KANA VS. KANJI PROCESSING IN THE RIGHT VS. LEFT HEMISPHERE

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1.0 INTRODUCTION

This paper reviews both the psychological literature and the medical literature on kana and kanji processing in Japanese, in an attempt to correct Western misinterpretations about claims regarding lateralization in processing Japanese kana vs. kanji.

2.0 CLASSICAL VIEW

Results from the early pioneering studies by experimental psychologists gave rise to the widely-held assumptions that phonologically-encoded kana are processed exclusively in the left linguistic hemisphere, while semantically-encoded, visuospatially-oriented kanji are processed in the right hemisphere. Some tachistoscopic studies of visual half-field recognition for high- and low-familiarity kanji showed left visual field (and thus right hemisphere) superiority for kanji and right visual field (and thus left hemisphere) superiority for kana. As a typical example, we might cite Hatta's (1977a) experimental results which confirmed left visual field superiority for kanji. He further suggested that Japanese orthography might therefore relate differently to cerebral asymmetry of function than the way that Latin scripts do, given that kana typically show right visual field superiority.

Such assumptions were often supported by other findings. For example, Sasanuma et al. (1977) tested normal subjects to ascertain whether there are lateral differences in performance when kana and kanji are tachistoscopically presented in the left and right visual fields. The results show that kana and kanji are processed differently in the cerebral hemispheres; performance on the kana task showed a significant right field superiority, while the kanji task showed a somewhat better performance in the left field.

Such results were also supported by experimental manipulations of the Stroop test. Thus, Hatta (1981) reports that Stroop test color stimuli produced greater interference in the left visual field when subjects were responding to kanji stimuli; such interference was not found for kana stimuli in the same visual field. Hatta interpreted these results as indicating that the right hemisphere is specialized for processing kanji.

This view was also supported by several clinical studies. Sasanuma (1977), for example, discusses two tests on kanji and kana processing administered to 10 Broca's aphasics, 10 simple aphasics, and 10 cerebrally damaged patients showing no aphasia. The most striking result of these tests was that, unlike the patients in the other two groups, those in the Broca's group showed a clear asymmetry in processing kanji and kana; their success rate in kanji processing was roughly around the 50% mark, whereas that of kana processing was almost 0%. Notably, all of their kana mistakes involved distinctive feature effects with proceeding or following phonemes. To

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account for this poor kana performance by Broca's patients, Sasanuma re-iterates a view of cerebral lateralization in which the right hemisphere, dominant for gestalt pattern-matching, is also responsible for kanji processing, and in which the left hemisphere, dominant for sequential, analytical processing, is also responsible for kana processing.

3.0 EVIDENCE IN CONTRAST TO THE CLASSICAL VIEW

This classical view of lateralization is, however, not in keeping with more recent psychological and clinical studies. Since the late 1970s, there have been a large number of studies dealing with kanji processing and lateralization, and the results reported by many of these studies do not square with the classical view of lateralization. It is worth reviewing some of the more pertinent of these experimental or clinical studies.

3.1 Experimental Studies

Experimental studies of this recent paradigm must be evaluated to examine the effect of two main experimental variables, the experimental stimuli involved and the specific tasks posed. In general, studies which employ tachistoscopic tests involving normal subjects, report that those physical variables in kanji which have visuospatial implications, such as the number of characters, number of strokes, size and rotation angles, and duration of exposure, show no decisive effects on lateralization for kanji processing. In contrast, qualitative variables, such as concreteness, familiarity, and part-of-speech classification, strongly influence lateralization (see Nagae, 1992); for example, abstract and/or unfamiliar kanji which are adjectives or verbs exhibit stronger left hemispheric superiority than concrete and/or familiar kanji which are nouns. Furthermore, many subsequent studies also report that lateralization is not solely influenced by these qualitative variables but also by the depth of processing involved in a specific task.

3.1.1 Physical Stimuli

Most work reports that physical stimuli, such as the number of characters, number of strokes, size and rotation angles, and duration of exposure, have no decisive effects on lateralization. For example, the number of strokes, or figural complexity in the orthography for kana or kanji could be a factor inducing the asymmetry. Bussing et al. (1987) tested 115 German subjects with kana, simple kanji, and complex kanji. The task consisted of indicating, as quickly as possible, whether two stimuli presented in sequence were the same or different. Visual field differences were not found for any of the script types, and the expected left field advantage for higher figural complexity in complex kanji was not found. The results generally suggest that figural complexity has no effect on the identification of kanji and kana.

There is no study which actually examines the effect of letter size on kana and kanji processing (Nagae, 1992). But if Kanda (1984) is correct, the size of characters should not have any effect on the processing of letter, and, hence, on lateralization.

