Review Article

Yawning and its physiological significance

Sharat Gupta, Shallu Mittal[1]

Departments of Physiology, Gian Sagar Medical College, Ramnagar, Patiala, [1]Government Medical College, Patiala, Punjab, India

Abstract

Although yawning is a commonly witnessed human behavior, yet it has not been taught in much detail in medical schools because, until the date, no particular physiological significance has been associated with it. It is characterized by opening up of mouth which is accompanied by a long inspiration, with a brief interruption of ventilation and followed by a short expiration. Since time immemorial, yawning has been associated with drowsiness and boredom. However, this age old belief is all set to change as the results of some newer studies have pointed out that yawning might be a way by which our body is trying to accomplish some more meaningful goals. In this review, we have tried to put together some of the important functions that have been proposed by a few authors, with the hope that this article will stimulate the interest of newer researchers in this hitherto unexplored field.

Key words: Arousal, brain thermoregulation, empathy, yawning

Submission: 20-08-2012 **Accepted:** 12-03-2013

Introduction

Yawning consists of an involuntary wide opening of mouth with maximal widening of jaw, together with a long and deep inhalation through the mouth and nose, followed by a slow expiration, associated with a feeling of comfort. The average duration of the yawn is 5 s.[1] Additionally, stretching of the limbs also frequently accompanies yawning in humans.[2] Yawning has long been thought to be a sign of boredom and is commonly interpreted as disrespectful when carried out in the presence of others. It is also contagious as seeing, hearing, reading or even thinking about yawning can trigger yawns.[3]

Remarkably little interest has been paid to yawning in research, even though it is an everyday phenomenon.[4] Modern science is still on the lookout for a complete explanation of the mechanisms and the purpose which yawning accomplishes, and the debate about its usefulness is still ongoing.[5] Through this review, we have tried to give a brief insight into the various theories that have been proposed by different authors world-wide, so as to explain the possible physiological significance of this seemingly useless act.

Address for correspondence: Dr. Sharat Gupta,
HNo# 849, SST Nagar, Rajpura Road, Patiala - 147 001, Punjab, India.
E-mail: sharatgupta29@yahoo.co.in

Access this article online	
Quick Response Code:	Website: www.ijabmr.org
	DOI: 10.4103/2229-516X.112230

Yawning and Arousal

Evidence suggests that drowsiness is the most common stimulus of yawn. Boredom occurs when the main source of stimulation in a person's environment is no longer able to sustain their attention. This induces drowsiness by stimulating the sleep generating system. At this moment, the mind has to make an effort to maintain contact with the external environment.[1] Vick and Paukner[6] observed the yawning pattern variations in a group of 11 captive chimpanzees with respect to their daily activities. It was seen that while the majority of the yawns were displayed in close proximity to some sort of activity (e.g., play bouts, feeding, sexual contexts, etc.), only a few were connected to sleepiness (e.g., just before sleeping or immediately upon awakening). A major limitation of this study which might affect the yawning rates and patterns might have been the presence of human observers in close proximity to the primates.

Various studies have indicated an increase in arousal level after yawning as reflected by a significant change in the various physiological variables. Corey *et al.*[7] investigated the physiological effect of yawning in a group of 48 students (mean age 18.94 ± 1.51 years) and found that there was a significant rise in the heart rate at the peak of yawning ($P < 0.001$), 10 s post-yawning ($P = 0.002$) and 15 s post-yawning ($P < 0.001$) as compared to baseline values. It was also reported that this rise in heart rate lasted atleast until 5 s since there was no significant difference in the heart rates at the peak of yawning and at 5 s post-yawning ($P = 0.049$). A significant increase was also seen in the skin conductance, at the peak of yawning and at 5 s post-yawning intervals as compared to baseline levels ($P < 0.01$). Barry *et al.*[8] examined the effect of single oral dose of caffeine on resting state arousal levels in a group of 18 healthy university students (mean age 21 years) and reported that caffeine intake resulted in a significant increase in the skin conductance levels and frequency of alpha waves of electroencephalogram. These results were found to be similar to those obtained in yawning subjects, by other researchers. Since caffeine is a well-known stimulant of the nervous system, thus it was argued that yawning, like caffeine, might also play a role in arousal reflex of brain.

