Original article

A Cognitive Neuropsychological Approach to the Mechanism of Kana-Kanji Dissociation in Oral Reading

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Key words : kana, kanji, triangle model, cognitive neuropsychology

Abstract

This study examines a fluent aphasic subject with word-finding difficulties and kanji dyslexia who showed significant picture cue effects in oral reading of kana but who showed no such effects when he performed oral reading of kanji. The study applies, based on the triangle model of oral reading, a cognitive neuropsychological approach to the mechanism of kana-kanji dissociation in oral reading exhibited by the subject. The approach was made on the hypothesis that kana words are mainly processed through the phonological route at high conversion rates from orthography to phonology, whereas kanji words are primarily processed through the semantic route at low conversion rates. It is also assumed that picture naming is processed through the semantic route. If the subject has damage to phonological representations, the phonology will not be sufficiently activated through the semantic route and, he may suffer from kanji dyslexia and word-finding difficulties as a result. The subject performed well in oral reading of kana because it is assumed that oral reading of kana effectively activated phonological representations through the phonological route. The subject also exhibited significant picture cue effects in oral reading of kana. This is probably because of the summation effects that were produced by the relatively strong activation of phonology through the phonological route, and by the activation of phonology through the semantic route prompted by picture cueing. In case of oral reading of kanji, on the other hand, it is suggested that the phonological activation through the phonological route did not take place nor did the summation effects by picture cueing.

INTRODUCTION

This thesis was written based on the model of cognitive neuropsychology that studies the normal cognitive processing systems and the mechanisms of impaired cognitive systems. The conventional neuropsychology focuses, as one of its central themes, on investigating the functions of specific brain sites by studying the relation between the damaged sites and the functions lost due to the damage. By contrast, the aim of cognitive neuropsychology is to examine the cognitive and language mechanisms in the case of brain damage as well as to find out where in the normal cognitive model the damage may be located to cause the disorder in a given case (Tatsumi, 2002). The study in this thesis observed a subject with aphasia caused by cerebral infarction who exhibited kana-kanji dissociation in oral reading and who showed improvement in oral reading of kana when prompted with picture cueing.

To analyze the impaired oral-reading processes in a case of brain damage, based on the approach of cognitive neuropsychology, we need a model that describes the oral-reading processes of a

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normal individual (Coltheart et al., 2001; Coltheart et al., 1993). Seidenberg and McClelland (1989) hypothesized the interactive computational model (Figure 1) that expressed the mechanism of speaking and comprehension of single words by using the lexical representations of orthography, phonology, and semantics. This framework of lexical processing is called the triangle model (Seidenberg & McClelland, 1989; Fushimi et al., 2000). Suppose that we call the patterns in the brain that are activated when we see written words (or non-words) as orthographic representations. Suppose that we call the patterns that are produced when we hear words (or non-words) as phonological representations. And suppose that we call the patterns that correspond to the meanings and characteristics of certain things as semantic representations. Then the patterns for orthography, phonology, and semantics in the triangle model (Figure 1) would each correspond to the representations of orthography, phonology, and semantics of single words, respectively, when the pattern are activated.

When we examine oral-reading processes of single words according to the triangle model, we find three types of processes appear to be working; those are 1) the process that activates

phonology directly from orthography (A in Figure 1), 2) the process that activates phonology from orthography via semantics (B in Figure 1), and 3) the process in which the phonology that has been activated by orthography is enhanced by the interaction with semantics (C, D in Figure 1).

As known, the Japanese language uses both kana and kanji letters. Kana is syllabic and functions the same way as the alphabets do. Kanji is morphemic and combines several phonic values and meanings. When a kana word is formed, the kana letter(s) will contain a single phonic value and meaning. By contrast, when a kanji word is formed, the kanji letter(s) will contain several phonic values and a single meaning. Consequently, it is postulated that oral reading of kana tends to occur via the route from orthography to phonology in the triangle model (A in Figure 1), whereas oral reading of kanji tends to occur, first, via the route from orthography to semantics (B in Figure 1) and, then, via the route from semantics to phonology (C in Figure 1).

