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Regional Cerebral Blood Flow in the Covert Reading of Kana Words: A Comparison with the Study of Reading Aloud Tasks

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In our positron emission tomography (PET) studies on reading aloud of kanji (Japanese morphograms) and kana (Japanese phonograms) [1, 2], we found that the left or both posterior inferior frontal gyri (PIF; the left side includes part of Broca's area) were activated together with the supplementary motor area (SMA), the left or both basal ganglia (predominantly the putamen), and the left or right thalamus and cerebellum. An unsolved problem in PET reading aloud studies, both English and Japanese [1–5], is whether the activation of the basal ganglia and thalamus occurs with language output or with the reading process (mainly comprehension). To address this question we performed a covert reading study (careful reading without utterance that differs from silent viewing of words) and compared it with our previous studies of reading aloud tasks.

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Fig. 1. Locations of ROIs projected on the MRI axial slices. The ROI sizes relative to the MRI axial image sizes are the same as the actual ROI sizes were to the actual MRI axial image sizes. OR = Orbital gyri; CB = cerebellar hemisphere; PIT = posterior inferior temporal area; PIF = posterior inferior frontal gyrus including part of Broca's area; BG = basal ganglia; PST = posterior superior temporal gyrus including part of Wernicke's area; PF = prefrontal area; HS = Heschl's gyri; TH = thalamus; LO = lateral occipital area; MO = medial occipital area; AC = anterior cingulate gyrus; SMG = supramarginal gyrus; AG = angular gyrus; SMA = supplementary motor area; SPL = superior parietal lobule.

Table 1. Mean rCBF (± SD in parentheses) during visual fixation and kana word covert reading tasks in activated areas, determined with ROIs (ml/100 g/min, n = 14)

Fixation
Covert reading

Difference ¹	t value	
L	54.99 (6.02) 2.23 2.31*	52.76(5.53)
R	42.48(2.81) 1.17 2.54*	41.31(3.67)
L	43.02 (3.20) 2.39 4.95**	40.63(2.81)
R	58.04(4.56) 1.33 2.90*	56.71(4.68)
L	57.73(5.10) 1.39 2.26*	56.34(5.26)
L	67.94(6.92) 1.85 2.49*	66.09 (6.03)

* p < 0.05, ** p < 0.01, paired t test with two or three replications of an activation scan and the preceding fixation scan. PIT = Posterior inferior temporal area; O = occipital. Difference denotes mean (covert reading – fixation).

Materials and Methods

Five Japanese under- or postgraduates (2 men and 3 women, right-handed, aged between 21 and 29 years) of the Faculty of Literature or Science participated in the study. All the subjects gave written informed consent and the protocol had been approved by the Research Ethical Committee of our school.

The general experimental design such as the number of subjects, the number of repetitions and the exposure duration and interval was the same as in the previous studies except for the instructions [1,2]. The subjects were instructed to gaze at a small fixation spot or read carefully without utterance (covert reading) a three-letter kana word presented vertically. Each subject underwent six scans, the fixation and kana reading tasks being performed in that order alternately 3 times. The kana words were the same as those in the reading aloud task [2].

The PET (Headtome IV, 10 mm at full width at half maximum) imaging and data analysis were described elsewhere [6]. Cerebral blood flow was measured with arterial blood sampling based on Kety’s single-compartment model. The regional cerebral blood flow (rCBF) values were normalized so that the whole CBF was constant (40 ml/100 g/min).

To quantify rCBF changes for statistical analysis, the activity was sampled in circular regions of interest (ROI, 16 mm in diameter, but 12 mm for the SMA; we previously described the size of ROI as 8 mm [1, 2], but 16 mm was correct) in several slices in individual scans (total of 31). The ROIs thus placed were identical to those used in the previous reading aloud studies [1,2] (fig. 1).

Statistical analysis of the data was performed by the two-tailed paired t test with replications for a total of 14 (one datum was missing) sets of an activation scan and the preceding fixation scan (note this method does not assume there are 14 independent comparisons).

Results and Discussion

Table 1 shows the activated sites. The rCBF in the PIF, SMA, basal ganglia, thalamus and cerebellum, which were activated in the reading aloud task [1, 2], remained unchanged when the subjects did not move their mouths or tongues, though in the SMA and basal ganglia the rCBF seemed to increase slightly. Further comparisons of the rCBF increase (against the fixation control) between two reading tasks by the nested design one-way ANOVA revealed significant differences in the left PIF and right basal ganglia (p < 0.05) in the left SMA and right thalamus (p < 0.01). This fact implies that these areas are more involved in language output than in the reading process itself. It is not clear whether the activation occurs merely with orolin-gua movement or with speech output specific to language. Among the above areas, the bilateral PIF was known to be activated when the subjects simply moved their mouths and tongues [3], though the activation focus was to some extent posterior to Broca’s area in that study.

It has already been reported that Broca’s area (or the surrounding area) and the SMA, together with some areas of the cerebellum, were simultaneously activated in language output tasks [3, 7]. Although the basal ganglia and thalamus are expected to participate in language production and comprehension from clinical observations, few PET language studies [3–5, 7, 8] have revealed activation of these regions. Our studies suggest that the basal ganglia and thalamus probably function in parallel with Broca’s area and the SMA in language output.

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