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# SENSORY CONTROL OF TONGUE MOVEMENTS IN INFANTS DURING PHONATION

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Changes in the shape and position of the tongue relative to the hard and soft palate and the front teeth determine the formation of the sounds of human speech. The appearance of resonance cavities and noise sources is connected with the participation of the tongue [1]. The formation of different sounds is determined by the degree of elevation of the tongue: The tongue assumes its highest position during pronunciation of the vowels *i* and *u* (closed), and its lowest position during pronunciation of the vowel *a* (open). The tongue plays an even greater part in the formation of consonants. The articulation-acoustic characteristics of different sounds allow the degree of participation of different parts of the tongue (tip, body, root) in their formation to be differentiated. From the point of view of pronunciation of voiced consonants, we can distinguish between posterior lingual (*k, k<sup>1</sup>, g, g<sup>1</sup>, kh, kh<sup>1</sup>*), middle lingual (the constant *j*), and anterior lingual consonants (*t, t<sup>1</sup>, d, d<sup>1</sup>, n, n<sup>1</sup>, s, s<sup>1</sup>, z, z<sup>1</sup>, zh, zh<sup>1</sup>, l, l<sup>1</sup>, ts<sup>1</sup>, shch*).

Sensory control of tongue movements during phonation is connected with the tactile receptor apparatus. The role of the sensory periphery in the control of speech formation was first noted in a model of speech as a servo system [3]. It was shown that tactile and proprioceptive channels provide information for the mechanics of speech. Accordingly attempts have been made to determine the role of oral sensation in the control of speech formation [3-5].

Meanwhile, the tactile papillae of the tongue undergo marked changes in postnatal development [2]. This has been shown by psychophysical investigations conducted on people of different ages, which have demonstrated a decrease in the tactile sensitivity of the tongue with age. However, the study of age differences in the oral tactile sensory periphery has been inadequately carried out, especially in connection with phonation.

The formation and participation of the sensory apparatus of the tongue in the control of production of the various sounds of speech have so far received little study, especially in infants during the first 6 months after birth. Meanwhile phonation is under oral sensory control.

Normally developing infants begin to babble at the age of 3-5 months. Linguists are well aware that an infant's babbling in the first year of life may contain the most widely different sounds from all existing human languages. It is considered that the "infant language" of infants of all nationalities is the same. Meanwhile, during the first 6 months of life the process of "vocalization" is not yet controlled by hearing, as may be shown by observation on deaf children: Children deaf from birth babble in just the same way as those with hearing.

The aim of the present investigation was to study and compare the characteristics of structural formation of the tactile apparatus of the tongue with the appearance of different sounds in infants during the first year of life.

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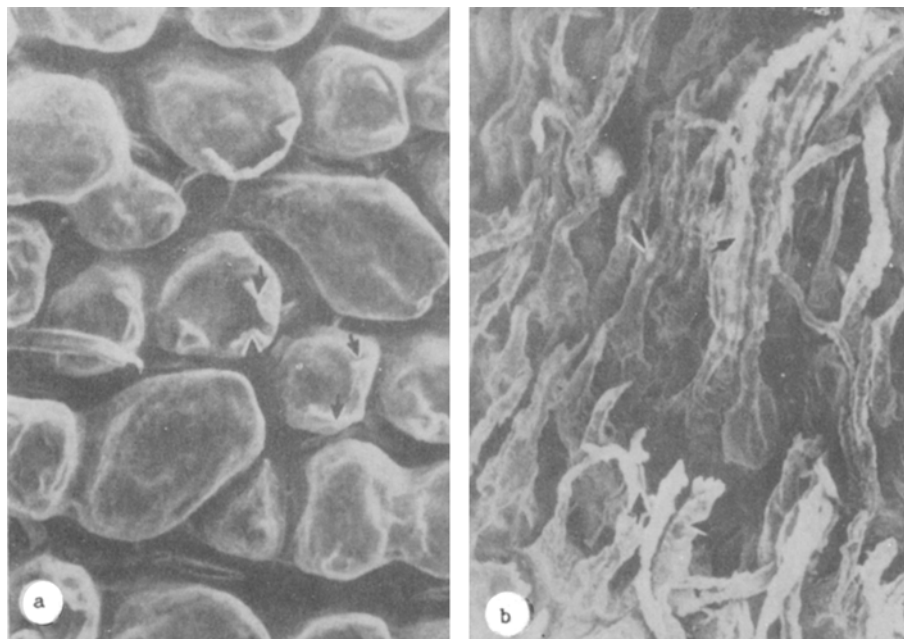


Fig. 1. Tactile receptors of the neonatal tongue: a) papillae on anterior free surface of tip of tongue. 100 $\times$ ; b) papillae on body and root of tongue. 50 $\times$ . Arrows indicate tactile outgrowths of papillae.

