Yawn

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The **yawn** is a stereotyped and often repetitive motor act characterized by gaping of the mouth accompanied by a long inspiration of breath, a brief acme, and then a short expiration of breath.

Introduction

Figure 1: A child yawns (modified from Walusinski *et al.*, 2005b)

Stretching and yawning (known as *pandiculation* when they occur together) are under-researched features of behavior. Ethologists agree that almost all vertebrates yawn (Deputte, 1974). Yawning is morphologically similar in reptiles, birds, mammals and fish. These behaviors may be ancestral vestiges maintained throughout evolution with little variation (phylogenetic old origins). Systematic and coordinated pandiculations occur in a similar pattern and form across all animals, and consistently occur during behaviors associated with cyclic life rhythms: sleep-arousal, feeding and reproduction. Pandiculation appears as one undirected response to an inner stimulation, underlying the homeostasis of these three behaviors (Provine, 2005; Walusinski & Deputte, 2004).

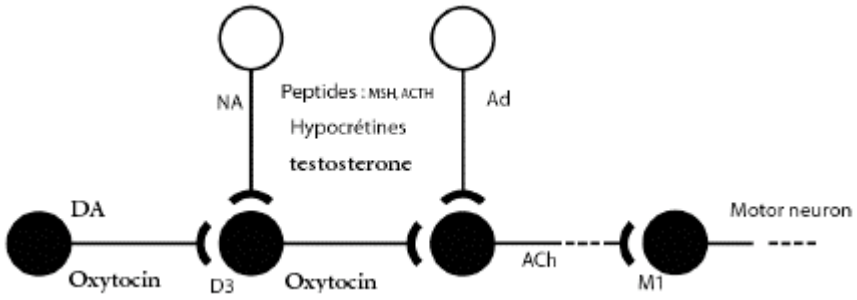
Relatively sedentary species that sleep very little, such as many herbivores, yawn infrequently; species that sleep 8 or 12 h and alternate between active and inactive periods (e.g., predatory carnivores and primates) yawn much more frequently following a circadian rhythm. In humans, daily frequency of yawning varies between 5 and 15 times per day. The diurnal distribution of yawning frequency is illustrated by higher frequency upon waking and before sleep (Baenninger et al., 1996).

In his 1755 book De perspiratione insensibili, Johan de Gorter was the first to describe yawning as accelerating blood flow, supposedly to improve the oxygenation of the brain, in response to cerebral anaemia. Well into the 20th century, there were regular references to this notion, even though it had never been demonstrated. The inaccuracy of this hypothesis was formally shown by Provine, Tate and Geldmacher in 1987. They had their subjects inhale air with higher than normal levels of CO2 (3-5% vs. <0.5%). In response, the subjects' breathing rates increased, but they did not yawn. Likewise, when the subjects inhaled pure oxygen, there was no inhibition of spontaneous yawning at normal rates. Hence yawning is not a physiological reflex to improve cerebral oxygenation.

Neurophysiology

A good number of clinical and pharmacological arguments indicate that yawning involves the hypothalamus (particularly the paraventricular nucleus, PVN), the bulbous and pontic regions of the brainstem, with frontal region connections in primates and to the cervical medulla (Argiolas & Melis, 1998). The PVN is an integration centre between the central and peripheral autonomic nervous systems. It is involved in a number of functions ranging from feeding, metabolic balance, blood pressure and heart rate, to sexual behavior and yawning. In particular, a group of oxytocinergic neurons originating in this nucleus and projecting to extra-hypothalamic brain areas (e.g., hippocampus, medulla oblongata and spinal cord) controls both yawning and penile erection (Kita et al., 2006).

Activation of these neurons by dopamine and its agonists, excitatory amino acids (N-methyl-D-aspartic acid), oxytocin itself, or by electrical stimulation leads to yawning; conversely their inhibition by gamma-amino-butyric acid (GABA) and its agonists or by opioid peptides and opiate-like drugs inhibits both yawning and sexual response. The activation of these neurons is secondary to the activation of nitric oxide synthase, which produces nitric oxide. Nitric oxide in turn causes, by a mechanism that is as yet unidentified, the release of oxytocin in extra-hypothalamic brain areas (Sato-Suzuki, 1998). Other compounds modulate yawning by activating central oxytocinergic neurons: sexual hormones, serotonin, hypocretin and endogenous peptides (adrenocorticotropin-melanocyte-stimulating hormone). Oxytocin activates cholinergic neurotransmission in the hippocampus and the reticular formation of the brainstem. Acetylcholine induces yawning via the muscarinic receptors of effectors from which the respiratory neurons in the medulla, the motor nuclei of the Vth,VIIth, IXth, Xth, and XIIth cranial nerves, the phrenic nerves (C1-C4) and the motor supply to the intercostal muscles. An arousal response accompanied by yawning behavior can be evoked by electrical and chemical stimulation of the hypothalamic paraventricular nucleus (PVN) in rats, although the mechanism responsible for the arousal response accompanied by yawning evoked by PVN stimulation is still unknown.



