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Using ECoG to understand the representation of vocal pitch in humans

The flexible control of vocal pitch during speech production and the perception of pitch during listening are fundamental aspects of human oral communication. Intonation patterns created by changing vocal pitch are a rich source of information for conveying and understanding meaning. Still, it is currently unknown how the brain generates the complex laryngeal motor commands that allow for prosody or how listeners are able to perceive it. Here, we used direct high-density cortical recordings from the human brain to determine the encoding mechanisms of vocal pitch control during natural speech production. We found neural activity at electrodes over the dorsal laryngeal motor cortex (dLMC) that was highly selective to vocal pitch encoding, but not for other features in speech articulation. Using a computational model of vocal pitch contours, we found that neural activity at a subset of dLMC electrodes was selective for producing pitch accents, but distinct from those that encoded voicing. The same neural populations showed similar pitch encoding in a non-speech singing task, suggesting a general control mechanism. Finally, we confirmed the causal, feed-forward involvement of dLMC in pitch production by using direct cortical stimulation to evoke laryngeal electromyographic responses and vocalizations. Together, these results reveal a neural basis for the voluntary control of vocal pitch in human speech.

When listening to speech, humans understand prosodic patterns across a variety of sentences, speakers, and vocal ranges. In order to investigate how prosodic patterns are perceived during listening, we synthesized sentences that varied across speaker gender, emphasis pattern, and syllabic content. In the superior temporal gyrus, interspersed among electrodes representing syllabic/phonemic information, we found electrodes that encoded absolute pitch as well as electrodes that encoded relative pitch. Most electrodes were remarkably specific in which of the three features it encoded. The separation of representation provides a key insight into how the human brain processes speech prosody.

Dr. Benjamin K Dichter studied under Dr. Edward Chang at UCSF, using electrocorticography in humans to uncover the neural mechanisms of speech production and perception. He is an NSF GRFP fellow, and received his PhD from the UC Berkeley - UCSF Joint Program in Bioengineering in 2017. Dr. Dichter recently joined the lab of Dr. Ivan Sotlesz at Stanford as a data scientist.