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(Degree)

博士（保健学）

(Date of Degree)

2011-03-25

(Date of Publication)

2011-09-08

(Resource Type)

doctoral thesis

(Report Number)

甲5148

(URL)

<https://hdl.handle.net/20.500.14094/D1005148>

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Do the left anterior and medial temporal lobes relate to kanji learning difficulty in a child?

Chiyomi Nakanishi, Takeshi Hashimoto, Keiko Seki¹

Abstract

It is widely accepted that acquired kanji alexia/alexia with agraphia in adults are caused by lesions in the left posterior inferior temporal regions. However, little is known about which brain region influences kanji learning in children. We investigated kanji learning difficulty in a 12 year-old child who had suffered from a stroke at 8 years of age. His lesions were located in the left anterior and medial lobes which are components of the ventral language stream. We evaluated his language, kanji words reading, kanji orthographic knowledge, and mnemonic ability.

His language was normal except for kanji reading/writing and naming. His reading ability was better for kanji words with more frequency, familiarity, and imageability, and was worse for kanji words with more number of pronunciations and complexity. These results suggested that his semantic system was impaired. The orthographic evaluations highlighted his difficulty in learning whole-kanji forms associated with pronunciation. This result was replicated in the mnemonic evaluation of paired-association learning test.

His lesions might have affected the functioning of the semantic system and mnemonic ability, thus resulting in kanji learning difficulties. This study implies that learning kanji words may require functions in the left anterior and medial temporal lobes in children.

Key words:

Kanji learning difficulty, The left anterior and medial temporal lobes, Semantic system, Orthographic knowledge, Mnemonic ability

Introduction

Japanese language is known for its combined use of two distinct writing systems, kanji (morphograms) and kana (phonograms). The characteristics of kanji are more complex than kana. Most kanji characters have several alternative readings, i.e. *On-reading* represents the original Chinese phonetic value, and *Kun-reading* conveys Japanese meaning. The reading of kanji characters is determined by the meaning of each character in a given context. For example, the kanji character 白 is read by [haku] in a compound word 白紙 (blank paper, [haku-shi]) and is read as [shiro] in 白熊 (white bear, [shiro-kuma]). Moreover, kanji characters are graphically complicated and have many homophones; e.g. 舶, 箔, 粕, 泊 consist of many strokes and have the same pronunciation [haku]. There are about 2000 kanji characters in common use and these have to be learned through nine years compulsory education.¹⁾ Due to the large number of kanji characters, the number of years of education significantly influences the degree of proficiency in handling kanji.²⁾

In contrast, kana letters have one definite phonetic value and no intrinsic meaning, i.e. さ is pronounced [sa] and does not represent any meaning. The relationship between each kana letter and its pronunciation has the strict grapheme-to-phoneme (GTP) correspondence, e.g. く is [ku] and ら is [ra]. Once

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one have learned this rule, they can correctly pronounce any kana words without any lexical knowledge, e.g. さくら (cherry) is pronounced [sa-ku-ra].²⁾ There are 46 kana letters which are graphically simple and they are learned in the first year of the elementary school.¹⁾

With the different characteristics of kanji and kana, adult acquired dyslexia can demonstrate some dissociation between kanji and kana. Researchers have inferred that these two scripts could be processed in different mechanisms involved in different routes.¹⁾⁻⁵⁾ Anatomically, the dual routes model is proposed to be as follows. The orthographic route which involves the inferior occipital, fusiform, and posterior inferior temporal gyri, is essential for the orthographic and semantic processing of kanji. The phonological route, which passes through the temporo-parietal areas, plays a role in the character-to-sound conversion of reading kana words.¹⁾⁶⁾ These ideas are widely accepted in the studies of adult acquired dyslexia.

Regarding kanji learning difficulty in children, there are some studies which investigated it with aphasic children,⁷⁾⁻¹⁰⁾ others mentioned it with developmental dyslexia cases.¹¹⁾⁻¹⁶⁾ However, little is known which brain lesion affects kanji learning difficulty in children. Because children who suffered brain lesion in their early schooldays and demonstrated kanji learning difficulty is scarce.

