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Review

YAWNING AND THE RETICULAR FORMATION

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Abstract

Any change in the steady state as perceived by the brain provokes a reaction by the reticular formation. Yawning may be triggered by boredom, sadness, surprise, suffering, fatigue, stress, somnolence, which represent a change in the central nervous system situation.

The brain areas involved in the elaboration of yawning are the neocortex, the límbic system, the hypothalamic-hypophyseal system, the autonomic nervous system and the reticular system. The reticular formation is a structure located in the brainstem, between the thalamus and the spinal cord, with a width of only an inch, having a critical function in the yawning mechanism.

Yawning entails a perfect match of the rhythmic vital functions of breathing and the cardiovascular circulation under a harmonic regulation of the nervous system. The complex biochemistry of the neuronal synapses involved in this action ensure the harmony and the perfect synchronization mechanism of the respiratory, cardio-vascular, and muscular systems, with the yawning. Inaccuracies in the harmonic regulation function occurs on pathologic basis, at different levels of the central nervous system, but always involving the essential regulator "the reticular network".

Keywords: *Yawning, steady state, boredom, hyperventilation, peripheral hearts, reticular system*

Rezumat

Orice schimbare în homeostazia (starea de echilibru dinamic) al sistemului nervos, provoacă o reacție a formației reticulare (ascendente sau descendente). Căscatul este provocat de plictiseală, tristețe, suroriza, suferință, oboseală, stres, somnolență.

Ariile cerebrale care reacționează împreună cu formația reticulară în elaborarea căscatului sunt neocortexul, sistemul limbic, sistemul nervos autonomic şi sistemul hipotalamic-hipofizar. Formația reticulată este o structură localizată în trunchiul

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cerebral, între talamus şi măduva spinării, de 2,5 cm grosime cu o importanță capitală pentru mecanismul căscatului.

Căscatul este armonizat cu funcțiile vitale ale organismului, printr-o perfectă adaptare a modificărilor inerente pe care le produce în respirație, funcțiile cardio-vasculare şi musculare. Biochimia complexă a sinapselor neuronale este cea care asigură această armonie. Neregularitățile acestei armonii au o bază patologică, la diferite nivele ale sistemului nervos, dar în special la nivelul formației reticulate.

Cuvinte-cheie: *Căscat, homeostazia (stare de echilibru dinamic), plictiseală, hiperventilație, "inimi periferice", formație reticulară*

The act of yawning begins during fetal life. The complex biochemistry involved in this action includes many enzymes and neurotransmitters, including: dopamine, acetylcholine, muscarine, histamine, adenosine, serotonin, nitric oxid, adrenocorticotropic hormine, oxytocin, alpha-melanocyte hormone, opioids and gammaaminobutyric acid.

An early research into the physiology of yawning was conducted by Charcot. His famous case was a woman with relentless yawning who was hospitalized for months in Salpetriere hospital. This patient presented with a yawning frequency of 8 yawns per minute, and Charcot noted that although her breathing pattern was severely disturbed her ventilation was not reduced **(figure no.1).**

