Demystifying Children's Speech-in-Noise Perception

By Nina Kraus, PhD, and Travis White-Schwoch

Numerous studies have attempted to map out the factors that support speech-in-noise perception in children with normal hearing. Several factors have been identified, including the integrity of the neural processing of speech, cognitive abilities such as attention and working memory, and children's language development. However, the majority of these studies have only tested one or two of these factors vis-à-vis speech-in-noise perception primarily due to the practical difficulties of large-scale, longitudinal studies in young children.

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UNDERSTANDING COGNITIVE, LINGUISTIC, AND AUDITORY LINKS

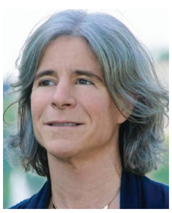
In the largest study of childhood listening to date, Thompson and colleagues comprehensively examined speech-in-noise perception in a cohort of 104 children ages 4 to 7 years old (doi.org/10.1016/j.dcn.2019.100672). They tested the children's ability to understand sentences in noise under two conditions: one where the sentence and noise came from the same location ("co-located") and another where the sentence and noise were spatially separated.

Next, they chose a battery of tests inspired by the factors hypothesized to support speech-in-noise perception:

- Cognitive tests measured the children's auditory short-term memory (imagine hearing a phone number and repeating it back immediately), auditory working memory (imagine hearing a phone number and repeating it back, rearranging the numbers so they go in descending order), and sustained attention (imagine hearing a series of phone numbers and pressing a button every time you hear the number five).
- Language tests measured the children's ability to form grammatically and syntactically-correct sentences (for example, if children are shown a picture of somebody talking on the phone, they would say, "He is talking on the phone") and their ability to correctly recognize the written structure of words (for example, that the plural of "child" is "children" and not "childs").
- Neurophysiological tests measured frequency-following responses to speech (FFRs). FFR measures focused on how robustly the pitch and harmonics of speech are processed and how quickly fine-grained details in speech are processed. The strength of the fundamental frequency (a pitch cue) and neural timing (to process consonants) have been identified as key neural factors that underlie listening-in-noise success by previous studies (*Hear Res.* 2010 270:151-157; *J Neurosci.* 2010 30(14): 4922-4926).

Study authors used a rigorous set of statistical techniques called structural equation modeling to examine links between neural, linguistic, and cognitive domains and performance on the hearing-in-noise test. This technique allowed the examination of simultaneous links between multiple measures by estimating how the tests in each domain interrelate and contribute to each theoretical construct (i.e., cognition, linguistic development, and neurophysiological processing) and how these constructs independently and jointly track with children's performance on the speech-in-noise tests.

All three domains made important contributions to children's success understanding sentences in noisy settings. However, they found that cognitive and linguistic development can be thought of as making a joint contribution that complements the contribution of neural processing. This suggests that children's general cognitive and linguistic development reinforce each other during early childhood, and that this reinforcement supports listening skills. They also found that neural processing of pitch information in speech was important for speech-in-noise perception in both the co-located and spatially separated conditions, but that only neural timing supported perception in the spatially separated condition. This builds on previous findings identifying FFR measures of pitch and neural timing as important factors in



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speech-in-noise perception, and highlights that both are vital to everyday listening.

PREDICTING FUTURE SKILLS

Next, Thompson, et al., used these insights to try to predict children's future performance on the speech-in-noise test. They reviewed data from when the children were 3 years old, and found that cognition, language, and neural processing of pitch information predicted their speech-in-noise performance when they were 6 years old. This reinforces the idea that all three domains make critical contributions to speech-in-noise perception during early childhood.

Early childhood sets the foundation for successful speech-in-noise perception–after all, learning environments such as classrooms are seldom quiet. Thus, it is critical to identify children who struggle to understand speech in noise and understand what factors underlie their difficulties. This study is the culmination of years of research into childhood listening, and highlights the complexity of speech-in-noise perception, particularly during early childhood, and the interdependence of cognition, language, and effective neural processing of sound.

While it might be tempting to throw our hands up and say, "It's complicated!" we have gained some tangible insights. First, this study highlights the joint importance of cognition and language. Children with academic and developmental delays might be at particular risk for difficulties understanding speech in noise, which could in turn impact feedback and cause further academic challenges. Thus, it is critical to evaluate speech-in-noise performance in these children and provide effective counseling and intervention. Second, this study shows the importance of multidisciplinary evaluations of childhood listening difficulties. While just examining one domain, such as neural processing or attention, could identify some children who are struggling, there is a risk of missing others. Finally, this study suggests there are many routes to successful speech-in-noise perception. Cognition, language, neural function, and combinations thereof are all plausible avenues for intervention to improve childhood listening.

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classification accuracy. As previously noted, the current study found 83 percent classification accuracy for professionals and 90 percent classification accuracy for students using the same discriminant function analysis technique. These findings suggest instrument stability in predicting membership in either AuD or SLP over a period of approximately 15 years (i.e., 2002 to 2016). Additionally, the first open-ended question on reasons for selecting their respective professions showed that personal life experiences, working in a profession that helps others, undergraduate major, or a professor were the respondents' top choices for choosing their profession. The second open-ended question regarding perceived differences between the professions of AuD and SLP revealed that two of the most significant perceived differences seen between the professions related to scope of practice and whether the focus is on diagnostics or treatment.

Some common responses to open-ended questions from the study by Evans[2] were also seen in the current study. Additionally, the results are similar to those reported by Guigen, et al.,[5] who found interest in the field and familial experience as two of the most common factors reported when choosing between the two professions. According to an earlier study by Brodsky and Cooke,[1] both AuDs and SLPs selected their careers based more on personal factors than educational or employment factors. Both groups expressed a desire to work with and help people in a variety of settings. Audiologists emphasized that undergraduate courses in hearing also played a large role in their decision.

Lastly, the survey may assist undecided undergraduate CSD students who find both professions appealing with making important career decisions. Future investigations should examine factors common to each profession in developing a vocational counseling instrument for AuD and SLP students. This may help attract more high-quality students to the profession of audiology.

References for this article can be found at http://bit.ly/HJcurrent.