Development in humans

At the beginning of the third month, the embryo becomes a fetus with the occurrence of the first oral and pharyngal motor sequences under the control of the neurological development of the brainstem which coordinates the respiratory, cardiac and digestive regulations. Circuits that generate organized and repetitive motor patterns, such as those underlying feeding, locomotion and respiration belong to the Central Pattern Generators in the medulla (CPG) which are genetically determined, subserving innate motor behaviors essential for survival. As an example, yawning occurs as early as 12 weeks after conception and remains relatively unchanged throughout life (Walusinski, 2005; Piontelli, 2010). Its survival without evolutionary variations postulates a particular importance in terms of developmental needs. The ability to initiate motor behavior generated centrally and linked to arousal and respiratory function is a property of the brainstem reticular formation, which has been remarkably conserved during the phylogeny of vertebrates including agnathans, fishes, amphibians, reptiles, and birds. Thus, yawning and stretching have the traits of related phylogenetic old origins.

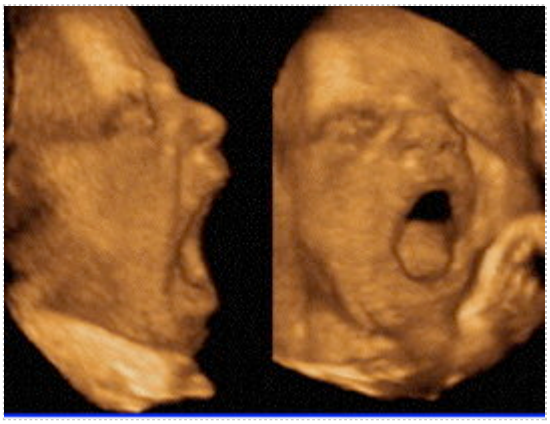


Figure 2: Yawn is present in fetuses as shown by this 3D sonography. Fetal yawning indicates a harmonious progress in the development of both the brainstem and the peripheral neuromuscular function (Walusinski et al., 2005b).

Short 3D sonography film of a fetus yawning (12 weeks):
Media:Fetal_yawning_13w.avi

Yawning and thermoregulation (the latest and debatable hypothesis)

As reviewer, Gallup adds his new theory: consistent with the role of the hypothalamus and the PVN, evidence from diverse sources suggests that yawning may be a thermoregulatory mechanism (Gallup & Gallup, in press). Multiple sclerosis, epilepsy, schizophrenia, treatment for opiate withdrawal, sleep deprivation, migraine headaches, stress and anxiety, and central nervous system damage are all related to thermoregulatory dysfunction and each of these conditions is associated with atypical yawning. Excessive yawning appears to be symptomatic of conditions that increase brain and/or core temperature, such as central nervous system damage, sleep deprivation, and specific serotonin reuptake inhibitors. Drugs that lead to hypothermia (e.g., opioids) inhibit yawning. Nasal breathing and forehead cooling, which have been identified as specific brain cooling mechanisms, diminish the incidence of yawning (Gallup & Gallup, 2007).

There is no work indicating that cerebral activity modifies the internal temperature of the brain in a variable way according to the level of attention. Parmeggiani (2007) has reported changes in brain temperature during the ultradian sleep cycle in several mammalian species. The temperature decrease in NREM sleep appears as a normal effect of thermoregulation operating at a lower set point temperature than in wakefulness. In contrast, the increase in brain temperature related to REM sleep appears paradoxical from the viewpoint of normal thermoregulation. The problem of the physiologic mechanisms underlying this temperature change remains unresolved. Changes in brain temperature are in general relevant to both the energy metabolism of the brain and the function of the preoptic-hypothalamic thermostat. It is obvious that brain homeothermy is altered essentially by quantitative imbalances between metabolic heat production and heat loss. Heat loss from systemic heat exchangers, affecting carotid blood temperature through the systemic venous return to the heart (systemic brain cooling), is the most important determinant of brain temperature in primates. Concerning humans, in particular, there is no consensus as to whether a mechanism for selective brain cooling plays a significant role. The arguments advanced by Gallup & Gallup by which yawning decrease body temperature are physically possible only if yawning effectively increases perspiration. The thermoregulatory hypothesis is interesting, and hypotheses are needed but they should be called hypotheses or theories, not conclusions or results, as long as convincing evidence is missing (Elo, 2010).

