The impact of the stomatognathic system on the development of human beings

Question

Which of the versatile complex functions of the stomatognathic system play a key role in human development?

Background

The stomatognathic system and its comprehensiveness and meaning for the entire organism is underestimated even by dentists. We usually only speak of the chewing organ and this concept alone seems to reduce our operating field to restoring the function of "chewing". However, the stomatognathic system has many other functions and plays a key role in the evolution from hominoids to homo sapiens as opposed to other organ systems. It consists of numerous structures that form a complex cypernetic regulatory circuit (Fig. 1a, Fig. 1b), which themselves show osseous, chondral, ligamentary, muscular, fascial, organic and neuronal connection with other systems.

The primary functions of the stomatognathic system were food intake, defense and the presentation of threatening gestures in order to establish a social ranking order. Presently, we find these simple functions in various phylogenetic inferior animal species. From the ectoderm, fangs evolved from what used to originally be skin scales to capture and fixate food [8]. A simple hinge joint with a one-dimensional flap motion was sufficient for this function. Food was devoured without chewing. A large part of the energy contained in food was therefore needed in processing the food in the intestinal tract. Multidimensional chewing, grinding of the food and predigesting through the addition of saliva's enzymes occurred more and more in the course of evolution. Chewing movements became increasingly complex and eventually led to the development of a new mandibular joint, which is still found in mammals (mammalia) today. The original hinge joint evolved to become the ossicles of the middle ear (ossicular chain). The osseous mandibular corpus is a mesoderm derivative that has a growth center specifically in the area of the ascending jawbone that links the condyle and caput mandibulae to the structures of the neurocranium. It is characteristic for our mandibular jaw that osseous and cartilaginous structures such as condyle, condylar cartilage, articular disk and articular capsule evolve in parallel and cluster together. This evolutionary process required perfect coordination of all growth processes considering the spatial limitation of the fast evolving structures of the neurocranium and viscerocranium as well as the neck. It may explain the difficulty in diagnosis of dysfunction of the stomatognathic system. Due to its many individual functions, the stomatognathic system in the human organism is linked to the brain, or CNS, in the most complex and versatile way. The brain stem is largely in charge of neuronal control of "simple" functions such as chewing, defending or threatening others. Among others, a central area referred to as a masticatory center is located here. It controls the chewing process after initiation by associated centers in the cerebral cortex mostly autonomously, but always fed back by sensible, sensory centers (that process peripheral information).

The basic functions of the stomatognathic system mentioned above are complemented by the formation of sounds in mammals (mammalia) and birds (aves) [2]. The main focus of the development of a sound is undoubtedly in the larynx, where its specific structure makes a modulation of sounds possible. But also the shape of the oral cavity plays a key role in sound formation and functions as a resonance space. The design and modification of the oral cavity with tongue, teeth, cheek and lip muscles, muscles of the soft palate and the mucosa all contribute significantly to the specific formation of sounds. Only in humans, the formation of sounds has evolved to the level of language. According to Popper [7] we differentiate the following stages of speech/articulation:

- Stage 1: Expressive or symptomatic function: The living being expresses inner emotional states

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such as fear or well-being, for example the purr of a cat
- Stage 2: Signal or signal-triggered function: For example, warning cries of birds that alert their fellow species to warn of danger and to trigger flight behavior.
- Stage 3: Descriptive function: items or conditions, such as the current or future weather, can be described to other living beings using articulation and can therefore be communicated
- Stage 4: Argumentative function: Exchange of abstract processes that can occur in different time levels (past, present, future) and spaces. Critical evaluations, plans and decision making on occurrences in the environment can be articulated.

Stage 3 and particularly stage 4 are only present in humans. Even chimpanzees (pan), our closest relatives are only capable of creating stage 1 and 2 sounds.

The attitudes differ on how far the primate morphology of the larynx does not allow speech. Unlike Liebermann [6], Tobias [10] shares the view that fundamentally, the higher primates' morphological differences in the upper airways are not an explanation for their inadequate speech functions. In a study in the USA a chimpanzee baby and a human baby were raised in the same family [4]. The surroundings and support were practically identical for both infants. While the human baby practiced its speech function through continuous babble and sound formation, the chimpanzee baby was mostly mute. It never learned our stage-3-speech function, to name objects in the room, and especially not stage-4-speech function, which the human baby learned in the course of its development.