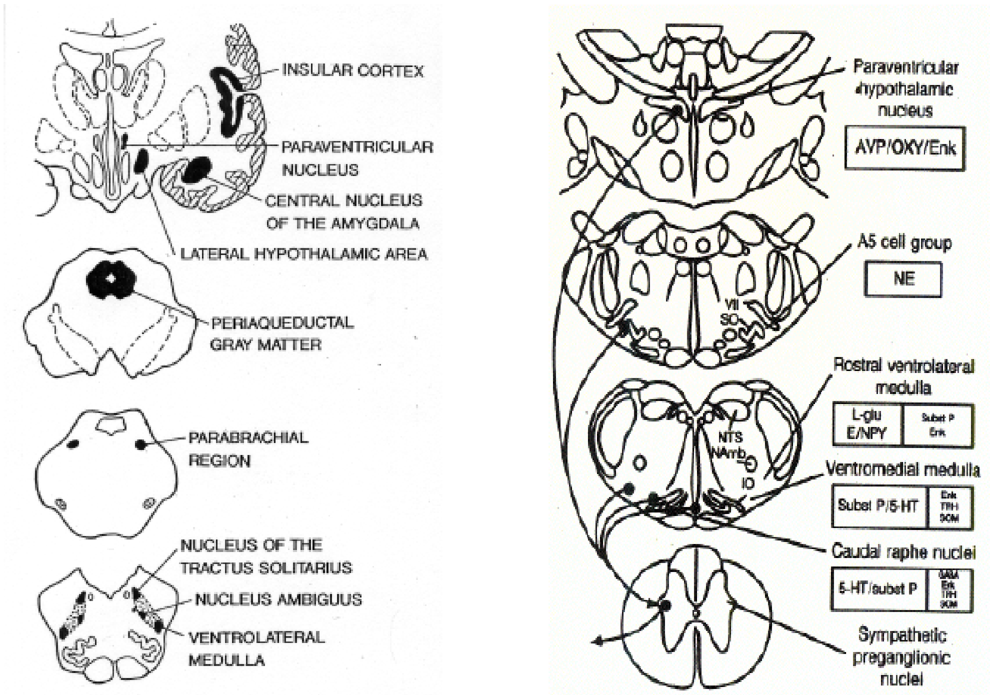


Figure 1 - Schematic diagram of the autonomic nervous system involvement in yawning on the left side and of the neurotransmitters involved on the right side.

Charcot then realized that the patient's yawning was functioning as deep inspirations replacing normal breathing movements (breathing through yawning). A single yawn can therefore be viewed as an isolated act of hyperventilation in which the oxygen saturation is increased and the PCO2 reduced.

K.P. van de Woestijne and D. Trop (1) have demonstrated in their research on dogs that alveoli collapse to 60% of their initial volume after 2 hours of anaesthesia. A similar finding has been observed in humans. The alveolar collapse suggests the existence of shunting of venous blood causing a decrease in blood oxygenation. A single deep inspiration or yawn can restore the alveoli to their initial capacity. This finding has led Forrester (2) to suggest that the function of yawning is maintenance of pulmonary alveolar patency, and that yawning serves as a defensive mechanism against alveolar collapse.

Observations in rats have shown an association between yawning and erection. Additional experiments found that castrating animals causes a decrease in yawning frequency and that a later course of testosterone replacement has the reverse effect of increasing yawning frequency. Since erection is function of autonomically mediated vasodilation, the connection of yawning to autonomic stimulation became an area of experimental interest.

The deep inspiration produced by yawning causes the dilatation of lung bronchial muscles, stimulating a vagal response with discharge of acetylcholine, and inhibition of sympathetic-adrenergic activity. Inhibition of sympathetic activity causes arterial dilatation which diminishes arterial resistance and accelerates the arterial circulation (Friedell 1974 (3), Lehman 1979 (4), Twiest (1974) (5). The decreased sympathetic activity during yawning was demonstrated by direct recording with the microneurographic technique by Askenasy and Askenasy (1996) (6). Shown in the picture is a decrease in sympathetic activity following every yawn (figure no.2):

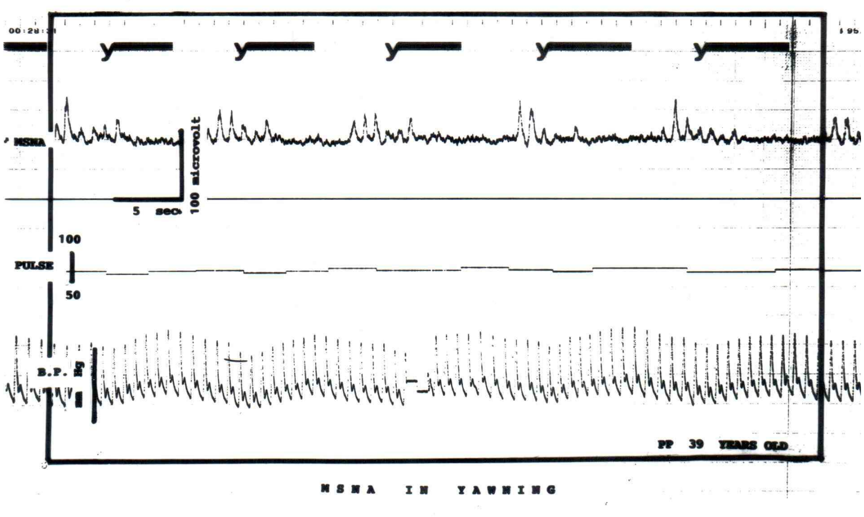
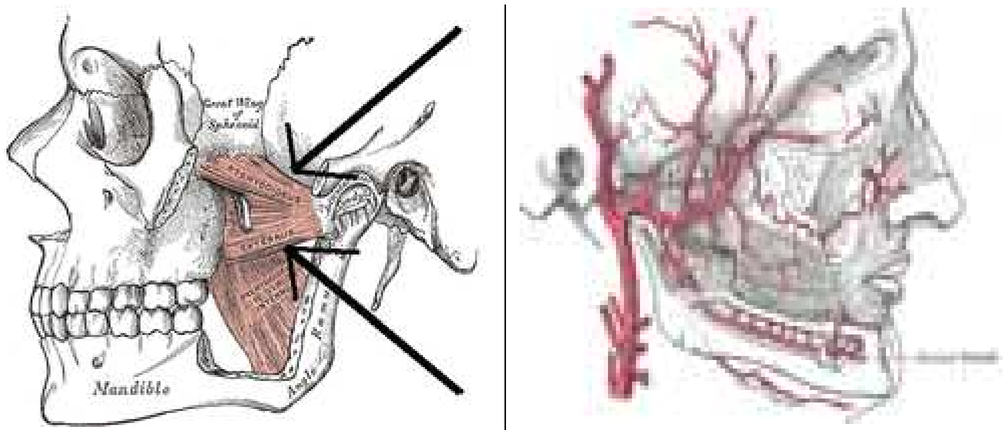