Although the origin and function of yawning has been subject to speculation for centuries, the first complete review of the experimental evidences for each of these hypotheses can only now be read (Guggisberg, Mathis et al, 2010).

Contagiousness of yawning

Although yawning often procures a sense of well-being for the yawner, attempting to mask this behavior is standard practice. Many worldwide cultural

beliefs and myths portray it as socially and singly offensive (Meenakshisundaram, 2008 in press). Hominids have the unique capacity to be receptive to the contagiousness of yawning (echokinesis would be a more accurate term). Yawning appears to trigger a sort of social coordination function (arousal synchrony) and reflects the capacity to unconsciously, automatically be influenced by the behavior of others, supporting the hypothesis that contagious yawning shares the neural networks involved in empathy. Echokinesis only occurs in situations of minimal mental stimulation (public transport, for example); people are not susceptible to this phenomenon during prolonged intellectual effort.

Using functional magnetic resonance imaging (fMRI), Schürmann *et al.* confirmed that whilst observation of facial gestures in another person caused activation of mirror neurons in motor areas of the human brain (left posterior inferior frontal cortex), there was no such activation during echokinetic yawning. These ethological and neurophysiological elements demonstrate that, strictly speaking, echokinetic yawning is *not* simply motor imitation.

Recognition of human faces involves specific dedicated neurons in the temporal lobe. The inferior temporal region (IT) allows immediate overall recognition of faces, both their identity and their expression, apparently through its own autonomous, non-hippocampal memory. As for the superior temporal sulcus (STS), it is specifically activated during perception of eye and mouth movements, which suggests its implication in the visual perception of emotions, once again by the activation of mirror neurons. These neurons mime the expression perceived, helping the observer to understand it. Schürmann et al. demonstrated that the STS is activated during echokinetic yawning. This activation, automatic and involuntarily, is transmitted to the left amygdala, the posterior cingulate cortex and the precuneus. These structures are thought to play a role in differentiating emotions expressed by the human face and, especially, in evaluating the sincerity of the sentiment expressed.

Using fMRI, Platek *et al.* found a correlation between personality traits and the activation of neuronal circuits beyond the STS. « In contrast to those that were unaffected by seeing someone yawn, people who showed contagions yawing identified their own faces faster, did better at making inferences about mental states, and exhibited fewer schizotypal personality characteristics. These results suggest that contagious yawning might be related to self-awareness and empathic processing». Subjects considered empathetic, who were very susceptible to echokinetic yawning, activated the amygdala and the cingulate cortex, whereas schizotypal subjects, who were not susceptible to this type of yawning, did not activate these structures. Neurophysiological studies of empathy show similar zones of activation (STS, insula, amygdala, cingulate cortex). These data imply that contagious yawning may reside in brain substrates which have been implicated in self-recognition and mental state attribution, namely the right prefrontal cortex (Platek, 2003, 2005; Schürmann, 2005). Consistent with this view, autistic children who are characterized by impaired mental state attribution do not show contagious yawning (Senju et al., 2007). Giganti and Ziello (2009) support the hypothesis of a link between contagious yawning and social abilities and the existence of different processes underlying spontaneous and contagious yawning.

In the interpersonal contact with individuals with schizophrenia we can often experience impaired empathic resonance. Haker H, and Rössler W (2009) try to determine differences in empathic resonance-in terms of contagion by yawning and laughing-in individuals with schizophrenia and healthy controls in the context of psychopathology and social functioning. They conclude Individuals with schizophrenia showed lower contagion rates for yawning and laughing but it may be argued that the treatment by neuroleptic drugs reduce drastically spontaneous and contagious yawning by themselves.

Pathology

On Tuesday, Oct.23, 1888, Jean-Martin Charcot presented, during one of his celebrated Tuesday gatherings at La Salpêtrière, the case of a young woman inconvenienced by 8 yawns a minute, that is 480 per hour! He qualified this as a form of hysteria, despite his examination revealing binasal hemianopsia, right-side cheirobrachial skin insensitivity to all stimuli and loss of smell. Given our contemporary knowledge, this points to a pituitary adenoma.

