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Conceptual Paper

Scientific Logic Language as a New Paradigm in Masticatory Rehabilitation. Part 1

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Abstract

The purpose of this conceptual paper is to introduce a paradigmatic change from a masticatory system considered to be only a biomechanical system to a fascinating neuromotor and cognitive phenomenon. The latest research, in fact, focuses on the sophisticated synchronism, synergy and symmetry between multiple centres of the Nervous System, and gives increasing consideration to the modulation of the basal nuclei, the hypothalamus, the amygdala and the cerebellum, as well as the specific trigeminal centres (nociceptive, mesencephalic and of the reticular substance) on masticatory function, affecting the quality of life of the patient treated with masticatory rehabilitation. Therefore, in this introductory chapter we will explore concepts of biomechanics, although mainly aspects of neurophysiology that lead us into new, innovative and contextually mysterious areas of knowledge.

In the past decade, studies have focused on biomechanical phenomena, and this period has given rise to schools of thought that are not always congruous. Consequently, concepts essentially related to the field of biology and medicine have been overlooked, due to the distortion of the phenomenon and apparent functioning of the system. These concepts refer to a set of variables that are not considered in the biomechanical systems, namely: the semi-randomness of biological phenomena and the “Emergent Behaviour” of a system that does not work in a linear but rather in a stochastic way. These concepts have led to a significant paradigm shift concerning biological systems and in particular to the masticatory system, leading to it being labelled as a “Complex System”. We should not be surprised at terms such as complex system, indeterministic and stochastic processes, even if they are more common in mathematical sciences as both physicians and dentistry must increase their bioengineering knowledge to deal with the paradigmatic changes of science.

Keywords: *Paradigm; Masticatory Rehabilitation; Complex System; Gnathology; Trigeminal Nervous System*

Neurophysiological Approach in Masticatory Functions

Only recently has the importance of the masticatory function as a “Complex System” become evident. Mastication can interact with a multitude of other nerve centres and systems, even those that are distant from a functional point of view [1].

The masticatory function has always been considered a local function attributable to phonetics and chewing. Following this scientific philosophy, countless schools of thought have arisen that focusing on the diagnosis and rehabilitation of mastication exclusively in the jaws, excluding any multi-structural involvement. This type of approach shows a clear reduction in the contents of the system itself, since in biology it is more realistic to consider the functioning of systems as “Complex Systems” that do not operate in a linear way. These systems employ a stochastic approach in which the interaction of the various constituents generates an “Emergent Behaviour” (EB) [2] of the system itself [3]. In this approach, analysing a single constituent element to interpret the EB of the system it is not sufficient - an integrated analysis of all constituent components should be undertaken both spatially and temporally [4].

The paradigmatic result reverses the tendency to consider the masticatory system as a simple kinematic organ and goes well beyond the traditional biomechanistics procedure of Classic Gnathology. This aspect also introduces a sort of indeterministic profile of biological functions in which the function of a system presents itself as a network of multiple correlated elements. Moreover, in order to interpret the state of this system, one must stimulate it from the outside to analyse the evoked response as is typical of indeterministic systems [5].

It is therefore essential to move from a simple and linear model of clinical dentistry to a complex stochastic model of masticatory neurophysiology. To support this more complex and integrated approach of interpreting masticatory functions, a study is presented here which shows the profile of a "Neural Complex System". In this study, the connection of the vestibular system with the trigeminal and masticatory system was analysed [6]. Acoustic stimuli can evoke EMG reflex responses in the masseter muscle, called Vestibular Evoked Myogenic Potentials (VEMPs). Although these have previously been attributed to the activation of cochlear receptors (high-intensity sound), they can also activate vestibular receptors. Since anatomical and physiological studies, both in animals and in humans, have shown that masseter muscles are a target for vestibular entrances, the authors of this study have re-evaluated the effect of vestibular stimulus on masseter reflexes [6]. This is a typical example of basic level "Complex System", as it is made up of only two cranial nervous systems which at the same time interact with each other by activating mono- and polysynaptic circuits (Figure 1).