Picture naming, on the other hand, first involves visual information processing, then the acquisition of phonological representations via the route from semantics to phonology (C in Figure 1), and finally the process of speech
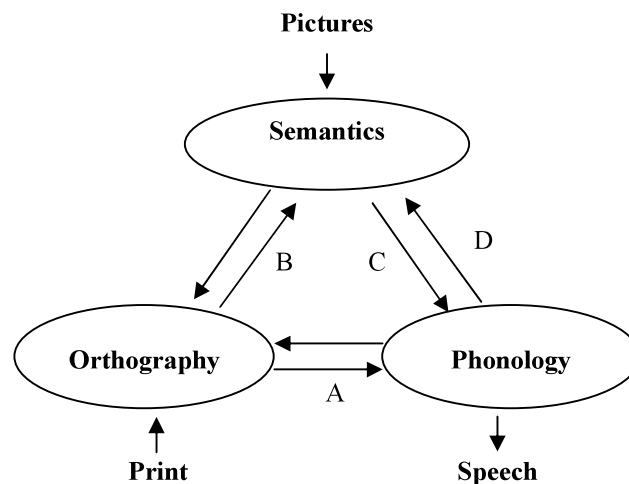

Figure 1 Triangle Model

production. Therefore, oral reading of kanji shares the same route (C in Figure 1) with picture naming and relies more heavily on this route than does oral reading of kana. This leads to an assumption that some cases of speech impairment may observe kana-kanji dissociation in oral reading as well as picture naming.

Kana-kanji dissociation is typically observed in a case with favorable oral reading of kana but with profound difficulties in oral reading of kanji and picture naming. Yamawaki et al. (2005) reported this type of dissociation in a case of anomia. Usui et al. (2003, 2005) also reported the same type of dissociation that was found during an electric stimulation test given in the cortex area as part of pre-surgical evaluation of intractable epilepsy. In the case of Yamawaki et al. the relevant site was located in the left inferior temporal gyrus, while in the case of Usui et al. the site was located in the left posterior basal area. The case in this study is different from these reported examples, however, in which it presents multiple infarcts in the insular in the left hemisphere, and in the frontal and temporoparietal regions. Also, this case exhibited evident difficulties in oral reading of kana and showed the similar dissociation as those found in the cases above between oral reading of kana and picture naming as well as oral reading of kanji.

CASE HISTORY

Age 69. Right-handed male. Company president. High-school graduate.

Current medical history: The subject experienced cerebral infarction in the left middle cerebral artery region due to cardiogenic cerebral embolism. Around a month postonset, he restored clear conscience; paralysis almost disappeared, but the aphasic conditions described later remained.

Test findings: Figure 2 shows the CT image in the head area at the onset. The image displayed multiple infarcts in the outer envelope of the left middle cerebral artery region, the insular region, and the frontal and temporoparietal regions.

Neuropsychological findings: The subject exhibited lucid consciousness and was cooperative in the tests. The Kohs block design test showed a raw score of 9 points and IQ of 47. His spontaneous speech consisted of fluent jargon and was incomprehensible. The spontaneous speech was rarely made, and when it was made, it was mostly made up of responses to questions. Repetition of single words was expressed in
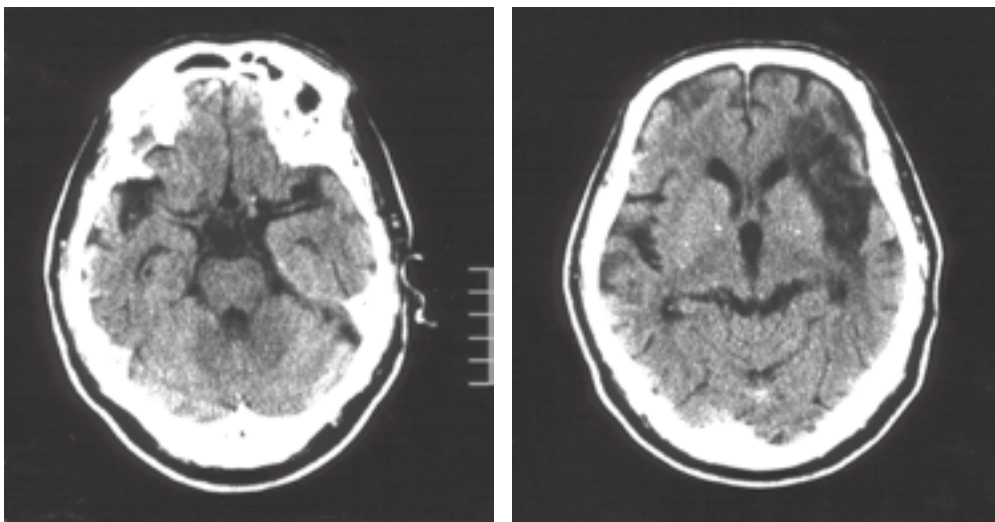

