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A case of naturally occurring visual field loss in a chimpanzee with an arachnoid cyst

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ABSTRACT

Deficits in the occipital cortex have varying consequences among mammalian species. Such variations are indicative of evolutionary transitions in the striate cortical contribution to visually guided behavior. However, little is known about the role of the striate cortex in visually guided behavior in chimpanzees due to ethical concerns about invasive experiments and methodological limitations such as the inability to monitor gaze movements. We had the opportunity to study the behavioral consequences of a deficit in the occipital cortex in a chimpanzee with a naturally occurring arachnoid cyst in her right occipital lobe. We assessed the chimpanzee's ability to detect a small light probe (0.5 visual degree, Michelson contrast > 0.9) presented at several locations in the visual field while monitoring gaze direction using an infra-red remote eye-tracker recently introduced to studies of great apes. The results showed the chimpanzee was unable to detect the probe in the lower left quadrant of the visual field, suggesting severe loss of contrast sensitivity in a part of hemivisual field that is retinotopically corresponded to the hemisphere of the cyst. A chimpanzee with a naturally occurring deficit in the right striate cortex and the availability of remote eye-tracking technology presented a unique opportunity to compare the role of the occipital lobe in visually guided behavior among various primate species.

1. Introduction

Comparisons of humans and nonhuman primates are of particular interest for understanding the evolution of the human brain. Differences in both the macroscopic organization of the visual cortex (Orban, Van Essen, & Vanduffel, 2004; Van Essen, 1979) and the microscopic structure of the primary visual cortex (Preuss, Qi, & Kaas, 1999) of human and nonhuman primates have been reported. Such structural differences suggest functional differences between species with regard to visual perception (Matsuno & Fujita, 2009); however, evidence of such differences remains elusive. Lesion studies provide insight into the function of a particular brain region. In recent years, knowledge of the structure and function of the brains of macaques and New World monkeys has accumulated; however, studies investigating occipital lobe deficits in great apes are limited.

Spence and Fulton (1936) performed the only reported lesion of the striate cortex in chimpanzees. They reported that removal of the entire left striate cortex of a chimpanzee caused a slight loss of visual acuity, ranging from 5% to 15%; however, removal of the entire striate cortex, leaving only the anterior portion of the right striatal area intact, resulted in complete loss of visual discrimination. The effect of deficits in the striate cortex on visual ability differ among mammals (Masterton & Berkley, 1974; Van Essen, 1979). Striate lesions generally cause severe visual impairment in primates (Cowey & Weiskrantz, 1963; Humphrey, 1974; Weiskrantz, 1972); however, non-primate mammals appear to have near-normal visual behavior following striate lesions (Doty, 1971; Hall & Diamond, 1968; Spear & Braun, 1969; Sprague, Levy, DiBerardino, & Berlucchi, 1977; Ware, Casagrande, & Diamond, 1972). Given the taxonomic relationship between monkeys, humans, and chimpanzees, the relatively minor effect of complete ablation of the left striate cortex in chimpanzees is peculiar. Spence and Fulton argued that their failure to find a significant impact of the lesion on chimpanzee vision was the result of methodological limitations. At the time Spencer and Fulton conducted their experiment, it was not possible to monitor and control the ape's gaze; thus, the chimpanzee may have performed the task using intact contralateral visual field. No study since that conducted by Spence and Fulton (1936) has investigated the visual consequences of striatal damage in chimpanzees due to ethical concerns surrounding invasive lesion studies in great apes. Likewise, no studies of the behavioral consequences of naturally occurring damage to the striate cortex in chimpanzees have been reported.

We recently had the opportunity to study the behavioral effects of naturally occurring striatal damage in a chimpanzee. An intracranial arachnoid cyst was detected in the right occipital convexity of a chimpanzee (Figs. 1–3) in the Primate Research Institute at Kyoto University in Japan, where comparative cognitive research on chimpanzees has

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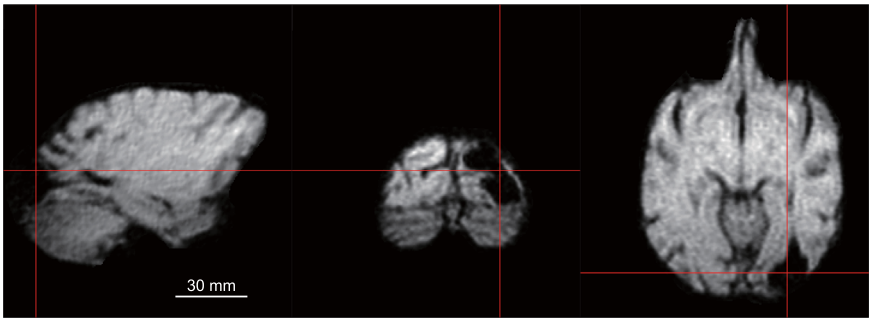

Fig. 1. MR image of the cyst from sagittal, coronal, and horizontal views. The cyst was located at the occipital convexity of the right hemisphere and extended both below and above the calcarine sulcus.