Figure 2 - Aspect of decrease in sympathetic activity following every yawn.

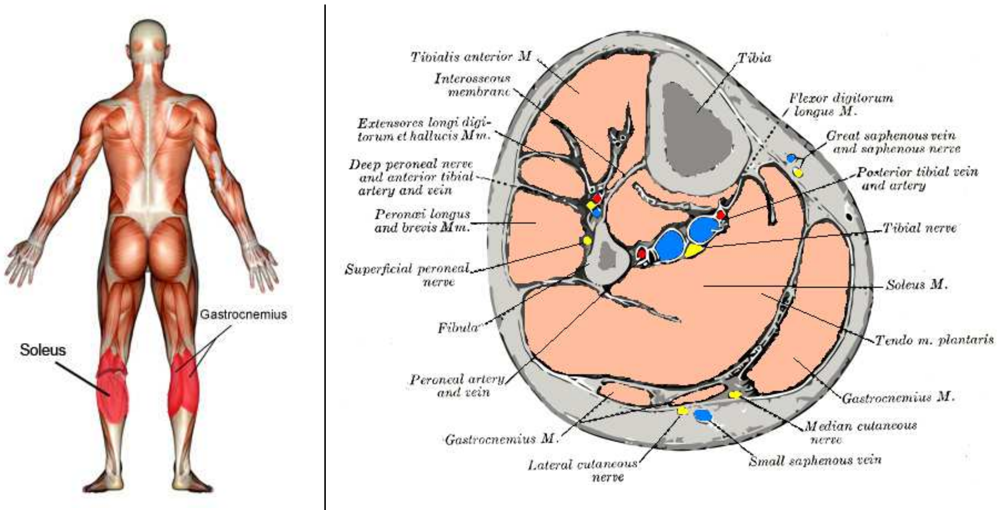
During the yawning movement additional muscular contraction occurs in addition to diaphragmatic contraction. These movements are termed gasping (the wide opening of the mouth) and pandiculation (limb stretch). Gasping and pandiculation serve a vascular effect by discharging the venous plexuses located within the pterygoid (figure no. 3a) and soleus muscles (figure no. 4), respectively into the circulation increasing the blood volume available for oxygenation. This mechanism is named "the peripheral hearts" or "the sural and tricipital pump". (Bhangoo 1974 (7), Last 1963) (8).

Arrows point to venous plexus location (figure no. 3b):