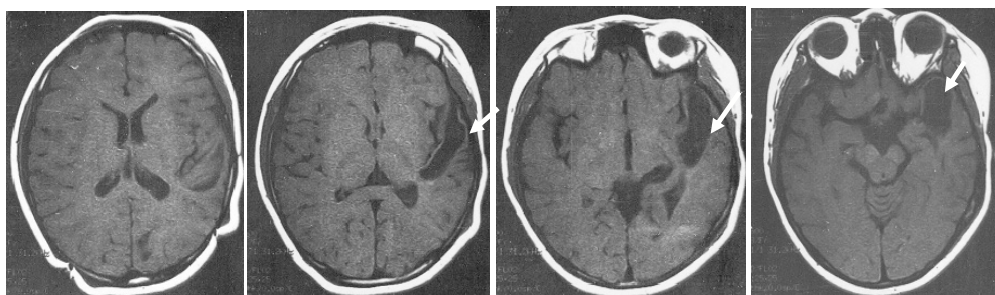
In this study, we investigated a child who suffered from stroke in his 8 years old and demonstrated kanji learning difficulty for 4 years from his onset. His lesion was located in the left anterior and medial temporal lobes, which was inconsistent with previously reported adults' dyslexia cases. The aims of this study are to know the characteristics of his kanji learning difficulty and to investigate the possible relation between the left anterior, medial temporal lobe and kanji learning in a child.

Subject

IG was a right-handed boy. At 8 years old, he was surgically treated for an arteriovenous malformation (AVM) in the left anterior temporal lobe and a hematoma caused by the AVM. Gamma x-ray treatment for the remaining AVM was performed. There were no remarkable neurological symptoms in his post-operation, except for right homonymous hemianopsia. He recovered and adapted to schoolwork smoothly. However, at the latter part of the third grade, 9 years old, he realized that his kanji learning was much worse than the other children. Third grade was a time in which Japanese children was introduced kanji learning with increased degree of visual and phonological complexity. Since he had not only been able to speak nor comprehend, but also read and write kana and numbers, teachers had not noticed his kanji learning difficulty as a peculiar symptom. Although he had not received a specific neuropsychological evaluation, according to his parents there was no notable retardation in his development of language or other cognitive functions before the onset of the hematoma.

Magnetic resonance images (MRI) of the brain at 12 years old revealed lesions, which located in the

Figure 1. IG's MRI images at 12 years old



MRI T1-weighted images leveled the lesion in the base of left temporal lobe and dorsally extend to the temporal stem at the subcortical area of left middle temporal gyrus.

base of the left temporal lobe and dorsally extended to the temporal stem at the subcortical area of middle temporal gyrus (Figure 1). The left entrhinal cortex, the left rhinal cortex and the left amygdala were partially damaged. The left hippocampus was spared, but slightly atrophied. The cortical area of the left superior temporal gyrus seemed spared.

Methods

1. General neuropsychological evaluation

Two standard language tests, the Standard Language Test of Aphasia (SLTA)¹⁷⁾ and the Test of Lexical Processing in Aphasia (TLPA)¹⁸⁾ were performed to evaluate IG's language ability. Intelligence, memory and visual analytical ability were evaluated by the Wechsler Intelligence Scale for Children-III (WISC-III),¹⁹⁾ the Wechsler Memory Scale-R (WMS-R)²⁰⁾ and visual analytical ability in the Visual Perception Test for Agnosia (VPTA)²¹⁾ respectively.

2. Evaluations for language functions

We clarified the underlying mechanisms of IG's kanji learning difficulty through the following tests. Eight junior high school students participated as controls. Informed consent from each child and informed parental consent was obtained prior to testing. Stimuli for these tests were extracted from the NTT psycholinguistic database,²²⁾ and they were taught during elementary school. Lexical properties of each word were used in these tests. Familiarity, imageability and complexity were rated on a 7-point scale, and frequency was based on a database that covered articles in a newspaper over 14 years.

2.1. Reading

(1) Kanji words reading test

We analyzed IG's kanji reading ability across the three points below. First, to compare the difference between *On-reading* and *Kun-reading*, we performed a 420 two-character kanji words reading test, which were mainly read by *On-reading*, and a 300 single-character kanji words reading test, which were usually read by *Kun-reading*. IG was asked to read aloud these kanji words one by one.