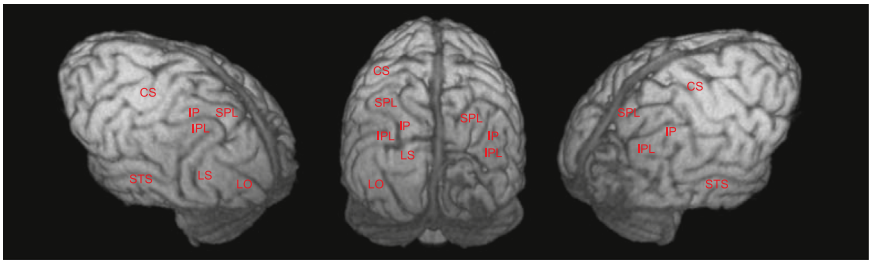

Fig. 2. Three-dimensional reconstructed brain-extracted images. On the lateral side, the anterior boundary of the cyst was just posterior to the lunate sulcus, which is known as a good indicator of the boundary of V1/V2 in chimpanzees. CS, central sulcus; IP, intraparietal sulcus; SPL, superior parietal lobe, IPL, inferior parietal lobe; STS, superior temporal sulcus; LS, lunate sulcus, LO, lateral occipital sulcus.

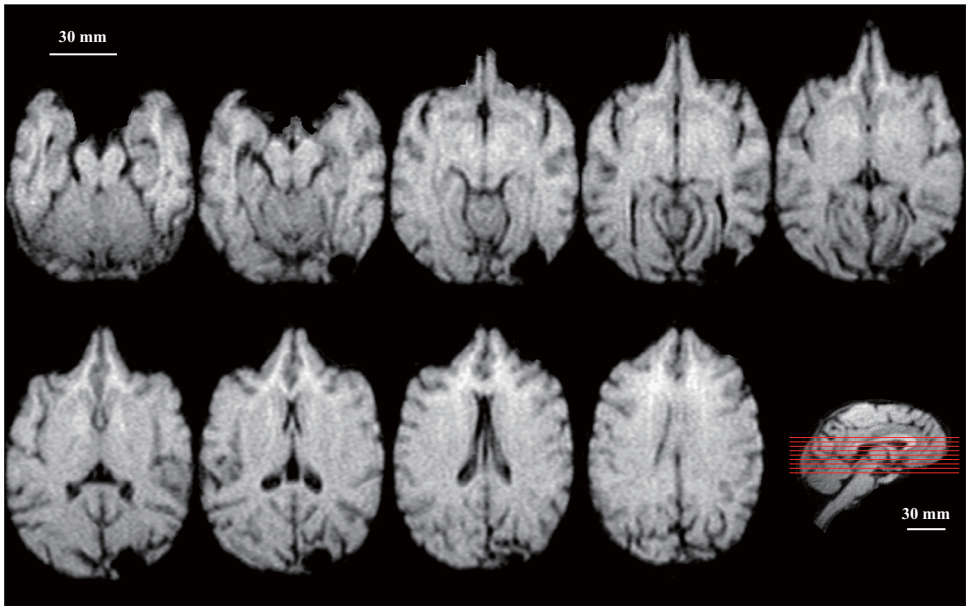

Fig. 3. Multiple slices of the horizontal section. The red lines in the bottom-right sagittal slice correspond to horizontal slices. The top-left image begins from the most ventral slice, and the dorsal slices are followed by the right direction and the bottom images. In the medial area, it was difficult to match the boundary of the cyst to the histologically-defined cortical area. It appeared that the medial parietal and posterior cingulate cortices remained relatively intact, and the cyst primarily affected the right visual cortex. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

been conducted for several decades (Matsuzawa, 2003; Matsuzawa, Tomonaga, & Tanaka, 2006; Tomonaga, 2001). An arachnoid cyst is an accumulation of intra-arachnoid fluid that can cause headaches, seizures, and more specific defects depending on its location. The cyst in this chimpanzee covered most of the occipital lobe posterior to the lunate sulcus in the right hemisphere and likely caused a deficit in visual function (Miyabe-Nishiwaki et al., in press). This individual had participated in various perceptual and cognitive studies (Matsuzawa, 2001, 2003; Matsuzawa, et al., 2006), and it was surprising that no behavioral deficits had been previously identified (see Table 1 in Miyabe-Nishiwaki et al. (in press)). This suggested that either the arachnoid cyst was asymptomatic or that the chimpanzee used its intact visual field to perform tasks, as in the study of Spence and Fulton (1936).

Our laboratory recently used a remote infra-red eye-tracker to record the gaze direction of apes (Kano & Tomonaga, 2009). This device is often used to study developmental psychology in human infants and was recently introduced for the study of great apes. The eye tracker does not require the head to be restrained and allowed the investigator to track gaze as the subjects freely moved