

Disentangling attentional and affective contribution to contagious yawning

Elisabetta Palagi^{a,b}, Alessia Celeghin^c, Marco Tamietto^{c,d,*}, Piotr Winkielman^{e,f}, Ivan Norscia^g

^a Unit of Ethology, Department of Biology, University of Pisa, Italy

^b Museum of Natural History, University of Pisa, Italy

^c Department of Psychology, University of Torino, Italy

^d Department of Medical and Clinical Psychology and CoRPS - Center of Research on Psychology in Somatic diseases - Tilburg University, Tilburg, The Netherlands

^e Department of Psychology, University of California, San Diego, USA

^f Faculty of Psychology, SWPS University of Social Sciences and Humanities, Warsaw, Poland

^g Department of Life Sciences and Systems Biology, University of Torino, Italy

corresponding author at: Department of Psychology, University of Torino, Via Verdi 10 – Torino, Italy.

E-mail address: marco.tamietto@unito.it; m.tamietto@tilburguniversity.edu

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In his commentary to our review on mimicry and emotional contagion (Palagi et al., 2020), Gallup (2021) raises concerns about the empirical evidence supporting the role of affective and social factors in modulating the frequency and likelihood of contagious yawning. The commentary recaps the author's theoretical perspective: attentional biases drive contagious yawning and its variations. The consensus on mechanisms modulating contagious yawning is still elusive and our review has extensively reported evidence supporting both attentional and emotional influences, despite the bewildering claim that we did not. Rather than "cherry-picking" piecemeal evidence in favor or against one of these accounts, we prefer to take the opportunity to address some foundational challenges or empirical advances needed to put the existing facts in a comprehensive and crossspecies perspective that might help disentangling extant controversies.

1) As we have clarified, attentional and emotional factors "*might not be mutually exclusive and, in certain cases, not easy to disentangle*" (Palagi et al., 2020, p. 154). Granted that attentional and affective processes likely contribute to the expression of contagious yawning, the crucial point is to empirically dissociate their relative influence in different ethological contexts and define their interplay more clearly.

2) The major criticism of Gallup against the influence of emotional factors on yawning is that "*if a strong matching was present between contagious yawning and emotional contagion, there should be a clear and positive correlation between these measures*" (Gallup, 2021, p. 18). Even though the argument seems intuitively straightforward, it relies on several implicit assumptions. First, it assumes that the two phenomena are linked linearly so that their relationship is captured exclusively, or primarily, by correlations. Second, it neglects the multidimensionality of both contagious yawning and emotional contagion, as well as the influence of other intervening factors on this relationship. This is cogently typified also when correlations are studied between facial mimicry, empathy, and emotion recognition, which are part and parcel of affective dimensions and sensitive to variations in emotional factors. A recent meta-analysis shows indeed that "*stronger facial mimicry responses are positively related to higher dispositions for*

empathy, but the weakness and variability of this effect suggest that this relationship is conditional on not-fully understood factors." (Holland et al., 2021, p. 150). A similar meta-analytic approach that addresses systematically and quantitatively the relationships between contagious yawning and emotional mimicry would be very informative.

3) According to the previous point, we consider social and emotional dimensions as modulatory factors that determine *variations* in the frequency and likelihood to display contagious yawning. Conversely, to the best of our understanding, proponents of the attentional account assume these factors to *drive* or *determine* yawn contagion. In this sense, affective and attentional mechanisms are not assigned the same relevance. The attentional account poses more stringent constraints than the emotional account as the explanatory principle of contagious yawning.