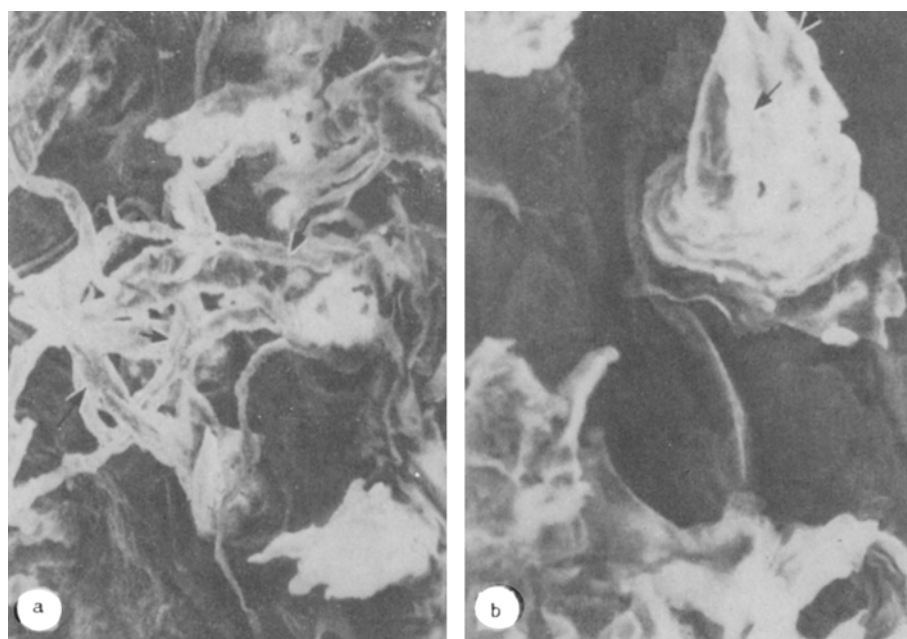


Fig. 2. Tactile papillae on anterior free surface: a) tip of tongue of infant aged 5 months. 150 $\times$ ; b) medial part of tongue of infant aged 1 year. 250 $\times$ . Arrows indicate tactile outgrowths.

#### EXPERIMENTAL METHOD

The formation of language receptors was studied by scanning electron microscopy. Tactile papillae of the tongue were studied in newborn infants and infants during the first year after birth, by the method described previously [2]. At the same time, phonation was studied in seven infants of different ages, starting from 2 months after birth. Sounds were recorded on a tape recorder and depicted visually on a type B/65 sonograph (Kay Elemetrics Co.). Posterior, middle, and anterior lingual sounds were analyzed.