Rotation angles may affect lateralization, and it is generally reported that rotated characters have left visual field advantage. For instance, Hayashi and Hatta (1978) examine laterality differences in levels of cognitive processing by using a mental rotation task in which subjects matched rotated kanji characters with upright kanji. Their finding was that not all mental rotation is processed in the right hemisphere, but that when a sizable mental rotation task requires the use of verbal mediators, the left hemisphere contributes more than the right hemisphere to task performance. In other words, although rotation may incur some lateralization effect, such effects do not stem from rotation alone. This conclusion is also supported by Nishikawa and Niina (1981), who failed to find visual field differences due to rotation.

Duration of exposure is not a decisive factor either. Many previous tachistocopic studies employed an exposure duration raging from 50 msec to 200 msec, and suggest that duration of exposure does not have a significant effect on lateralization. One thing to note, however, is that once the duration of exposure exceeds 200 msec, then visual field effect cannot be effectively measured because information has already begun flowing across the corpus callosum. When such defective studies are excluded, one concludes that duration of exposure does not have an effect on lateralization (Nagae, 1992).

3.1.2 Qualitative Stimuli

In contrast to such physical stimuli, qualitative stimuli, such as part-of-speech classification, familiarity, and concreteness can have significant effects on lateralization. One experiment by Elman et al. (1981a) on part-of-speech classification has subjects verbally report the grammatical category each word belonged to, while their reaction times to tachistoscopic presentation was taken as the response measure in the second experiment. The results suggest that lateral differences for processing kanji are more complex than previously claimed, with the expected right hemisphere superiority obtained only for nouns, but not for adjectives and verbs. Adjectives and verbs were in fact processed more rapidly in the right visual field, thus suggesting left hemisphere superiority. One reason why part-of-speech classification has such lateralization effect is that nouns tend to denote high imagery objects while adjectival and verbal items fail to provoke such imagery.

Many studies report the significance of familiarity on lateralization (see Kess and Miyamoto, 1994). For instance, Kawakami (1993) examines the effect of script familiarity on lexical decision tasks in an experiment which created familiar/unfamiliar words, three to five kana in length, by writing half of the stimulus words in the kana script they are not usually written in. Subjects judged whether these stimuli, some of which were misspelled, were real words. Reaction times increased in proportion to word length for unfamiliar script words, but this increase was not found with familiar script words. Kawakami's conclusion is that visually familiar sequences of kana are treated as chunks in reading, but that visually unfamiliar sequences are not. In other words, familiar words have more left visual field (and hence right hemisphere) advantage than unfamiliar words due to their visual familiarity.

Concreteness also appears to have an effect. For instance, Ohnishi and Hatta (1980) report that when high concrete kanji are presented to the left visual field and low concrete kanji to the right visual field simultaneously, high concrete kanji are processed better than low concrete kanji, showing that concrete kanji have a left visual field (and hence right hemisphere) advantage. Hatta (1977b) also examined whether there are processing differences for kanji with highly concrete meanings and those with highly abstract meanings. His findings show that concrete kanji are more correctly recognized in the left visual field than abstract kanji, and he therefore argues that, since the right hemisphere facilitates pattern recognition, and since concrete kanji are high in imagery, the factor of concreteness/abstractness affects efficiency of visual information processing and that the process of pattern recognition for verbal stimuli which are processed in the right hemisphere is facilitated by imagery. The above finding was also replicated by Elman et al. (1981b) who report that there was a right hemisphere advantage for concrete kanji nouns, but that the left hemisphere was superior in identifying abstract kanji.

In sum, as far as experimental stimuli are concerned, physical stimuli have no significant effect on lateralization, while qualitative stimuli, such as familiarity and concreteness of orthography, have significant effects on lateralization due mainly to their ability to evoke imagery.

3.1.3 Experimental Tasks

Having examined the effects of experimental stimuli on lateralization in the majority of studies, we might also examine the effect of experimental tasks asked of subjects. That is, do the requirements posed by the differing requirements of the various graphemic, phonemic, and semantic tasks employed with subjects have any effects on lateralization of kana and kanji processing?

Experimental studies which employ graphemic processing tasks generally have a pair of letters presented simultaneously to just one visual field for identification, to avoid any involvement of memory. Many previous studies (see Kess and Miyamoto, 1994) show that when there is an advantage, it is usually a left visual field (and hence right hemisphere) advantage. This generalization is hardly surprising, given that the right hemisphere is dominant for gestaltic pattern-matching, and hence responsible for analysis of the configurational aspects of kana and kanji. This generalization works for kana as well, as demonstrated by Kawakami (1993) and Besner and Hildebrandt (1987). Familiar kana words can be treated as visual chunks (i.e., by recourse to a deep orthography) and can be processed without intervention by phonemic decoding procedures. When kana is involved with pure graphemic processing tasks, kana or kana words show this left visual-field (and hence right hemisphere) advantage.

