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Speech perception when the motor system is compromised

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In a recent contribution, Lotto, Hickok and Holt[1] have made a compelling argument that findings on mirror neurons do not support a strong version of the motor theory of speech perception. However they go further in arguing that there is “little evidence that motor activity plays a necessary part in perception”, a claim based primarily on the observation that speech production can be impaired in syndromes such as Broca's aphasia while leaving comprehension relatively intact[2]. Alternatively, this dissociation could reflect redundancy in the speech perception network, coupled with preserved access to top-down contextual information. So the dissociation doesn't rule out a role for the motor system in speech perception, a view supported by several lines of evidence.

In a striking demonstration of redundancy in the brain regions supporting speech perception, Hickok and colleagues reported that in patients undergoing the Wada procedure, the right hemisphere alone made fewer than 10% phonemic errors[3]. This apparent redundancy limits the extent to which speech perception deficits can be observed when any single region, such as speech motor cortex, is damaged. Secondly, all listeners, including patients with Broca's aphasia[4], make extensive use of contextual information in speech comprehension. For example, an altered phoneme midway between /d/ and /t/ is more often perceived as /d/ in the context *_ash*, because *dash* is a word and *tash* isn't. This “lexical effect” is actually larger than normal in Broca's aphasics, suggesting that they rely more on top-down information and less on the phonetic detail of the input[5].

These observations imply that any specific role for the motor system in perception will be manifest only as a graded decrease in performance, and will emerge only in experimental settings which preclude reliance on contextual information. Several studies fit these criteria. First, Broca's aphasics showed poor auditory comprehension when stimuli were temporally compressed and presented in noise[6]. Degrading the acoustic input reveals the suboptimal functioning of the speech perception system. Second, Broca's aphasics performed worse at discriminating place of articulation than voicing, and made more errors when forced to rely on just one phonetic feature than on two[7]. Task-related processes[2] cannot account for differences between conditions determined by phonetic factors, so these data suggest a specifically phonetic impairment. Third, patients with Broca's aphasia showed reduced priming when primes were acoustically altered to create poorer phonetic exemplars[8], suggesting involvement of the motor system in accounting for sub-phonemic variation.

Speech perception deficits in Broca's aphasia do not unambiguously implicate the speech motor system, because lesions are typically extensive, and often impact attentional, executive and other processes[2]. Transcranial magnetic stimulation (TMS) studies in normal controls permit more anatomically specific investigations. Temporary inactivation of

premotor cortex impaired phoneme discrimination in noise but not subtle color discrimination[9]. The phonetic and visual tasks were precisely matched in difficulty and task demands, suggesting that the induced deficit was phonetic rather than attentional or executive. Another TMS study found that stimulation of motor areas for different articulators (e.g. tongue) selectively facilitated identification of phonemes relying on those articulators (e.g. alveolar consonants)[10]. This phoneme-specificity suggests that the role of the motor cortex relates to articulatory representations, and provides further evidence against a non-specific effect.

In sum, the speech motor system appears to play a crucial role in speech perception which cannot be entirely supplanted by temporal regions. Speech production regions may instantiate top-down production-based models of the input, which are especially important under acoustically degraded conditions[11,12]. This functionality is important because in everyday language use, suboptimal auditory input is the norm, not the exception.

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