The disappearance of yawning may be due to an extrapyramidal syndrome, to the use of opioid drugs or high doses of caffeine, but is rarely a cause for complaint. The family-medicine practice shows that excessive yawning is a source of embarrassment in social circles. There are multiple causes of excessive yawning, that is, a cluster of 10 to 30 yawns, many times a day. Of short duration, they may predict a vasovagal reaction or neurovegetative disorders (dyspepsia, migraine-like syndromes). All insults to the intra-cranial central nervous system or the hypothalamo-hypophyseal region may be involved: tumors with intracranial hypertension, infections, temporal epilepsy, strokes, etc. For example, we coined the term “parakinesia brachialis oscitans” to describe cases of hemiplegia where the onset of yawning coincides with involuntary raising of the paralysed arm. We argued that a lesion in the internal capsule affecting an inhibitory pathway liberates certain subcortical structures that coordinate the massive inspiration of yawning and the motor control associated with quadrupedal locomotion (Walusinski, 2005).

The development of psychotropic drugs has given rise to a rich iatrogenic pathology: serotoninergic agents, apomorphine, acetylcholinesterase inhibitors, sismotherapy and, opiate withdrawal are triggers of yawn clusters. Excessive sleepiness with excessive yawning should suggest examination for an obstructive sleep apnea syndrome. Finally, after after ruling out all other causes, some patients may be suffering from a type of chronic motor tic disorder, associated with yawn clusters, and treated with haloperidol (Walusinski, 2009).

Selective serotonin reuptake inhibitors (SSRI) have significant side effects from stimulation of 5-HT2A, 5-HT2C and 5-HT3, from noradrenergic receptor stimulation, as well as from interactions at other receptors including muscarinic, histaminergic, and postsynaptic alpha1-adrenergic. Complex neurotransmitter systems make pin-pointing an exact mechanism of yawning induction difficult and conflicting data exist regarding the role of specific neurotransmitters. Yawning as side effect was described with paroxetine, escitalopram, duloxetine. The excessive yawning was not accompanied with drowsiness. The error would be to believe in the aggravation of the depression and to increase doses of SSRI treatment. This side effect disappeared completely once treatment was terminated (Gutiérrez-Álvarez, 2007).

Conclusion

Yawning and pandiculation are a universal behaviour amongst vertebrates, closer to an emotional stereotypy than a reflex. Phylogenetically ancient and ontogenetically primitive, they exteriorize homeostatic processes of systems controlling wakefulness, satiety and sexuality in the diencephalon. An arousal response accompanied by yawning behavior can be evoked (Baenninger, 1997; Walusinski, 2006).