Second, we evaluated whether IG's kanji reading was affected by the lexical properties on his kanji reading ability. The relationship between IG's correct and incorrect reading performances across 420 two-character kanji words were compared for each lexical property.

Third, we clarified whether IG's kanji reading was influenced by the consistency of word pronunciation on his kanji reading ability. The 420 kanji words were divided into two groups by their consistency of word pronunciation; i.e. whether each component of kanji characters is read by a single pronunciation or not. Consistency was defined by the same procedure as used Fushimi's study²³⁾ using a dictionary of Chinese characters.²⁴⁾ Consistent words are comprised two kanji characters, each of which is read only by a single *On-reading* in the dictionary, while inconsistent words consist of two kanji characters, one or both of which have more than one legitimate pronunciation. Moreover, IG's errors were analyzed to ascertain which types of errors occur in each level of consistency.

(2) Kana words reading test

Thirty low-frequency kana-words and thirty kana-nonwords were evaluated. Low-frequency kana-words consist of three and five kana letters. Kana-nonwords were formed by transposing the sequential order of three- and five-letters of low-frequency words randomly. IG was asked to read aloud them one by one.

2.2. Orthographic awareness

Two tests were conducted to clarify whether IG had learned kanji orthographic knowledge. The exemplars of two test are shown in Figure 2 A and B.

(1) Pseudo-kanji character identification test

Figure 2. Examples of phonological awareness tests

(A) Pseudo-kanji character identification test

Radical modified condition

	Correct	Incorrect	
Eraseure	総	総	erasing some stroke
Addition	担	担	adding some stroke

Radical exchanged condition

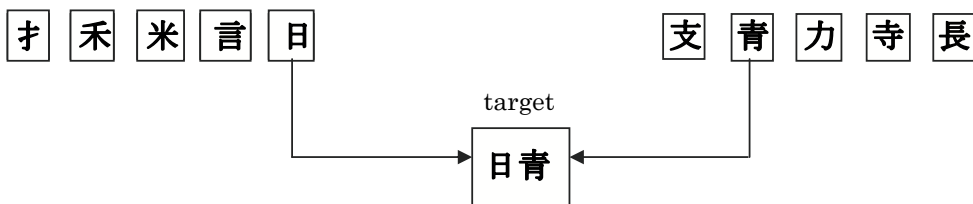
	Correct	Incorrect	
	汗, 利	汗, 利	combining each radical randomly

When these characters were presented one to one, subjects were asked to identify whether these character forms were correct or not. These stimuli were constructed according to Nakagawa.²⁵⁾

(B) Kanji character construction test

Five radical cards for left side component of target

Five radical cards for right side component of target



Arranging correct radical cards from five choices

Two groups of cards, which were comprised five cards, were arranged in front of subject. One group was for the right side component and the other was for the left side component in which each card represented a radical. Subjects were asked to construct a kanji character with these cards when examiner presented a target word aurally. This test was created based on the same procedure as that used by Iwata.²⁶⁾

This test consisted of two conditions (Figure 2 A). In the radical-modified condition, radical forms were modified by adding some strokes (addition) or by erasing some strokes (erasure). In the radical-exchanged condition, each radical maintained its form but was inappropriately combined with other radicals. Each condition had 60 stimuli; half of them were modified and others remained in their original forms. Subjects were asked to identify whether each character form was correct or not. This test allowed us to evaluate the subjects' whole-character kanji orthographic knowledge and radical orthographic

Figure 3. The exemplars of paired association learning test

	Geometric figure	meaning
Simple figure condition		----- respect
Complex figure condition		-----discipline

Subjects were asked to learn by repeating the word which was presented aurally by the examiner and copying the figure accompanied with the word. They were later asked to recall the words associated with the specific figure. The recalls were analyzed at the 20 minute delay and 1 week delay.

knowledge.

(2) Kanji character construction test

Forty-five kanji characters, consisting of two radicals, were used as test characters. The subjects were asked to construct the target selecting appropriate radical cards from five choices. The examiner gave a compound-word which was accompanied by the typical *On-reading* pronunciation of the target character (Figure 2 B). This test allowed us to evaluate the subjects' kanji orthographic knowledge linked with the corresponding pronunciation.

