Contagious yawning and laughing: Everyday imitation- and mirror-like behavior

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Abstract: Infectious yawning and laughing offer a convenient, noninvasive approach to the evolution, development, production, and control of imitation-like and mirror-like phenomena in normal, behaving humans.

The analysis of a scientific problem can benefit from taking a broad perspective before turning to narrower and more reductive issues. In this spirit, I nominate contagious yawning and laughing for consideration, which are two of the most familiar cases of human behavior with imitation-like and mirror-like properties. Even their relegation to special-case status would help set parameters and inform readers who are more familiar with these acts than such esoteric and inaccessible phenomena as mirror neurons. An attractive feature of contagious yawning and laughing as scientific problems is that we can use ourselves as subjects – no electrophysiological laboratory is required. They also offer tantalizing insights into the evolutionary process through which a motor act may become mirrored or imitated.

Contagious yawning and laughing involve a chain reaction of behavior and physiology that propagates through and synchronizes the state of a group. Being unconsciously controlled, the contagious responses do not involve a desire to replicate an observed yawn or laugh – we just do them. Although the sensory vector for contagious yawns is primarily visual and that for laughter is primarily auditory, both contagious acts involve the replication of observed movements, whether the facial contortions of the yawn, or the respiratory movements that produce the vocalization of laughter.

Although the focus of this commentary is on the mirror-like and imitation-like properties of contagion, the analysis of mechanism must begin with the motor act brought under stimulus control. Yawns and laughs evolved before the stimulus triggers responsible for their contagion. This is a case of *motor precocity*, the common tendency of motor systems to develop or evolve prior to receiving sensory inputs. Organisms often "spond before they respond." Motor systems can be adaptive, stand-alone processes, unlike sensory systems that, by themselves, lack adaptive significance because they have no behavioral consequence. (By extension, reflexes are unlikely to emerge de novo because they require the improbable simultaneous genesis of both a sensory and motor process.) Let us now consider the evolution of yawning and laughing and how they came under sensory control.

Yawning (Provine 1986) is an ancient, stereotyped motor pattern that is performed by most vertebrates and develops prenatally in humans. Once initiated, a yawn goes to completion – recall the difficulty of stifling a yawn. There are no half-yawns. The motor pattern generator for yawning probably resides in the brain stem along with other pulmonary and vasomotor control centers. A yawn, like a laugh, is not under voluntary control and cannot be produced on command.

Contagious yawning (Provine 1986; 1989) probably emerged many millions of years after the ubiquitous motor act and, although it may be present in other species, has been clearly demonstrated only in humans. Lacking the remarkable precocity of the motor act, contagious yawning of humans appears sometime during early childhood, a developmental trajectory that suggests the involvement of a separate and higher brain mechanism. Contagious yawns can be triggered by the observation of the overall configuration of the animate, yawning face, regardless of its axial orientation or presence of the gaping mouth. (Shielding a yawn will not block its contagion.) The neurological yawn detector is so broadly tuned that almost any stimulus associated with yawning can trigger the act, including, as some readers have noticed, even thinking about or reading about yawning. The broad tuning in-

sures contagion in darkness or in the absence of line-of-sight visual contact with a yawner.

Laughter has a clearer and much shorter history than yawning and is associated with the evolution of social play in mammals (Provine 1996; 2000). Laughter is literally the sound of labored breathing in rough and tumble play, where the sound of panting has come to represent the playful act that produced it. Ethologists refer to such processes as ritualization. Laughter evolved as a play vocalization, an unconsciously controlled, therefore *honest signal* that an encounter has playful intent and is not a physical assault. In humans, the "pant-pant" laughter of our primate ancestors morphed into "ha-ha." Laughter is the clearest example of how a vocalization evolved – it does not involve the arbitrary pairing of a sound with a meaning. (The transition from "pant-pant" to "ha-ha" laughter reflects the increased vocal control of humans enabled by bipedality and ultimately explains why we can speak and other great apes cannot.) Laughter and speech time-share the same vocal apparatus, but each maintains unique features and neurological mechanisms. Laughter lacks the voluntary control of spoken words, and we tend to either laugh or speak, with speech being dominant because laughter seldom interrupts the phrase structure of speech. Laughter *punctuates* the speech stream (Provine 1993).

