Short communication

Contagious yawning and the brain

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Abstract

Contagious yawning, the onset of a yawn triggered by seeing, hearing, reading, or thinking about another person yawn is a well-documented phenomenon. The mechanisms that drive contagious yawning are as yet unknown, but there is recent evidence of a link between contagious yawning and self-processing (S.M. Platek, S.R. Critton, T.E. Myers, G.G. Gallup Jr., Contagious yawning: the role of self-awareness and mental state attribution, Cogn. Brain Res. 17 (2003) 223–227.) that is negatively impacted by schizotypal personality traits. The neural substrates involved in contagious yawning, however, are unknown. Here, using fMRI, we show that viewing someone yawn evokes unique neural activity in the posterior cingulate and precuneus. Because of the role these areas play in self-processing (e.g., self-referential processing, theory of mind, autobiographical memory), our findings provide further support for the hypothesis that contagious yawning may be part of a neural network involved in empathy.
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1. Introduction

Contagious yawning, the onset of a yawn triggered by seeing or hearing someone yawn, or even reading, or thinking about another person yawn is a well-documented phenomenon [18,21,22]. Contagious yawning is independent of generalized emotional contagion [18], occurs in 40–60% of adult human research subjects [18,21], and has also been reported in chimpanzees [1].

It has been hypothesized that contagious yawning may be related to empathy [14,18]. Specifically, contagious yawning is thought to be a primitive expression of cognitive processes involved in self-awareness and theory of mind, the ability to empathize with and infer what others want, know, or intend to do [8,27]. Seeing or hearing another person yawn may act as a releasing stimulus that activates neurological substrates that initiate yawning. Thus, it may be that contagious yawning occurs by activating a system that is also involved in modeling other aspects of interpersonal mentality at conscious levels. Two recent studies have provided support for this hypothesis. Platek et al. [18] demonstrated that susceptibility to contagious yawning increases among people that can identify their own face faster and do better on theory of mind tasks. Further, Platek et al. [18] demonstrated that susceptibility to contagious yawning is negatively correlated with expression of schizotypal personality traits, which have been shown to impair self-processing and theory of mind. Anderson et al. [1] has also provided support for the empathic modeling hypothesis of contagious yawning by demonstrating contagious yawning in chimpanzees. The importance of this study is that chimpanzees, unlike most other primates, also show rudimentary forms of empathy [10,11] and self-awareness [7]. In line with these data, the empathic modeling hypothesis [18] predicts that species who do not recognize themselves in mirrors and do not show evidence of mental

state attribution ought to fail to show evidence for contagious yawning.

An alternative hypothesis of contagious yawning is that it may be related to an innate imitation system driven by the so-called mirror neuron system [2,13]. That is, contagious yawning is presumed to be an automatic mirroring mechanism related to synchronizing one's own behaviors with others. One way of investigating these hypotheses is to explore the neural correlates of contagious yawning. However, the neural substrates recruited during contagious yawning are unknown.

In the present study, we used functional magnetic resonance imaging (fMRI) to investigate the brain substrates involved in contagious yawning when compared to laughing, which is also reported to be contagious, and a neutral expressive condition. We hypothesized that neural substrates known to be involved in self-processing and mental state attribution would be recruited when viewing yawn videos. Specifically, we predicted significant activation in right prefrontal substrates [19,20] and midline cortical structures [17].

2. Materials and methods

2.1. Subjects and stimuli

Ten (4 male, 6 female, mean age: 21.5) right-handed college student volunteers watched twenty-four, 7-s digital videos of eight volunteers (4 male and 4 female) in three separate conditions (neutral, laughing, or yawning)[1] during functional magnetic resonance imaging (fMRI) at 1.5 T. The videos were presented using Neurobehavioral Systems Presentation software (www.neurobs.com) through goggles designed for use in the fMRI environment (Resonance Technologies, Inc.).

2.2. Imaging parameters

Images were collected by a Siemens Magnetom Vision 1.5 T scanner with echoplanar capability (25 mT/m, rapid switching gradients). Initially, the scanning began with collection of high-resolution T1-weighted imaging sequence acquired in the axial plane to locate the positions for in-plane structural images. Twenty-six (whole brain) contiguous (no gap) 5 mm axial high-resolution T1-weighted structural images (matrix size = 256 × 256; TR = 600; TE = 15 ms; FOV = 21 cm; NEX = 1; and slice thickness = 5 mm) were collected for spatial normalization procedures, and overlay of functional data. Precise localization based standard anatomic markers (AC–PC Line) were used for all subjects [24]. Next, functional images were acquired with a

gradient-echo echo planar free induction decay (EPI-FID) sequence (T2* weighted: 128 × 128 matrix; FOV = 21 cm; slice thickness = 5 mm; TR = 4 s; and TE = 54 ms) in the same plane as the structural images. The size of the imaging voxel was 1.72 mm × 1.72 mm × 5 mm.