2.3. Phonological awareness

Two tests were conducted, and the stimuli were the same set as that used in the kana-words and kana-nonwords reading tests.

(1) Syllable deletion test

This test asked the subjects to remove one syllable from three- or five-syllable words, which were aurally presented by the examiner. In the case of three-syllable words, subjects were asked to remove the middle syllable. For the five-syllable words, half of them required the removal of the second syllable and others required the removal of the third syllable. This test requires the ability to manipulate phonological information precisely.

(2) Nonword repetition test

Subjects were asked to repeat three-and five-syllable nonwords after the examiner presented them aurally. This test requires the ability to discriminate the phonemes and to memorize the sequential order without lexical knowledge.

2.4. Paired-association learning

Learning kanji character requires linking orthographic and phonological information. The test procedure resembles this process, and employs geometric figures instead of kanji orthographies. Thus, this test allowed us to evaluate IG's learning ability to link visual and phonological information. The exemplars of this test are shown in Figure 3. Ten simple and ten complex geometric figures were constructed. The words were low-frequency abstract words, and were presented aurally by the examiner. The subjects were asked to learn by repeating the utterance and copying the geometric figure. Stimuli were presented randomly five times. After the learning period finished, the subjects were asked to recall the corresponding

Table1. IG's scores on the general neuropsychological tests

SLTA	TLPA		WISC-III, WMS-R, VPTA	
SLTA (Japanese Standard Language Test of Aphasia)	TLPA (Test of Lexical Processing in Aphasia)		WISC-III	
Spoken word-to-picture matching	10/10	Spoken words Lexical decision	Verbal IQ	99
Spoken sentence comprehension	10/10	Spoken word synonym decision	Performance IQ	114
Spoken command comprehension	10/10	Written kanji words lexical decision	Total IQ	107
Written kanji word-to-picture matching	10/10	Written kana words Lexical decision		
Written kana word-to-picture matching	10/10	Spoken word comprehension	WMS-R	
Written sentence comprehension	10/10	Picture naming	(Wechsler Memory Scale-Revised)	
Written command comprehension	8/10*	High-frequency word	Verbal memory	117
Picture naming (noun)	20/20	Low-frequency word	Visual memory	111
Picture naming (verb)	10/10		General memory	119
Scene description	6/6		Attention/Concentration	100
Word fluency (animals within 1 min)	16/15		Delayed recall	99
Word repetition	10/10			
Sentence repetition	5/5		VPTA	
Reading aloud kanji words	5/5		(Visual Perception Test for Agnosia)	
Reading aloud kana words	5/5		Discrimination figures	6/6
Written naming with kanji word	3/5*		Discrimination angles	3/3
Written naming with kana word	5/5		Discrimination line length	5/5
Writing to dictation with kanji	3/5*		Copy of figures	3/3
Writing to dictation with kana	5/5		Object naming	8/8
Writing to dictation sentence	3/5*		Naming of familiar person's photographs	3/3
			Color naming	8/8

* The IG's performance was below two standard deviations from the mean of controls.

Table 2. Results of IG's performance in reading tests

(A) Kanji words reading test				
420 two-character kanji words reading			300 single-character kanji words reading	
<Total correct response>				
124/420 (29%)			134/300 (45%) *	
<The effect of lexical properties >				
	Correct	Incorrect	Correct	Incorrect
Frequency	253.7**	192.5	141.6	157.6
Familiarity	280.3**	181.5	187.9**	120.2
Imageability	256.3**	191.5	—	—
Complexity	—	—	129.0**	167.8

(B) Kana words reading (n=30)				
<u>Kana words</u>			<u>Kana nonwords</u>	
Three-letter words	30 (100%)		Three-letter nonwords	30 (100%)
Five-letter words	30 (100%)		Five-letter nonowrds	30 (100%)

*P<0.05 calculated by the Chi-square test.