Eccles sees an explanation of this situation in brain development as well. Brain size does not solely play a key role. In humans – approximately 30.000 years ago – the development of both brain halves took a new direction into cerebral hemispheres. The brain halves, which would have practically fulfilled inversely identical functions, specialized on the contrary to other mammals. In homo sapiens, we differentiate a dominant and a non-dominant brain half [2, 5]. The dominant left cerebral hemisphere has a connection to our self-consciousness as an independent person. It analyzes verbal, linguistic descriptions, conceptual similarities, analyzes time and is capable of arithmetic and computerized functions. (Fig. 2). The dominant left cerebral hemisphere has a connection to our self-consciousness as an independent person. It analyzes verbal, linguistic descriptions, conceptual similarities, analyzes time and is capable of arithmetic and computerized functions. The right cerebral hemisphere is linked to consciousness (however, not self-consciousness). It processes non-verbal information, tactile geometric information e.g. of the room and analyzes image and space patterns, visual similarities and can carry out syntheses on this time period.

We owe the ability of speech of stage 3 and 4 cross-modal links of different sensory centers of both hemispheres as well as specially developed areas of the left hemisphere. These are the anterior speech cortex (Broca's

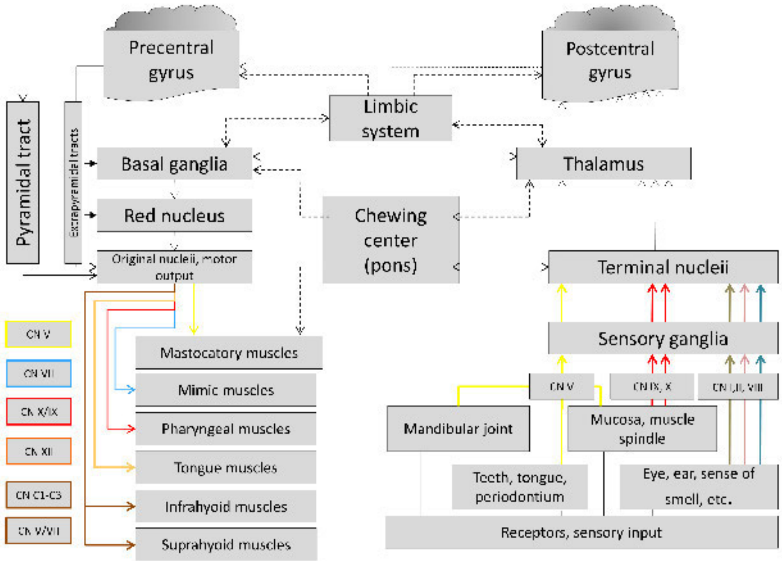


Figure 1a Cybernetic regulatory circuit and neuromuscular control of masticatory function.

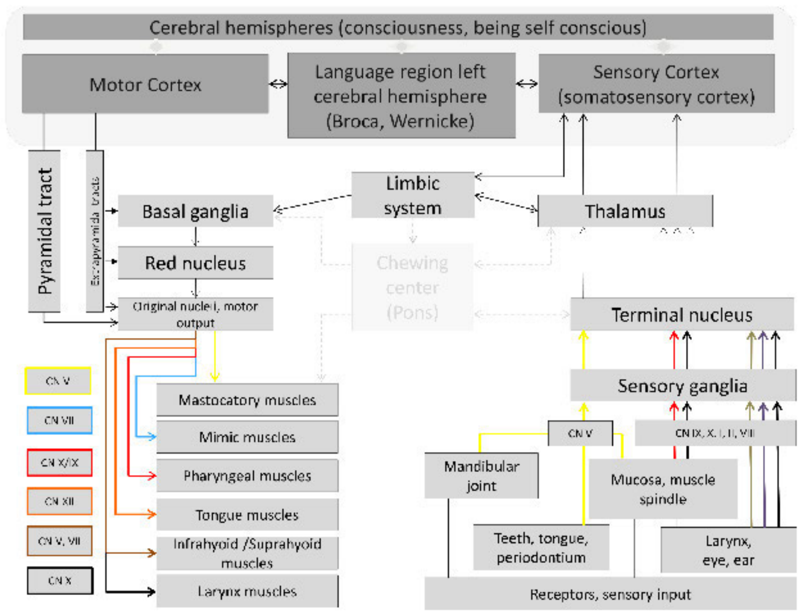


Figure 1b Cybernetic regulatory circuit and neuromuscular control of speech function.

