Attention to speech, speech perception, and referential learning

doi:10.1017/S0142716418000231

Janet Werker's Keynote article is a comprehensive summary of the literature on the development of infant speech perception and its relation to several aspects of language learning, particularly those relating to reference and word meaning. This review stems from an impressive amount and breadth of work on this topic from her laboratory over the past several decades, including findings from both monolingual and bilingual learning infants. In this Commentary, we focus our remarks on attention to speech and the bidirectional relationship between speech perception and referential learning, draw on the findings from deaf infants who learn spoken language.

FOUNDATIONAL TUNING: ATTENTION TO SPEECH

Werker and colleagues proposed the developmental framework for processing rich information from multidimensional interactive representations (PRIMIR; Curtin, Byers-Heinlein, & Werker, 2011; Werker & Curtin, 2005). This model posits that three dynamic filters, the initial biases, the requirements of the specific language task, and the developmental level of the child, work together to direct infants' attention to language-specific distributional properties, leading to successful word representation. Research from Werker's lab has established that human neonates with normal hearing (NH) show perceptual biases for attending to speech compared with a variety of other sounds (Vouloumanos & Curtin, 2014; Vouloumanos & Werker, 2004, 2007). In addition to behavioral evidence, infants also show neural specificity for speech compared to nonspeech sounds by the first month; this specificity becomes increasingly enhanced over the next 3 months (May, Gervain, Carreiras, & Werker, 2018). The foundational tuning to speech within the first months of life seems to be an emergent source of support for spoken language development, as perceptual reorganization takes place over the next several months.

However, there has been very little empirical support so far for the role of attention to speech on early speech perception and later language development. In a recent study, Vouloumanos and Curtin (2014) found that preference for speech over nonspeech sounds at 12 months significantly predicted expressive vocabulary at 18 months in children with NH. While these findings are very exciting, the relation between attention to speech and language development warrants further investigation with infants who have difficulty encoding speech, and in particular in the population with congenital hearing loss who later receive cochlear implants (CIs) or hearing aids (HAs). Research along this line in our lab examines the effects of auditory deprivation and subsequent cochlear implantation on the development of attention to speech and spoken language in infants with hearing loss. For example, Houston, Pisoni, Kirk, Ying, and Miyamoto (2003) demonstrated that infants with CIs who had 6 months of hearing experience showed

https://doi.org/10.1017/S0142716418000231 Published online by Cambridge University Press

significantly reduced attention to speech, as compared to their hearing age-matched peers with NH. In a follow-up 10-year longitudinal study, we further found that attention to speech at 3 to 6 months postimplantation predicts word recognition measures gathered during 2 to 11 years postimplantation (Wang, Shafto, & Houston, 2018). Taken together, our findings are consistent with Werker and colleagues' proposal that perceptual bias toward speech provides a foundation for subsequent language development.

An open and intriguing question concerns which properties of speech particularly draw infants' attention? Werker proposed that while infants are perceptually biased to speech, they would show interest in other kinds of sounds if presented in the context of meaning exchange. Findings from a broad range of infant-directed speech (IDS) literature, to a certain extent, support this view. Researchers proposed that IDS facilitates language development because it serves to better direct and engage attention and convey enhanced communicative intent than adult-directed speech (ADS; Cooper & Aslin, 1990; Fernald, 1989; Werker & McLeod, 1989). The unique properties of IDS seem to play a crucial role in attention to speech and language development in children with hearing loss as well. Infants with CIs or HAs, similar to their hearing age-matched peers with NH, showed perceptual preference for IDS over ADS (Robertson, von Hapsburg, & Hay, 2013; Wang, Bergeson, & Houston, 2017). In addition, the degree of IDS preference over ADS was associated with Preschool Language Scales collected 18 months postimplantation in infants with CIs (Wang, Bergeson, & Houston, 2017).

Although not explicitly stated, the PRIMIR model also implies that a lack of attention to speech would affect language-specific attunement, leading to poor language outcomes. Specifically, infants who show significantly attenuated attention to speech may not develop normal sensitivities to language-specific properties; therefore, they may not have the speech perception skills or processing strategies that are developed to a point equivalent to the infants who have normal levels of attention to speech. Evaluation of these predictions requires research examining group differences in early speech perception skills as well as longitudinal studies investigating relations between infants' attention to speech and their performance in a range of speech perception tasks. Findings from this research would, in turn, illuminate our understanding of the mechanisms underlying the relation between attention to speech and language development.

RECIPROCAL RELATIONSHIP BETWEEN SPEECH PERCEPTION AND REFERENTIAL LEARNING

Werker systematically laid out the evidence from infants with NH to demonstrate that the relationship between speech perception and referential learning is bidirectional. Specifically, she proposed that whereas the changing speech perception sensitivities contribute to word learning, the word–object occurrences also guide speech perception development. In support of this view, Klein, Walker, Kirby, and McCreery (2017) found that children with HAs who had

https://doi.org/10.1017/S0142716418000231 Published online by Cambridge University Press

larger vocabularies showed better performance in speech perception tasks than those with smaller vocabularies. We further speculate that the top-down referential learning may play an even more important role in language learning in infants with hearing loss as compared to infants with NH. The following findings from infants with CIs are of relevance to this argument.

