# PURE KANA AGRAPHIA AS A MANIFESTATION OF GRAPHEMIC BUFFER IMPAIRMENT

# Kae Kokubo<sup>1</sup>, Kyoko Suzuki<sup>1</sup>, Atsushi Yamadori<sup>1</sup> and Kei Satou<sup>2</sup>

(<sup>1</sup>Section of Neuropsychology, Division of Disability Science, Tohoku University Graduate School of Medicine; <sup>2</sup>Department of Rehabilitation Medicine, Tohoku-kosei-nenkin Hospital)

### Abstract

We report a left-handed man who demonstrated a pure agraphia limited to words written in Kana characters (syllabograms) following a right putaminal hemorrhage. Writing words in Kanji characters (logograms) was well preserved. His performance in Kana writing was characterized by intact ability to write single syllables, error increase in the second half of words directly proportional to the word length and correct but slow writing of words using kana blocks. Errors were more prominent in Hiragana words than Katakana words which are usually used to transcribe foreign words. Acoustic-grapheme sequencing per se was not impaired as shown by his correct performance in arranging character blocks. These findings suggest selective damage to the graphemic buffer, a module that temporarily maintains the graphemic representation elaborated in previous stages before it is sent to the peripheral systems for its motor realization.

Key words: agraphia, Kana, graphemic buffer

# INTRODUCTION

Agraphia is an acquired inability to write following brain damage. As writing is a highly complex function combining linguistic, acoustic, praxic, spaceconstructional, visual and motor components, agraphia can occur at many different levels. In the linguistic domain, at least two levels of disturbance have been described and labeled superficial and deep agraphia (Beauvois and Derouesné, 1981; Shallice, 1981; Roeltgen and Heilman, 1984).

The Japanese writing system is characterized by the hybrid use of Kana (syllabogram) and Kanji (logogram) characters. Kana consists of 45 characters, each corresponding to one syllable. All pronounceable Japanese sounds can be transcribed into Kana characters. The correspondence between a Kana character and a syllable is very regular with only a few exceptions. Because the syllable constitutes the smallest unit of writing in transcribing Japanese sounds, "spelling" errors in sequencing alphabetical letters, which are typical of western languages, do not occur in Japanese.

There are two types of Kana: Hiragana and Katakana. Hiragana is used most frequently in newspapers and books, while Katakana is only used for words from foreign origin or for onomatopoeic words. Hiragana and Katakana use different characters, which are, however, of the same complexity and number. In contrast, a Kanji character represents a word or a morpheme that is related to a meaning. Dissociation of the ability to write Kana and Kanji characters have been reported and attributed to their different functional nature (Kimura, Matsuda, Kuroiwa et al., 1986; Abe, Yokoyama, Yorihuji et al., 1993; Toyokura, Shigeno and Murakami, 1993).

We recently encountered a very rare case of pure agraphia limited to Kana word writing. Here we report the investigations carried out to clarify the underlying mechanism.

## CASE REPORT

A 69-year-old left-handed man was admitted to a hospital because of weakness on the left side and mutism. He had a laterality quotient of 10 on the Edinburgh Handedness Inventory (Oldfield, 1971) and had a left-handed son. CT scan revealed a right putaminal hemorrhage, which was evacuated two days later. After the operation, the neurological examination showed mild aphasia, left hemiparesis, hypoesthesia and increased deep tendon reflexes on the left side. Cranial nerves and cerebellar function were intact. He underwent rehabilitation for three months and his symptoms improved gradually. One year later, he attended a day-care center for speech therapy where the following neuropsychological examination was performed over five months. During this period, his neurological and neuropsychological symptoms remained unchanged.

On neurological examination, he was alert and cooperative. He showed left spastic hemiparesis and hypoesthesia. A CT scan performed three months after the onset confirmed a hemorrhagic lesion in the right putamen (Figure 1).

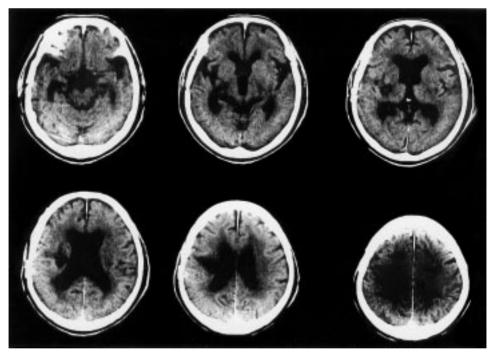


Fig. 1 – CT scan revealed a right putamenal lesion.