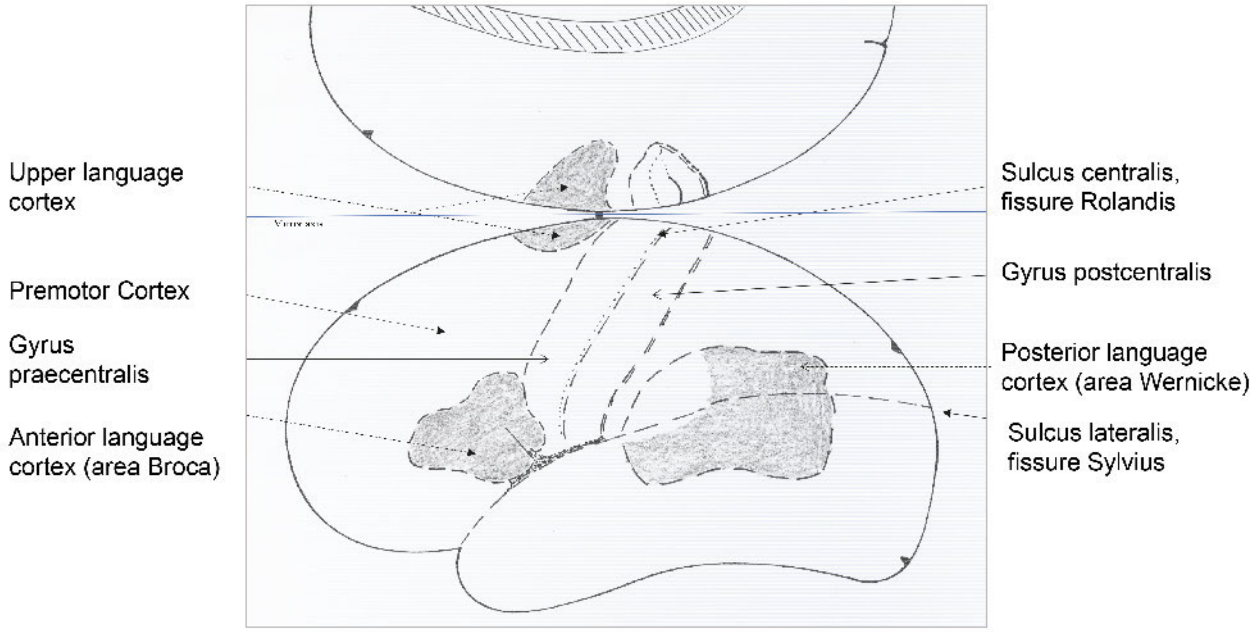
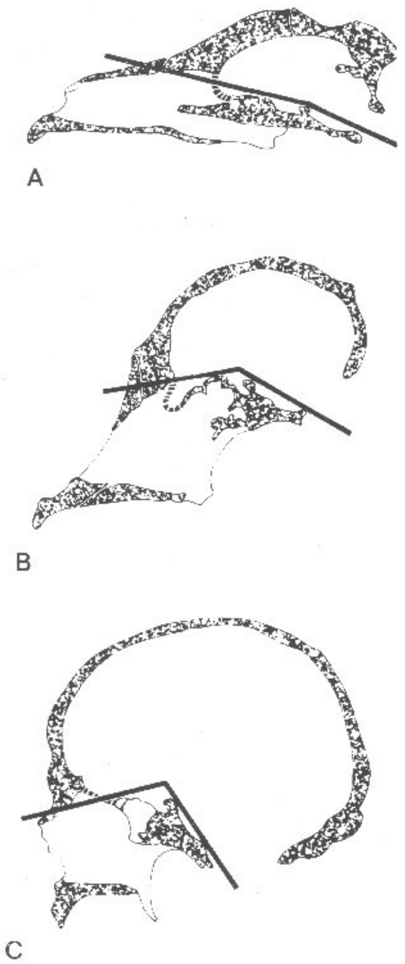


Figure 2 Cortical language fields of the left dominant cerebral hemisphere. The left cerebral hemisphere is depicted laterally (from below) and medially (from above). Re-drawing after [2].



(Fig. 3: By courtesy of Leopoldina)

Figure 3A–C The changing of sphenoid-clivus angles (basicranial angulation) of the skull of a dog (canis familiaris) (**A**), an ape (pan) (**B**) and a human (homo sapiens) (**C**) in the course of evolution [3].

speech area), the upper speech cortex and especially the posterior speech cortex (Wernicke's speech area) (Fig. 2). In the animal kingdom tactile, visual or auditory sensory stimuli are always connected with a "limbic stimulus" [2], and therefore determine the living beings action. Human beings can also associate not-limbic sensory stimuli, become conscious of them and can orient their actions accordingly. Using language, the division between different senses can be overcome. It helps us to merge different sensory modalities into one unit, recognition and experience. Teuber [9] expressed this fact in the following way: "Language frees us to a great extent of the tyranny of the senses." Through language, human beings have succeeded to formulate, evaluate, and share sensory experiences with others, or rather, to profit from the wealth of experience of other people. Through language, the benefits of the upright walk (verticalisation) and an subsequent modification of the skull base could fully unfold (Fig. 3) [3], which leaves the hands of manual tasks free to develop their full potential. The results of manual skills were "discussed" and more importantly passed on, so that a further growing wealth of experience could be formed. Language development encouraged it and made it possible to develop advantages of altruistic action and the value of cultural effort (Fig. 4). The potential of human evolution exponentiated explosively. It is no longer dependent on random "improvements" through mutations in genetic material, and is no longer reliant on other living beings [2].