References

- Argiolas A, Melis MR. The neuropharmacology of yawning. *Eur J Pharmacol*. 1998;343(1):1-16.
- Baenninger R. On yawning and its functions. *Psychonomic Bul Rev*. 1997;4(2):198-207.
- Baenninger R., Binkley S., et al. Field observations of yawning and activity in humans. *Physiol Behav*. 1996; 59:421-425.
- Deputte BL. Revue sur le comportement de bâillement chez les vertébrés. Bull Int Soc Fr Etud Comport Anim. 1974;1:26-35.
- Elo H. Yawning cannot cause significant temperature decreases in humans. Sleep Med. 2010 (in press).
- Giganti F, Ziello ME. Contagious and spontaneous yawning in autistic and typically developing children. Current Psychology Letter 2009;25(1)
- Gallup AC, Gallup GG Jr. Yawning as a brain cooling mechanism: Nasal breathing and forehead cooling diminish the incidence of contagious yawning. *Evol Psychol*. 2007;5:92-101.
- Gallup AC, Gallup GG Jr. Yawning and thermoregulation. *Physiol Behav*. 2008;95:10-16
- Guggisberg AG, Mathis J, Schnider A, Hess CW. Why do we yawn ? *Neurosci Biobehav Rev. 2010;34:1267-1276*.
- Gutiérrez-Álvarez ÁM. Do your patients suffer from excessive yawning? Acta Psychiatrica Scandinavica 2007;115(1):80-81.
- Haker H, Rössler W. Empathy in schizophrenia: impaired resonance. Eur Arch Psychiatry Clin Neurosci. 2009, in press.
- Kita I, Yoshida Y, Nishino S. An activation of parvocellular oxytocinergic neurons in the paraventricular nucleus in oxytocin-induced yawning and penile erection. *Neurosci Res*. 2006;54(4):269-275.
- Meenakshisundaram R, Walusinski O, et al. Yawning, comparative study of knowledge and beliefs popular and medical. "J Ethnobiology Ethnomedicine". 2008 Submitted
- Parmeggiani PL. REM sleep related increase in brain temperature: a physiologic problem Archives italiennes de biologie 2007;145(1):13-21 .
- Piontelli A. Develpment of Normal Fetal Movements. The Fisrt 25 Weeks of Gestation. Springer Ed. 2010. 133p.
- Platek SM, Critton SR, Myers TE, Gallup GG Jr. Contagious yawning: the role of self-awareness and mental state attribution. *Brain Res Cogn Brain Res*. 2003;17(2):223-227.
- Platek SM, Mohamed FB, Gallup GG Jr. Contagious yawning and the brain. *Brain Res Cogn Brain Res*. 2005;23(2-3):448-452.
- Provine R.R., Tate B.C., Geldmacher L.L. Yawning: no effect of 3-5% CO2, 100% O2, and exercise. *Behav Neural Biol*. 1987;48:382-393.
- Provine RR. Yawning. *American Scientist*. 2005;93(6): 532-539.
- Sato-Suzuki I, Kita I, Oguri M, Arita H. Stereotyped yawning responses induced by electrical and chemical stimulation of paraventricular nucleus of the rat. *J Neurophysiol*. 1998;80(5):2765-2775.
- Schürmann M, Hesse MD, Stephan KE, Saarela M, Zilles K, Hari R, Fink GR. Yearning to yawn: the neural basis of contagious yawning. *Neuroimage*. 2005;24(4):1260-1264.
- Seuntjens W. On yawning or the hidden sexuality of the human yawn. *Thesis. Vrije Universiteit*. 464p. Amsterdam. Oct 2004.
- Senju, A, Maeda, M, Kikuchi, Y, Hasegawa, T, Tojo, Y, Osanai, H. Absence of contagious yawning in children with autism spectrum disorder. *Biology Letters*. 2007;3: 706-708.
- Walusinski O, Deputte BL. Le bâillement: phylogenèse, éthologie, nosogénie. *Rev Neurol (Paris)*. 2004;160(11):1011-1021.
- Walusinski O, Quoirin E, Neau JP. Parakinesia brachialis oscitans. *Rev Neurol (Paris)*. 2005a;161(2):193-200.
- Walusinski O, Kurjak A, Andonotopo W, Azumendi G. Fetal yawning assessed by 3D and 4D sonography. *The Ultrasound Rev Obs Gyncecol*. 2005b;5(3):210-217.
- Walusinski O. Yawning: Unsuspected avenue for a better understanding of arousal and interoception. *Med Hypotheses*. 2006;67(1):6-14.
- Walusinski O. Yawning in Diseases. Eur Neurol. 2009;62(3):180-187.

Internal references

- Joseph E. LeDoux (2008) Amygdala. Scholarpedia, 3(4):2698.
- Valentino Braitenberg (2007) Brain. Scholarpedia, 2(11):2918.
- Seiji Ogawa and Yul-Wan Sung (2007) Functional magnetic resonance imaging. Scholarpedia, 2(10):3105.
- Eugene Roberts (2007) Gamma-aminobutyric acid. Scholarpedia, 2(10):3356.
- Howard Eichenbaum (2008) Memory. Scholarpedia, 3(3):1747.
- Giacomo Rizzolatti and Maddalena Fabbri Destro (2008) Mirror neurons. Scholarpedia, 3(1):2055.
- Peter Jonas and Gyorgy Buzsaki (2007) Neural inhibition. Scholarpedia, 2(9):3286.
- David Myers (2007) Psychology of happiness. Scholarpedia, 2(8):3149.
- Marco M Picchioni and Robin Murray (2008) Schizophrenia. Scholarpedia, 3(4):4132.
- Julian Lim and David F. Dinges (2007) Sleep deprivation. Scholarpedia, 2(8):2433.
- Robert E. Burke (2008) Spinal cord. Scholarpedia, 3(4):1925.
- Arkady Pikovsky and Michael Rosenblum (2007) Synchronization. Scholarpedia, 2(12):1459.

Further reading

- In English: The Mystery of Yawning in Physiology and Disease. O. Walusinski Editor. In series "Frontiers of Neurology and Neuroscience". Basel. Karger Ed. 2010. 180p.

- In Italian: Lo sbadiglio dello struzzo. Gianluca Ficca and Piero Salzarulo. Torino, Bollati Boringhieri Ed. 2002. 90p.
- In French: Bâillements et pandiculations. Olivier Walusinski. Brou, Oscitatio Ed. 2004. 200p.

External links

- An exhaustive website on yawn by the author (http://www.baillement.com) in French with significant content in English.
- Gaap! (http://www.wolterseuntjens.nl/) A website on yawning in Dutch

See also

- Mirror neurons by G. Rizzolatti

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