#### Neuropsychological Assessment

He was oriented to time, place and person. His general attention was preserved and digit span forward was five. He showed mild anomic aphasia with agraphia for Kana words. Calculation and constructional skills were preserved. Ideomotor and ideational apraxia and left unilateral spatial neglect were not observed. WAIS-R Performance IQ was 83. His episodic memory seemed intact.

Table I shows the results of The Japanese Standard Language Test for Aphasia. His spontaneous speech was mildly dysarthric but informative and did not contain paraphasic errors. Confrontation naming was impaired. Auditory and reading comprehension, and word repetition were normal. His ability to read aloud both Kana and Kanji words and to point to single characters and words written in Kana or Kanji characters following their auditory presentation was intact. He could also discriminate words and non-words written in Kana characters without difficulty. He was able to transcribe single auditorily presented syllables in Kana character, but had marked difficulty in writing Kana words. In contrast, he made no mistakes in writing Kanji words. In the following experimental investigations, we tried to clarify the nature of his impairment in Kana writing and to elucidate the functional level of the deficit.

Testing condition	Score Testing condition		Score
Auditory comprehension		Reading comprehension	
Word recognition	10/10	Kanji words	10/10
Sentence recognition	9/10	Kana words	10/10
Oral commands	7/10	Sentences (Kana and Kanji)	9/10
Speech		Written commands	8/10
Confrontation naming	14/20	Writing	
Word repetition	10/10	Written naming (kanji)	5/5
Description of activities	7/10	Written naming (kana)	2/5
Narrative	4/6	Spontaneous writing	2/5
Sentence repetition	3/5	Dictation	
Verbal fluency	5/15	Single Kana character	8/10
Oral reading		Kanji words	5/5
Kanji words	5/5	Kana words	2/5
Kanas (single Kana character)	10/10	Sentences (Kana and Kanji)	1/5
Kana words	5/5	Calculation	17/20
Sentences (Kana and Kanji)	5/5	Calculation	17/20

TABLE I Standard Language Test for Aphasia (SLTA)

## **EXPERIMENTAL INVESTIGATIONS**

### 1. Writing and Reading Words

Our patient performed three types of writing tasks; writing to dictation, writing the names of drawings and copying. Reading words aloud, reading comprehension, and pointing to a heard word were also tested. Stimuli consisted of 20 words written in Hiragana or Kanji, which were selected from 10 semantic categories, with two words per category. He was able to name the drawings corresponding to the these 20 words and to repeat them without difficulty. In the reading comprehension task, he had to point to a drawing out of 10 in response to a written word.

Table II shows the results. He performed flawlessly on any task involving

Kanji words. For Hiragana words, his ability to read and comprehend words was intact, but he run into difficulty in writing them except when copying. All errors were substitution of one or a few characters with other Hiragana characters. No scrawl, neologism or incomplete character were observed. The number of characters he wrote matched that of the target word. His penmanship was smooth with fair speed. He recognized his errors, pronounced the words appropriately, but failed when trying to write the correct characters.

	TAB	LE II	
Reading	and	Writing	Tasks

		Kana word	Kanji word
Writing to dictation	N = 20	12	20
Writing drawing names	N = 20	9	20
Copying	N = 20	20	20
Reading aloud	N = 20	20	20
Reading comprehension	N = 20	20	20
Pointing to a heard word	N = 20	20	20

## 2. Writing to Dictation Words and Non-Words of Different Length

Writing words to dictation was tested with Hiragana, Katakana and Kanji, while non-words writing was only tested with Hiragana. Five sets of 10 words, each set consisting of words having the same number of characters from one to five, were presented. Hiragana non-words corresponded to the arbitrary combinations of more than two Hiragana characters. He could repeat the same words and non-words easily.

Figure 2 shows the results and examples of his responses are listed in Figure 3. Writing Kanji words was perfect. In contrast, his performance with Hiragana and Katakana words and non-words showed a progressive deterioration as the number of the characters of the stimulus increased. The deterioration was most marked for Hiragana non-words. All errors were substitution of one or a few characters with other characters of the same type (Hiragana or Katakana).