Landsberger, Padilla, Martinez, and Eisenberg (2017) examined prelingually deaf children with CIs (between 5 to 15 years) and their peers with NH on the Spectral-temporally Modulated Ripple Test (SMRT), which measures spectral and temporal processing skills. They found a positive correlation between age and SMRT score for children with NH; however, for children with CIs, no significant relationship between age and SMRT score was found. The findings that spectral resolution does not improve with age for children with CIs may suggest that the degraded representation of the auditory signal provided by CIs limits the spectral resolution development. However, infants with CIs are able to develop spoken language perception and production skills close to their peers with NH, particularly if implanted early in life. This points to the possibility that the top-down referential learning may play a more important role in shaping speech perception and language learning in deaf children with CIs relative to children with NH. Indeed, infants with CIs show robust word-learning skills if implanted very early. Houston, Stewart, Moberly, Hollich, and Miyamoto (2012) tested word-learning skills in deaf children with CIs and their peers with NH. Deaf children who received CIs prior to 12 months of age performed similarly to their chronological age-matched peers with NH, whereas children who received CIs between 14 and 21 months of age performed more poorly. In addition, performance in word-learning tasks was also associated with later measures of vocabulary size.

A remaining puzzle is how do children with CIs successfully develop word-learning skills despite the degenerated auditory input? Houston et al. (2012) suggested that earlier implanted children show better word-learning ability because early auditory–visual experience allows them to develop enhanced sensory integration skills that are important for word learning. This is in line with Golinkoff et al.'s (2000) proposal that children integrate different sources of information, such as perceptual cues, attention biases, social cues, sentential context, and so on, while learning novel words. Therefore, it is possible that infants with CIs may rely less on lower level perceptual cues, but more on the integration of multiple cues, to facilitate them in learning novel words. The higher order referential learning skills then reach down into perception and facilitate the development of speech perception skills in infants with CIs. Research examining the role of cognitive skills, IDS, and caregiver–infant interaction on novel word learning on children with CIs will provide much insight into our understanding of the underlying mechanisms of novel word learning in this population.

The work of Werker and others has done much to advance our understanding of early speech perception and language development. This Commentary provides additional evidence from deaf children who learn spoken language to Werker's proposals. However, there is still much about the process and mechanism of language learning that are still unknown. An important future direction would be to take a multivariate approach to examine interactions among

https://doi.org/10.1017/S0142716418000231 Published online by Cambridge University Press

perceptual, cognitive, social, and motor processes and how they may explain variances in language learning in normal and clinical populations. Findings from this research will not only inform theoretical models of language development but also contribute much to the prediction of developmental disorders of language acquisition and therefore lead to more effective early interventions.

ACKNOWLEDGMENTS

Preparation of this work was supported by a Research Grant R01 DC008581from the National Institute on Deafness and Other Communication Disorders.

REFERENCES

Cooper, R. P., & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development*, *61*, 1584–1595.

Curtin, S., Byers-Heinlein, K., & Werker, J. F. (2011). Bilingual beginnings as a lens for theory development: PRIMIR in focus. *Journal of Phonetics*, *39*, 492–504.

Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Development*, *60*, 1497–1510.

Golinkoff, R., Hirsh-Pasek, K., Bloom, L., Smith, L. B., Woodward, A. L., Akhtar, N., … Hollich, G. (Eds.). (2000). *Becoming a word learning: A debate on lexical acquisition*. Oxford: Oxford University Press.

Houston, D. M., Pisoni, D. B., Kirk, K. I., Ying, E., & Miyamoto, R. T. (2003). Speech perception skills of deaf infants following cochlear implantation: A first report. *International Journal of Pediatric Otorhinolaryngology*, *67*, 479–495.

Houston, D. M., Stewart, J., Moberly, A., Hollich, G., & Miyamoto, R. T. (2012). Word learning in deaf children with cochlear implants: Effects of early auditory experience. *Developmental Science*, *15*, 448–461.

Klein, K. E., Walker, E. A., Kirby, B., & McCreery, R. W. (2017). Vocabulary facilitates speech perception in children with hearing aids. *Journal of Speech, Language, and Hearing Research*, *60*, 2281–2296.

Landsberger, D. M., Padilla, M., Martinez, A. S., & Eisenberg, L. S. (2017). Spectral-temporal modulated ripple discrimination by children with cochlear implants. *Ear and Hearing*. Advance online publication.

May, L., Gervain, J., Carreiras, M., & Werker, J. F. (2018). The specificity of the neural response to speech at birth. *Developmental Science*, *21*, e12564.

Robertson, S., von Hapsburg, D., & Hay, J. S. (2013). The effect of hearing loss on the perception of infant- and adult-directed speech. *Journal of Speech, Language, and Hearing Research*, *56*, 1108–1119 doi: 10.1044/1092-4388(2012/12-0110)

Vouloumanos, A., & Curtin, S. (2014). Foundational tuning: How infants' attention to speech predicts language development. *Cognitive Science*, *38*, 1675–1686.

Vouloumanos, A., & Werker, J. F. (2004). Tuned to the signal: The privileged status of speech for young infants. *Developmental Science*, *7*, 270–276.

Vouloumanos, A., & Werker, J. F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. *Developmental Science*, *10*, 159–164 doi: 10.1111/j.1467-7687.2007.00549.x

Wang, Y., Bergeson, T., & Houston, D. M. (2017). Infant-directed speech enhances attention to speech in deaf infants with cochlear implants. *Journal of Speech, Language, and Hearing Research*.

https://doi.org/10.1017/S0142716418000231 Published online by Cambridge University Press

Wang, Y., Shafto, C., & Houston, D. M. (2018). Attention to speech and spoken language development in deaf children with cochlear implants: A 10-year longitudinal study. *Developmental science*, e12677.

Werker, J. F., & Curtin, S. (2005). PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development*, *1*, 197–234.

Werker, J. F., & McLeod, P. J. (1989). Infant preference for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. *Canadian Journal of Psychology*, *43*, 230–246.

Yuanyuan Wang and Derek M. Houston
The Ohio State University

https://doi.org/10.1017/S0142716418000231 Published online by Cambridge University Press