**P<0.0001 calculated by the Mann-Whitney U tests.

Table 3. The error types of consistent and inconsistent kanji words

Example	Consistent words	Inconsistent words
	完全 (perfect, [kan-zen]) n=187	分配 (distribution [bun-pai]) n=233
Correct response	66/187(35%)*	59/233(25%)
Summation of errors	121/187	174/233
<Error type>		
	Non-response	96
	Incomplete response	14
	Regularization error	2
	Semantic error	2
	Visual error	3
	Other response	4

<Error type> Incomplete error: IG produced only part of the correct whole-word pronunciation. Regularization error: IG produced inappropriate but legitimate reading for consistent characters in a word, e.g. IG assigned typically used pronunciation to the target (作業 [sa-gyou] (work) → [saku-gyou], 作 is more frequently read by [saku] than [sa]), or he assigned inappropriate *Kun*-reading to the target (田園 [den-eN] (rice-field) → [ta-eN], 田 was misread by *Kun*-reading [ta] instead of *On*-reading [den]. Semantic error: those responses corresponded to words that are semantically related to the target: 愛情 (affection [ai-jou] for 恋愛 (love [ren-ai]), *Kun*-reading 悲 [kana/i] (sorrow) → [sabi/i] (lonely). Visual error: those responses corresponded to words that are visually similar to the target: 基地→墓地, 置→買. Other response: those responses are not visually or semantically related with the target. These error type was classified the same definition of Fushimi.²³⁾

*P<0.05 calculated by the chi-square test.

Table 4. The evaluations for orthographic awareness, phonological awareness and paired-association learning

(A) Orthographic awareness test					
1) Pseudo-kanji identification test					
	<u>Radical-modified condition</u>			<u>Radical-exchanged condition</u>	
	IG	Control (n=8)		IG	Control (n=8)
Erasure	58/60	59.5 ± 0.59		14/60*	57.4 ± 0.63
Addition	59/60	58.2 ± 0.49			
2) Kanji construction test					
	IG	Control (N=8)			
	13/45*	42.5 ± 0.65			
(B) Phonological awareness test					
	1) Syllable deletion			2) Nonword repetition	
	IG	Control (n=8)		IG	Control (n=8)
Three-syllable words	30/30	30 ± 0	Three-syllable nonwords	30/30	30 ± 0
Five-syllable words	30/30	30 ± 0	Five-syllable nonwords	30/30	30 ± 0
(C) Paired association learning test					
	<u>20 minutes delay</u>			<u>1 week delay</u>	
	IG	Control (n=8)		IG	Control (n=8)
Simple figure condition	10/10	9.8 ± 1.5		8/10	6.2 ± 1.5
Complex figure condition	10/10	9.7 ± 1.6		3/10*	5.6 ± 1.4

* IG's performance was below two standard deviations from the mean of controls.

utterance to each figure. Follow-up tests were conducted after a 20-minute delay and one-week after the paired-association learning.

Results

1. General neuropsychological evaluation

The results are shown in Table 1. IG performed normally in auditory comprehension tasks, repetition and kana reading/writing/comprehension in the SLTA and the TLPA. However, he showed a marked difficulty in kanji reading/writing/comprehension in both language tests. Concerning naming difficulty, although he correctly named 20 out of 20 in the naming task in the SLTA, he misnamed 21 out of 100 in the naming low-frequency-words task in the TLPA.

IG's intelligence and mnemonic ability scored average in the WISC-and the WMS-R, respectively. He showed fair visual analytical ability in the VPTA.

2. Evaluations of language functions

2.1. Reading

IG showed a remarkable difference in reading ability between kanji and kana (Table 2 A and B). His reading performances in both kanji reading tests were extremely poor; he correctly read only 124 out of 420 two-character kanji words (29%) and 134 out of 300 single-character kanji words (45%). On the other hand, his reading performances in kana words and kana-nonwords were good; he correctly read

every stimulus in both tests (100%).

Concerning the difference between *On-reading* and *Kun-reading* (Table 2 A), the number of IG's correct responses in reading 420 two-character kanji words and 300 single-character kanji words were compared using a chi-test. IG was better able to read 300 single-character kanji words, which are usually read by *Kun-reading*, than 420 two-character kanji words, which are usually read by *On-reading* ($P < 0.001$, $F = 1$, 18.128).

