PHYSIOLOGY

Role of Tactile Receptor Structures of the Tongue in Speech Sound Production of Infants of the First Year of Life

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The development of mechanosensory papillae of the tongue in the early postnatal ontogeny is studied by morphological and physiological methods: the tactile receptor structures first appear on the body and root of the tongue and then on its anterior surface. This heterochrony in the formation of tactile papillae of the tongue determines the involvement of its different zones in articulation. The appearance of velar, dorsal, and point consonants in the vocal repertoire of hearing and deaf infants is revealed. The same consequence of consonant appearance is demonstrated in infants of different nationalities.

Key Words: *tongue; tactile receptors; speech development in ontogeny; vocalization*

Human orosensory apparatus located in the beginning of the digestive tract plays an important role in nourishment. Chemo- and mechanosensory (MS) structures (MSS) of the tongue control the quality of food, regulate secretory processes in the salivary and gastric glands, and oromotor reactions such as sucking, mastication, and swallowing. Oral and tongue MSS are responsible for not only food consumption but also speech articulation [2,6,8].

Previous studies demonstrated heterochrony in the development of tongue MSS during ontogeny [1,2, 4,5]. However, the role of MSS in articulation and the relationships between the structural and functional maturation of tactile sensory structures and the dynamics of prespeech sound production during postnatal ontogeny remain poorly understood.

The present study explores the role of tongue MSS in sound production in infants of the first year of life.

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MATERIALS AND METHODS

Tactile structures of the dorsal tongue surface were examined in 30-40-week fetuses, newborns, and infants of the first year of life by scanning electron microscopy (JSM-50A).

Hearing disturbances were detected with an AUD-174 audiometer. Cooing and babbling were recorded and the phonograms were analyzed using a Signal Viewer high-precision sound visualization system (imputed through a Sound Galaxy sound card).

Emotional state of infants during babbling and crying was evaluated by heart rate (HR) and muscular tension (recorded with an MM-01 medical monitor) as well as by mimic and behavioral reactions (videotaped with a Panasonic-6-120 camcorder).

RESULTS

Previous studies demonstrated systemic heterochrony in the maturation of chemosensory structures in the human tongue. In particular, its anterior free surface

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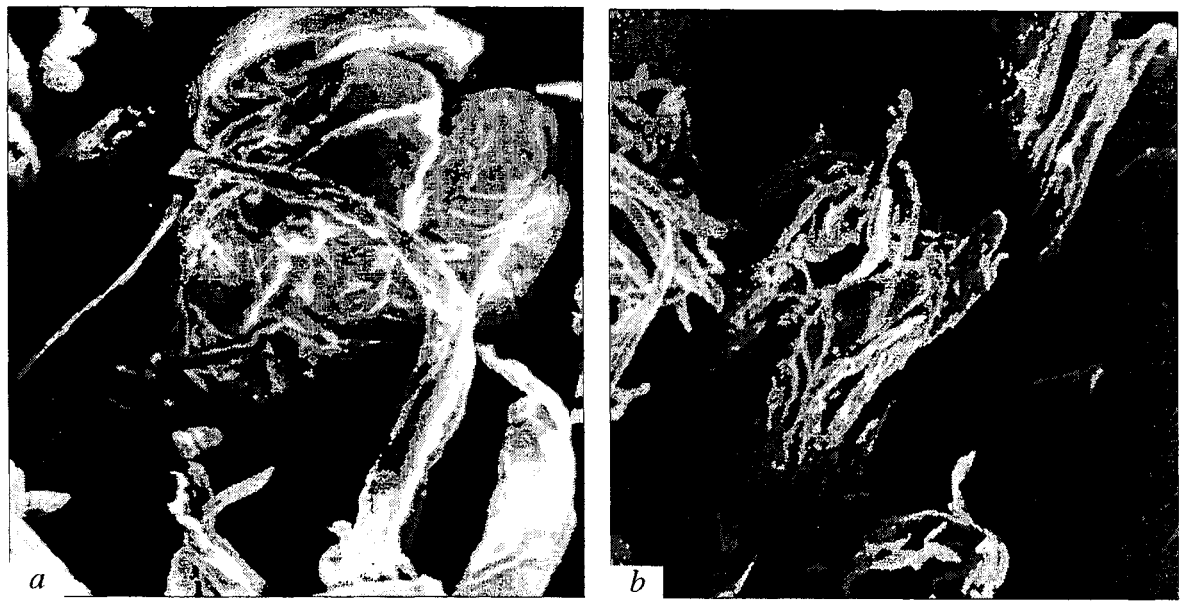

Fig. 1. Mechanoreceptors from the median part of tongue tip in adult man, ×50.

