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**PSYCHOPHYSICS OF SPEECH**

The “psychophysics of speech” describes an interdisciplinary approach to understanding speech perception. The approach considers speech as a complex acoustic signal sharing much in common with other complex perceptual events and posits that, as such, speech may be studied in the broader context of general perceptual, cognitive and sensorineural systems. This approach is distinguished from approaches that consider speech to be a special signal processed in a manner distinct from non-speech sounds. The essence of a psychophysical approach is to determine the extent to which speech perception makes use of general cognitive and perceptual processes before postulating mechanisms specialized to the speech signal. Thus, understanding the psychophysics of speech may include utilization of animal models of auditory behavior and physiology to examine how much of speech perception may be accounted for by general, rather than specialized, mechanisms and relating speech perception to neural coding at peripheral and central levels of processing.

“Psychophysics” often connotes bottom-up or peripheral processing and, in fact, a great deal of research of the psychophysics of speech can be characterized this way. However, “psychophysics” is perhaps an unfortunate moniker to describe this approach because auditory memory, attention, object recognition, cross-modal processing, learning, plasticity and development all play important roles in processing complex auditory signals and these processes relate to speech processing, as well. The psychophysics of speech might be more broadly described as an auditory cognitive neuroscience approach to speech perception, considering the richness of the acoustic (and, in fact, cross-modal) perceptual environment, the influence of long-term experience, and effects of higher-order knowledge and processing.

Adherence to a general cognitive/perceptual account of speech perception has meant that the psychophysical approach to speech perception has played a central role in the theoretical debate of whether speech is perceived in a mode distinct from other acoustic signals. A major contribution of the psychophysical approach apart from this theoretical debate has been its insistence on attention to the precise spectrotemporal characteristics of the speech signal and to the neural mechanisms of auditory processing involved representing these signals.

An application of the psychophysical approach is observed in the study of phonetic context effects. A great deal of early research documented the considerable variability inherent in the acoustics of speech. To summarize this broad literature very briefly, there do not appear to be acoustic signatures that uniquely specify phonetic categories. Thus, listeners are faced with the perceptual challenge of mapping highly variable acoustic signals onto speech in a many-to-one manner. Behavioral studies demonstrate that listeners appear to meet this variability in speech acoustics by perceiving speech in a wholly context-dependent manner. Many studies have reported phonetic context effects in which physically identical acoustic signals are judged by listeners to be different speech sounds as a function of the phonetic context in which they are presented.

Phonetic context effects are ubiquitous in speech perception and have been documented for many speech segments. Of interest in understanding the mechanisms that give rise to such effects, Japanese quail (*Coturnix coturnix japonica*) trained to peck a lighted key in response to presentation of /g/ endpoints of a /ga/ to /da/ stimulus series peck more vigorously to novel ambiguous mid-series speech stimuli when they were preceded by /l/. A second set of birds trained to peck in response to /d/ responded more robustly to the same novel stimuli when they were preceded by /r/. The directionality of the effect is the same as for human listeners. The extension of phonetic context effects to a non-human species suggests that general auditory processing may assist in accommodating the complex variability present in speech.

To pose the results in a general way, context sounds with higher-frequency acoustic energy (like /l/) shift perception of the following syllable toward the category alternative with greater low-frequency energy, /g/. Thus, contrastive processes by which the auditory system exaggerates change in the acoustic signal may be sufficient to explain phonetic context effects. This conclusion is supported by research demonstrating that adult human listeners shift phonetic categorization responses not only as a function of neighboring speech contexts, but also as a function of non-speech tones, chirps and noises that precede or follow speech. In the case of human and non-human perception of speech and non-speech contexts, speech perception appears to be relative to and contrastive with the acoustics of context sounds, whether speech or non-speech.

This portfolio of research findings is indicative of a psychophysical approach to speech perception in that it pays careful attention to the spectrotemporal information available to listeners, it makes use of nonhuman animals as a means of examining the generality of the mechanisms available to speech processing, and it examines the extent to which complex non-speech signals may give rise to some of the same patterns of perception as speech. Research relating the context-dependent coding of acoustic signals to neural response adds to the understanding of how phonetic context effects may arise from general characteristics of the perceptual system. The constellation of available results suggests that general perceptual mechanisms play a role in phonetic context effects.

In other domains, the psychophysical approach has contributed to understanding of auditory representation, auditory learning, and cross-modal processing as they relate to speech processing. There remains much potential for understanding the perceptual, cognitive and neural underpinnings of speech communication from a general perceptual/cognitive perspective.

--Lori L. Holt

Works Cited and Suggestions for Further Reading

Diehl, R. L., Lotto, A. J. and Holt, L. L. 2004. “Speech perception.” *Annual Review of Psychology* 55: 149-179.

This review contrasts theoretical approaches to speech perception

Diehl, R. L. and Kluender, K. R. 1989. "On the objects of speech perception." *Ecological Psychology* 1: 121-144.

Discussion of a general approach to speech perception

Lotto, A. J. and Holt, L. L. 2006. “Putting phonetic context effects into context: A commentary on Fowler (2006).” *Perception & Psychophysics* 68: 178-183.

Briefly reviews phonetic context effects literature

Schouten, M. E. H. 2003. ”The Nature of Speech Perception.” *Speech Communication* 41 (August): 1-271.

A collection of 20 papers on the psychophysics of speech perception