Figure 2 CT scan

jargon and hardly distinguishable. The Japanese standard language test of aphasia (SLTA) was given at 3 months and 16 months post onset (Figure 3). The scores of picture naming were extremely poor at 1/20 and 4/20, respectively. It appeared that the subject understood picture contents through gestures given during the tests. The scores of oral reading of kana declined from 5/5 at 3 months post onset to 1/5 at 16 months post onset. This may be due to different conditions at the test sites.

The findings of oral reading of single words indicate that the subject was capable of oral reading of kana to some degree when he read letter-by-letter although he performed poorly in reading single words. He performed even more poorly in oral reading of kanji and appeared to have understood from gestures rather than from reading. His oral reading of kanji hardly improved even though the corresponding picture cards were presented simultaneously with the kanji cards at the test sites. By contrast, his oral reading of kana showed a sign of improvement when picture cards were accompanied with kana cards. To find out the difference in oral reading between kana and kanji as well as the difference of cueing effects in picture presentation, the following tests were administered at 3 months and 20 months

post onset, respectively:

Test 1: Oral reading of the same words written either in kana or kanji, and cueing effects of picture cards

Stimuli: 55 sets of kana and kanji cards of daily-used words (e. g., "たばこ", "煙草" [tobacco], "あし", "足" [foot], "つくえ", "机" [desk]), and 55 picture cards matching with those cards.

Procedure: (1) Present a kana card only and ask the subject to read it aloud. (2) Present the corresponding kanji card and ask the subject to read it aloud. (3) First, present a picture card and confirm by observing gestures of the subject that he has fully understood the picture content. Then, present the corresponding kana card and ask the subject to read it aloud. (4) Repeat the same procedure as (3) for the corresponding kanji card.

Results: Without cueing effects of picture cards, the oral reading score for kana was 7/55 and that for kanji 1/55. With cueing effects, the score for kana was 30/55 and that for kanji 1/55. The overall scores of oral reading were poor for both kana and kanji. Without cueing effects, there was a significant difference in oral reading between kana and kanji (χ^2=4.8, p<0.05). With picture cueing, the subject showed a marked improvement in oral reading of kana (McNemar's
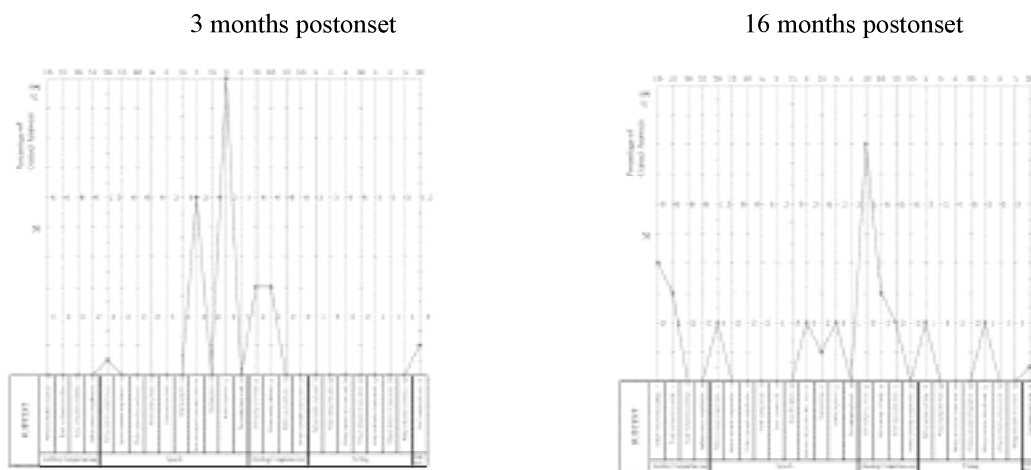
3 months postonset

16 months postonset

Figure 3 SLTA profiles

χ^2=21.0, p<0.001), although he showed no such improvement in oral reading of kanji.