We analyzed the position of literal paraphasias in each response to Hiragana words and non-words on writing to dictation task (Table III). Errors increased in the final portion of the response, especially for non-words. Only few errors affecting the first character were made both with words and non-words.

# 3. Word Construction Task

We requested the patient to compose a word, pronounced by the examiner, by arranging the Hiragana characters needed to form it. They were presented randomly in front of him along with an equal number of foils. Four sets of ten words, from two to five Hiragana characters, were given.

He made one sequencing error out of 40 words. The word HA-KU-SA-I (Chinese cabbage) was written HA-SA-KU-I. However, his performance was very slow. He proceeded piecemeal, first uttering the syllable and then choosing the corresponding Kana character.

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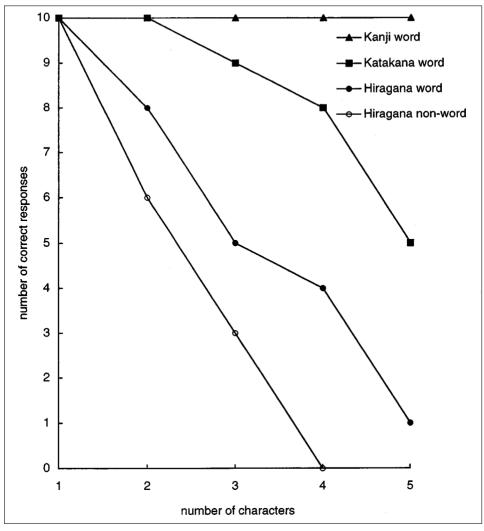


Fig. 2 – Distribution of correct responses as a function of stimulus length. Note the deterioration of Kana writing as the number of Kana characters increased.

TABLE III
The Relation of Literal Paragraphias of Hiragana Words and Non-Words to Character Position in Writing to Dictation

			Character position						
		First	Second	Third	Fourth	Fifth			
2-letter word	N = 10	0	2						
2-letter non-word	N = 10	1	3						
3-letter word	N = 10	0	2	3					
3-letter non-word	N = 10	2	5	5					
4-letter word	N = 10	1	3	4	4				
4-letter non-word	N = 10	2	3	6	8				
5-letter word	N = 10	$\overline{0}$	2	3	5	3			

Katakana	target word patient's writing	*	د	、 、	( ) ( ) (	t U U	-ro ン シ	° ~- 4		el +	ME-RU + h	1	ot X	o ∤ 11
		orange	O-RE-N-JI			concert	KO-N-SA-TO			caramel	KYA-RA-ME-RU			
gana	patient's writing	5		ں کب		N L	0 15	<b>.</b>	Ø3	λ	Ŧ.	。 ス	2	د،
Hiragana	target word	>	10	+1+6		Ч	Ŕ	×	ю	لد	ţ	3	だ	()
nji	patient's writing	4	-	5		At.	Ś.	d'		H	D .	142		e s
Kanji	target word		₽			₩	採			呰	- <del> </del> 1 110	40		
ľ		car	KU-RU-MA			gloves	TE-BU-KU-RO			clock tower	TO-KE-I-DA-I			

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## DISCUSSION

Our patient showed agraphia for Kana words with preserved writing for Kanji words. His Kana agraphia was marked by increasing difficulties for longer stimuli and more frequent errors in the second half of the word despite his preserved ability to repeat the whole word. Analysis of error types revealed that substitution was the most common error independently of the modality of input (i.e., writing to dictation, written naming). In contrast, his ability to select and arrange Hiragana characters into a correct word and to match a spoken syllable to a corresponding single Hiragana character was preserved. He was only able to write Kana words when he wrote or copied characters one by one.

Wing and Baddeley (1980) suggested that a predominance of spelling errors toward the end of a word may reflect an abnormally rapid decay of graphemic representations. Caramazza, Miceli, Villa et al. (1987) proposed a model of the spelling process, in which a graphemic buffer is assumed to play a crucial role in storing temporally graphemic representations before they are converted into specific letter shapes. Damage to this store would result in agraphia with the following features: (1) increasing errors for longer stimuli, (2) increasing errors toward the end of a stimulus, (3) agraphia for both words and non-words independently of the modality of input or output, (4) error types consisting in substitutions, insertions, deletions or transpositions of letters.