2.3. Design

The study was designed to measure blood oxygenation level dependent (BOLD) responses to viewing and responding to videos of people yawning and laughing. A boxcar (block) design was used, in which participants were shown three 7-s video clips in a 24-s block (1 s inter-stimulus interval). There were three video conditions: neutral, laugh, and yawn. Each block consisted of only one type of video. There were 6 neutral/null blocks and 5 yawn and laugh blocks. Participants were asked to look at the images and respond yawn or laugh using a button press using an MRI compatible response pad (Resonance Technologies, Inc.). Stimuli were delivered through stereoscopic goggles designed for use within the fMRI environment (Resonance Technologies) and Neurobehavioral Systems Presentation software (www.neurobs.com).

2.4. fMRI image processing and analysis

The post-acquisition preprocessing and statistical analysis was performed using SPM'2 (Statistical Parametric Mapping, Wellcome Department of Cognitive Neurology, University College of London, UK), run under the Matlab® (The Mathworks, Inc., Natick, MA) environment. Images were converted from the Siemens format into the ANALYZE (AnalyzeDirect, Inc., Lenexa, KY) format adopted in the SPM package. A 3 D automated image registration routine (six-parameter rigid body, sinc interpolation; second-order adjustment for movement) was applied to the volumes to realign them with the first volume of the first series used as a spatial reference. All functional and anatomical volumes were then transformed into the standard anatomical space using the T2 EPI template and the SPM normalization procedure [3]. This procedure uses a sinc interpolation algorithm to account for brain size and position with a 12-parameter affine transformation, followed by a series of non-linear basic function transformations seven, eight, and seven nonlinear basis functions for the x, y, and z directions, respectively, with 12 nonlinear iterations to correct for morphological differences between the template and given brain volume. Next, all volumes underwent spatial smoothing by convolution with a Gaussian kernel of 8 cubic mm full width at half maximum (FWHM), to increase the signal-to-noise ratio (SNR) and account for residual intersession differences.

Subject-level statistical analyses were performed using the general linear model in SPM2. The conditions and the baseline were modeled using a canonical hemodynamic response function. Contrast maps were obtained through the

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[1] A sample video of a volunteer yawning is available online at http://psychology.drexel.edu/ECNL/yawnTEM.1.avi or by request to the first author (S.M.P).

following linear contrasts of event stimuli type: yawn vs. baseline, laugh vs. baseline, yawn vs. laugh, and laugh vs. yawn. Laughing was used as a control because it involves similar face and mouth movements as yawning and may also show a contagion effect. Group-level random effects analyses for main effects were accomplished by entering whole brain contrasts into one-sample t tests. A significance threshold based on spatial extent using a cluster probability of a false discovery rate [FDR] corrected $P \le 0.01$ and spatial extent >12 voxels was applied to the effects of interest and surviving voxels were retained for further analyses.

3. Results

No significant activation was observed when contrasting laugh with the null stimulus, nor was there any significant activation when contrasting laugh minus yawn. Table 1 and Fig. 1 depict the significant activations associated with the yawn minus laugh contrast. This contrast revealed significant (FDR-corrected $P < 0.01$) activation in bilateral posterior cingulate (BA 31) and precuneus (BA 23), and bilateral thalamus and parahippocampal gyrus (BA 30), which supports the hypothesis that viewing yawns may evoke self-referent information. Activation in the posterior cingulate/precuneus region has been associated with self-referent processing and retrieval of autobiographical memories. Activation in the thalamus and parahippocampal gyrus may be related to general sensory aspects of face perception.

4. Discussion

In contrast with laughter contagion, our findings suggest that there are unique neural substrates involved in contagious yawning. This phenomenon has been of interest to researchers for decades but until now no one had identified the neurobiological substrates involved in the process.

Our findings also support the empathic modeling hypothesis by showing significant activation in bilateral precuneus
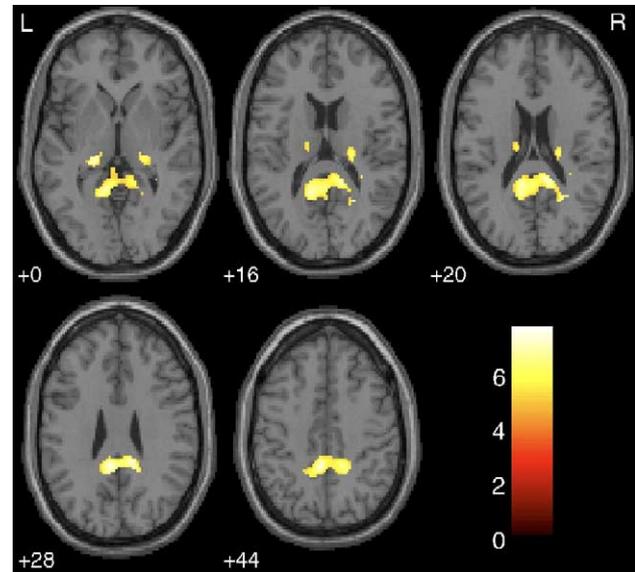
Fig. 1. Significant activation when contrasting yawn with laugh corrected for spatial extent using height threshold FDR-corrected $P < 0.01$, minimum of 12 voxel cluster size. Images are displayed in neurological convention.