Test 2: Oral reading of single words, and cueing effects of picture cards and picture naming of those cards

Stimuli: 10 sets of kana and kanji cards, respectively, with words indicating animals on them (e. g., "うま", "馬" [horse], "ねこ", "猫" [cat], "ぞう", "象" [elephant]), as well as 10 picture cards matching with those cards.

Procedure: (1) Present a kana card only and ask the subject to read it aloud. (2) First, present a picture card and confirm by observing gestures of the subject that he has fully understood the picture content. Then, present the corresponding kana card and ask the subject to read it aloud. (3) Repeat the same procedures as (1) and (2) for the corresponding kanji card. (4) Finally, present a picture card only and ask the subject to name the picture.

Results: Without cueing effects of picture cards, the oral reading score for kana was 5/10 and that for kanji 1/10. With cueing effects, the score for kana was 8/10 and that for kanji 1/10. The score of picture naming was 0/10. Test 2 used different sets of words and picture cards from those used in Test 1, but the results of Test 2 confirmed the same results as those obtained from Test 1. That is to say that the performance of picture naming was absolutely inferior although picture cueing was effective for oral reading of kana.

Test 3: Oral reading of single words written either in kana or kanji, and cueing effects of picture cards

Stimuli: 22 kana cards of daily-used words (e. g., "テレビ" [television], "いちご" [strawberry], "かえる" [frog]), 18 kanji cards of daily-used words (e. g., "眼鏡" [glasses], "時計" [clock], "自動車" [automobile]) that are different from those used for kana cards, and 40 picture cards matching with those cards.

Procedures: (1) Present a kana or a kanji card randomly and ask the subject to read it aloud. (2) First, present a picture card and confirm by observing gestures of the subject that he has fully understood the picture content. Then, present the corresponding word card and ask the subject to read it aloud.

Results: Without cueing effects of picture cards, the oral reading score for kana was 6/22 and that for kanji 1/18. With cueing effects, the score for kana was 19/22 and that for kanji 6/18. Unlike Test 1, Test 3 used different words for kana cards from those used for kanji cards to avoid a condition in which kana and kanji cards would serve as cueing effects for each other during oral reading. Still, the results of cueing effects in Test 3 are similar to those in Test 1.

Test 4: Picture naming

Stimuli: 20 picture cards of three categories such as foods, vehicles, and daily necessities (e. g., apple, bicycle, battery).

Procedure: Present picture cards and ask the subject to name them.

Results: The score was 0/20. Picture naming was performed independently from Tests 1 and 2; however, the deficit was apparent.

Test 5: Selection of 4 picture cards that match with word cards written in kana or kanji

Stimuli: 10 sets of daily-used words written in kana or kanji, and 10 picture cards matching with those cards.

Procedure: Select 4 word cards randomly from kana or kanji cards and present them to the subject. Present a picture card that matches with one of the selected word cards and ask the subject to point to the card that matches with the picture.

Results: The score for kana cards was 8/10 and that for kanji 9/10. This indicates that the subject was generally capable of matching picture cards with kana or kanji cards.

DISCUSSION

The case in this study observed a profound deficiency in picture naming and oral reading of

kanji. The case also exhibited a deficiency in oral reading of kana; however, it was significantly milder than the deficiency with kanji. Picture cue effects were apparent in oral reading of kana, whereas they were not seen for kanji. The triangle model was applied (Figure 4) to analyze the mechanism of the observation results.

First we will examine the oral reading scores for kana and kanji. In Test 1, oral reading of the same words written in kana or kanji was performed, and the scores were poor for both kana and kanji at 7/55 (13%) and 1/55 (2%), respectively. Tests 2 and 3 observed the similar results as those in Test 1. According to the triangle model, oral reading of kana is mainly processed from orthography to phonology, whereas oral reading of kanji is primarily processed from orthography to phonology via semantics. Because oral reading of kana and kanji both goes through orthography and phonology, the results of Tests 1, 2, and 3 suggest that the impairment in this case may lie either in the orthographical or the phonological unit. The result of Test 5 indicates, however, that an orthographical impairment is unlikely because the subject scored 80% for kana and 90% for kanji in the task of selecting a kana or a kanji word that matches with the picture card presented.