The development of these unique, new cross-modal links are readable in the human brain's topography (Fig. 2). We find the anterior language center directly before zones that are responsible for controlling relevant muscles. In the case of motoric aphasia the cause of the malfunction is in the use of the muscles used for articulation, rather than their paralysis. The posterior language center of the left cerebral hemisphere is crucial for the initiation, execution and understanding of language. If this structure is disrupted, neither written nor spoken language can be understood. When looked at in a side by side comparison, a hypertrophy of the structure referred to as planum temporale of the posterior language center can be seen in the area of the superior temporal gyrus in the left hemisphere.

Topographic and functional relationships can be demonstrated in the peripheral nervous system. The cranial nerves V (trigeminal nerve), VII (facial nerve), IX (glossopharyngeal nerve), X (vagal nerve) and XII (hypoglossal nerve) supply all structures of the masticatory apparatus. Cranial nerves IX (glossopharyngeal nerve) and X (vagal nerve) supply the speech apparatus structures within and outside of the larynx. Thus, cranial nerves as well as masticatory and speech apparatus are demanded simultaneously in various diseases (common cold, childhood illnesses).

Lastly, the limbic system of the cerebrum is mentioned. This is a non-homogenous structure that consists of the cingulate gyrus, hippocampus formation, as well as the amygdaloid corpus. This system is responsible for emotions and memory. It is functionally linked to the chewing and speech apparatus: For example, memorable emotions are created while eating meals that taste delicious or terrible. We then speak emotionally about our sensation. The stomatognathic system and speech apparatus are equally involved.

Statement

For the stomatognathic system, the widespread neural crosslinking imply that its muscles serve multiple functions [1]. While the control pulses for chewing are derived mainly from the older/more ancient parts of the hindbrain (pons, cerebellum), midbrain and basal ganglia, the neural impulses for speech formation are derived mainly from the more juvenile speech areas of the left cerebral hemisphere.

In addition to the afore mentioned spatial complexity in the set up of the stomatognathic system during the growth phase into skull structures, another complexity in neurological „wiring“ of the stomatognathic system exists (Fig. 1a, Fig. 1b), which contains impulses of different neurological centers with various tasks. Furthermore, this complexity explains the difficulty to diagnose and understand problems in the stomatognathic system’s function.

As dentists, we should be aware of this truth. For example, someone who changes the position of occlusion, moves teeth in the jaw or places implants in the jaw bone interacts with an extremely sensitive and highly complex biocybernetic regulatory circuit (Fig. 1a, Fig. 1b). We are not just practicing in a chewing organ, it is an essential part of our body that makes us who we are: humans.

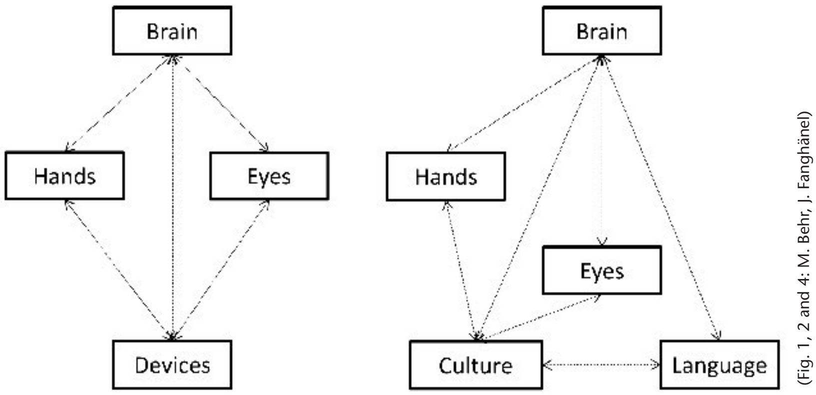


Figure 4 Left: System of positive reinforcement between 3 biological and a cultural element. Right: Modified feedback system across generations considering language, a biological determined skill to pass on cultural views and practices of survival value to further generations. Language possibly plays a key role in the autocatalytic system. Re-drawing after [2].

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