With phonemic tasks, the procedure is usually presentation of stimuli, either in sequence or parallel, to one of the visual fields for identification. Not surprisingly, much previous work (see Kess and Miyamoto, 1994) demonstrates a right visual field advantage not only for kana but for kanji as well. This finding is also not surprising, in that the left hemisphere is dominant in phonemic processing, given that kana (and at times kanji) are endowed with phonemic properties. Hence, if a task involves phonemic processing of kana and kanji, there will be an effect of lateralization by the left hemisphere.

Lastly, semantic tasks usually employ categorical indentification tasks or Stroop tasks. Most experimental studies based on such semantic tasks report a right visual field (and hence left hemisphere) advantage for kana and kanji processing tasks with semantic overtones. For instance, Hayashi et al. (1982) examine the relationship between semantic processing and cerebral laterality effects by measuring response times in a categorial classification task with kanji. The results demonstrate right visual field superiority regardless of response hand for both concrete and abstract kanji, suggesting superiority for the left hemisphere in the semantic processing required for kanji categorization.

Finally, there are also several studies which examine the interactive effects of graphemic, phonemic, and semantic tasks on lateralization. An excellent study which illustrates this point is Sekiguchi et al. (1992), which clearly demonstrates this functional lateralization as determined by the functional requirements of the processing task. This study examines hemispheric differences in kanji processing by employing a sophisticated apparatus for brain-wave measurement. Event-

Related Brain Potentials were measured at several points in the brain, monitoring brain-wave activity in processing graphemic, phonemic, and semantic aspects of kanji compounds. Experimental stimuli were constructed in order to ask subjects whether the same kanji was found in a pair of compounds (graphemic task), whether a given pair of kanji compounds was pronounced the same (phonemic task), and whether a pair of kanji compounds belonged to a specific semantic category (semantic task). The authors then measured brain-waves corresponding to the subjects' activation of a micro-switch in responding to these questions. Brain wave activity was significant in the right hemisphere when graphemic aspects of kanji were being processed; brain wave activity was significant in the left hemisphere when phonemic and semantic aspects of kanji compounds were being processed. The results demonstrate further support for considering the functional effects of lateralization, one which is directly tied to functional requirements of the task before the subject, and not simply to the global fact that it is a task involving kanji processing. The processing requirements of all previous studies should in effect be re-evaluated with this criterion in mind, and simple generalizations about kanji vs. kana processing must be re-interpreted with this fact in mind.

3.2 Conclusion

It is clear that we cannot maintain the classical view that kana is processed by the left hemisphere and kanji by the right hemisphere. Our examination of the effect of experimental variables on lateralization clearly shows that, regardless of script type, those which invoke imagery exhibit a right hemisphere advantage. Very simply, familiar kana and kanji words tend to be processed by the right hemisphere. And kana and kanji words denoting concrete objects also tend to exhibit a right hemisphere advantage. Regardless of script type, the configurational aspects of both kana and kanji are predominantly processed by the right hemisphere.

In contrast, the phonemic and semantic aspects of kana and kanji processing are predominantly handled by the left hemisphere. In sum, the cerebral shift to predominance in lateralization is very much affected by the functional requirements of the processing task, rather than by the simple feature of script type.

4.0 CLINICAL STUDIES

Clinical studies of patients with unilateral brain damage or split-brain surgery provide even more convincing evidence that a simplistic view of kana and kanji processing cannot be maintained (see Kess and Miyamoto, 1994). Their performance in dichotic listening and tachistoscopic tests suggest that kana and kanji are processed in both left and right hemispheres, and that kana processing is more lateralized than kanji processing. Thus, the left hemisphere is capable of processing the graphemic, phonemic, and semantic information required for kana and kanji interpretation, while the processing ability of the right hemisphere is both limited and different.

4.1 Contrasting Views

There is not much doubt that both kana and kanji are essentially processed mainly by the left hemisphere. The issue is, then, assessing the nature and degree of the contribution of the right hemisphere for the processing of kana and kanji. Clinical studies in the vast medical literature offer two opposing views, however. One view advocates that the right hemisphere is divorced from processing any aspect of kana and kanji. The opposing view admits that the contribution of the right hemisphere is limited, but suggests that it does make a contribution that we cannot deny. Sugishita and his research group are prototypical of those who advocate the first view, while Yamadori and his research group are representative of those who advocate the second view.

