fMRI analysis of the olfactory responses to home-stream water in sockeye salmon

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Introduction

Salmon are known to return to their home stream for spawning. Previous electrophysiological and behavioral studies have shown that juvenile salmon imprint the olfactory memory of the home-stream odor during downstream migration, and adult salmon utilize this stream-specific odor to identify their home stream during upstream migration [1,2]. In other studies on olfactory imprinting and homing in salmon, the home-stream olfactory-information processing in the central nervous system, especially in the olfactory bulb and telencephalon, has been investigated using electrophysiological techniques [3]. However, because of the spatial limitations of the electrophysiological techniques, the processing of home-stream odor information in the central nervous system has not been completely elucidated. In this study, to investigate the home-stream odor-information processing, we used BOLD fMRI to visualize the olfactory bulb and telencephalon of salmon and measure the response to home-stream water in these regions. To this end, we first established an in vivo fMRI method for sockeye salmon (*Oncorhynchus nerka*).

Materials and Methods

Four-year-old female and male lacustrine sockeye salmon (*O. nerka*) reared in the Toya Lake Station, Hokkaido University, were anesthetized using FA100 (0.5 mL/L) and immobilized by intramuscular injection of gallamine triethiodide (3 mg/kg b.w.). The fishes were secured on a holder in a flow-through system, and perfusion tubes were inserted in their mouth (gill perfusion, 400 mL/min). The stream water from Toya Lake Station and L-serine, i.e., the home-stream water and a popular odorant for fish, respectively, were used as the odorant stimuli. The stimulation paradigms for a 1-block design were employed. The odorant was delivered through polyethylene tubes into the olfactory rosette at the rate of 10 mL/min for 3 min. MRI experiments were performed on a horizontal 7 T magnet interfaced to a Varian^{INOVA} console with a circular radio-frequency transmit-receive surface coil. fMRI data were acquired using a gradient-echo sequence with scan parameters as follows: TR/TE = 470/10 ms, slice thickness = 1 mm, FOV 20 × 20 mm^2, matrix size = 64 × 64 for five slices. Activated regions were represented as Student's t maps for each run. Anatomical images were obtained (image dimension = 128 × 128 pixels; FOV 20 × 20 mm^2; slice thickness = 1.0 mm; repetition delay = 5.0 s; echo time = 15 ms).

Results and Discussion

Both home-stream water and L-serine elicited substantial BOLD signals in the olfactory bulb and telencephalon (Fig. 1). Although the experimental concentration of L-serine (10^{-3} M) was higher than that of home-stream water (total amino acids concentration, 3.5 μM), the signals elicited by home-stream water at each activated region were stronger than the corresponding signals elicited by L-serine. The home-stream water induced activation in the lateral region of the dorsal area (Dl) and the central region of the dorsal area in the telencephalon (yellow circle in Fig. 1A, slice 3 and 4), while L-serine did not induce activation in these regions. The dorsal area in the telencephalon of teleosts is thought to be homologous to the pallial regions of the cerebrum in mammals, and Dl includes structures that are possibly analogous to the mammalian hippocampus [4,5]. Therefore, these results suggest that the odor information for home-stream water was specifically projected to the dorsal area in the telencephalon of sockeye salmon.

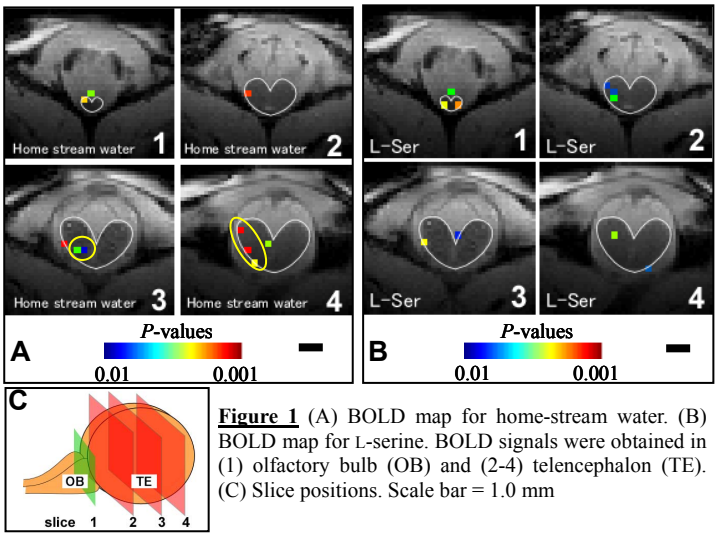

Figure 1 (A) BOLD map for home-stream water. (B) BOLD map for L-serine. BOLD signals were obtained in (1) olfactory bulb (OB) and (2-4) telencephalon (TE). (C) Slice positions. Scale bar = 1.0 mm

References

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