18 (58.1%) demonstrated unilateral spatial neglect. The patients made the highest number of errors during the copying test. In addition, patients with unilateral spatial neglect made significantly more errors during the copying test than those without spatial neglect.

We found that visuospatial omission was the most common subtype of dysgraphia in Korean patients with right brain stroke, and this result was consistent with a study by Yoon et al. (5) Unexpectedly, we found that our patients usually showed right space omission (Fig. 2A and B). In contrast to previous studies including that of Yoon et al. that showed left space omission (1, 4, 5), our patients tended to ignore the right space. Korean graphic system whereby an onset always begins with a consonant on the left side, and Korean people have been educated to keep the strictly defined position for each grapheme within a syllabic

Table 3. Comparison between dysgraphia and unilateral spatial neglect (n = 31)

Variables	Dysgraphia		P value
	-*	+†	
Spontaneous writing			
No neglect	11	2	
Neglect	10	8	
Total	21	10	0.129
Writing to dictation			
No neglect	11	2	
Neglect	10	8	
Total	21	10	0.129
Copying			
No neglect	9	4	
Neglect	4	14	
Total	13	18	0.013

All values represent number of patients. Fisher's exact test. *The number of patients who had no error; †The number of patients who had dysgraphia at least once.

square. Hence, regardless of left side unilateral spatial neglect, Korean patients with right brain damage try to keep the left margin exaggeratedly starting the writing due to visuospatial impairments. We believe that this pattern of error could be specific to the Korean language.

Stroke addition and omission were also common errors in our study, as has been described previously (1, 2, 5). Ardila et al. (1) reported that stroke addition was more frequent after right frontal lobe damage and suggested that a motor perseveration due to frontal lobe lesion may cause additions. However, in the present study, frontal lobe damaged patients as well as those with subcortical lesions (basal ganglia and thalamus) showed stroke addition errors, particularly during the copying test. We believe that the genesis of stroke addition errors could be related to more complex mechanisms involving visuospatial and motor control systems. Interestingly, in the present study, a stroke addition pattern was represented by a top to bottom (vertical) as well as from left to right (horizontal) error on any part of the grapheme (Fig. 3A and 2B). A similar error has been reported in kanji letters (Japanese ideogram writing system) (2), and the vertical patterns of stroke addition errors may be distinctive of language systems that have a combinatorial rule. Roman alphabetical writing systems do not have this rule, and for these writing systems, stroke additions usually run from left to right (1). We could not speculate on the explanations for the genesis of stroke omission, and further study is needed to decipher the underlying mechanisms.

In the present study, spontaneous writing was relatively unaffected by right brain damage. In contrast, the greatest number

of errors was made in the copying test. This may occur because the copying test depends on the longer distance processing from the visual cortex to the motor cortex when writing. However, for spontaneous writing, the process distance may be shorter and open to less potential disruption. Performing the copying test may be more affected by changes in visuoperceptual processing and motor control systems after stroke.

Finally, our results showed that the unilateral spatial neglect was significantly related to dysgraphia in the only copying test. It may be caused that the copying needs more visuoperceptual processing than the spontaneous writing or dictation tests. Seki et al. (2) also found that patients with unilateral spatial neglect had difficulty in performing copying in kanji (Japanese ideogram writing system), and they suggested that this was caused by an impaired perception of the model. However, the exact mechanism between an impaired perception and writing error is unclear, further study is required.

There are some limitations to our present study. First, we only assessed a single-center cohort with a relatively small number of patients. Second, we only used single characters for the writing tests. Therefore, we could not investigate the disturbance of spatial arrangement on the page. Third, we did not find any relationship between dysgraphia and the location of brain lesions. However, a larger stroke population may reveal an association between the site of the brain lesion and dysgraphia patterns in the Korean language writing.

Based on our findings, we suggest that right brain injury-induced dysgraphia could be affected by complex mechanisms including language-specific graphic systems, visuoperceptual processing, motor control systems, and educational strategy. In addition, unilateral spatial neglect appears to specifically affect the copy writing system of Korean patients with right brain stroke.

DISCLOSURE

All authors declare no conflicts of interest to disclose.

AUTHOR CONTRIBUTION

Conception and coordination of the study: Jang DH, Kim MW. Design of ethical issues: Jang DH, Kim MW, Park KH, Lee JW. Enrolled patients: Jang DH, Kim MW. Acquisition of data: Park KH, Lee JW. Data review: Jang DH. Statistical analysis: Jang DH. Manuscript preparation: Jang DH, Kim MW. Manuscript approval: all authors.

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