4.1.1 Sugishita's View

Sugishita (1980) reviews previous studies on split-brain (commissurotomy) patients' abilities to manipulate visual and tactile stimuli, and draws several conclusions regarding cerebral lateralization. One can say that the left hemisphere is specialized for language processing, but there is no other function in which the left hemisphere is superior to the right hemisphere. Secondly, the claim that the right hemisphere is involved in several aspects of language processing (e.g., object-naming, picture-word matching, copying) must be accepted with reservation; studies which drew such conclusions often employed split-brain subjects who had undergone commissurotomy several years prior to the actual tests. Thirdly, the right hemisphere is superior to the left in visuo-spatial processing, given split-brain patients' performance in copying figures such as Necker cubes and tetrahedrons. Lastly, results with split-brain patients confirm that the left hemisphere processes both kanji and kana; while the right hemisphere is involved with certain aspects of kanji and kana processing, such abilities are limited and are only observed a few years after commissurotomy. In sum, Sugishita questions the view that both left and right hemispheres are involved in language processing, and that the difference between the two hemispheres resides in their functional differences.

Thus, patients who have undergone commissurotomy usually exhibit their total inability of processing both kana and kanji immediately after their operations. The right hemisphere begins to regain processing ability only a few years after such operations. What is suggested by these facts is one of three possibilities: the un-transected part of the corpus callosum has started to function to send linguistic information from the left to right hemisphere; or some of the fibers have been restored so that the transmission of the linguistic information has become possible from the left to the right hemisphere; or the right hemisphere has developed some compensatory mechanism which allows the right hemisphere to be able to process kana and kanji. But it is not the case that the right hemisphere is itself inherently capable of processing kana and kanji, at least not according to Sugishita's interpretation of the clinical evidence.

Others are less prone to actively deny that the right hemisphere also has some part in processing kana and kanji. For instance, Iwata (1973) has shown that, in a kanji and picture matching task which requires semantic processing, split brain patients do indeed exhibit 100% performance with their left hemisphere; but they also exhibit a 56% success rate when using the right hemisphere, suggesting that the right hemisphere does have some part in processing kanji. An experiment by Otsuka and Shimada (1988) which employed unilaterally brain-damaged patients shows that left unilaterally brain-damaged patients show more severe damage with kana than kanji, suggesting that kanji processing involves the right hemisphere to some unknown extent.

4.1.2 Yamadori's View

The opposing view argues that, although limited, the right hemisphere can and does process some aspects of kana and kanji. The right hemisphere is specialized in processing pattern matching problems, but is unable to sequence linguistic segments. This inability is often seen in the way that split brain patients are impaired in copying tasks. For instance, Yamadori et al. (1983) report a case of disconnection-type agraphia coupled with alexia, caused by lesions destroying the posterior half of the corpus callosum and the left medial occipital lobe. The result was a dissociated agraphia of the disconnection type for kana and kanji, suggesting that the neural substrate of both kana and kanji necessary for writing is stored bilaterally, while the neural substrate for ordering these graphemes into a meaningful sequence is confined to the left hemisphere.

Another instance is cited in Yamadori (1980), which discusses two case studies of right-handed Broca's patients whose symptoms support the above hypothesis. Both patients were able to copy kanji and some kana with their left hands. The author suggests that the right hemisphere is associated with 'motor engrams' for kanji and kana, explaining how patients with symptoms paralleling those of total aphasics can nevertheless copy kanji and kana. Secondly, although these patients could write single kana, they could not sequence kana into words, suggesting that the right hemisphere critically lacks the ability to sequence phoneme-dependent linguistic units.

If Yamadori and his group are correct, we cannot say that the right hemisphere is completely unable to process kana and kanji. What is not known is just how much of the phonological and semantic aspects of processing kana and kanji are participated in by the right hemisphere. So far as we know at this point, the phonemic and semantic processing capabilities of the right hemisphere appear to be minimal when compared to the left hemisphere, but so far no one has clearly demonstrated the extent of its involvement in kana and kanji processing.

5.0 CONCLUSION

It is clear that we cannot maintain the simplistic view that the cognitive considerations in processing Japanese orthography are unique, with kana processed by the left hemisphere and kanji processed by the right hemisphere. The issue has more to do with the types of processing tasks involved, and the cognitive requirements they impose. It is, however, safe to assume that, in general, the configurational, or graphemic, aspects of kana and kanji identification and interpretation are handled by the right hemisphere, while the phonemic and semantic aspects of kana and kanji processing are handled by the left hemisphere. Conversely, we neither know clearly if, or the extent to which, the left hemisphere is involved in processing graphemic information, nor the extent to which the right hemisphere is involved in processing phonological and semantic aspects of kana and kanji. Most importantly, we are severely limited in knowing how the left and right hemispheres interact in processing, and this will obviously be the challenge for future studies in psycholinguistics, neuropsychology, and clinical aphasiology.

In sum, the classical view that kanji are processed in the right hemisphere and kana in the left is simply incorrect. A more accurate view reflects the fact that both left and right hemispheres are involved in processing both kanji and kana, but that their participation in processing tasks inevitably reflects different aspects of the task as the human brain responds to varying functional requirements posed by the task at hand.

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