The effect of the lexical properties of each kanji reading tests was assessed using the Mann-Whitney U tests (Table 2 A). In the 420 two-character kanji words, IG read the kanji words with high frequency, familiarity, and imageability significantly better than those with low frequency, familiarity, and imageability ($P < 0.0001$). In the 300 single-character kanji words, he was significantly better able to read high-familiarity words as well as low-complexity words ($P < 0.0001$), while the frequency of words did not affect the number of correct and incorrect responses.

The number of correct responses and error types of consistent versus inconsistent kanji words are shown in Table 3. IG correctly read 66 out of 187 (35%) consistent kanji words while he correctly read 59 out of 233 (25%) inconsistent kanji words. He was significantly better able to read consistent kanji words than inconsistent kanji words ($P < 0.05$, $F = 1$, 4.289). Although the majority of his errors were non-response, he also made substantial errors. Most of these occurred in the inconsistent kanji words; 22 incomplete errors observed in the inconsistent kanji words reading out of the summation of 36 incomplete errors, 20 regularization errors observed out of the summation of 22 regularization errors, and 10 visual errors observed out of the summation of 13 visual errors.

2.2. Orthographic awareness

The results are shown in Table 4 A. In the pseudo-kanji character identification test, IG correctly identified pseudo-kanji characters in the pseudo-radical condition, 58 out of 60 (97%) in erasure and 59 out of 60 (98%) in addition, while in the pseudo-radical-combination condition, he identified only 14 out of 60 (23%).

IG also showed severe difficulties in constructing kanji characters by choosing a radical from among five radicals corresponding to pronunciations (Table 4 A). He correctly constructed only 13 kanji characters out of 45 (29%).

2.3. Phonological awareness

The results are shown in Table 4 B. IG showed fair phonological manipulation ability in the syllable deletion and nonwords repetition tests. He correctly deleted specific syllable from both three- and five-syllable words; 30 out of 30 (100%). He also correctly repeated both three- and five-syllable nonwords; 30 out of 30 (100%).

2.4. Paired-association learning

The results are shown in Table 4 C. In the simple figure condition, IG correctly recalled the same number of responses as the controls at both 20 minutes and one week after the test; he correctly recalled 10 out of 10 (100%) with 20-minute delay and 8 out of 10 (80%) with one-week delay. In the complex figure condition, the number of correct recalls at 20-minute delay was the same as the controls; he correctly recalled 10 out of 10 (100%). However, the number of correct recalls in the complex figure condition at one-week delay was lower, with two standard deviations below than that of the controls; he correctly recalled 3 out of 10 (30%).

Discussion

We have analyzed kanji learning difficulty in a child, IG, who demonstrated fair cognitive abilities. His

lesions were located in the left anterior and medial temporal lobes. Recent studies showed the analogous relation between children's higher brain dysfunctions and brain lesions those found in adults.¹³⁾²⁷⁾ Therefore, we will consider IG's symptoms based on adult's findings.

According to the widely accepted dual route model,¹⁶⁾²⁸⁾ kanji are essentially processed by the orthographic route, which proceeds from the primary visual cortex to the inferior temporal gyrus via the fusiform gyrus. Around the end of this route, the orthographic lexical information is stored. The semantic storage site extends from the posterior inferior temporal cortex to the anterior part of the temporal lobe where lexico-semantic information is stored. In most adult cases, the pure kanji alexia/alexia with agraphia occurred when the left posterior inferior temporal region was injured. Thus, it is of interest to analyze how the left anterior and medial temporal lesions affect IG's kanji learning.

Reading kanji words and the left anterior temporal lobe

IG demonstrated the severe difficulty in reading kanji words. When we examined his reading ability in *On-reading* and *Kun-reading*, he was better able to read kanji words in *Kun-reading*. The pronunciations of *Kun-reading* usually correspond to Japanese meanings, while *On-reading* mainly represents phonemes. Thus, it would be easy for him to read kanji words with meanings. In his performances of *On-reading*, he was better able to read kanji words with high frequency, high familiarity, and high imageability. In *Kun-reading*, he was better able to read kanji words with high familiarity and low complexity. These results suggested that he could read kanji words whose characteristics easily evoke the meanings in *On-* and *Kun-reading*. This phenomenon corresponded to the traditional view that kanji are strongly correlated with meaning.²⁾⁵⁾²⁹⁾³⁰⁾

IG's lesions are located in the left anterior temporal lobe and the subcortical area of the left middle temporal gyrus. The left anterior temporal lobe has been implicated as being a component of semantic system,³¹⁾⁻³³⁾ and the middle temporal gyrus is thought to be a supportive component of semantic processing.³⁴⁾⁻³⁷⁾ Therefore, it seemed that IG's semantic system was impaired by his lesions and that his impairment of the semantic system affected his kanji words reading.

