

Feel the Vibrations

Understanding the Hearing-Emotion Connection

By Nina Kraus, PhD, and Travis White-Schwoch

Sound is air in motion. We all know that sound moves our hair cells, but sound moves us in other ways too. Hearing is coupled with feeling: In the brain, the auditory and emotional systems are interconnected by feedforward and feedback pathways, and reward-related neurotransmitters such as dopamine are expressed in the auditory centers of the brain. Over the past decade, audiology has made a conceptual leap by recognizing that cognition is involved in hearing. We think that emotion—how we feel about sound and how sound moves us affectively—is an equally important part of hearing (*Trends Cogn Sci.* 2015;19[11]:642).

Most of us probably have an intuitive sense of the hearing-emotion connection. Think about the pleasure felt from listening to music or the sadness endured when a favorite musician passes away. And of course, listening difficulties such as auditory processing disorder or hearing loss exert a significant emotional toll by affecting patients' quality of life.

Despite these intuitions, audiology education rarely formalizes the connections between hearing and emotion. Here are interesting examples of these connections that illustrate just how much hearing and emotion interact.

AUDITORY-LIMBIC INTERACTIONS ARE ABERRANT IN TINNITUS

Treating tinnitus is one of the most vexing challenges in audiology. Several possible causes have been put forward, but many of these explanations boil down to the idea that the auditory regions in the brain try to compensate for cochlear damage and “turn up the noise” in the cortex, generating a phantom sound.

Neuroimaging studies have long identified unusual activity in the limbic system—the brain's emotional network—of tinnitus patients. The traditional view was that this was a stress reaction



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to tinnitus. However, recent evidence challenges this view, and instead suggests that the limbic system may generate the tinnitus percept.

Rauschecker and colleagues have proposed an interesting model (*Neuron.* 2010;66[6]:819). They pinpointed thalamic interconnections between the auditory pathway and the nucleus accumbens, a limbic structure involved in motivation, reward, and learning. The model suggests that damage to the auditory pathway creates hyperactivity in the auditory system, which is “tuned out” by projections from the nucleus accumbens—a noise-canceling headphone within the brain. But when the limbic network is compromised, this compensatory mechanism breaks down, letting the tinnitus percept bleed through. This reinforces the idea that hearing and emotion interact, and may be one of the reasons why psychological interventions may help alleviate tinnitus.

REWARDS CATALYZE AUDITORY LEARNING

One of the amazing abilities of the auditory system is its capacity for change. Experiments conducted in animal models, in which the response profiles of individual neurons can be mapped, have shown that training animals to do basic auditory tasks drives improvements in behavioral performance and changes in the firing properties of auditory neurons.

We've long known that it's important to include rewards when training animals on basic tasks. For example, imagine you want to train a mouse to push a lever following an ascending



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sequence of tones, but to sit still following a descending sequence. Giving the mouse food following a correct response will help the animal learn.

But pairing the stimulus itself with a jolt of activity in the brain's reward centers is like flooring the gas pedal in a car—auditory learning is rapidly accelerated. Experiments by Bakin and Weinberger and Kilgard and Merzenich have shown that driving activity in the nucleus basalis, a limbic structure that releases the neurotransmitter acetylcholine, speeds up the auditory learning process and leads to lasting changes in the auditory cortex (*Proc Natl Acad Sci USA*. 1996;93[20]:11219; *Science*. 1998;279[5357]:1714).

This observation has important implications for auditory therapies. For one, when evaluating auditory training regimens it's crucial to ensure they incorporate reward triggers. The trend to "gamify" computerized brain training is one way to incorporate a reward stimulus. Second, there is exciting new work by Kilgard and colleagues that applies this approach to auditory learning on tinnitus, attempting to address some underlying auditory-limbic aberrations (*Nature*. 2011;470[7332]:101).

MUSICIANS' BRAINS TUNE INTO EMOTIONAL SOUNDS

Now that we've seen how hearing and emotion are connected, we might wonder whether this hearing-emotion connection can be strengthened. This has important therapeutic implications

because changing the connection can affect hearing disorders such as tinnitus. Musicians provide an excellent model to study auditory learning because making music integrates hearing, thinking, and feeling. And of course, listening to and playing music trigger the limbic networks throughout the brain (*Trends Cogn Sci*. 2015; *Proc Natl Acad Sci USA*. 2013; 110[Suppl 2]:10430).

Strait and colleagues explored this question by measuring neural responses to an emotional sound (a baby's cry) in individuals with and without musical training (*Eur J Neurosci*. 2009;29[3]:661). They found that musicians had a strengthened neural response to the sound, but only to the emotionally salient portion of the sound. In contrast, their brains downplayed the simpler and less meaningful parts of the sound, suggesting an economy of resources to pull out the most important component of the sound. It would be a stretch to conclude from this study that music training can be a therapy, say, for tinnitus, but it is an interesting topic to contemplate for future research.

Together, these three examples highlight the hearing-emotion connection in the brain. We also hope these examples can be useful when counseling patients. Broaching topics such as social and emotional quality of life can be difficult, especially with a patient who has come in for a hearing aid fitting. These simple examples might be good conversation starters to illustrate just how many connections there are between how we hear and how we feel. 