The arousal occurring after yawning is being considered to be due to the mechanical stimulation of carotid body. The strategic location of this structure results in its stimulation due to the compressions and movements caused by yawning. The carotid bodies are highly vascularized, and their compressions may thus affect their shunt system, thereby leading to release of hormones such as adenosine and catecholamines, which subsequently mediate the arousal response.[9]

More frequent yawning is associated with viewing uninteresting repetitive stimuli rather than viewing interesting stimuli.[10] Majority of the yawning episodes have been recorded during activities requiring minimal interaction, such as attending lectures, studying, driving, and watching television. The opposite has been reported with activities that are of a faster and more interactive nature, such as cooking, cleaning, washing, and talking. This further supports the notion that yawning sub-serves arousal and is implicated in higher brain activation following yawn episodes.[11]

Yawning and Brain Cooling

Recently, another physiological function of yawning has been proposed, that is, it regulates the temperature of the brain. It has been postulated that yawning might "cool" down the brain when its temperature increases.[12] An evidence for this proposition comes from a research in which the prelimbic cortical brain temperature recordings were continuously monitored in rats (*Rattus Norvegicus*) during the 3 min prior to and following a yawn, it was seen that cortical temperatures were significantly raised until the onset of yawn, followed by a significant fall and return to baseline in the next 3 min after yawning.[13]

In addition, studies in both animal and human models provide a growing evidence that yawning occurs before, during and after instances of abnormal thermoregulation, heat stress and hyperthermia. One of this studies[14] was carried out in parakeets (*Melopsittacus undulatus*), who were chosen due to their relatively large brain size. In this, the authors observed that a rise in the ambient temperature was associated with a significant increase in the incidence of yawning. Additionally, yawning also became more frequent as the ambient temperature rose to within 0.5°C of the parakeet body temperature, indicating the occurrence of a breech in the thermal homeostasis at this point. Accordingly, it was proposed that temperature has a decisive role in yawning. However, a leading concern was the presence of some uncontrolled factors, such as the differences in the individual drowsiness levels of parakeets, as well as an absence of a direct comparison with controls, both of which might have affected the outcome of the study.

The effect of alteration of the brain temperature on the frequency of contagious yawns was investigated by Gallup and Gallup.[15] In a separate study in which they induced yawning in the subjects by showing them videos of yawning persons. The effect of placing a warm pack or an ice pack on the foreheads of these subjects on their yawning frequency was also noted simultaneously. It was observed that the cold pack was associated with a decrease in contagious yawning while the warm pack increased the frequency of yawning. This was interpreted as evidence of the role of brain thermoregulatory mechanism in the genesis of yawning. However, this experiment did not control the confounding factors. For instance, having an ice pack on one's forehead might itself be responsible for the arousal effect while a warm pack would tend to induce relaxation and drowsiness. Thus, it is not possible to distinctly distinguish between the effects of temperature and sleepiness in this study.

The physiological consequences of yawning are analogous to those which are needed to effectively cool the brain, such as increase in the peripheral and cerebral blood flow.[16,17] The contraction and relaxation of facial muscles during a yawn, increases the facial blood flow which subsequently aids in dissipation of heat through emissary veins. The gaping of mouth and deep inhalation of cool air during a yawn also alters the temperature of blood going from the lungs to the brain via convection. Tearing from the eyes, which some people experience, at the peak of yawn may likewise play a role in dissipation of heat from skull.[14]

Patients with clinical disorders such as multiple sclerosis, epilepsy, migraine, stress, anxiety, head trauma, and stroke experience excessive yawning which is followed by temporary cessation of their symptoms. This is because these conditions lead to an increase in the body core temperature, thereby resulting in abnormal thermoregulation, which the body then tries to correct transiently by way of yawning.[18-22]

Yawning and Social Empathy

Yawning has a well-known contagious effect in humans and this effect is now frequently used to induce yawning for research purposes. The susceptibility to contagious yawning correlates with empathic skills in healthy humans.[23,24] Various clinical, psychological and neurological clues link the yawn contagion with empathy. Millen and Anderson[25] conducted a two part study on infants and preschool children to investigate whether they also showed susceptibility to contagious yawning like older children and adults or not. In the first part of the study, 20 mothers were asked to record the occurrence, time, and context of every yawn that occurred in their children (aged 6-34 months) on a logbook, over a 1 week period. A total of eight logs were returned and analyzed. It was observed that the most common context of yawns was on awakening after morning or afternoon naps (31.7%). Furthermore, none of the mothers made any reference to any possible contagious yawning episode. In the second part of study, 22 infants and toddlers were observed for contagious yawning while viewing the video clips of their yawning mothers. These clips were inserted within a series of images of unfamiliar individuals who were either smiling or yawning. It was seen that 16 children did not yawn at all throughout the entire study, while two children yawned once during the presentation and the rest of the four children yawned once, post-presentation. On the basis of these observations, the authors proposed that infants and preschool children appear largely immune to contagious yawning, even if the stimulus is an emotionally significant one. This is in marked contrast to older children and adults. The small data group analyzed was recognized as a major limitation in this study by the authors. The latter also maintain that some discrepancies might also have arisen if the parents may have missed some of their child's yawns. Therefore, contagious yawning can be induced in children only after 4-5 years of age, as below this age group, the neural mechanisms required to understand the mental state of others are still under development.[26]

