# QnAs with Patricia Kuhl

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Machines that can precisely recognize and decode human speech remain a largely unrealized challenge facing scientists and engineers. Yet infants below the age of one recognize and attempt to imitate the sounds of human speech even before they begin to grasp the meaning of words or produce them. Around 12 months of age, however, infants hone this ability, gradually gaining proficiency in discerning vowels and consonants in their native language while losing a similar knack for nonnative languages. Such fine-tuning of perception is the focus of recent work by Patricia Kuhl, a neuroscientist at the University of Washington, Seattle, and a National Academy of Sciences member who is widely recognized for her discoveries on brain development during language acquisition among children. Kuhl recently spoke to PNAS about the significance of her findings on infant speech perception.

**PNAS:** Your Inaugural Article (1) addresses a change in infants' speech perception that manifests as they reach a certain age. Can you explain the nature of this change?

**Kuhl:** Until six months of age, infants worldwide can distinguish between sounds in different languages. Two months later, a process of perceptual narrowing begins and children gradually lose the ability to distinguish between sounds in foreign languages, even as the same ability improves for the native language. Japanese children, for example, begin losing the ability to hear the distinction between "r" and "l" sounds, which are not native to Japanese.

**PNAS:** Your study addresses a longstanding conundrum embodied by a pair of speech perception theories: the "motor theory" and the "analysis by synthesis" theory. Can you explain the distinction between these theories?

**Kuhl:** In this study, we asked how infants' knowledge of speech production might play a role in the transition in discriminatory ability seen in the second half of the first year of life. Motor theory, which dates back to the 1950s, sought to explain how innate knowledge of speech production might influence speech perception as a means of uncovering the sensory cues that we use to perceive speech. The "analysis by synthesis" theory, which originated in the artificial intelligence community, also holds that we use motor knowledge of speech production, but it is an experience-based model; listeners build internal, predictive models based on their own speech-production experience, and this "synthesis" is used to effectively perceive speech. Meanwhile, neuroscience studies in monkeys had shown that mirror neurons in a brain region corresponding to the human Broca's area (implicated in speech production) are activated both by the sight and performance of actions. We don't know whether mirror neurons exist in humans, but that hypothesis was another impetus for studying the action–perception relationship in speech.

**PNAS:** To test these hypotheses, you developed magnetoencephalography (MEG) for brain imaging in infants. What are the advantages of MEG?

**Kuhl:** Brain imaging with babies is enormously challenging. The babies have to remain completely still in a tube for fMRI [functional MRI] scans, so MRI is not appropriate for children under five years of age. Moreover, fMRI provides only a snapshot of brain activity, not how the activity changes over time. Also, MRI machines are too loud to conduct experiments involving auditory stimuli. Over a decade, we developed MEG for babies with a Finnish company, which also helped us develop head-movement compensation software. The machine looks like a hair-dryer from Mars, but it is entirely safe and noninvasive, and we have developed head models for babies that can serve as reference atlases for future studies.

**PNAS:** Can you describe your experiment with the seven-month-old and one-year-old infants to parse the contribution of motor and auditory brain activation in speech discrimination? What did you find?

**Kuhl:** The baby sits in an MEG machine and listens to strings of native and nonnative sounds from a loudspeaker. We then monitor changes in brain activity as the babies begin to engage in sound discrimination. As early as seven months of age, babies show activation of both auditory regions and in Broca's area. At 11 or 12 months of age, there is an increase in activity in the auditory regions when babies discriminate native sounds and an increase in activity in the Broca's area when they discriminate nonnative sounds.

Patricia Kuhl. Image courtesy of the Institute for Learning and Brain Sciences (University of Washington, Seattle).

**PNAS:** You note that these findings suggest that infants might generate internal motor models of speech early in development. Can you explain?

**Kuhl:** I am hypothesizing that the brain generates an internal model to synthesize and mimic what it hears. This may also be why one-on-one interaction and "motherese"—the exaggerated, articulatory speech that mothers use with babies—as we previously showed, is positively correlated with language development. Because motherese might promote motor engagement, it might lead to better language development.

**PNAS:** Your findings may have implications for children with developmental disabilities, such as autism spectrum disorder. You speculate that language deficits in such children might be associated with reduced motor response to linguistic and social cues in certain brain regions.

**Kuhl:** If the machinery for speech perception and production is part of our system of

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social understanding and interaction, it is possible that there is something awry about this machinery in autism and other developmental disabilities. We are interested in testing this hypothesis.

**PNAS:** In June 2014, the American Academy of Pediatrics recommended that all parents read aloud to their children right from infancy. Given your expertise in speech perception among infants, what are your thoughts on the recommendation?

**Kuhl:** I tell parents that the act of sitting down with their babies and reading to them in a slow, motherese tone of voice helps language development. Babies can recite from memory things they have heard parents reading to them. Who would have imagined that the brain is this active in motor regions when listening to native and nonnative sounds even before it can understand the meaning of words or produce words? So yes, I am in favor of routinely reading aloud to babies.

**1** Kuhl PK, Ramírez RR, Bosseler A, Lin JF, Imada T (2014) Infants' brain responses to speech suggest Analysis by Synthesis. *Proc Natl Acad Sci USA* 111(31):11238–11245.