Beat-Keeping Ability Relates to Reading Readiness

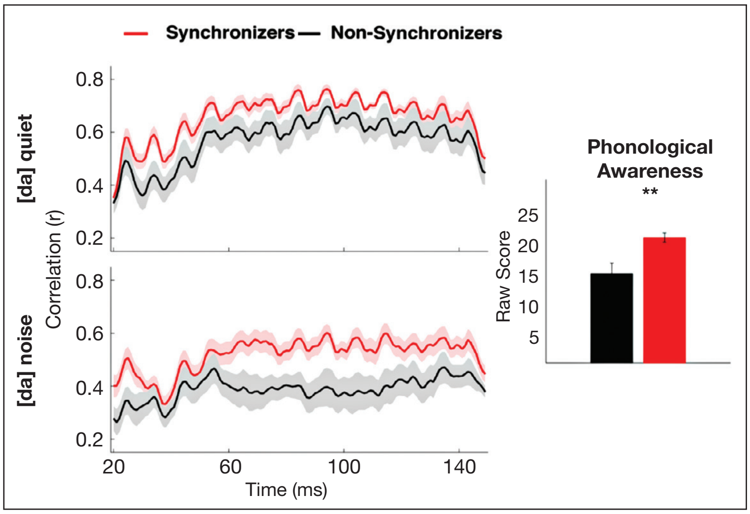
By Nina Kraus, PhD, & Samira Anderson, AuD, PhD

Children with language-based learning impairments, such as dyslexia or specific language impairment, may be referred for audiologic evaluation to rule out hearing loss or auditory processing disorder (APD).

Although these learning impairments are likely to have heterogeneous origins, a substantial body of evidence suggests that auditory temporal processing deficits can lead to reading disorders (*Science* 1996;271[5245]:77-81). Impaired temporal processing reduces the accuracy of the sound-to-meaning connections that are necessary building blocks for learning to read.

The ability to follow the rhythms of speech is one aspect of temporal processing that has been linked to reading ability. For example, adults with dyslexia have a reduced ability to recognize rhythm patterns in nursery rhymes compared with controls (*Front Hum Neurosci* 2014;8:96).

Furthermore, children with dyslexia have a less accurate perception of musical rhythm than typically developing children do (*Cortex* 2011;47[6]: 674-689). Sensitivity to musical rhythm predicts phonological awareness and reading development.



Children who are better able to synchronize to an acoustic beat have more faithful neural encoding of speech responses (higher stimulus-to-response correlations) in quiet and noise, and have higher phonological awareness scores—an early indicator of reading ability. The ""symbol stands for a *P* value less than 0.01. (Image adapted from *Proc Natl Acad Sci U S A* 2014;111(40):14559-14564.)**

Compared with children who have dyslexia, typically learning children demonstrate superior auditory stimulus representation in the delta band of cortical evoked responses, suggesting a neural basis for the rhythmic deficit in dyslexia (*Front Hum Neurosci* 2013;7:777).

Furthermore, cortical measures of speech envelope representation account for up to 50 percent of the variance in reading and phonological awareness among children with a range of reading abilities (*J Neurosci* 2009;29[24]:7686-7693).

RHYTHM ASSESSMENT IN CHILDREN

Sensitivity to rhythm develops early in life. Infants show preferential responses to rhythms that are characteristic of their own languages (*Science* 2000;288[5464]:349-351).

Most of the tests in the current auditory processing assessment battery are constrained by language and memory requirements, making them difficult to interpret in children younger than 8 years old. However, a reliable assessment of rhythm abilities can be accomplished at a much younger age.

The Kraus lab recently completed a study investigating the relationships among rhythmic abilities, brainstem speech encoding, and reading readiness in preschoolers between the ages of 3 and 4 years (*Proc Natl Acad Sci U S A* 2014; 111[40]:14559-14564).

To assess rhythmic abilities, Kali Woodruff Carr and colleagues implemented a social drumming paradigm that used two identical conga drums, one played by the child and one played by the experimenter.

The experimenter drummed to a beat heard through in-ear headphones and encouraged the child to drum along at the same pace. The drum hits of both the child and the experimenter were recorded.

Each child was classified as a synchronizer or non-synchronizer based on the degree to which the child was able to maintain a consistent temporal relationship between his or her drum hits and the stimulus hits.

The synchronizers had more accurate brainstem processing of speech compared with the non-synchronizers, as assessed

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. **Dr. Anderson**, right, is an alumna of Dr. Kraus's Auditory Neuroscience Laboratory and assistant professor in the University of Maryland Department of Hearing & Speech Sciences, where she is studying the effects of hearing loss and aging on neural processing in older adults.

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by correlating the waveform of the syllable /da/ with brainstem responses to this syllable obtained in quiet and in noise.

The synchronizers also had higher pre-reading skills (phonological processing, auditory short-term memory, and rapid naming) compared with non-synchronizers. Overall, the results supported the idea that accurate temporal processing is important for developing the foundational skills needed in order to learn how to read.

This study has a number of exciting implications for the fields of audiology and early education. Because beat synchronization and neural activity can be evaluated in young patients, it may be possible to identify children who are at risk for an auditory-based reading disorder.

The use of an objective neural metric, such as the auditory brainstem response to complex sounds (cABR), combined with a nonverbal behavioral test of rhythmic ability, can enhance our ability to detect auditory temporal processing disorders in young children.

This testing may also be used to evaluate treatment efficacy. The ability to synchronize to auditory or visual rhythms is malleable with experience, as demonstrated by the improved ability to synchronize to visual flashes in deaf people compared with hearing people (***Cognition*** **2015;134:232-244**) and children's better rhythmic ability after one year of music training (***PloS ONE*** **2013;8[10]:e77250**).

A number of different commercial approaches aimed at auditory processing or sensory integration disorders currently are available. Some of these approaches specifically target temporal processing; for example, the Interactive Metronome training program purports to improve synchronized neural timing.

The efficacy of these programs could be verified in independent groups using metrics of neural timing, such as the cABR and behavioral tests of rhythmic ability.