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Review article

# Why contagious yawning does not (yet) equate to empathy

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ABSTRACT

Various studies and researchers have proposed a link between contagious yawning and empathy, yet the conceptual basis for the proposed connection is not clear and deserves critical evaluation. Therefore, we systematically examined the available empirical evidence addressing this association; i.e., a critical review of studies on inter-individual differences in contagion and self-reported values of empathy, differences in contagion based on familiarity or sex, and differences in contagion among individuals with psychological disorders, as well as developmental research, and brain imaging and neurophysiological studies. In doing so, we reveal a pattern of inconsistent and inconclusive evidence regarding the connection between contagious yawning and empathy. Furthermore, we identify study limitations and confounding variables, such as visual attention and social inhibition. Future research examining links between contagious yawning and empathy requires more rigorous investigation involving objective measurements to explicitly test for this connection.

## 1. Introduction

### 1.1. Yawning

Yawning is characterized by a powerful gaping of the jaw with deep inspiration, followed by a temporary period of peak muscle contraction with a passive closure of the jaw during expiration (Barbizet, 1958). Yawns are not under conscious control and, once initiated, go to completion with minimal influence of sensory feedback (Provine, 1986). Yawns have a more complex spatio-temporal organization than simple reflexes, and activate disparate physiological systems. In humans, yawns produce extended stretching of the orofacial musculoskeleton; are accompanied by head tilting, eye closure, tearing, salivating, and opening of the Eustachian tubes in the middle ear; and generate significant cardiovascular changes (Provine, 2012).

Yawning appears to be a universal human act that occurs throughout the lifespan, with an average duration of between four and seven seconds per yawn (Askenasy, 1989; Baenninger and Greco, 1991; Barbizet, 1958; Gallup et al., 2016a; Provine, 1986). Self-report studies indicate that people yawn between six and 23 times per day, which depends upon an individual's circadian rhythm or chronotype (Baenninger et al., 1996; Provine et al., 1987a; Zilli et al., 2007). Evolutionarily conserved, yawning or a similar form of mandibular gaping behavior has been observed in all classes of vertebrates (Baenninger, 1987; Craemer, 1924; Gallup et al., 2009; Luttenberger, 1975). As further evidence that yawns are most probably phylogenetically old, ontogenetically this response occurs as early as 11 weeks gestation in humans (de Vries et al., 1982).

While the neural structures necessary for yawning appear to be located within the brainstem (Heusner, 1946), a recent case study demonstrated that electrical stimulation of the putamen, which has extensive connectivity between the brain stem and cortical regions, induces yawning in humans (Joshi et al., 2017). Pharmacological research on non-human animals indicates yawning is under the control of several neurotransmitters and neuropeptides in the paraventricular nucleus (PVN) of the hypothalamus; yawning is induced by dopamine, nitric oxide, excitatory amino acids, acetylcholine, serotonin, adrenocorticotropic hormone-related peptides, and oxytocin, and is inhibited by opioid peptides (Argiolas and Melis, 1998; Daquin et al., 2001). A more recent review has identified at least three distinct neural pathways involved in the induction of yawning, all of which converge on the cholinergic neurons within the hippocampus (Collins and Eguibar, 2010). Abnormal or frequent yawning is symptomatic of numerous pathologies, including migraine headaches, stress and anxiety, head trauma and stroke, basal ganglia disorders, focal brain lesions, epilepsy, multiple sclerosis, schizophrenia, sopite syndrome, and even gastrointestinal and some infectious diseases (reviewed by Daquin et al., 2001; Gallup and Gallup, 2008; Walusinski, 2010). Yawning has also been thought to be an indicator of hemorrhage (Nash, 1942), motion sickness (Graybiel and Knepton, 1976), encephalitis (Wilson, 1940), and rises in cortisol (Thompson, 2011). The multifaceted motor expression and activation of yawning suggests it has a fundamental

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neurophysiological significance. Consistent with this view, recent comparative research demonstrates that across mammals species' average yawn durations are robustly correlated with their average brain weight and cortical neuron number (Gallup et al., 2016a).

Attempts to identify the physiological function of yawning provide little consensus. Yawning has been hard to characterize functionally, primarily because there are numerous eliciting stimuli. Smith (1999) outlined over 20 functional hypotheses for why we yawn; however, few have received empirical support. Hypotheses range from increasing alertness (Baenninger and Greco, 1991; Baenninger et al., 1996), to inducing relaxation of social tension in groups (Sauer and Sauer, 1967), and to aiding in the removal of potentially infectious substances from the tonsils (McKenzie, 1994).

One of the most well documented features of yawning relates to its circadian variation. In humans, yawning occurs with greatest frequency within the hours just after waking and right before sleeping (Baenninger et al., 1996; Giganti and Zilli, 2011; Provine et al., 1987a; Zilli et al., 2007), and this response follows a circadian pattern in other animals as well (Anias et al., 1984; Miller et al., 2012a; Zannella et al., 2015). Consistent with this evidence, it has long been suggested that yawns are representative of boredom, drowsiness, and fatigue (Barbizet, 1958; Bell, 1980; Suganami, 1977); yet, it is hard to reconcile these views with observations of Olympians yawning immediately prior to competition, musicians yawning while waiting to perform, and paratroopers yawning excessively leading up to their first free-fall (Provine, 2005). Despite the temporal association with sleep, and the fact that yawning frequency is positively correlated with subjective ratings of sleepiness throughout the day (Giganti and Zilli, 2011), the frequency of yawning is not significantly correlated with wakeup time, sleep time, or sleep duration (Baenninger et al., 1996; Zilli et al., 2007). In fact, subjective ratings of sleepiness account for less than 30 percent of the variance in spontaneous yawning frequency (Giganti and Zilli, 2011). Therefore, while the yawn/sleep relationship is significant, yawns are not simply signals of sleepiness or fatigue.