(tip of the tongue) in newborns is characterized by more pronounced functional and structural immaturity in comparison with the root and body of the tongue [3,5]. The dynamics of maturation of tactile structures is similar to that of chemosensory elements.

Scanning electron microscopy showed that similarly to gustatory papillae, tactile receptors of the tongue tip in 30-week fetus and newborn are characterized by structural immaturity, in particular, MS papillae have no tactile processes typical of mature receptors in adults (Fig. 1). In contrast to the tip of the tongue (Fig. 2*a*), MS papillae of the body and root of the tongue (Fig. 2, *e, f*) are structurally mature at birth. They have tactile processes and are capable to perform their sensory function. Early maturation of MS papillae in the root and body of the tongue is essential for sucking, since this process as well as swallowing require strict sensory control over close attachment to the mother's nipple (Fig. 3). At later stages of infancy, when solid food is added to the ration, tactile papillae are responsible for sensory control over the solid food components.

Tactile papillae also participate in articulation during speech sound production. It was found that successive appearance of velar, dorsal, and point sounds in the repertoire of infants of the first year of life correlates with the dynamics of structural and functional maturation of tactile receptors in the corresponding tongue areas [2]. Tactile processes of the root and medial part of the body of the tongue (areas responsible for sucking and swallowing, Fig. 2, *d-f*) develop prenatally. Tactile MS papillae on the tip of the tongue (Fig. 2, *a-c*) controlling quality of solid food are formed by the 5th-6th month, when solid food is added to the ration. Tactile processes of MS papillae on the total tongue surface are developed to 3 years.

Thus, heterochrony is typical for the formation of MS apparatus in humans: tactile papillae of the anterior surface (tip) developed later that in the body and root of the tongue.

Maturation of the MS apparatus during ontogeny determines the development of articulation. The role of MSS in speech formation was first discussed in 1950s [7]; however, this question remains poorly understood.

Analysis of phono- and sonograms revealed the order of appearance of tongue sounds (consonants) in hearing and deaf infants during the first year of life (Fig. 4, *a, b*). These data suggest that speech mechanics in the early postnatal period depends on tactile apparatus rather than on hearing. In other words, heterochronic maturation of the tactile receptor apparatus of the tongue detected by scanning electron microscopy determines heterochronic development of articulation and acoustic functions, which manifests itself in a certain sequence of prespeech vocalizations in infants of the first year of life.

During the first few months of life, articulation and acoustic repertoire of babbling in hearing and deaf infants consist of vowels only (Fig. 4, *I, a, b*). First consonants appeared at the age of 3-5 months: velar consonants in various combinations with vowels (*agu, akku, akky*, etc., Fig. 4, *II, a, b*). Because of prevalence of velar consonants, infant babbling during the first 5 months of life is termed cooing.

The dorsal consonant *yi* first appeared in 7-month infants, while point (tip) consonants t, t', d, d', n, n',