Laughter triggers the laughter of those who hear it, synchronizing and amplifying the neurobehavioral status of a group. It is the basis of the notorious television laugh tracks. Crying is another infectious vocalization, at least among human infants (Simner 1971). As suggested by Arbib, such processes are probably common among animals. Contagious laughs occur almost immediately after the stimulus laugh, in contrast to contagious yawns where there is a gradual increase in the probability of yawning during the seconds after the observed yawn.

A challenge of comparing the mirror systems of Arbib with those of yawning and laughter is that so little is known about the neurology of the latter. The laughing/yawning systems may, for example, more resemble systems involved in monkey vocalizations (midbrain and cingulate cortex) than those for language (e.g., Broca's and Wernicke's regions) or the specific mirror system considered by Arbib, the hand and orofacial system of monkey premotor area F5. However, the yawning/laughter systems may be a convenient exemplar of a class of processes at the foundation of Arbib's proposal that can teach us about mirror/imitation mechanisms and their evolution. The parsimony of biological systems suggests that, in whole or in part, standard processes, components, and circuits in the neurological tool kit are likely to find many applications.

Motivation rather than imitation determined the appearance of language

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Abstract: Arbib derives the origin of language from the emergence of a complex imitation system; however, it is unlikely that this complication could occur without a prior complicating within the imitated systems. This means that Arbib's hypothesis is not correct, because the other systems determined the appearance of language. In my opinion, language emerged when the motivational system became able to support goal-directed processes with no innate basis.

In the target article Arbib derives the origin of language from the emergence of a complex imitation system among ancient *Homo*. Describing in detail how the complex imitation system could facilitate the formation of protosign and protospeech, he says nothing, however, about why this system must have emerged. This is a serious problem; imitation is, by definition, copying of other pro-

cesses, therefore the complexity of the imitation system of an organism cannot exceed the complexity of the systems to be imitated. This principle seriously constrains the possibility of the emergence of a new, more complex imitation system without the corresponding complicating within the systems to be imitated. Such a possibility seems to underlie Arbib's approach because, in emphasizing the changes in the imitation system, he does not require similar fundamental changes in other systems.

Of course, it is impossible to abandon the idea that the complex imitation system could emerge as a result of a single mutation without the corresponding changes in other systems of some ancient hominids; but such hominids occasionally benefited from their new possibilities, thereby surviving successfully, until other systems achieved the complexity of the imitation system; and then natural selection started working more conventionally again. The probability of this scenario is extremely low, obviously. Another approach to the origin of the complex imitation system, which seems much more probable, is that a certain complication of other systems preceded this system and made its appearance necessary. This, however, means that Arbib's hypothesis suggesting that the complex imitation system is the "missing link" is not correct, because other systems in fact determined the appearance of language.

Like other hypotheses of language origin, Arbib's hypothesis is based on the idea that language is a means of communication. This definition is correct but incomplete: language is a means of communication for people engaged in a joint activity. There is a clear correlation between the diversity of activities and the complexity of the language serving these activities. Modern languages consist of hundreds of thousands of words only because these languages are applied in thousands of diverse activities. Each human activity is goal-directed, hence, the complexity of languages is a consequence of the ability of the human brain to construct diverse goals. Indeed, most human goals are not constrained by any innate basis; they are social, and result from interactions between people. So, there is an obvious connection between language and the ability to construct and maintain long-term motivations with no innate basis.