and posterior cingulate. These regions have been implicated in identifying self-referent information [4,6,15,16]. Thus, it is possible that contagious yawning is a primitive form of empathic modeling that is subserved by substrates that are precursors to a more sophisticated and distributed system involved in conscious self-processing (e.g., theory of mind, self-face recognition). The posterior cingulate/precuneus region has been implicated in identifying words that describe oneself [15], retrieval of autobiographical events/memories [16], engaging in self-generated actions and self-monitoring [4], and discriminating between theory of mind stories and "physical" stories [6]. Furthermore, several studies have also implicated medial/midline cortical structures in self-processing [9,15,17,23,25,26]. For example, Vogely et al. [25] demonstrated that medial prefrontal regions are associated with taking one's own (first person) perspective and another person's (third person) perspective when solving an avatar task. Gusnard et al. [9] demonstrated that activation in

Table 1

Local maxima of CBF change for experimental contrast (height threshold $P < 0.001$ [FDR corrected], minimum of 12 voxels cluster size)

Yawn–laugh region	BA	HEM	x	y	z	Z score	P (FDR-cor)
Posterior cingulate gyrus	31	R	14	−38	26	4.13	0.001
Posterior cingulate gyrus	31	L	−12	−50	14	4.10	0.001
Parahippocampal gyrus	30	L	−10	−48	2	4.02	0.001
Precuneus	7	L	−14	−44	48	3.88	0.001
Thalamus	–	L	−20	−21	3	4.10	0.001
Thalamus	–	R	24	−23	8	3.91	0.001

Note. [BA = Brodmann's Area; HEM = Cerebral Hemisphere; coordinates in Talairach space [24]; P (FDR-cor) = False Discovery Rate corrected voxel level probability].
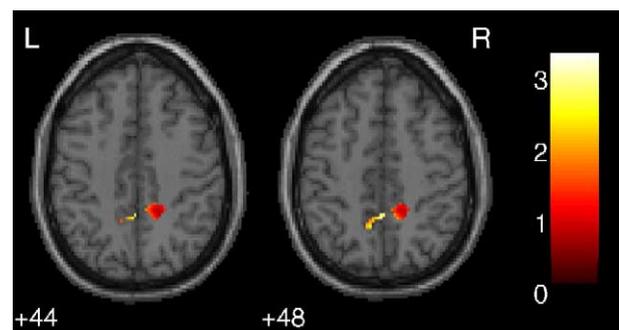
Fig. 2. Significant activation when contrasting yawn with neutral conditions. Analysis did not correct for P value [FDR] or spatial extent. Images are displayed in neurological convention.

medial prefrontal and anterior cingulate regions vascillates depending upon attentional demands of self-referent or externally cued conditions. We did not find significant activation in other regions that have been associated with self-processing, such as the right prefrontal cortex. This lack of involvement is consistent with the empathic modeling hypothesis, which suggests that contagious yawning is a primitive, unconscious form of empathic modeling and hence would not be expected to activate regions associated with conscious recognition of self-processing.

Additionally, the yawn minus laugh contrast revealed significant bilateral thalamic and parahippocampal gyrus (BA 30) activation. These activations are likely related to the visual and facial sensory processing of the stimuli. In a recent study of familiar face recognition, Blonder et al. [5] report that presentation of both human and dog faces activated so-called "face areas" (e.g., fusiform gyrus, inferior occipital gyrus), but the parahippocampal gyrus was uniquely activated by human faces. We observed similar activations when contrasting yawn with the null condition (neutral face video) when we did not apply *P* value [FDR] correction (see Fig. 2).

Our findings support our hypothesis that viewing yawns activate regions implicated in self-processing, but not the hypothesis that viewing yawns activate areas associated with the mirror neuron system. In fact, we found no evidence of activation in areas that would suggest contagious yawning is related to the mirror neuron system (e.g., left inferior frontal gyrus, frontal–parietal network, etc.).

Platek et al. [18] reported that the susceptibility to contagious yawning was reduced in subjects with increased levels of schizotypal personality traits and suggested that schizophrenic-spectrum traits negatively impact susceptibility to contagiously yawn. Patients with schizophrenia and schizotypal personality disorder show metabolic decreases and structural asymmetries in the posterior cingulate region [12], which may contribute to a failure to show contagious yawning. Also, given that chimpanzees, but not monkeys, show the capacity for mirror self-recognition, theory of mind *and* contagious yawning, it would be interesting to study the behavioral and neural correlates of contagious yawning in other species as well.

In conclusion, our findings point to a relationship between watching videos of people yawn and posterior midline cortical regions, which supports the hypothesis that contagious yawning may be a primitive form of self-processing, subserved by similar neural substrates.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.cogbrainres.2004.11.011.

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