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## Preview

## A small, but vocal, brain

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In the May issue of *Cell Reports*, Jafari et al.<sup>1</sup> used ultra-high-field fMRI to show that marmosets, like humans and macaques, possess an extensive network of voice-selective areas.

Common marmosets (*Callitrix jacchus*) are small new-world primates that diverged from the human lineage approximately 35 million years ago. Because of their complex social organization, high reproduction rate even in captivity, and small brain with very few cortical sulci they have become an increasingly valuable model in neuroscience.<sup>2</sup> They are also highly vocal, with a complex call repertoire used in many social contexts, suggesting the existence of cerebral mechanisms for processing voice information. Yet up until now, only a single publication has hinted at the existence of cortical areas selective for vocalizations in the marmoset brain.<sup>3</sup>

In the May issue of *Cell Reports*, Jafari et al.<sup>1</sup> brought crucial new data that shed detailed light on a network of voice-sensitive brain areas in marmosets. They used functional magnetic resonance imaging (fMRI, a technique measuring blood oxygenation as an indirect index of neuronal activity) to scan marmosets during auditory stimulation.

Taking advantage of the small size of marmosets, the authors used a rodent-dedicated magnet with a smaller bore and a much stronger magnetic field (9.4T) than the larger magnets typically used for human or macaque fMRI, dramatically increasing signal-to-noise ratio. Moreover, they scanned the marmosets while awake—avoiding anesthesia-related issues—and lying in an ingenious custom MRI bed that maintained the marmoset's head fixed with closely placed receiver coils and allowed the delivery of auditory stimuli while attenuating scanner noise.<sup>4</sup>

Marmosets were trained to tolerate the equipment and to stay still for the duration of a scanning experiment in as little as 3 weeks, a time considerably shorter

than the many months required for training a macaque to undergo awake fMRI. This amazingly short training time could have been aided by the fact that long periods of immobility are part of the species' natural behavioral repertoire.

The authors used a scanning protocol similar to those used to measure cerebral voice selectivity in humans<sup>5</sup> and macaques<sup>6,7</sup>: auditory stimulation consisted of short (12 s) blocks of conspecific vocalizations (CVs) or of control stimuli, including natural non-vocal sounds—sounds of wind or rivers—and acoustically manipulated versions of the vocalizations—a version of “scrambling” that preserved long-term spectral structure but disrupted short-time envelope.

When contrasting fMRI volumes acquired during stimulation with CVs to those acquired during stimulation with controls, Jafari et al. observed a wide network of areas showing significantly greater activity during the vocalization condition. This network included large areas of the temporal cortex, which were essentially symmetrical, along with the cingulate cortex and several subcortical regions.

Furthermore, the authors made clever use of recent, well-organized open-access databases of tracer-derived anatomical connectivity<sup>8</sup> and resting-state fMRI<sup>9</sup> to explore the connectivity of the voice-sensitive network and in doing so uncovered strong connections between temporal and cingulate voice-selective regions.

Much of the investigation of marmoset auditory cortex so far has concentrated on primary auditory areas, bringing valuable insight (e.g., Bendor and Wang<sup>10</sup>) but leaving much of secondary auditory areas unexplored. By scanning the whole brain using powerful fMRI methodology,

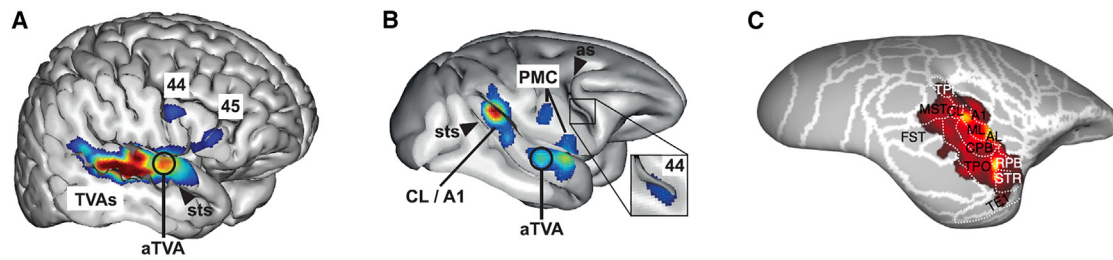
Jafari et al. provided precise neuroanatomical detail, uncovering an essentially symmetrical network of extra-primary cortical and subcortical voice-sensitive areas, fairly similar in distribution to the voice-processing network observed in humans.<sup>5</sup>

In particular, the confirmed involvement of anterior temporal lobe areas in voice processing, as initially reported<sup>3</sup> and as observed in humans<sup>5</sup> and macaques,<sup>6,7</sup> suggests that this voice region originates from a common ancestor (Figure 1). This indicates that the marmoset vocal brain could provide a simpler, less variable model of human cerebral voice processing that can be explored with more invasive techniques such as fMRI-guided electrophysiology, as widely done for the macaque and marmoset face patches.

The work by Jafari et al. opens a number of questions for future research. First, additional controls could be employed, using, for instance, more complex natural non-vocal sounds. The non-vocal sounds used here (wind, water, etc.) were considerably simpler in their acoustical and temporal structure than were the complex vocalizations that included multiple call types in the vocal condition. Part of the activation difference observed could be related to the difference in acoustical complexity. Studies in humans or macaques have used more complex and varied non-vocal sounds.<sup>5,6</sup> Additionally, other versions of acoustic scrambling could be used, controlling for different aspects of acoustical structure, e.g., long-term spectrum.

Also, the notion of functional homology between the marmoset and human voice areas could be further tested by comparing the representational geometry of these voice-sensitive areas for a larger





**Figure 1. Voice-selective areas in primates**

(A) Human temporal voice areas (TVAs).

(B) Macaque TVAs. Reproduced with permission from Bodin et al.<sup>7</sup>

(C) Marmoset voice-selective areas, reproduced from Jafari et al.<sup>1</sup>

array of sounds from multiple categories, as was used for demonstrating functional homology between the human and macaque voice areas<sup>7</sup> in categorizing CVs apart from other sounds.

Finally, detailed individual-level investigation of more individuals will provide valuable insight into inter-subject variability and whether voice sensitivity in the marmoset is organized as continuous maps or in separate “voice patches,” as seems to be the case in humans<sup>5</sup> and macaques.<sup>6,7</sup>

In summary, the vocalization-processing network revealed by Jafari et al. using fMRI in awake marmosets expands our understanding of voice-processing mechanisms in primates and opens up new avenues for research by demonstrating that the marmoset is an appropriate model for investigating primate voice-processing mechanisms.

#### DECLARATION OF INTERESTS

The authors declare no competing interests.

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