A model of mother-infant interaction that guides vowel acquisition based on maternal imitation of infant's cooing

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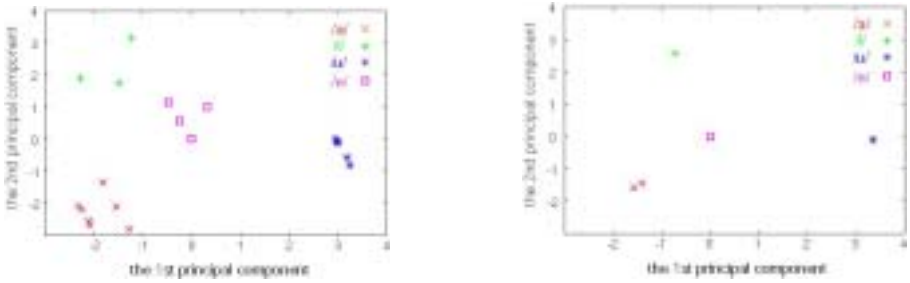
Inspired by the observation that infants acquire phonemes common to adults without having the capability to articulate, nor having *a priori* knowledge about the relationship between the sensorimotor system and phonemes, a constructivist approach to building a robot that reproduces a similar developmental process is conducted. Two general issues are addressed: what are the interactive mechanisms involved and what should be the behavior of the caregiver/teacher? Based on findings in developmental psychology, it is conjectured that (a) the caregiver's vocalization in response to infants' cooing reinforces the infant's articulation along the caregiver's phonemic categories, and (b) the caregiver's repetition with adult phonemes helps to specify the correspondence between cooing and the caregiver's phonemes as well as determining the acoustic properties of the phonemes.

We build a robot that consists of an artificial articulatory system with a 5-DoF mechanical system deforming a silicon vocal tract connected to an artificial larynx, an extractor of formants, and a learning mechanism with self-organizing auditory and articulatory layers. Starting off with random vocalizations, the system uses the caregiver's repetitive utterances to bootstrap its learning. In the first experiment, we let the robot learn the connection between the auditory and the articulation layer by the normal Hebbian learning rule and observed which units in the articulation layer are activated by the propagation because the activated units can be regarded as vowels matching those of the caregiver. Fig. 1(a) shows distribution of the articulation vectors of the most strongly activated units by 30 input, which are the caregiver's utterances, for each vowel. The propagation for the input vowels in the same category activates the articulation vectors in a cluster that causes corresponding sounds. It means that the robot succeed in learning to match its articulations with the caregiver's vowels. However, we can see that there is arbitrariness in selecting the matched articulation with the caregiver's utterances since a unit in the auditory layer has multiple connections.

To match a heard vowel with a unique articulation, we introduce the learning rule with the toil criterion that minimize the torque to deform the tract and its resultant deformation are minimized. We examine how the robot acquires vowels in the same manner as the first experiment and show the result (see Fig. 1(b)). We can see that fewer articulation vectors are selected than in Fig.1(a) while the articulation vectors that causes corresponding vowel-like sounds are selected. Therefore, we confirmed that the robot can match its articulations with the caregiver's vowels by the learning rule with the toil criterion and, furthermore, that the toil criteria decrease the arbitrariness. Please see [1] for more detail and discussion.



(a) normal Hebbian learning (b) Hebbian learning with toil criterion

Fig. 1: Distribution of the articulation vectors

Reference

[1] Y. Yoshikawa, M. Asada, K. Hosoda, and J. Koga, A Constructive Approach to Infant's Vowel Acquisition through Mother-Infant Interaction, *Connection Science*, 2004 (to appear).