Building a Conceptual Framework for Auditory Learning

By Nina Kraus, PhD

Here's a question: What do you get when you combine a rabbit, a violin, and a patient who is struggling to hear in noise?

You probably didn't guess "a life in auditory neuroscience," but, when taken together, the three encapsulate my research: the biology of auditory learning.

I began my career measuring responses from single neurons in the rabbit auditory cortex. I trained rabbits to associate a particular sound with a particular meaning and found striking changes in neural activity within the auditory cortex following this learning experience.

Having witnessed the potential for brain plasticity firsthand, I moved my focus to improving human communication. Since then, I have pursued several lines of work to understand how the brain is changed by experiences such as music training,[1] second language learning,[2] and computerized brain training (Listening and Communication Enhancement [LACE];[3] BrainHQ[4]).

These studies demonstrate the potential for brain plasticity, and we've defined signature neural changes stemming from each experience.[5] I've covered many of these neural signatures in the Hearing Matters columns Samira Anderson, AuD, PhD, and I have written for *The Hearing Journal* (**HJ January 2015 issue, p. 38**), but, in this editorial, I want to take a step back and ask: What factors drive the biological changes?

THREE ELEMENTS

Effective training covers these bases:

- Cognitive: A listener has to direct attention to sound, remember that sound, and connect that sound to meaning.

"What factors drive the biological changes?"

- Sensorimotor: A listener has to learn to hear fine-grained sound details, such as recognizing the difference between "b" and "p," and associate those sounds with precise motor actions, such as articulating those consonants.
- Reward: Emotional systems in the brain have a chief role in sparking neuroplasticity, and this rewarding jolt makes changes last.[6,7]

If all these brain systems are engaged together, they have the potential to change automatic sound processing in the brain, providing a lasting benefit for listening even after training has stopped.

In my research I have sought biological metrics of automatic processing that reflect this cognitive–sensorimotor–reward trifecta, first using the mismatch negativity (MMN)[8,9] and now the auditory brainstem response to complex sounds (cABR).[10]

Take the case of playing a musical instrument. Making music demands attention and memory while you're honing in on fine acoustic details such as timbre and pitch and carefully coordinating motor action on the instrument, all while drawing pleasure from the sounds you're creating and manipulating.

It's no coincidence, then, that comparisons of children engaged in active music making versus music appreciation classes have found brain changes only in the former.[11] These themes extend past music to cut across research in auditory learning, including experiments in humans[12,13] and animal models.[6,14]

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2014 APEX AWARDS FOR PUBLICATION EXCELLENCE

CI LEADERS WIN RUSS PRIZE

From second on the left, Blake S. Wilson, DSc, DEng, DrMedHC; Michael Merzenich, PhD; Erwin Hochmair; and Ingeborg Hochmair, PhD, received the 2015 Fritz J. and Dolores H. Russ Prize. They are shown here with Ohio University President Roderick J. McDavis, MS, PhD, far left, and National Academy of Engineering President C. D. Mote Jr., MS, PhD, far right. Graeme Clark, MB, MS, PhD, who isn't pictured, also was an award recipient.

The National Academy of Engineering and Ohio University awarded the 2015 Fritz J. and Dolores H. Russ Prize to five pioneers in the development of the multichannel cochlear implant:

- **Graeme Clark**, MB, MS, PhD, is laureate professor emeritus at the University of Melbourne, honorary professor of electrical engineering at the Melbourne School of Engineering, and director emeritus of the Bionic Ear Institute.
- **Ingeborg Hochmair**, PhD, and **Erwin Hochmair** are cofounders of MED-EL.
- **Michael Merzenich**, PhD, is professor emeritus in the Department of Otolaryngology–Head and Neck Surgery at the University of California, San Francisco.
- **Blake S. Wilson**, DSc, DEng, DrMedHC, is codirector of the Duke Hearing Center at Duke University Medical Center (DUMC), adjunct professor of surgery at DUMC, adjunct professor of electrical and computer engineering and of biomedical engineering at Duke University, and chief strategy advisor for MED-EL.

Established in 1999 and awarded biennially, the Russ Prize recognizes bioengineering achievements that are in widespread use and improve the human condition. It's named after engineer Fritz Russ, who cofounded Systems Research Laboratories, and his wife, Dolores Russ.

EDITORIAL

But where does this information leave that person who's grasping at straws to hear in noise? These biological lessons in learning tell us a lot about how to help her. They teach us that simply improving the sensory component (such as amplification) may only begin to improve how the brain processes sound.

Auditory training might be a good strategy, and we now know that a promising intervention must tick three boxes: cognitive, sensorimotor, and reward.

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