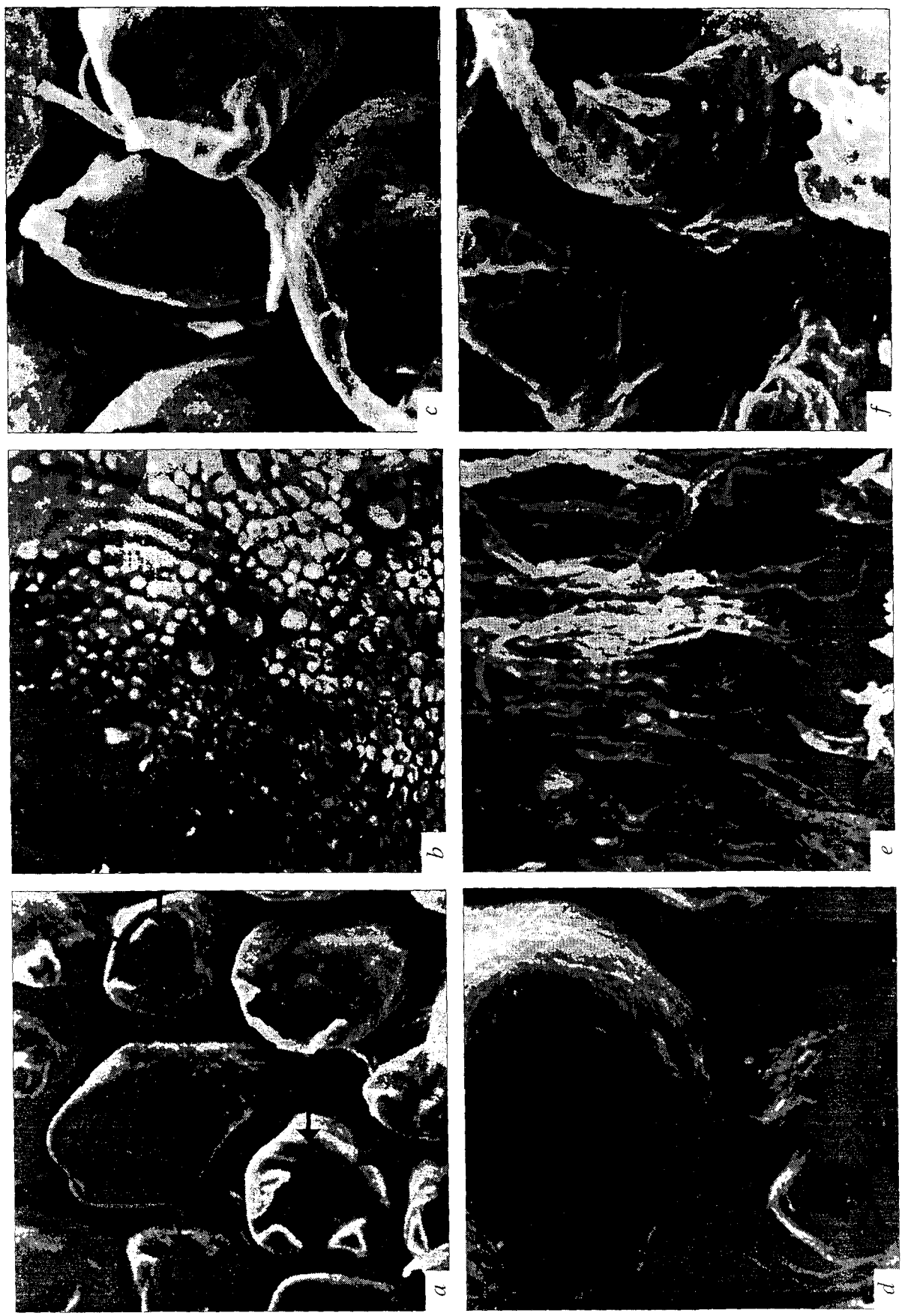

Fig. 2. Tactile receptor structures of newborn tongue (scanning electron microscopy). *a*) tactile papillae of the anterior free surface of newborn tongue (arrows indicate tactile processes), ×100; *b*) fragment of the lateral dorsal surface of newborn tongue, ×20; *c*) mechanoreceptors of the medial part of the tongue body from newborn, ×200; *d*) tactile papillae of the medial part of the tongue root from 30-week fetus, ×100; *e*) mechanoreceptors of the medial part of the tongue root from newborn, ×50; *f*) tactile papillae medial part of the tongue root from newborn, ×150.

l, l', ts, and ts' appeared by the 9th-12th months (Fig. 4, *IV*, *a*, *b*).

These findings suggest that sensory mechanisms of vocalization are the same in hearing and deaf infants of the first year of life.

When studying the dynamics of sound production in Russian, Mongol, and Kazakh infants we found that consonants in infants of different nationalities appeared in the same order as in hearing and deaf infants (Fig. 4, *I*, *c*, *II*, *c*, *d*, *IV*, *c*, *d*).

Evaluation of autonomic reactions and mimics showed that babbling and cooing in infants of all ages are associated with hedonic reactions, as evidenced by a significant decrease in HR (Fig. 5, *a*) and tension index to the relaxation level (Fig. 5, *b*).