Extensive evidence indicates that the susceptibility of contagious yawning is reduced in patients who are suffering from disorders that affect the ability of social interaction. Haker and Rössler[27] investigated the changes in yawning patterns in a group of 43 schizophrenic outpatients, after presenting them with video sequences of yawning, laughter, and neutral faces. On comparing the results with those obtained in an age and sex matched group of healthy controls, they observed that schizophrenic individuals showed significantly lower contagion rates for yawning as well as laughter. Similarly, in another study carried out by Senju *et al.*[28] analysis of yawning patterns was carried out in a group of 24 children with autism spectrum disorder and results were compared with a control group of 25 healthy children. Both groups were observed closely while viewing yawning videos or control video clips (of mouth opening) in a random sequence. It was observed that yawning videos induced lesser yawns in autistic children as compared to healthy ones ($P = 0.01$), but the control video clips showed no significant difference between the two groups in the no. of yawns ($P > 0.1$). Also, in the healthy children, yawning videos elicited more yawns as compared to control videos ($P = 0.038$) while children with autism did not show any significant difference between yawning and control videos ($P > 0.1$).

Different neuroimaging studies also support the empathic basis of contagious yawning. Significantly higher functional magnetic resonance imaging activations in response to contagious yawning have been observed in posterior cingulated area,[24] bilateral superior temporal sulcus[29] or venteromedial prefrontal cortex.[30] Although all these areas are divergent, but they seem to be a part of a distributed neural network related to empathy and social behavior.[26]

Recently, the mirror neuron system of the brain, a collection of neurons in the right posterior inferior frontal gyrus has been suggested to be involved in contagious yawning.[29,31] Mirror neurons are considered to be important for perception and understanding of motor actions, which is a pre-requisite for "true-imitation," that is, the exact copying of a goal directed behavior.[32]

The results of a study conducted by Norscia and Palagi[33] have provided evidence for the fact that the social bond associated with empathy affects the yawn contagion in humans in terms of occurrence, frequency and latency. In this study, a total of 109 adults (>16 year old) of various nationalities, were observed closely in their natural settings (e.g., in workplaces, restaurants, etc.). All the yawns that were triggered by a person (yawner) and by the potential responder (observer) who was in possible audio/visual contact with the yawner were recorded. A total of 613 bouts of yawning were observed, out of which only 480 were analyzed, since only they could be definitely assigned as being triggered in an observer by a specific audio-visual contact with a yawner, within a 3 min time slot. It was seen that the social bond had a strong significant effect on yawn contagion ($P < 0.001$) since the latter showed a definitive empathic gradient, increasing from strangers < acquaintances < close friends < kin. The importance of the social bond in shaping the yawn contagion demonstrates that empathy and yawning are strongly correlated.

The link between empathy and contagious yawning is further supported by the data collected by Campbell and de Waal.[34] In this study, 23 adult chimpanzees were observed for contagious yawning while viewing the videos of yawning and control movements of the mouth of ingroup (same species) or outgroup (different species, i.e., humans) individuals. The ingroup videos were shown before the outgroup videos to all the subjects. It was ensured that all the subjects paid similar attention to both types of videos. Each chimpanzee was exposed to the videos for a total of 20 min on one or more days, depending upon his interest and cooperativeness, to eliminate the effect of stress. Also, none of the test subjects were able to see the other chimpanzees while viewing the videos. It was observed that the subjects yawned more frequently in response to ingroup yawn videos than to ingroup control videos ($P = 0.002$) while no difference was observed in the rate of yawning between the outgroup yawn and control videos ($P = 0.175$). Also, the yawning response was more to the ingroup yawn video as compared to the outgroup yawn video ($P = 0.012$). Even though, the authors do maintain that their results suggest a possible relationship between yawning and empathy, yet they also admit a few limitations of their study. One of these is the smaller size of the study sample and the other might be attributed to the social behavior of the chimpanzees', that is, even though there are only chimpanzees in the ingroup videos, yet even these "ingroup individuals" might actually be recognized as "outgroup individuals," especially if the chimpanzees in the videos and the ones being tested belong to separate groups. This may be due to the fact these animals are territorial and form small coteries, which are aggressive to neighboring ones. Such a kind of behavior is absent in humans since the latter do not always view strangers as belonging to an outgroup.

