How Feedback Synchronizes the Auditory Brain

By Nina Kraus, PhD, and Travis White-Schwoch

Making sense of sound is about a lot more than just hearing: The auditory brain is suffused with connections to the cognitive, language, reward, sensory, and motor systems. In fact, auditory-motor connections are arguably among the strongest in the brain. Speech production, for example, involves motor activity that is constantly and automatically synchronizing with feedback as we hear our own voice and the sounds around us. For example, without even thinking about it, we speak more loudly if we're in a noisy room and more softly in a quiet room.

Much of what we know about the connections between auditory and motor systems comes from studies on simple rhythmic tasks, such as beating a drum in time to a steady metronome or a sample of music. Studies have shown that children and adults who are better at maintaining a steady beat also perform better on tests of language and reading skills. Moreover, their brains processes sound more reliably (see Brainvolts). These studies suggest that a brain "in time" is primed for more efficient communication skills because it does a better job synchronizing during communication tasks.

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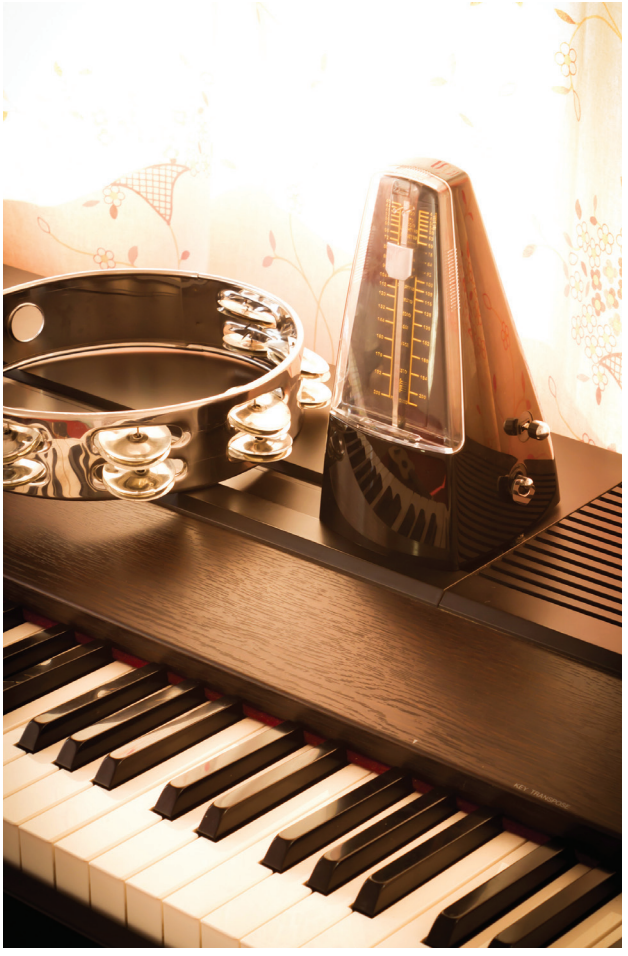
These synchronization tasks rely heavily on our ability to incorporate ongoing feedback while we're performing, but often they are simplified so that feedback is only implicit. Interactive Metronome (IM) is an innovative technology that uses auditory or visual cues to guide subjects as they clap in time.[1] This feedback can be used as part of IM training to boost a subject's ability to clap in time. It has been hypothesized that boosting time-keeping abilities can pay dividends for other skills, but this hypothesis presumes that clapping in time with feedback connects to other cognitive and language abilities. What are those cognitive and linguistic functions?



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ROLE OF VISUAL FEEDBACK

Bonacina and colleagues recently asked this question in a study of 64 children between 5 and 7 years old (*Ann NY Acad Sci.* 2018;1423:338). The children's ability to clap in time was measured while they received visual feedback that helped them adjust their time-keeping. The visual feedback consisted of a series of lights on a computer screen, color-coded to indicate if they clapped too early or too late. The children had one minute to synchronize with the beat and use the feedback to clap in time.

Dr. Kraus, left, is a professor of auditory neuroscience at Northwestern University, investigating the neurobiology underlying speech and music perception and learning-associated brain plasticity. **Mr. White-Schwoch** is a data analyst in the Auditory Neuroscience Laboratory (www.brainvolts.northwestern.edu), where he focuses on translational questions in speech, language, and hearing.

Children who performed better on the clapping test—those who made use of visual feedback more accurately to clap to the beat—performed better on early language and reading tests. For example, they had better knowledge of the sound structure of spoken language, which is a key skill in reading development (for example, knowing that the sounds 'd' and 'a' go together but the sounds 'd' and 'x' do not). They also had a better understanding of the morphological and syntactic structure of language (for example, knowing that "six ducks" is grammatically correct but "six mouses" is not).

NEURAL RESPONSES TO SOUND

Moreover, these children also had more robust brain responses to sound. Specifically, Bonacina, et al., measured neural responses to speech sounds and looked at how consistently the brain processes formants. Formants are the fine acoustic details of speech that provide crucial information about a speech sound's identity (for example, "d" vs. "t"). These results suggest that individual differences in the ability to exploit auditory-motor feedback is tethered to crucial speech and language processing skills. Specifically, children who are more sensitive to auditory-motor feedback have more robust neural and behavioral abilities to process fine features in speech. Because these are the exact features of speech that challenge children with language abilities, this suggests that trainings such as IM could have important therapeutic applications.

Interestingly, the findings of Bonacina and colleagues are parallel with those of a study on IM in adolescents (*Brain Lang.* 2017 Jan;164:43). In adolescents, IM relates to similar reading and language skills, albeit with more sophisticated and complex tasks appropriate for adolescents. Moreover, adolescents who performed better on IM had more adult-like brain responses to speech, suggesting that the maturation of the auditory system could tie into its ability to exploit motor feedback.

Together, these results suggest that auditory-motor brain connections play an important role in speech, language, and overall brain development. Specifically, the feedback conveyed by auditory-motor integration tasks can synchronize the auditory brain to process sound more robustly and efficiently. This may indicate a promising approach to remediate issues in auditory processing, language, and reading.

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