Due to the overt respiratory component of yawning, one commonly held belief is that yawns function to equilibrate oxygen levels in the blood (e.g., Askenasy, 1989). Despite the widespread acceptance of this hypothesis among both the layperson and medical physicians (Provine, 2005), it was tested and subsequently falsified 30 years ago. Provine et al. (1987b) demonstrated that neither breathing pure oxygen nor heightened levels of carbon dioxide increased yawning frequency in human participants, though each significantly increased breathing rates. It was also demonstrated in this report that physical exercise sufficient to double breathing rates had no effect on yawning. Therefore, contrary to popular belief, yawning and breathing are controlled by separate mechanisms (Provine et al., 1987b).

Instead, the powerful gaping of the jaw appears to be the most important feature of this motor action pattern. Patients who cannot voluntarily open their mouth due to tetraplegia, for example, have been reported to extensively gape their jaws during yawning (Bauer et al., 1980; Geschwend, 1977), suggesting that the mandibular muscular contractions are essential for the proper function of this response. The importance of jaw stretching is also evidenced by the fact that people asked to clench their teeth while yawning report feeling left in mid-yawn, or being unable to experience the relief of completing a yawn (Provine, 1986). Similarly, clenched teeth yawns are perceived as unpleasant compared to positive hedonistic effects attributable to normal, uninhibited yawns.

To date, comparative research supports a role of yawning in promoting state change (e.g., but not limited to, sleep/wake state changes) and cortical arousal. Provine (1986) first proposed the state change hypothesis based on observations that yawning was associated with numerous behavioral transitions. The general hypothesis was then extended to suggest that yawning facilitates a number of behavioral shifts such as from boredom to alertness, changes from one activity to another, and, importantly, between sleeping and waking (Provine, 1996, 2005). Consistent with this hypothesis, a large body of comparative research aligns with the view that yawning functions to stimulate or facilitate arousal during environmental transitions (reviewed by Baenninger, 1997). In support of this, yawning occurs in anticipation of important events and during behavioral transitions across vertebrate taxa. Baenninger (1997) also summarizes evidence from endocrine, neurotransmitter, and pharmacological studies that supports the view that yawning is an important mediator of arousal levels. Accordingly, it has been proposed that the adaptive function of yawning is to modify levels of cortical arousal. A recent reformulation of this idea proposes that yawns activate the attentional network of the brain (Walusinski, 2014). This notion is supported by research on humans, chimpanzees, and laboratory rats, showing that yawns reliably precede increases in activity (Anias et al., 1984; Baenninger et al., 1996; Giganti et al., 2002; Vick and Paukner, 2010). Individual variation in total yawn frequency per day among humans has also been linked to activity levels (Baenninger et al., 1996). People who are active, for example, tend to yawn less frequently than those who are less active. Also consistent with the view that yawning produces an arousing effect, yawns are common following stressful events, threats, and increases in anxiety (e.g., Eldakar et al., 2017; Liang et al., 2015; Miller et al., 2010; Miller et al., 2012b). In addition, numerous studies have revealed that yawning is associated with hormonally-induced penile erection (reviewed by Baenninger, 1997), a well-defined indicator of sexual arousal.

Further evidence for an arousing effect of yawning comes from various neurophysiological studies. For example, yawning in humans has been shown to produce significant changes in heart rate and skin conductance (Greco and Baenninger, 1991; Guggisberg et al., 2007), as well as sympathetic nerve activity (Askenasy and Askenasy, 1996). Research has shown that arousal responses in laboratory rats, as measured by electrocorticogram, are accompanied by yawning behavior following electrical, chemical, and light stimulation of the PVN of the hypothalamus (Kita et al., 2008; Sato-Suzuki et al., 1998, 2002; Seki et al., 2003). Furthermore, yawning is a common response among patients undergoing anesthesia (Kim et al., 2002), and actually produces a transient arousal shift as measured by electroencephalographic (EEG) bispectral index (Kasuya et al., 2005). This result has been interpreted as yawning representing a mechanism to enhance arousal during the progressive loss of consciousness caused by induction of anesthesia. It should be noted, however, that other studies have failed to show yawn-associated increases in cortical arousal as measured by EEG (see Guggisberg et al., 2010).

One mechanism by which yawns facilitate state change and arousal appears to be through enhanced intracranial circulation. Generally, yawning produces global increases in heart rate (Corey et al., 2011; Heusner, 1946) and blood pressure (Askenasy and Askenasy, 1996), and the jaw stretching and deep inhalation accompanying yawning produces profound intracranial circulatory alterations (Provine, 2012; Walusinski, 2014). The constriction and relaxation of facial muscles during a yawn increase facial blood flow, which, in turn, increases cerebral blood flow (Zajonc, 1985). The deep inspiration during yawning also produces significant downward flow in cerebrospinal fluid and an increase in blood flow in the internal jugular vein (Schroth and Klose, 1992). The pterygoid plexus, a network of small veins within the lateral pterygoid muscle activated by yawning, operates as a "peripheral pump" that aids venous return by the pumping action of the pterygoid muscle during yawning (Sinnatamby, 2006). Furthermore, cadaveric dissections suggest that the posterior wall of the maxillary sinus flexes during yawning, which could serve to ventilate the sinus system (Gallup and Hack, 2011).

In an attempt to unite the existing research linking yawning to state change, arousal, and enhanced circulation to the skull, it has recently been proposed that yawns function to cool the brain by altering the rate and temperature of the arterial blood supply (Gallup and Gallup, 2007). While some researchers do not accept this as a viable explanation of