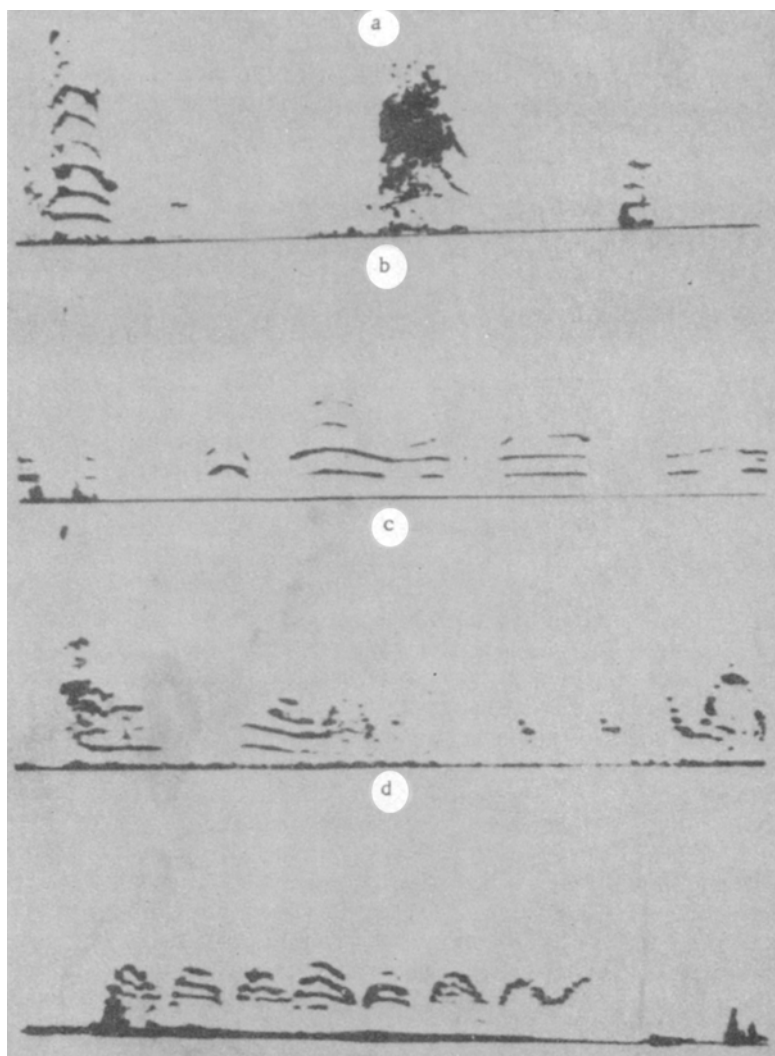


Fig. 3. Fragments of sonograms of babbling by infants: a) aged 3.5 months, b) 5 months, c) 7 months, d) 8 months.

#### EXPERIMENTAL RESULTS

Mechanoreceptors at the tip of the tongue in newborn infants do not have the fungiform papillae characteristic of the human adult. Most papillae are present as small prominences above the dorsal surface of the tongue, in some of which fungiform outgrowths are only just visible (Fig. 1a), and in papillae on the anterior free surface of the tongue they are distinctly formed by the 5th-6th month after birth (Fig. 2a). Their final formation is not complete until much later. Meanwhile, at birth, the infant's tactile papillae on the body and root of the tongue, controlling liquid feeding processes, are already formed. Sensory control of tongue movements in the acts of sucking and swallowing, and also making an airtight fit between the mouth and the mother's nipple, is connected with these papillae. Investigation by scanning electron microscopy showed that at birth of the child the mechanosensory formations located on the root of the tongue around the lateral and medial fungiform papillae, have long outgrowths (Fig. 1b).

However, the first 6 months of the child's life are characterized by rapid growth of the most mechanosensory formations of the tongue. By 4-5 months nearly all papillae of the infant's tongue have finger-shaped outgrowths (Fig. 2). Other types of tactile papillae can be distinguished at this time, such as club-shaped papillae, whose central processes are gathered into a "rosette," and so on.

Such rapid growth of papillae during the first 6 months of the infant's life may be associated with the fact that by this age sensory analysis of the mechanical properties of the food has now become necessary, because after the age of 6 months the infant begins to take not

only the mother's milk, but also other types of food. Meanwhile sensory evaluation of the shape and size of various objects, familiarity with which arises with the aid of the tactile apparatus of the tongue and mouth, begins in infants. However, papillae of the medial part of the anterior free surface of the tongue remain incompletely developed for a long time (for 2-3 years).

The human tongue is thus characterized by asynchronous formation of the mechanosensory apparatus: tactile papillae of the tongue are first formed, and control liquid feeding (sucking and swallowing). Mechanosensory accessory formations on the body and tip of the tongue are formed later.

Asynchronous development of the tactile apparatus of the tongue also is reflected in sensory control of tongue movements during formation of the sounds of speech.

Analysis of tape recordings and sonograms showed that in the first months of life the infant's babbling and crying consist mainly of open vowels, in the formation of which the tongue plays a negligible part. Later other vowels appear, including *i* and *u* (closed), pronunciation of which now requires quite high elevation of the tongue (Fig. 3a). After the age of 3-5 months, the first lingual consonants begin to be found among vowels in the child's babbling. First to appear are the posterior lingual sounds, consonants combined with vowels: *akku*, *agu*, *akki*, and so on (Fig. 3b). The earlier appearance of posterior lingual sounds is evidence that the root of the tongue participates in phonation before the anterior free surface. That is evidently why the period of appearance and perfection of posterior lingual consonants is called "gurgling."\* The middle lingual consonant *j* appears much later and is connected with elevation of the lateral parts of the body of the tongue (Fig. 3c). Anterior lingual consonants combined with vowels appear in babbling of the child after the age of 8 months. Thus although different tongue movements (horizontal, vertical) are formed in the child at birth, more precise tongue movements necessary for phonation develop later, and necessitate the development of its tactile apparatus. This is confirmed by results obtained by scanning electron microscopy, and also by the times of appearance of the various sounds. The part of the tongue on which tactile papillae are formed soonest of all is the first to participate in phonation, and the appearance, first of posterior lingual, later of middle and anterior lingual sounds is connected with it. The medial part of the anterior free border of the tongue is structurally formed last of all (2-3 years): Pronunciation of the *r* sound in the Russian language is connected with it (in certain other languages the *r* sound is posterior lingual). This is evidently associated with the later formation of this sound in the child's speech.

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\*The nearest appropriate equivalent of the Russian "gulenie."