Therefore, it is assumed that there is not a major impairment in the route from pictures to orthography via semantics in the triangle model, and that a possibility of orthographical impairment does not account for the subject's severe deficiency in oral reading. Consequently, it is postulated that the oral reading deficiency in this case would arise from a deficit in the phonology.

In this case a characteristic of deficiency in oral reading is the dissociation between kana and kanji. The results of Tests 1, 2, and 3 demonstrate that oral reading of kanji is inferior to that of kana. When considered according to the triangle model, this type of dissociation cannot be explained by a phonological deficit alone because the processing of kana and kanji words does not take place separately in the phonological unit. Thus, we should look for another possibility in which there are deficits in other elements as well as in the phonological unit in the triangle model.

Another dissociation between kana and kanji was seen in cueing effects of picture cards for oral reading. Test 1 observed a significant improvement in oral reading of kana when picture cueing was provided, whereas it saw no improvement in oral reading of kanji even with picture cueing. A similar tendency as in Test 1
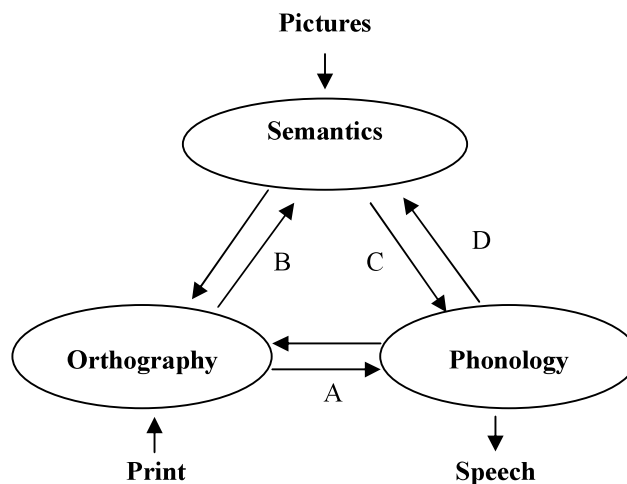
Figure 4 Triangle Model of Oral Reading

was confirmed in Tests 2 and 3. One argument is that the subject seemingly appeared to be able to read aloud because he could name the picture cards that were presented during oral reading of kana. This argument was denied; however, because the subject was unable to perform the task of picture naming itself although the picture cards were effective as cueing signs as were seen in Test 2. Another argument is that, when kana and kanji words were sequentially presented, their presentation served as cueing for each other, producing seeming effects of picture cueing. This argument was also denied because Test 3 used different sets of words for kana and kanji to avoid cueing effects. Consequently, we must look for another explanation for the kana-kanji dissociation in cueing effects of picture cards for oral reading.

The case in this study exhibited an apparent naming deficit. The SLTA naming task was given at 3 months and 16 months post onset, and the results were both inferior at 1/20 and 4/20, respectively (Figure 3). Also, in Tests 2 and 4, the subject performed naming of 30 picture cards of four different categories such as animals, foods, vehicles, and daily-used items, and he scored none. This suggests that the naming deficit in this case may be due to the impairment of semantic representations. That is that we could assume a possibility of semantic impairment in the triangle model. This possibility is improbable, however, as we have already observed in the result of Test 5. Therefore, it is concluded that there is not a major impairment in the routes from pictures to orthography through semantics in the triangle model, and that a semantic deficiency does not account for the profound naming deficit in this case.

Yamawaki et al. (2005) and Usui et al. (2003, 2005) have reported that a naming deficit and kanji dyslexia would coincide as seen in this case because picture naming and oral reading of kanji both share the same processing route of semantic

pathway. They have also reported that the processing route for oral reading of kana, which is the phonological pathway, is independent of other processing routes. That is to say, it is assumed that the processing route for picture naming and oral reading of kanji is dissociated from the processing route for oral reading of kana. The naming deficit as well as the kana-kanji dissociation in oral reading indicate that the disorder in this case is likely to be located in the processing route that is used for both picture naming and oral reading of kanji, but that is not used for oral reading of kana. This leads to an assumption that the problem may exist either in the semantics or in the route from semantics to phonology (C in Figure 4) in the triangle model. As we have already discussed, semantic impairment is improbable. Consequently, we can conclude that this is a case of double deficits located in the phonological unit as well as in the processing route from semantics to phonology. In other words, we can assume that the phonological unit is partially impaired, and that the processing for oral reading of kana and kanji is incomplete as a consequence. In addition, the deficit in the route from semantics to phonology may have further intensified the problem of oral reading of kanji.