Thus, similar dynamics of sound production in hearing and deaf infants as well as in infants of different nationalities suggests that prespeech vocalizations in infants are controlled by orosensory structures rather than hearing. It can be hypothesized that hearing participate in acquisition of language-specific sound patterns during subsequent speech practice.

It should be noted that successive maturation of tactile receptor elements of the tongue first of all ensures sensory control over nutrition-related processes

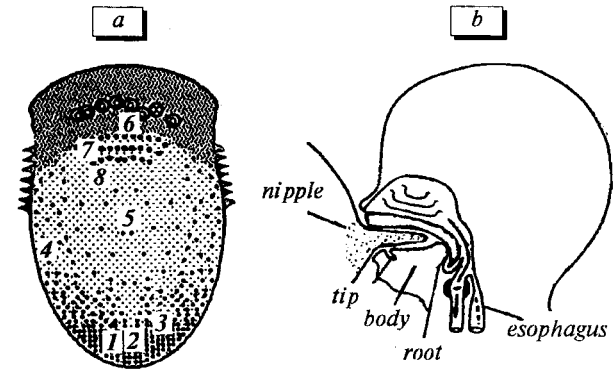

Fig. 3. Topography of tactile papillae on the dorsal tongue surface (*a*) and contacts of tactile receptors in different tongue areas during sucking (*b*). *a*) figures 1-8 point tongue areas shown on Fig 1, *a* (*1*), *b* (*2*), Fig 2, *a* (*3*), *b* (*4*), *c* (*5*), *d* (*6*), *e* (*7*), *f* (*8*).

(sucking and swallowing) during the lactotrophic period: priority development of the tactile apparatus on the tongue root and body and then on the anterior surface (tip) of the tongue [1,3-5]. This nutrition-oriented dynamics of the maturation of tactile re-ceptors determines also the development of prespeech vocalizations.