No nonhuman animals have a motivational system with similar characteristics. Animals have long-term motivations (e.g., sex, hunger), but these are all innate. An animal can form learned motivations, but only when its basic drives are activated. The hypothesis that the motivation of animals is always constrained by the activation of basic drives was suggested by Kohler (1917/1927), and despite intensive researches, there have still been no data inconsistent with it (Suddendorf & Corballis 1997). With the limited and stable number of long-term motivations, animals are constrained in using and developing their languages. Since all their motivations are connected with vital functions, any serious misunderstanding in the process of communication can be fatal; as a result, the number of signals in animal languages must be limited, and the signals must have unequivocal meanings. Roughly speaking, animals do not have a language similar to human languages because they simply do not need it.

I have suggested elsewhere that the emergence of the ability to construct and maintain long-term goals with no innate basis was the missing link for language (Prudkov 1999c) and for the other distinctively human characteristics (Prudkov 1999a; 1999b) because the ability allowed ancient humans to overcome the constraints of innate motivations, thus providing the possibility of constructing new, flexible, and open systems. In other words, protolanguage emerged because in new situations conditioned by goals having no innate basis, the innate communicative means became inefficient for interactions between ancient hominids, and those who were able to construct new means succeeded in reproduction. Of course, language, imitation, and the theory of mind had started evolving then. It is very important to emphasize that without the prior (or parallel) formation of the system able to construct learned, long-term motivations, any changes in other systems (e.g., in intelligence) were not sufficient to overcome innate

constraints. For example, the capacity of birds to navigate in three-dimensional space on the basis of visual cues obviously exceeds that of humans, but innate mechanisms determine the behavior of birds.

It is reasonable to think that there was a reciprocal interaction in the evolution of human language and motivation. The new motivational ability spurred the development of language; afterwards language was used to construct efficient, purposeful processes, and this interaction likely determined all stages of human evolution. This joint evolution was facilitated by the fact that a common mechanism that evolved within these systems is the capacity to form and execute complex, hierarchical, goal-directed processes (such processes are rapid and relatively simple in language and are slow and complex in motivation) (Prudkov & Rodina 1999). In other words, I agree with Arbib that humans have a language-ready brain rather than special mechanisms embedded in the genome. The capacity was also involved in the development of the imitation system, because a basic characteristic distinguishing the human imitation system from its animal analogs is the possibility to imitate more complex and long-term processes. But the development of the imitation system itself is not sufficient to construct protolanguage, because only the new motivational system could make imitation voluntary and arbitrary. Indeed, in emphasizing that at a certain stage of evolution communication became voluntary and intentional, Arbib does not explain what mechanisms underlay such possibilities of communication.

In my opinion, the gestural and vocal components of protolanguage emerged together, but the latter gained advantage in the development because, unlike gestures, which are effective only in dyadic contacts, vocalizations are more effective in group actions (group hunting, collective self-defense, etc.), which became the first actions guided by goals having no innate basis.

Vocal gestures and auditory objects

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Abstract: Recent studies in human and nonhuman primates demonstrate that auditory objects, including speech sounds, are identified in anterior superior temporal cortex projecting directly to inferior frontal regions and not along a posterior pathway, as classically assumed. By contrast, the role of posterior temporal regions in speech and language remains largely unexplained, although a concept of vocal gestures may be helpful.

In his target article, Arbib maintains (and before him, Rizzolatti & Arbib 1998) that language originated from a system of mirror neurons coding manual gestures, rather than from vocal communication systems present in nonhuman primates (and other animals). I do not doubt the usefulness of the mirror-neuron concept, which brings back to mind the motor theory of speech perception (Liberman et al. 1967). In fact, many recent neuroimaging studies have independently demonstrated a simultaneous activation of what were previously thought of as separate centers for the production and perception of human language, Broca's and Wernicke's areas, respectively. These designations go back more than a century to crudely characterized single-case studies of neurological patients, which have been shown by modern magnetic resonance imaging (MRI) techniques (Bookheimer 2002) to have missed much more brain than the relatively small regions that now bear their discoverers' names.

Both on that basis and on the basis of his own belief in intertwined systems of perception and action, it is surprising that Arbib continues to use this outdated terminology. "Broca's area" at least is redefined by him as part of a system that deals with, among others, "sequential operations that may underlie the ability to