Moreover, the processing route from semantics to phonology may also be partially impaired because the case exhibits kana-kanji dissociation in picture cue effects for oral reading. Oral reading of kana depends primarily on the route from orthography to phonology (A in Figure 1). Therefore, when picture cards are presented as cues at the time of oral reading of kana, the phonology will be activated from both routes of orthography and semantics. Unlike usual oral reading of kana, reading kana aloud with picture cueing would activate the phonology simultaneously from the dual routes to produce summation effects, which, as a result, bring about the improvement in oral reading of kana. On the

other hand, oral reading of kanji depends primarily on the route from orthography to phonology via semantics (B, C of Figure 1), and, thus, the phonological activation would take place via the semantic route only, even with picture cueing. This means that, in case of oral reading of kanji, picture cueing would produce no summation effects or improvement in the performance. To conclude, kana-kanji dissociation in cueing effects for oral reading was seen in this case because it is assumed that the processing route from semantics to phonology is not totally damaged and functional to some degree.

Hypothesis

The test results indicate that the subject exhibits dissociation in oral reading between kana and kanji and that neither performance is satisfactory. Therefore, it is hypothesized that this case has some defects in the phonological route, not in the semantic route; which is why the phonological unit is not fully activated. As shown in Figure 5, it is postulated in this case that the phonological conversion through the semantic route alone is not strong enough to fully activate the phonology, and that the inferior performance

in picture naming and in oral reading of kanji may have resulted in the complication of kanji dyslexia and a naming deficit.

In the case of oral reading of kana, it is assumed that the phonology would receive high level of activation from the phonological route, and that relatively favorable performance should result, compared with the performance in kanji. If accompanied with picture cueing, oral reading of kana would be activated cumulatively from the semantic route as well, and the phonological representations would be further enhanced.

In the case of oral reading of kanji, however, it is assumed that the phonology would receive no activation from the phonological route or summation effects from the semantic route, even though picture cueing is provided.

CONCLUSION

We can conclude that kanji dyslexia and a naming deficit in this case may have derived from the weakening of the phonological representations, and not from defects in the semantic route.

Picture cueing was effective for improving oral reading of kana but not for oral reading of kanji. This difference may be caused by the following reasons:
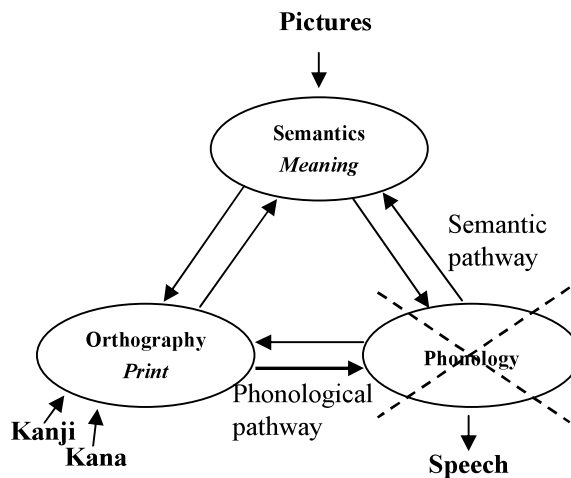

Figure 5 Hypothesis of cueing effects mechanisms in oral reading of kana seen in this case

Provided that oral reading of kana tends to be processed largely through the phonological route and that oral reading of kanji through the semantic route. If so, it is assumed that picture cue effects observed for kana may be caused by the summation effects that are produced by the activation of phonology through the phonological route as well as through the semantic route prompted by picture cueing. By contrast, it is suggested that oral reading of kanji as well as picture naming are both processed through the semantic route and that the summation effects seen for kana by picture cueing would not be produced.

Acknowledgement

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