Language rhythms in baby hand movements

Hearing babies born to deaf parents babble silently with their hands

The vocal babbling sounds universally uttered by healthy babies at around 7 months of age are fascinating, and have been interpreted as reflecting both the origins of language production in humans[1] and the vestiges of the evolutionary origins of language in our species[2]. Here we study the hand movements of hearing babies born to profoundly deaf parents and find that these children produce a class of hand activity that is distinct from other uses of their hands and which contains the specific rhythmic patterns of natural language ('silent' babbling). Our findings support the idea that babies are sensitive to rhythmic language patterns and that this sensitivity is key to launching the process of language acquisition.

The biological basis of babbling has been debated for decades. One possibility is that babbling, as in modern accounts of the origins of human language, is a purely non-linguistic motor activity that results from the opening and closing of the mouth and jaw[3-6]. Alternatively, babbling could be a linguistic activity that reflects babies' sensitivity to specific patterns at the heart of human language and their capacity to use them[7-9] — particularly the rhythmic patterns that bind syllables, the elementary units of language, into baby babbles, and then into words and sentences.

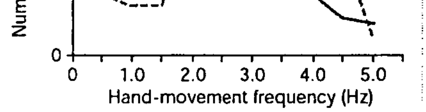

Figure 1 Hand-movement frequencies calculated for the rhythmic hand activity of sign-exposed (full line) and speech-exposed (dashed line) babies across all ages; for each group, 400 movement segments (200 per group) were randomly selected. Only sign-exposed babies had a bimodal distribution of movement frequencies: the first mode (left peak) falls at around 1 Hz (range, 0.5–1.5 Hz) and the second mode (right peak) falls at around 2.5 Hz (range, 2.0–3.0 Hz). In contrast, hand-movement frequencies of speech-exposed babies were unimodal, falling at around 3.0 Hz (range, 2.5–3.5 Hz). Comparison of the two groups further revealed that the pattern of movement frequencies produced by sign-exposed babies was significantly different from that of speech-exposed babies at the same age (20, $n=200$; $\chi^2=389.65$, $P<0.001$); χ^2 was calculated at 21 quarter-intervals and is shown here at half-intervals for clarity.

To test the motor and linguistic hypotheses, we studied three hearing babies who received no systematic exposure to spoken language and who instead saw only signed language from their profoundly deaf parents, and three hearing babies who were exposed to spoken language. We previously compared the capacity of hearing and deaf babies to babble in another study, in which group differences may have resulted from the babies' different sensory experiences[10].

The two hearing baby groups were equal in all developmental respects, with the only difference being in the form of language input they received (by hand or mouth). Because hearing babies exposed to sign language do not use their mouth and jaw to learn speech, the motor hypothesis predicts that their hand activity should be fundamentally similar to that of hearing babies acquiring spoken language. If, however, babies are born with sensitivity to specific rhythmic patterns that are universal to all languages, even signed ones, then the linguistic hypothesis predicts that differences in the form of language input should yield differences in the hand activities of the two groups.

We recorded all babies' hand activity in three dimensions using Optotrak, an opto-electronic position-tracking system. The hand activity was carried out during presentation with objects and during game-playing in 60-min experimental sessions conducted when the babies were aged about 6, 10 and 12 months. Optotrak sensors accurately measure the trajectory and location over time of light-emitting diodes on the babies' hands with a 0.1-mm precision. Optotrak computations were carried out blind to videotape recordings of the positions of the babies' hands, which on their own are a subjective way to analyse hand movements[11]. Online videotapes were made of all babies independently for post-Optotrak analysis.

Optotrak analyses revealed that sign-exposed babies showed a significantly different type of low-frequency rhythmic hand activity from speech-exposed babies, as well as another type of high-frequency rhythmic hand activity that speech-exposed babies also showed and used almost exclusively (Fig. 1).

The low-frequency hand activity of sign-exposed babies was mainly generated within a tightly restricted space (Fig. 2), corresponding to the obligatory 'sign-phonetic' space in front of a signer's body that binds all linguistic expression in signed languages (82%); high-frequency hand activity was mainly outside this space (73%). Speech-exposed babies produced most of their high-frequency hand activity

Figure 2 Learning language: a class of hand movements made by babies with profoundly deaf parents have a slower rhythm than ordinary gestures and are restricted to space in front of the body.

outside the crucial linguistic space (92%). Quantitatively, the low-frequency hand activity corresponds to the rhythmic patterning of adult sign-syllables[12]. We also discovered, after lifting the blind on videotape recordings, that only these low-frequency movements had the qualitative properties of silent linguistic hand babbling[10].

Remarkably, and without relying on the mouth, this silent linguistic babbling was conveyed by babies' hands in a different class of movement from non-linguistic hand activity. These linguistic and motor movements are differentiated by their distinct rhythmic frequencies, which could only result if babies are able to use the specific rhythmic patterns that underlie human language.

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1. Locke, J. L. *The Child's Path to Spoken Language* (Harvard Univ. Press, Cambridge, Massachusetts, 1993).
2. Lieberman, P. *Human Language and Our Reptilian Brain: The Subcortical Bases of Speech, Syntax, and Thought* (Harvard Univ. Press, Cambridge, Massachusetts, 2000).
3. MacNeilage, P. F. & Davis, B. L. *Science* 288, 527–531 (2000).
4. Locke, J. L. *Science* 288, 449–451 (2000).
5. Studdert-Kennedy, M. G. in *Cognition and the Symbolic Processes: Applied and Ecological Perspectives* (eds Hoffman, R. R. & Palermo, D. S.) 38–58 (Erlbaum, Hillsdale, New Jersey, 1991).

6. van der Stelt, J. M. & Koopmans-van Beinum, F. J. in *Precursors of Early Speech* (eds Lindblom, B. & Zetterstrom, R.) 163–173 (Stockton, New York, 1986).
7. Pinker, S. & Bloom, P. in *The Adapted Mind: Evolutionary Psychology and the Generation of Culture* (eds Barkow, J. H. *et al.*) 451–493 (Oxford Univ. Press, New York, 1992).
8. Jusczyk, P. W. *The Discovery of Spoken Language* (MIT Press, Cambridge, Massachusetts, 1997).
9. Vihman, M. M. *Phonological Development: The Origins of Language in the Child* (Blackwell, Cambridge, MA, 1996).
10. Petitto, L. A. & Marentette, P. F. *Science* 251, 1493–1496 (1991).
11. Meier, R. P. & Willerman, R. in *Language, Gesture, and Space* (eds Emmorey, K. & Reilly, J. S.) 391–409 (Erlbaum, Mahwah, New Jersey, 1995).
12. Petitto, L. A. *et al. Proc. Natl Acad. Sci. USA* 97, 13961–13966 (2000).