The errors made in Kana word writing by our patient resembled the pattern of agraphia consequent to the impairment of the graphemic buffer. In addition, comprehension, repetition, naming and copying of the target words were all preserved, suggesting that auditory perception, lexical retrieval, and motor implementation were not impaired. Matching a syllable to a Kana grapheme was also intact as he could write a Kana character in response to a single syllable. Difficulties emerged only when he had to write a polysyllabic Kana word, especially when it contained more than three Kana characters. His errors increased for longer words and towards the end of the word. The assumption that his agraphia for polysyllabic Kana words was contingent upon dysfunction of the graphemic buffer is not contradicted by the patient's ability to estimate the number of characters, which of its own does not imply Kana character knowledge.

However, this interpretation fails to account to the dissociation between the patient's impairment to write Kana words and his ability to write Kanji words even when they required up to five Kanji characters. Two accounts can be advanced: (1) There are two separate graphemic buffers for Kanji and Kana words or (2) The read-out process from the graphemic buffer is more efficient for Kanji words than for Kana words, as the former correspond to tightly combined semantic units. The patient's performance in writing Katakana words was intermediate between Hiragana and Kanji words. Katakana words are different from Hiragana because they usually represent words from foreign origin, which stand out in sentences, and can be processed as a semantic unit, similar to Kanji words.

Table IV summarizes the cases of pure Kana agraphia reported in the literature. A dissociation between correct production of a single Kana character

	Present	Tanaka et al. (1987)	Abe et al. (1993)	Sakamoto and Takeda (1986)	Kimura et al. (1986)
Age, diagnosis	69, hemorrhage	52, infarction	81, infarction	58, tumor	59, infarction
Lesion	R. putamen	L. parietal lobe L. corona radiata	L. middle frontal gyrus	L. parietal lobe	L. parietal lobe
Spontaneous writing	×	×	×	×	×
Dictation	×	×	×	×	×
Writing the name of a drawing	×	×	×	?	×
Type of errors	Literal paragraphia	Literal paragraphia No-response	Literal paragraphia	Perseveration No-response	Literal paragraphia No-response
Effect of the number of characters	×	×	?	?	?
Correspondent to the number of characters	0	Approximation	0	×	×
Word construction	0	?	?	×	?
Copying	0	0	0	0	0

TABLE IV Cases of Pure Kana Agraphia

*Legend*:  $\bigcirc$  = correct performance, × = impaired performance.

and impaired writing of Kana words was reported in two patients (Tanaka et al., 1987; Abe et al., 1993). They made numerous literal paragraphias in writing longer words and sentences, but the number of characters produced was usually a good approximation to that of the target words. In Tanaka et al.'s patient, errors increased as a word became longer. The pattern of Kana agraphia of these patient was similar to that of our patient, but writing Kanji words was impaired to some extent. In the case of Sakamoto and Takeda (1986), word construction with Kana blocks was incorrectly performed. In the case of Kimura et al. (1986) most of errors were no-response. A similar pattern of deficit in writing Kana words was reported in a Japanese patient with conduction aphasia (Yamadori and Ikumura, 1975), whose errors however were not confined to writing Kana words but also involved naming, reading and repetition. Thus our case was 'pure' in two ways, impaired Kana word writing with normal Kanji writing and impaired Kana writing with normal oral output.

The anatomical basis for Kana agraphia remains unclear. The case of Tanaka et al. (1987) had lesions in the left angular gyrus, the adjoining posterior superior temporal gyrus and the left corona radiata. The case of Abe et al. (1993) had a lesion in the left middle frontal gyrus. In our patient, damage involved the right putamen and the surrounding white matter. The mutism observed in early stage of disease, then followed by a mild aphasia, suggests that the hemisphere dominant for language was the right in this left-handed patient with a family history of left-handedness. Laine and Marttila (1981) reported a Finnish patient with pure agraphia caused by damage to the left

caudate nucleus and the anterior limb of the internal capsule. Their patient demonstrated a dissociation similar to that of our case between correct production of single letters and incorrect writing of words.

He also made numerous paragraphias, both literal and syllabic, in writing longer words and sentences. Lesions in the deep white matter in the language dominant hemisphere likely affect the structures of the writing system dedicated to the graphemic buffer.

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Kae Kokubo, Hyogo Institute for Aging Brain and Cognitive Disorders, 520 Saisho-Ko Himeji, 670 Japan. E-mail: kokubo@hiabcd.go.jp

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