112. Sanders, L. D., Newport, E. L. & Neville, H. J. Segmenting nonsense: an event-related potential index of perceived onsets in continuous speech. *Nature Neurosci.* **5**, 700–703 (2002).
113. Golestani, N. & Zatorre, R. J. Learning new sounds of speech: reallocation of neural substrates. *Neuroimage* **21**, 494–506 (2004).
114. Wang, Y., Sereno, J. A., Jongman, A. & Hirsch, J. fMRI evidence for cortical modification during learning of Mandarin lexical tone. *J. Cogn. Neurosci.* **15**, 1019–1027 (2003).
115. Winkler, I. *et al.* Brain responses reveal the learning of foreign language phonemes. *Psychophysiology* **36**, 638–642 (1999).
116. Koyama, S. *et al.* Cortical evidence of the perceptual backward masking effect on /l/ and /r/ sounds from a following vowel in Japanese speakers. *Neuroimage* **18**, 962–974 (2003).
117. Temple, E. *et al.* Neural deficits in children with dyslexia ameliorated by behavioral remediation: evidence from functional MRI. *Proc. Natl Acad. Sci. USA* **100**, 2860–2865 (2003).
This fMRI study of children with dyslexia showed that an auditory processing and oral language remediation programme produced increased brain activity in areas that are usually activated in children who have no difficulty in reading.
118. Cheour, M. *et al.* Magnetoencephalography (MEG) is feasible for infant assessment of auditory discrimination. *Exp. Neurol.* (in the press).
119. Dehaene-Lambertz, G., Dehaene, S. & Hertz-Pannier, L. Functional neuroimaging of speech perception in infants. *Science* **298**, 2013–2015 (2002).
The authors used fMRI to show that, like adults, language activates areas in the left hemisphere, with additional activation in the preforntal cortex of awake infants.
120. Pena, M. *et al.* Sounds and silence: an optical topography study of language recognition at birth. *Proc. Natl Acad. Sci. USA* **100**, 11702–11705 (2003).
121. Mills, D. L., Coffey-Corina, S. & Neville, H. J. Language comprehension and cerebral specialization from 13–20 months. *Dev. Neuropsychol.* **13**, 397–445 (1997).
122. Kuhl, P. K. A new view of language acquisition. *Proc. Natl Acad. Sci. USA* **97**, 11850–11857 (2000).
123. Dehaene, S., Spelke, E., Pinel, P., Stanescu, R. & Tsivkin, S. Sources of mathematical thinking: behavioral and brain-imaging evidence. *Science* **284**, 970–974 (1999).
124. Iverson, P. *et al.* A perceptual interference account of acquisition difficulties for non-native phonemes. *Cognition* **87**, B47–B57 (2003).
125. Friederici, A. D. & Wessels, J. M. I. Phonotactic knowledge of word boundaries and its use in infant speech perception. *Percept. Psychophys.* **54**, 287–295 (1993).
126. Mattys, S., Jusczyk, P., Luce, P. & Morgan, J. L. Phonotactic and prosodic effects on word segmentation in infants. *Cognit. Psychol.* **38**, 465–494 (1999).
127. Werker, J. F., Fennell, C., Corcoran, K. & Stager, C. Infants' ability to learn phonetically similar words: effects of age and vocabulary size. *Infancy* **3**, 1–30 (2002).
This study showed that 14-month-old infants could not learn to pair phonetically similar words with different objects, whereas 20-month-old infants could. Vocabulary size was a predictive factor in the younger infants.
128. Stager, C. & Werker, J. F. Infants listen for more phonetic detail in speech perception than in word-learning tasks. *Nature* **388**, 381–382 (1997).
129. Morgan, J. L. & Demuth, K. *Signal to Syntax: Bootstrapping from Speech to Grammar in Early Acquisition* (Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1996).
130. Tsao, F. M., Liu, H. M. & Kuhl, P. K. Speech perception in infancy predicts language development in the second year of life: a longitudinal study. *Child Dev.* **75**, 1067–1084 (2004).
131. Pang, E. *et al.* Mismatch negativity to speech stimuli in 8-month-old infants and adults. *Int. J. Psychophysiol.* **29**, 227–236 (1998).
132. Kuhl, P. K., Nelson, T., Coffey-Corina, S., Padden, D. M. & Conboy, B. Early brain and behavioral measures of native and non-native speech perception differentially predict later language development: the neural commitment hypothesis. *Soc. Neurosci. Abstr.* 15935 (2004).
133. Knudsen, E. I. in *Fundamental Neuroscience* (ed. Zigmond, M. J.) 637–654 (Academic, San Diego, 1999).
134. Lenneberg, E. H. *Biological Foundations of Language* (Wiley, New York, 1967).
135. Newport, E. Maturational constraints on language learning. *Cognit. Sci.* **14**, 11–28 (1990).
136. Johnson, J. & Newport, E. Critical period effects in sound language learning: the influence of maturation state on the acquisition of English as a second language. *Cognit. Psychol.* **21**, 60–99 (1989).
137. Piske, T., MacKay, I. & Flege, J. Factors affecting degree of foreign accent in an L2: a review. *J. Phonetics* **29**, 191–215 (2001).
138. Long, M. Maturational constraints on language development. *Stud. Second Lang. Acquis.* **12**, 251–285 (1990).
139. Birdsong, D. & Molis, M. On the evidence for maturational constraints in second-language acquisition. *J. Mem. Lang.* **44**, 235–249 (2001).
140. Flege, J. E., Yeni-Komshian, G. H. & Liu, S. Age constraints on second-language acquisition. *J. Mem. Lang.* **41**, 78–104 (1999).
A study of second language learning in Korean speakers who arrived in the United States at different ages. Age of arrival in the United States predicted the strength of perceived foreign accent, but grammaticality scores were more related to education and use of English.
141. Mayberry, R. I. & Lock, E. Age constraints on first versus second language acquisition: evidence for linguistic plasticity and epigenesis. *Brain Lang.* **87**, 369–84 (2003).
142. Greenough, W. T. & Black, J. E. in *The Minnesota Symposia on Child Psychology*, *Vol. 24: Developmental Behavioral Neuroscience* (eds Gunnar, M. & Nelson, C.) 155–200 (Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1992).
143. Oh, J. S., Jun, S.-A., Knightly, L. M. & Au, T. K.-F. Holding on to childhood language memory. *Cognition* **86**, B53–B64 (2003).
144. Au, T. K.-F., Knightly, L. M., Jun, S.-A. & Oh, J. S. Overhearing a language during childhood. *Psychol. Sci.* **13**, 238–243 (2002).
This study showed that adults speak a second language with a more native-like accent if they overheard the language regularly during childhood.
145. Pallier, C. *et al.* Brain imaging of language plasticity in adopted adults: can a second language replace the first? *Cereb. Cortex* **13**, 155–161 (2003).
146. Flege, J., Bohn, O. & Jang, S. Effects of experience on non-native speakers' production and perception of English vowels. *J. Phonetics* **25**, 437–470 (1997).
147. Morgan, J. L., Meier, R. & Newport, E. L. Structural packaging in the input to language learning: contributions of intonational and morphological marking of phrases to the acquisition of language. *Cognit. Psychol.* **19**, 498–550 (1987).
148. Saffran, J. R. Statistical language learning: mechanisms and constraints. *Curr. Dir. Psychol. Sci.* **12**, 110–114 (2003).
149. Hauser, M. D., Chomsky, N. & Fitch, W. T. The faculty of language: what is it, who has it, and how did it evolve? *Science* **298**, 1569–1579 (2002).

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Competing interests statement

The author declares no competing financial interests.

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