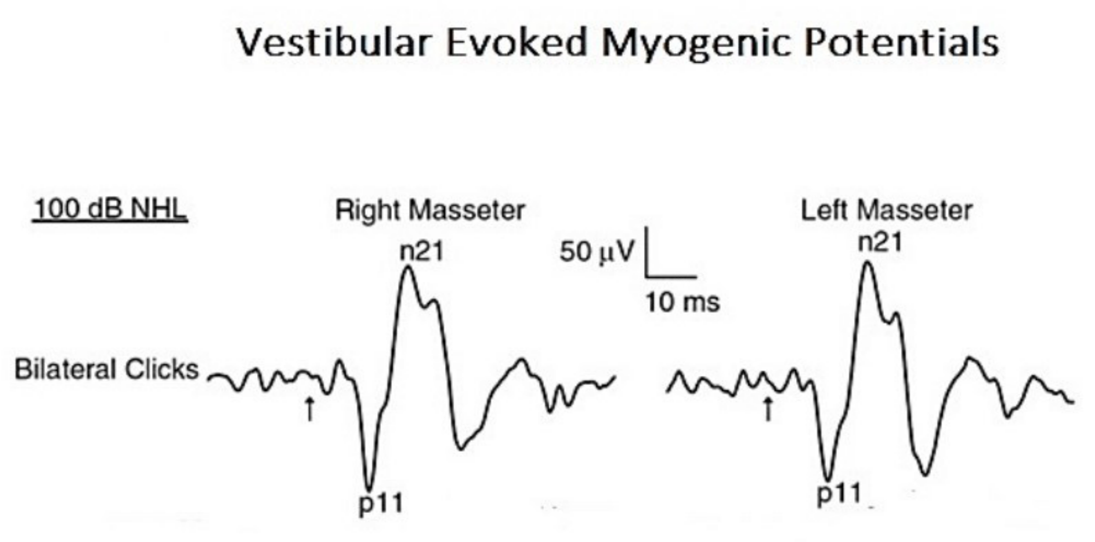

Figure 1: *EMG tracing representing a vestibular evoked potential registered on the masseter muscles. Note that p11 and n21 indicate the latency of the 11 and 21 ms potential from the acoustic stimulus.*

In recent years, mastication has been a topic of discussion on the effects of maintaining and sustaining cognitive performance. An elegant study performed using fMRI and Positron Emission Tomography (PET) has shown that mastication leads to increased cortical blood flow and activates the supplementary somatosensory cortex, motor and insular cortex, as well as the striatum, the thalamus and the cerebellum. Chewing immediately before performing a cognitive task increases the levels of oxygen in the blood (BOLD of the fMRI signal) in the prefrontal cortex and in the hippocampus. These structures play an important role in learning and memory, thus improving the performance of the task [7]. Previous epidemiological studies have shown that a reduced number of residual teeth, inadequate use of prostheses and limited development of maximum strength of mandibular closure are directly related to the development of dementia, further supporting the notion that mastication helps to maintain cognitive functions [8].

A recent study [9] provided further evidence to support the interaction between masticatory processes, learning and memory, focusing on the hippocampal function that is essential for the formation of new memories. Occlusal disharmony, such as loss of teeth and increases in the vertical occlusal size of crowns and prosthetic bridges, causes bruxism or pain in masticatory muscles and temporomandibular dysfunction (TMD) [10,11]. Therefore, to describe the impaired function of the hippocampus in a situation of reduced or abnormal masticatory function, the authors employed an animal model (mice) called "molarless senescence-accelerated prone mice" (SAMP8) in order to draw an analogy with man. In SAMP8 mice, on which occlusion was modified by increasing the occlusal vertical dimension by about 0.1 mm with dental materials showed that occlusal disharmony hinders learning and memory. These animals showed an age-dependent deficit in spatial learning in the Morris water maze [11-13]. Raising the bite in SAMP8 mice decreases the number of pyramidal cells [13] and the number of their dendritic spines [14]; increases hypertrophy and fibrillary acidic protein hyperplasia in astrocytes in the CA1 and CA3 hippocampal regions [15]. In rodents and monkeys, occlusal disharmonies created by increasing the vertical dimension by acrylic elevations on the incisors [16,17] or the insertion of bite blocks into the maxilla is associated with increased levels of urinary cortisol and elevated plasma corticosterone levels, suggesting that occlusal disharmony is also a source of stress.

In support of this notion, SAMP8 mice with learning deficits show a marked increase in plasma corticosterone levels [11] and down-regulation of Glucocorticoid receptor (GR) and Glucocorticoid receptor mRNA (GR mRNA) in the hippocampus.

Occlusal disharmony also conditions catecholaminergic activity. By altering the bite closure by inserting an acrylic bite on the lower incisors, an increase in dopamine and noradrenaline (norepinephrine) levels occurs in the hypothalamus and in the frontal cortex [16,18] and a decrease in thyroxine hydroxylase, GTP cyclohydroxylase and immunoreactive serotonin in the cerebral cortex and in the caudate nucleus, in the nigra substance, in the locus coeruleus and in the dorsal raphe nucleus, which are similar to changes induced by chronic stress [19].

These changes in the catecholaminergic and serotonergic systems induced by occlusal disharmonies clearly condition hippocampal innervation. The conditions of increase of the vertical dimension alter neurogenesis and lead to apoptosis in the dentate hippocampal gyrus, thus decreasing hippocampal brain expression derived from neurotrophic factors. All this may contribute to the negative effects on learning observed in animals with occlusal disharmony [9].