a. Anatomic aspect | **b.** Aspect of venous plexus

Figure 3 (a, b) - Aspect of pterygoid muscles



a. Anatomic aspect | **b.** Aspect of tranversal section

Figure 4 (a, b) - Soleus muscle

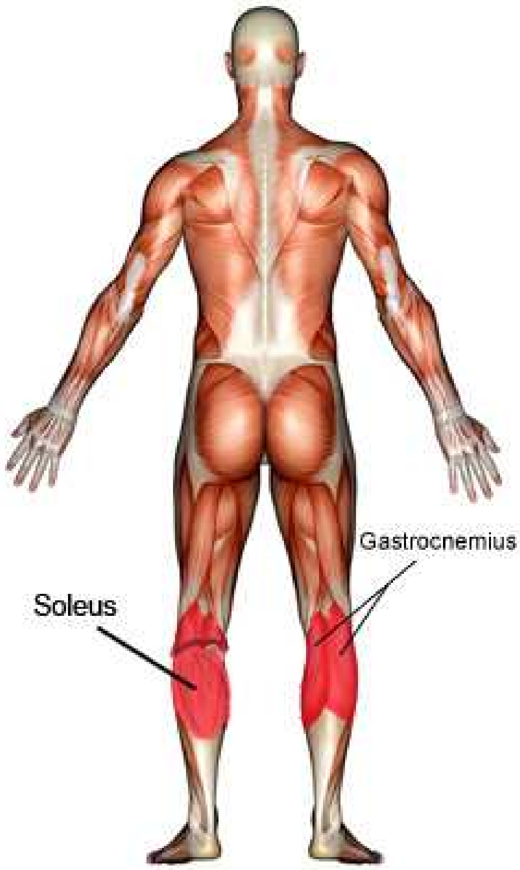


Figure 4a - Soleus muscle

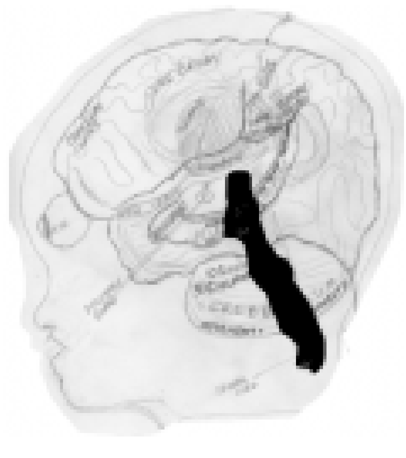


Figure 5 - Aspect of formatia reticulata in the brain.

Yawning is considered by Bell and Suganami as being provoked by boredom, a consequence of diminished interest and stimulation by a source of information. The difficulty in maintaining cortical attention becomes a neural stimulus named "down-attention" which announces a change in the cerebral state.

The harmonic inter-connection between yawning, breathing and even coughing implies to the existence of a perfect synchronization mechanism of the respiratory, cardiovascular, and muscular systems. Such intricate control is naturally found in the central nervous system. The brain areas involved in the elaboration of such a harmony are: the neocortex, the límbic system, the hypothalamic-hypophyseal system and the reticular system.

Neocortical involvement in the regulation of yawning is demonstrated by the contagiosity of yawning. Simply viewing another person yawn may be a sufficient trigger for a yawn by the observer (Provine 2005) (9). Involvement in yawn regulation of the parvocellular oxytocinergic neurons in the paraventricular nucleus of the hypothalamic system was proved experimentally by Kita I et.al (10), and the involvement of the autonomic system was proved by microneurography (Askenasy & Askenasy). Reticular involvement is the subject of the present presentation.

The generally accepted causes of yawning are boredom, fatigue and drowsiness.

The yawning center was hypothesized to be localised in the reticular formation (Askenasy 1989) (11). The reticular formation is located in the brainstem. The brain stem is located between the thalamus and the spinal cord. This structure, with a width of only an inch has a critical function in the brain.

The brain relates to the environment through sensory information reaching the thalamus and to the body through ascending neurons from the spinal cord. The Corpus callosum connects the two hemispheres of the brain, and the pons (latin for bridge) connects the two sides of the cerebellum, connecting each side of the cerebellum with the opposite side and with the cerebral hemispheres. The Pons also connects the upper part of the nervous system with the medulla oblongata. The Medulla oblongata is the caudal part of the brain stem and sits above the top end of the spinal cord. Both types of inputs supply the reticular formation. In the time it takes you to say these two words, the medulla oblongata will have regulated your breathing, blood pressure, heart rate and all cathartic reactions in the states of sleep and wakefulness.

Salzarulo (12) intuition about the signaling role of yawning was stipulated in his theory about the stabilization effect on transitory periods of the sleep/wake cycle.

Karasawa (13) and his team have studied the consequences of serial yawning on the electroencephalography and O_2 saturation in patients with cerebral vascular accidents of the thrombotic type (1982). They found a significant decrease in electroencephalographic activity and yawning associated with a decrease in the partial pressure of sanguine oxygen, as it occurs during boredom, somnolence and fatigue. The authors stipulated that this effect is caused or provoked by a decreased activity of the ascending reticular system.

Monatagu (1962) (14) consider that the reticular system stimulation is the result of the accelerated blood circulation and hyperoxygenation.

Robert Provine, suggested several times yawning as a result of a disturbed harmony of the nervous system.

Yawning entails a perfect match of the rhythmic vital functions of breathing and the cardiovascular circulation under a harmonic regulation of the nervous system. The proximity of the centers of these functions and the yawning center in the reticular formation explains the perfect harmony. Yawning (11) is a signal initiated by the reticular system and brough to our consciousness, that a change in the functional state of the nervous system occurs and need help.

Any change in the steady state as perceived by the brain provokes a reaction by the reticular formation. Therefore a yawn may be triggered by a diverse array of states which represent a change in situation: boredom, sadness, surprise, suffering, fatigue, stress, somnolence (15).

The reticular system's anatomy of intense proximity (under 2 inches) of both activating and inhibitory neuronal networks may explain why yawning appears in situation which are seemingly paradoxes such as boredom and excitation.

Inaccuracies in the harmonic regulation function occurs on pathologic basis, at different levels of the central nervous system, such as the cortical, limbic, hypothalamic and autonomic nervous system, but always involving the essential regulator “the reticular network”.

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