It is thus concluded that yawning may be a part of action repertoire of empathic and communicative processes in adult humans and some other mammals which provide for a strong social role of yawns in these species.[12]

Yawning and Ear Pressure

Yawning relieves the ear discomfort and hearing problems that are commonly experienced by people during rapid altitude changes in airplanes and elevators. This is achieved by opening of the eustachian tubes due to the contraction and relaxation of tensor tympani and stapedius muscles. This observation has led to another proposition that yawning might actually serve as a "defence reflex" of the ear, which is triggered either by rapid altitude changes or by other conditions that lead to trapping of air in the middle ear, and is helpful in equalising the air pressure in the middle ear with the outside air pressure. An crucial experimental evidence that provides support to the above proposition comes from the work of Winther *et al.*[35] In this study, a contrast dye kept at the nasopharyngeal orifice of the eustachian tube was found to reflux into the middle ear cavity, in four out of a total of six healthy volunteers, during yawning. The contrast material was detected in middle-ear by computerized tomographic scan of the temporal bone.

However, since the eustachian tube can also be opened by swallowing and Valsalva manoeuvre, thus yawning, by itself, does not appear to offer an indispensable evolutionary advantage of releasing middle ear pressure. The latter effect thus does not seem to be the primary purpose of yawning.[12]

Yawning and Brain Hypoxia

For the past several centuries, a commonly held notion associated with yawning is that it is triggered when blood or brain oxygenation is insufficient, that is, when oxygen (O_2) levels decrease and carbon dioxide (CO_2) concentration rises. Yawning is thought to remove "bad air" from the lungs and increase O_2 circulation in the brain.[36]

However, this belief has been discarded in wake of the results of a recent study in which the yawning frequency was unaffected in subjects who breathed air mixtures containing either more than normal CO_2 or even pure O_2.[37]

Conclusion

In 1986, Provine, the pioneer of yawning research wrote that "Yawning may have the dubious distinction of being the least understood, common human behavior."[2] Today, more than 20 years later, this may well still be the scenario as we are yet to find a definitive solution to this age old conundrum.

Yawning research is intriguing because the ubiquity of this phenomenon across most of the vertebrate classes and even in a 20 week old human fetus,[9] suggest that considering it merely as an act of boredom and drowsiness is unjustified and that it may have a definitive underlying physiological importance which needs to be meticulously explored. However, till we get a conclusive answer, it is safe to assume that yawning could represent a para-linguistic signal that may have multiple functional outcomes across various species.

Acknowledgment

The authors would like to thank Robert R. Provine and Oliver Walusinski for their invaluable online archive of articles on yawning, which greatly facilitated the research for literature for this article.