The mesencephalic district is an area of relays that connects the upper centres of the brain, the cerebellum and the spinal cord and provides the main sensory and motor innervation of the face, head and neck through the cranial nerves. This plays a determining role in the regulation of breathing, mobility, posture, balance, excitation (including intestinal and bladder control, blood pressure and heart rate) and is responsible for the regulation of numerous reflexes including swallowing, coughing and vomiting. The midbrain is controlled by upper brain centres from cortical and subcortical regions including the basal ganglia and diencephalon, as well as feedback cycles from the cerebellum and spinal cord. Neuromodulation can be achieved by the "classical" mode of glutamatergic neurotransmitters and GABA (gamma-amino butyric acid) as well as through primary stimulus and inhibition of the "anatomical network". However, it can also be achieved through the use of transmitters that act upon G-proteins.

Such neuromodulators include monoamines (serotonin, norepinephrine and dopamine) and acetylcholine, and also glutamate and GABA. Furthermore, neuropeptides and purines act as neuromodulators. Other chemical mediators such as growth factors may also have similar actions [20].

The neural network described above does not end at the correlation between trigeminal somatosensory centres and other motor cortex areas, but also borders with the amygdaloid processes through a correlation with the trigeminal mesencephalic area. The amygdala is activated by fear and plays an important role in the emotional response to life threatening situations. When laboratory mice feel threatened, they respond by biting fiercely. The bite force is regulated by the trigeminal motor nucleus and the trigeminal mesencephalic nuclei (Me5). Me5 transmits proprioceptive signals from the masticatory muscles and periodontal ligaments at the trigeminal motor and premotor nuclei. Amygdaloid projections of Central Amygdaloid Nucleus (ACe) send connections to the trigeminal motor nucleus and reticular premotor formation and directly to Me5.

To confirm this assumption in a study conducted on mice, the neurons of the Central Amygdaloid nucleus (ACe) were labelled after the injection of a retrograde tracer, Fast Blue, into the caudal nucleus of Me5, into the fibres and the terminal synaptic buttons from the ACe indicating that the Amygdaloid nuclei send direct projections to the Me5, suggesting that the amygdala regulates the force of the bite by modifying neuronal activity in the Me5 [21].

Changing the occlusal relationships can alter the oral somatosensory functions and the rehabilitation treatments of the masticatory system should restore somatosensory functions. However, it is not clear why some patients fail to adapt to restoration and sensorimotor disturbances remain. At first glance changes would appear to be structural and not only functional. The primary motor cortex of the face [9] is involved in the generation and control of orofacial movements and sensory inputs or altered motor functions may result in neuroplastic changes in the cortical area M1 [22].

In conclusion, it is clear from the premise how the masticatory system should be considered not as a system simply governed by mechanical laws, but as a "complex system" of an indeterministic type in which one can quantify their "Emergent Behaviour" only after having stimulated and after having analysed the output response (Figure 2).

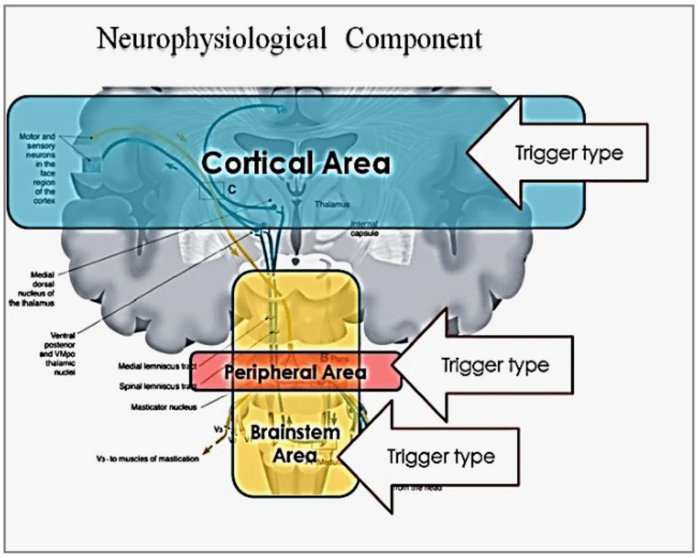

Figure 2: *The masticatory system considered as a "Complex System" that interacts with the whole Central Nervous System (CNS).*

The system also uses its own encrypted machine language (action potentials and ionic currents) and therefore it is not possible to interpret the symptoms reported by the patient through natural language. This concept deepens knowledge of the health of a system because it elicits a response from within or at least from a large part of the network allocating the normal and/or abnormal components of the various nodes of the network.

A Scientific Logic Language concept that introduces the new paradigm in the study of the masticatory system is called " Neuro Gnathological Functions" (NGF paradigm).

Therefore, in order to reach this target, a different scientific-clinical approach is required, and the horizons of competence must be broadened in fields such as bioengineering and neurophysiology, etc. It is therefore essential to focus on the way to collect trigeminal electrophysiological signals in response to a series of triggers evoked by an electrophysiological device, to treat the data and to determine a value of organic-functional integrity of the trigeminal masticatory system.

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