He was better able to read consistent kanji words than inconsistent ones, when the effect of kanji words' consistency was examined in IG's performances of *On-reading*. He made many incomplete-errors, regularization-errors, and visual-errors in reading inconsistent kanji words. These results suggested that it was difficult for him to select suitable pronunciation from multiple candidates. This phenomenon was observed in semantic dementia which involves atrophy of the anterior temporal regions.²³⁾³⁸⁾³⁹⁾ Furthermore, IG demonstrated a difficulty of naming low-frequency words, which also observed in semantic dementia cases. These findings also suggested that his semantic system was impaired by the lesion in the left anterior temporal lobe and that the difficulty in reading kanji words was attributed by the dysfunction in the semantic system.

Learning kanji orthographies and the left medial temporal lobe

Difficulty in learning kanji orthographies was a distinctive feature amongst IG's symptoms. In the pseudo-kanji identification test, he identified pseudo-radical-forms and misidentified pseudo-radical-combinations. Furthermore, in the kanji-character construction test, he could not construct kanji characters using radicals associated with pronunciation. These results suggested that he could not learn whole-kanji characters corresponding to pronunciation. This phenomenon was confirmed by the paired-association learning test. In the simple-figure condition, his number of correct recall was the same as controls both 20-minute and one-week delays. However, in the complex-figure condition, he made as many correct responses as the controls after 20-minute, he made fewer correct responses after one-week. These results suggested that his ability to memorizing complex-figures associated with pronunciation was declined. This process might require a higher degree of integrative memorizing.

Recent studies have postulated that the anteromedial temporal lobe is critically involved in the formation, and that processing of complex, multimodal (visual-auditory) object information and the post superior temporal gyrus/middle temporal gyrus play supportive role during multimodal integration.⁴⁰⁾⁻⁴³⁾ IG have lesions in the left medial temporal lobes and the subcortical area of the middle temporal gyrus. Therefore, it is suggested that his lesions in the left medial temporal lobe affected his mnemonic ability integrating visual-auditory information.

The left posterior inferior temporal lesions have been focused on adult cases of kanji alexia/alexia with agraphia.¹⁾²⁷⁾²⁹⁾⁴⁴⁾⁴⁵⁾ While, the relation between the anterior temporal lobe and the difficulty of kanji reading/writing have been mentioned in the studies of semantic dementia.²³⁾³⁷⁾³⁸⁾

In IG's case, the kanji learning difficulties were probably caused by his lesions in the left anterior and medial temporal lobes, suggesting that the left anterior, medial temporal lobes might be necessary for kanji words learning in children.

Conclusions

IG demonstrated kanji learning difficulties due to the lesions of his anterior and medial temporal lobes. The results of reading tests suggested that IG has an impairment of his semantic system. The analysis of kanji orthography suggested that he could not learned whole-kanji character-forms associated with pronunciation. The paired-association learning test confirmed that his integrative mnemonic ability was declined.

In conclusion, the results suggested that IG's semantic system should be affected by the lesions in the base of anterior temporal lobe and the subcortical area of middle temporal gyrus, and that his visual-auditory multimodal memorizing ability should be affected by the lesion of the left medial temporal lobe. This study and our findings implicate that learning kanji words require the functions of anterior and medial temporal lobes in children. Given these findings, it could be worthwhile to continue this line of engagement through empirical studies focusing on children. Moreover, it would be more important to elucidate what kind of method would improve kanji learning in such a child.

There was a possibility that IG's language lateralization was somewhat irregular because of his AVM. Moreover, high plasticity of child's brain was possibly to influence his functional lateralization. Our findings should be interpreted with caution and additional evaluations are needed to clarify the mechanism of the kanji learning difficulty in children with regional cerebral blood flow or functional MRI.

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