References

1. Askenasy JJ. Is yawning an arousal defense reflex? J Psychol 1989;123:609-21.
2. Provine RR. Yawning as a stereotyped action pattern and releasing stimulus. Ethology 1986;72:109-22.
3. Provine RR. Yawning. Am Sci 2005;93:532-9.
4. Simonds AK. Curbside consult: Why do people yawn? West J Med 1999;170:283.
5. Walusinski O. Popular knowledge and beliefs. Front Neurol Neurosci 2010;28:22-5.
6. Vick SJ, Paukner A. Variation and context of yawns in captive chimpanzees (Pan troglodytes). Am J Primatol 2010;72:262-9.
7. Corey TP, Shoup-Knox ML, Gordis EB, Gallup GG Jr. Changes in physiology before, during, and after yawning. Front Evol Neurosci 2011;3:7.
8. Barry RJ, Rushby JA, Wallace MJ, Clarke AR, Johnstone SJ, Zlojutro I. Caffeine effects on resting-state arousal. Clin Neurophysiol 2005;116:2693-700.
9. Matikainen J, Elo H. Does yawning increase arousal through mechanical stimulation of the carotid body? Med Hypotheses 2008;70:488-92.
10. Provine RR, Hamernik HB. Yawning: Effects of stimulus interest. Bull Psychon Soc 1986;24:437-8.
11. Kasuya Y, Murakami T, Oshima T, Dohi S. Does yawning represent a transient arousal-shift during intravenous induction of general anesthesia? Anesth Analg 2005;101:382-4.
12. Guggisberg AG, Mathis J, Schnider A, Hess CW. Why do we yawn? Neurosci Biobehav Rev 2010;34:1267-76.
13. Shoup-Knox ML, Gallup AC, Gallup GG, McNay EC. Yawning and stretching predict brain temperature changes in rats: Support for the thermoregulatory hypothesis. Front Evol Neurosci 2010;2:108.
14. Gallup AC, Miller ML, Clark AB. Yawning and thermoregulation in budgerigars (*Melopsittacus undulatus*). Anim Behav 2009;77:109-13.
15. 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.
16. Askenasy JJ, Askenasy N. Inhibition of muscle sympathetic nerve activity during yawning. Clin Auton Res 1996;6:237-9.
17. Greco M, Baenninger R. Effects of yawning and related activities on skin conductance and heart rate. Physiol Behav 1991;50:1067-9.
18. Postert T, Pöhlau D, Meves S, Nastos I, Przuntek H. Pathological yawning as a symptom of multiple sclerosis. J Neurol 1996;243:300-1.
19. Yankovsky AE, Andermann F, Dubeau F. Post-ictal forceful yawning in a patient with nondominant hemisphere epilepsy. Epileptic Disord 2006;8:65-9.
20. Jacome DE. Compulsive yawning as migraine premonitory symptom. Cephalalgia 2001;21:623-5.
21. Witterseh T, Wyon DP, Clausen G. The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work. Indoor Air 2004;14 Suppl 8:30-4.
22. Cattaneo L, Cucurachi L, Chierici E, Pavesi G. Pathological yawning as a presenting symptom of brain stem ischaemia in two patients. J Neurol Neurosurg Psychiatry 2006;77:98-100.
23. Smith EO. Yawning: An evolutionary perspective. Hum Evol 1999;14:191-8.
24. Platek SM, Mohamed FB, Gallup GG Jr. Contagious yawning and the brain. Brain Res Cogn Brain Res 2005;23:448-52.
25. Millen A, Anderson JR. Neither infants nor toddlers catch yawns from their mothers. Biol Lett 2011;7:440-2.
26. Saxe R, Carey S, Kanwisher N. Understanding other minds: Linking developmental psychology and functional neuroimaging. Annu Rev Psychol 2004;55:87-124.
27. Haker H, Rössler W. Empathy in schizophrenia: Impaired resonance. Eur Arch Psychiatry Clin Neurosci 2009;259:352-61.
28. Senju A, Maeda M, Kikuchi Y, Hasegawa T, Tojo Y, Osanai H. Absence of contagious yawning in children with autism spectrum disorder. Biol Lett 2007;3:706-8.
29. Schürmann M, Hesse MD, Stephan KE, Saarela M, Zilles K, Hari R, *et al*. Yearning to yawn: The neural basis of contagious yawning. Neuroimage 2005;24:1260-4.
30. Nahab FB, Hattori N, Saad ZS, Hallett M. Contagious yawning and the frontal lobe: An fMRI study. Hum Brain Mapp 2009;30:1744-51.
31. Arnott SR, Singhal A, Goodale MA. An investigation of auditory contagious yawning. Cogn Affect Behav Neurosci 2009;9:335-42.
32. Rizzolatti G, Craighero L. The mirror-neuron system. Annu Rev Neurosci 2004;27:169-92.
33. Norscia I, Palagi E. Yawn contagion and empathy in Homo sapiens. PLoS One 2011;6:e28472.
34. Campbell MW, de Waal FB. Ingroup-outgroup bias in contagious yawning by chimpanzees supports link to empathy. PLoS One 2011;6:e18283.
35. Winther B, Gwaltney JM Jr, Phillips CD, Hendley JO. Radiopaque contrast dye in nasopharynx reaches the middle ear during swallowing and/or yawning. Acta Otolaryngol 2005;125:625-8.
36. Schiller F. Yawning? J Hist Neurosci 2002;11:392-401.
37. Provine RR, Tate BC, Geldmacher LL. Yawning: No effect of 3-5% CO_2, 100% O_2, and exercise. Behav Neural Biol 1987;48:382-93.

How to cite this article: Gupta S, Mittal S. Yawning and its physiological significance. Int J App Basic Med Res 2013;3:11-5.

Source of Support: Nill. **Conflict of Interest:** None declared.