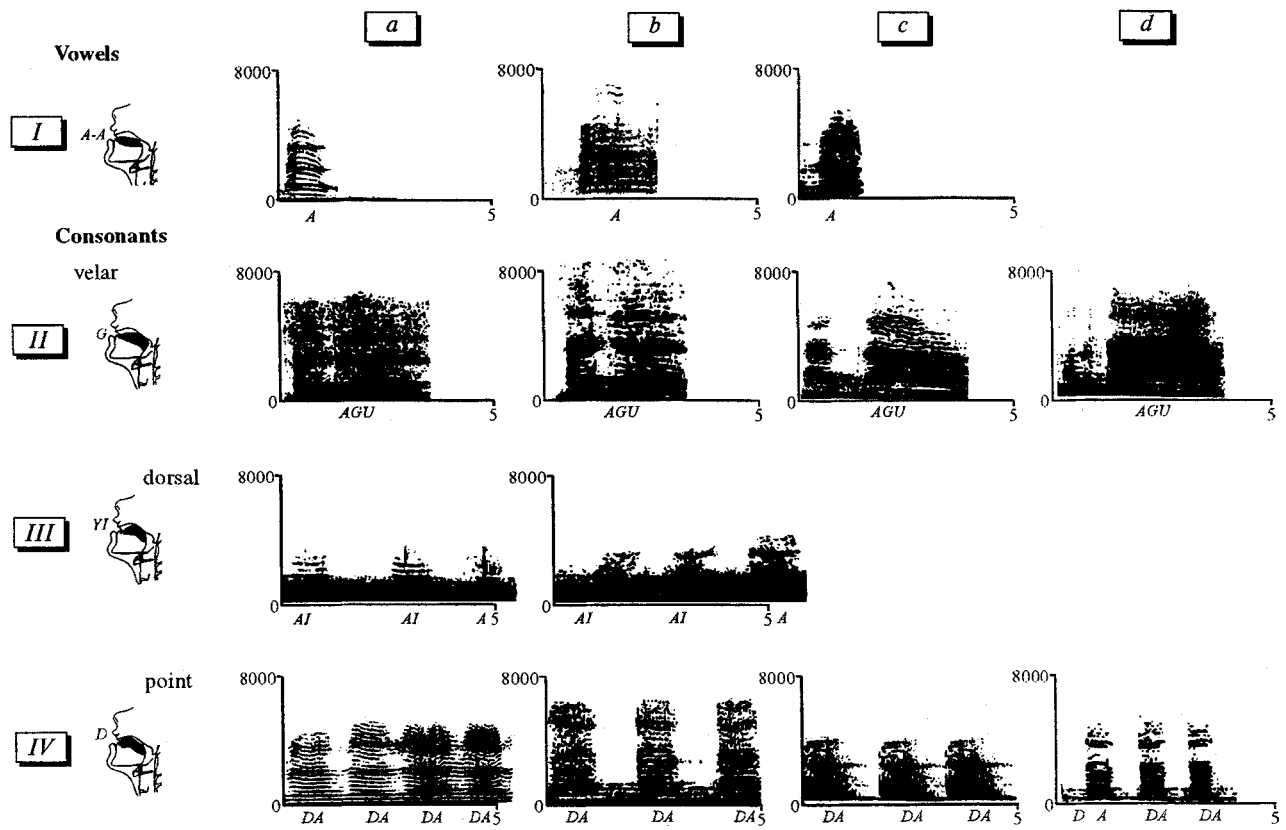

Fig. 4. Appearance of vocalizations during the first year of life. Sonogram of 3-month- (*I*), 5-month- (*II*), 7-month- (*III*), and 11-month-old (*IV*) infants. Hearing (*a*) and deaf (*b*) infants Russian, Mongol (*c*), and Kazakh (*d*) babies. Ordinate: frequency, Hz; abscissa: time, sec; filling reflects the intensity of acoustic signal.

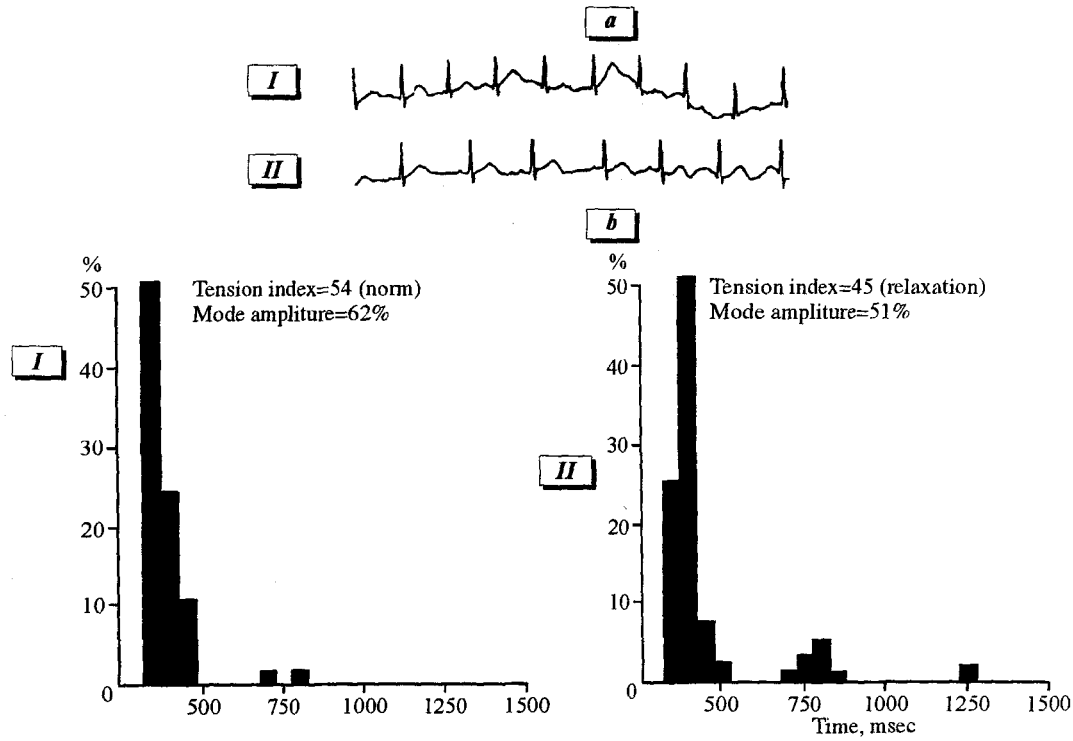

Fig. 5. Heart rate (*a*) and muscular tension index (*b*) in 7-9-month-old infants before (*I*) and during babbling (*II*). Ordinate: mode amplitude, %.

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