4) Experimental psychology and neuroscience are replete with data indicating that the encoding of emotional signals is less dependent on attention resources than neutral stimuli and may not even require visual awareness (Tamietto and de Gelder 2010; Pourtois, Schettino and Vuilleumier 2013; Tamietto et al., 2005). Moreover, pre-attentive and non-conscious processing of affective signals from structures of ancient evolutionary origin, such as the amygdala or the pulvinar, triggers expressive and goal-directed behaviors. For example, facial mimicry and familiarity assessment also occur when the subject is not aware and does not pay attention to the eliciting stimulus (Borneman et al., 2012; Solcà et al., 2015; Tamietto et al., 2009). Direct testing on whether yawning can be induced without attention and visual awareness has not been carried out yet and it would be central evidence to disentangle affective and attentional factors.

5) Social closeness is a multifaced concept that has been variably operationalized as ingroup/outgroup membership or as familiarity according to different degrees (e.g., personal familiarity, indirect familiarity for famous persons etc.). The broad majority, but not all, studies investigating social closeness found that *personal* familiarity increases contagious yawning, a result interpreted as supporting the impact of affective processes on yawning. This hypothesis is egregiously discarded by Gallup (2021) because "*Massen and Gallup (2017) describe the findings from 14 publications at the time, with six (43 %) showing no effect or the opposite result (i.e., unfamiliar > familiar).*" Nevertheless, what are the actual numbers that quantify convergence/divergence among studies, as reported in the seminal review by Massen and Gallup (2017)? First, the papers reported in Table 1 were 15, not 14. Second, five papers found no effect of familiarity in either direction. It is notoriously difficult to draw any conclusion on negative findings, especially in the context of statistical significance, and we should remind ourselves that the absence of (statistically significant) evidence does not equate to evidence of absence. Therefore, out of the ten remaining studies, nine showed that familiarity increases yawn contagion, whereas 1 study found an opposite trend; a remarkable convergence of results rarely attained in other fields of social and behavioral sciences.

6) Familiarity is not only a proxy of emotional bonds but may also influence the allocation of attention. It is a matter of debate whether the evolutionary benefits lay more on focusing attention towards unexpected events or signals from outgroup members, rather than those coming from familiar individuals (possibly including top-down processes). In this context, Campbell and de Waal (2011) study is remarkable because the authors analyzed and dissociated the impact of familiarity on both attention and yawning. Chimpanzees pay more attention to unfamiliar than familiar conspecifics' yawns, but respond contagiously more to familiar yawns. If this dissociation were confirmed in other species and contexts, it would be paramount to clarify the role of social closeness in attention orienting and yawn contagion.

7) Cognitive and emotional aspects of empathy-based contagion are often mistakenly conflated. Recent literature shows that these aspects do not always converge. For example, subjects with higher levels of psychopathic traits (impaired emotional empathy) can be less likely to respond to others' yawns regardless of their attention to the eyes of the triggers. On the other side, in subjects with autistic traits, yawn contagion can be negatively correlated with eye gaze levels

(Helt et al., 2021), but not in subjects showing a high concentration of blood oxytocin, who yawned more regardless of their eye gaze levels (Mariscal et al., 2019). Data on the role of oxytocin should be treated with caution, also considering that contextual and individual factors can mitigate or even reverse the effects of oxytocin administration (Beery 2015; Olff et al., 2013; Declerck et al., 2020; Churchland and Winkielman 2012). According to the available evidence, emotional components may play a modulatory rather than driving role in yawn contagion, as anticipated at point 2.

8) Quantification of yawning often varies between objective measurements of actual yawning, self-reports, or questionnaires about the feel and urge to yawn. This variety in the measures dampens a cross-species comprehensive approach to the phenomenon. In addition, the perceptual encoding (often measured by self-scoring questionnaires) and the actual yawning activity do not necessarily go in tandem. For example, Chan and Tseng (2017) found an association between the subjective urge to yawn, as reported by study participants, and their attentional levels to the stimulus. However, such correlation failed to reach statistical significance when the authors considered the yawns actually performed. In summary, we welcome theoretical discussions that can foster scientific advancements, providing that plain facts are reported fairly and alternative views not trivialized. Otherwise, the debate readily risks turning sterile and an exercise of loyalty to underqualified theories.

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