Echokinetic yawning, theory of mind, and empathy

Humans are social beings. One of the primordial functions of the brain is to enable optimal interaction with others. The success of social interaction resides in the capacity to understand others in terms of motor actions (intentionality), emotional perception, and a mnemic and comparative cognitive integration which separates the self from others (empathy, altruism). In psychology, all these capacities are referred to collectively as Theory of Mind (TOM). It has long been known that yawning is "contagious"; ethologists speak of behavioural imitation and neurologists refer to echokinesis, a term coined by JM. Charcot. How does such echokinesis turn yawning into a form of nonverbal social communication related to TOM and empathy?

The discovery of mirror neurons by Rizzolatti and Gallese (1) offers a neurophysiological explanation for TOM. In most vertebrates, developing the capacity to explore the environment, making decisions (especially in a life-or-death response to a predator) and general preparation for action involve the activation of these mirror neurons, along with motor neurons, in cortical motor areas. Mirror neurons are activated when the movements and actions of conspecifics are perceived, indicating that intentional action and the corresponding mental imagery share the same neuronal structures. Hence, when a single pigeon senses the approach of a pedestrian, the entire flock automatically flies away, even though most of the birds did not actually perceive the danger. This cooperative motor automatism is a result of adaptive responses selected by evolution. It serves the group by providing protection from predators. Echokinesis-induced yawning does not correspond to this mechanism, as indicated by its latent appearance and its inconsistency. In fact, echokinesis only occurs in situations of minimal mental stimulation (public transport); during prolonged intellectual effort, people are not susceptible to this phenomenon. Using functional MRI (fMRI), Schürmann et al. (2) confirmed that during echokinetic yawning, there is no activation of mirror neurons in motor areas of the human brain (left posterior inferior frontal cortex), whereas these neurons are activated during observation of other types of facial gestures (decoding of intentionality). These ethological and neurophysiological elements demonstrate that, strictly speaking, echokinetic yawning is not motor imitation.

Visual recognition of one's environment involves various neuronal circuits which distinguish inanimate objects from living creatures (3). Recognition of human faces involves specific dedicated neurons in the temporal area. 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 (4). 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. (2) 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. (5) 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 memal states, and exhibited fewer schizotypal personality characteristics. These results suggest that contagious yawning might be related to selfawareness and empathic processing »(6). 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 (7) 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 attribulion, namely the right prefrontal cortex.

During echokinetic yawning, frontal lobes show no inhibitor activity. Therefore, it appears that while the understanding of intentionality (motor mirror neurons) and the sharing of the emotions (mirror neurons in the insula, amygdala and right parietal cortex) require a common action-perception neuronal activation and, simultaneously, frontal inhibition (orbitofrontal activation) to prevent motor exteriorisation, echokinetic yawning cannot be inhibited involuntarily due to the potentially absence of frontal inhibiting relays. In contrast, the right temporoparietal activation makes it possible to differentiate between the self and others, and thus identify on a conscious level that another person's yawn has acted as a trigger (8). Yawning could thus illustrate the simulation theory of mind.

Whereas yawning is universal amongst vertebrates, it appears that only primates are capable of echokinetic yawning. Anderson (9) reported that chimpanzees yawn while watching a video of their conspecifics yawning, but not while watching other facial expressions. Chimpanzees thus appear to be susceptible to echokinetic yawning in the same way humans are. Although the existence of a TOM in chimpanzees remains controversial (10), the observation of echokinetic yawning in this species argues in favour of different levels of TOM, which are perhaps secondary to the different evolutionary paths of cognitive development in hominids. Human psychiatric pathology also dissects TOM in a similar way (11).

Senju et al. showed video clips of people either yawning or simply opening and closing their mouths to 49 children who were 7 years or older, half of whom were autistic. The yawning faces triggered more than twice as many yawns in non-autistic children than in their autistic counterparts. This study suggests that contagious yawning is impaired in autism spectrum disorders, which may relate to their impairment in empathy (14).

Anderson (12) showed that children were only susceptible to echokinesis-induced yawning during their sixth year, i.e. after acquiring the ability to reflect on what others are thinking and attribute mental states accordingly. In other words, one must possess a state of cognitive maturity on a functional level to be susceptible to echokinetic yawning. Consequently, there is a phenomenological link between the capacity to attribute mental states to others (TOM), which is the basis for empathy, and what is commonly referred to as contagious yawning. In addition to the neuroanatomical hierarchy separating TOM into sensorimotor, emotional and cognitive levels, echokinetic yawning makes it possible to disassociate TOM, via its ontogenesis and its phylogenesis, into various developmental levels, an approach which is reinforced by the differential activation of specific neuronal circuits (13). This type of yawning may have conferred a selective advantage by synchronising the level of vigilance between the members of a social group. It may also take part in a form of involuntary instinctive empathy, which could be qualified as rudimentary and probably appeared late in the course of hominid evolution (in the neomammalian brain proposed by P. McLean).

1 - Rizzolatti G, Fadiga L, Gallese V, et al. Premotor cortex and the recognition of motor actions. Brain Res Cogn Brain Res. 1996;3:131-141.

2 - Schürmann M, Hesse MD, Stephan KE, et al. Yearning to yawn: the neural basis of contagious yawning. Neuroimage. 2005;24:1260-1264.

3 - Puce A, Perrett D. Electrophysiology and brain imaging of biological motion. Philos Trans R Soc Lond B Biol Sci. 2003;358:435-445.

4 - Afraz SR, Kiani R, Esteky H. Microstimulation of inferotemporal cortex influences face categorization. Nature. 2006;442:692-695.

5 - Platek SM, Mohamed FB, Gallup GG Jr. Contagious yawning and the brain. Brain Res Cogn Brain Res. 2005;23:448-452.

6 - Platek SM, Critton SR, Myers TE, Gallup GG. Contagious yawning: the role of self-awareness and mental state attribution. Brain Res Cogn Brain Res. 2003;17(2):223-237.

7 - Carr L, Iacoboni M, Dubeau MC, et al. Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas. Proc Natl Acad Sci USA. 2003;100:5497-5502.

8 - Decety J, Grezes J. The power of simulation: imagining one's own and other's behavior. Brain Res. 2006;1079:4-14.

9 - Anderson JR, Myowa-Yamakoshi M, Matsuzawa T. Contagious yawning in chimpanzees. Proc Biol Sci. 2004;271 Suppl 6:S468-470.

10 - Povinelli DJ, Vonk J. Chimpanzee minds: suspiciously human? Trends Cogn Sci. 2003;7:157-160.

11 - Blair RJ. Responding to the emotions of others: dissociating forms of empathy through the study of typical and psychiatric populations. Conscious Cogn. 2005;14:698-718.

12 - Anderson JR, Meno P. Psychological influences on yawning in children. Current Psychology Letters Behaviour, Brain, & Cognition. 2003;2:390.

13 - Singer T. The neuronal basis and ontogeny of empathy and mind reading: Review of literature and implications for future research. Neurosci Biobehav Rev. 2006;30:855-863.

14 - Senju A, Maeda M, Kikuchi Y et al. Absence of contagious yawning in children with autism spectrum disorder. Biology letters 2007; in press.