Visual Motion Sensitivity and Literacy Skills in Japanese

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Abstract: The primary aim of the present study was to investigate the relationship between literacy skills in Japanese and visual motion sensitivity as an index of visual magnocellular system function. A test battery using measures of auditory, phonological, orthographic, and visual processing, intelligence and literacy skills was administered to 43 unselected 7-8 year-old primary school children. The results suggest that children's visual motion sensitivity predicted literacy development in both Kana and Kanji after controlling for intelligence. Importantly, visual motion sensitivity explained the highest proportion of the variance in orthographic processing, replicating previous findings in alphabetic writing systems. These results suggest that visual motion sensitivity may play an important role in the development of literacy skills, irrespective of the script or writing system. Possible links between visual motion and literacy skills will be discussed in terms of the anatomical and physiological characteristics of the visual magnocellular system. In addition, Kana literacy development was best predicted by phonological short-term memory for nonwords, followed by orthographic processing. Kanji learning seemed to depend on multiple cognitive modalities, phonological, orthographic and visual domains. This result may reflect the nature of Kanji, which is visually more complex than Kana and needs to be pronounced at the whole-word orthographic level according to the context.

Keywords: Reading and Spelling in Japanese, Visual Motion Sensitivity, Visual Magnocellular System, Phonological short-term memory, Orthographic processing, Visual short-term memory

1. Introduction

The ability to read and spell depends upon a number of sensory and cognitive processing components, irrespective of the writing system. Although there is wealthy evidence showing the importance of phonological and orthographic processing skills in the development of literacy in both alphabetic (e.g. Gathercole & Baddeley, 1998, Muter et al 2004, Talcott et al 2002,) and logographic scripts (e.g. Ho & Bryant 1997, Siok & Fletcher 2001), the extent to which visual processing contributes to literacy development remains controversial.

Recently, visual motion sensitivity as an index of the visual magnocelluar system (M-system) function has attracted great interest in studies of literacy development (e.g. Stein 2003). Talcott et al (2002) showed that visual motion sensitivity is correlated with orthographic processing skills that predict reading ability in unselected 10 year olds. Furthermore, reduced visual motion sensitivity is correlated with impaired reading performance in both alphabetic (Talcott et al 2003) and logographic scripts (Zhou in personal communication). Therefore, we hypothesized that visual motion sensitivity may also play an important role in literacy development in both phonetic Kana and logographic Kanji.

2. Method

A test battery using measures of auditory, phonological, orthographic, visual processing, intelligence and literacy skills were administered to 43 Japanese 2nd graders (22 boys and 21 girls, M=7.83 years, SD=3.27 months). Children with sensory or attentional problems were excluded according to parental questionnaires, leaving 36 children in the study.

3. Results

Kana reading was excluded from the set of variables further analysed because of a ceiling effect, which reflects the early mastery of Kana reading (Shimamura et al 1994). Multiple regression analysis revealed that visual motion sensitivity predicted literacy skills in both Kana and Kanji after controlling for IQ measures. Furthermore, visual motion accounted for the highest proportion of the variance (33%) in orthographic processing. In general, phonological short-term memory and orthographic processing predicted literacy skills in both Kana and Kanji, although the predictive power of phonological short-term memory was greater for Kana and

Kanji. Additionally, visual short-term memory explained unique variance in literacy skills in Kanji, but not in Kana.

4. Discussion

Visual motion sensitivity was a significant predictor of literacy skills in both Kana and Kanji, and also the strongest predictor of orthographic processing. This suggests that the visual magnocellular system nay play an important role in the development of orthographic skills for learning to read and spell, irrespective of the writing system. “Why might visual motion sensitivity as an index of the visual magnocelluar system be important for reading (and spelling)?” Words or letters are stationary, but the actual retinal images during reading are not. Visual information is only taken in during brief fixations (250 ms), between which a rapid eye movement, so-called “saccade” (30 ms) is made. Therefore, the visual magnocellular system may be important to maintain stable fixations on words or letters to be read before the next saccade is made, creating a stationary retinal image (no retinal slip) (Stein 2003).

Physiologically, mango cells, large retinal ganglion cells, are characterized by large receptive fields and heavy myelination that allows high conduction velocities (fast response). Thus, the M-system is thought to be sensitive to transient changes such as those caused by visual motion. Anatomically, the M-system projects to the posterior parietal cortex, frontal eye fields, superior colliculus, and subsequently the cerebellum, all of which are important for eye movement control. In particular, within the first two cortical regions, there are tight connections between attention and oculomotor processes (e.g. Corbetta et al 1998, Konen et al 2004). Taken all together, the M-system may play important roles in controlling both the focus of attention and eye movements during reading.

In general, phonological short-term memory and orthographic processing seem to play essential roles in literacy development in both Kana and Kanji, replicating previous findings for alphabetic and logographic scripts. In addition, visual short-term memory, which is unrelated with reading development in English (Pickering, in personal communication), may be a necessary cognitive component for learning Kanji, but not for leaning Kana. This multi-modal involvement in Kanji literacy skills reflects the properties of Kanji script, which is visually complex and needs to be read at the word-specific orthographic level due to multiple phonological representations for each character.

5. Conclusion

Visual motion sensitivity as an index of the visual magnocellular system may play a crucial role in the development of orthographic skills for learning to read and spell, irrespective of the writing system. In accordance with previous findings in both alphabetic and logographic writing systems, phonological and orthographic processing skills are important for literacy skills in both Kana and Kanji. In addition, learning Kanji, but not Kana, seems to also depend on visual short-term memory, suggesting the greater importance of visual processing skills in Kanji than in Kana. These results describing the normal development of literacy skills in Japanese may help us to understand the nature of dyslexia in Japanese.

6. References

1) Corbetta, M., Akbudak, E., Conturo, T., Snyder, A., Ollinger, J., Drury, H., Linenweber, M., Petersen, S., Raichle, M., Van Essen, D., & Shulman, G. (1998). A common network of functional areas for attention and eye movements. *Neuron*, *21*(4), 761-73.
2) Gathercole, S., & Baddeley, A.D. (1993). *Working Memory and Language*: Psychology Press.
3) Konen, C.S., Kleiser, R., Wittsack, H.-J., Bremmer, F., & Seitz, R.J. (2004). The encoding of saccadic eye movements within human posterior parietal cortex. *NeuroImage*, *22*(1), 304-314.
4) Muter, V., Hulme, C., Snowling, M., & J, S. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: evidence from a longitudinal study. *Developmental Psychology*, *40*(5), 665-81.
5) Shimamura, N., & Mikami, H. (1994). Acquisition of Hiragana Letters by Pre-school Children: A Comparison with the 1967 Survey by the National Language Research Institute
6) Stein, J. (2003). Visual motion sensitivity and reading. *Neuropsychologia*, *41*(13), 1785-1793.
7) Talcott, J., Witton, C., Hebb, G., Stoodley, C., Westwood, E., France, S., Hansen, P., & Stein, J. (2002). On the relationship between dynamic visual and auditory processing and literacy skills; results from a large primary-school study. *Dyslexia*, *8*(4), 204-5.
8) Talcott, J.B., Gram, A., Van Ingelghem, M., Witton, C., Stein, J.F., & Toennessen, F.E. (2003). Impaired sensitivity to dynamic stimuli in poor readers of a regular orthography. *Brain and Language*, *87*(2), 259-266.

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