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Tongue motor cortex: The back door of the reward system

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ABSTRACT

In paragraph 3.5 of their article, the authors provide some information about the nonmotor properties of tongue motor cortex. As a complement to the interesting work of Bono et al. (2022), in this commentary we focus on this aspect by addressing the link of the tongue motor cortex to the reward system, and its relevance for emotion processing, social cognition and psychopathology via connections of tongue motor area with other brain structures.

Understanding the neural processes underlying reinforcement is fundamental for comprehension of human behavior, from primitive reactions (e.g., fight/flight response, ingestion/regurgitation) to complex conducts (buy/sell, moral decision making), including psychopathological and criminal behaviors.

In their review article, Bono et al. (2022) provide an in-depth analysis of the properties of the tongue muscle, and its central nervous system representations in non-primates, and non-human and human primates. This work focuses on an extremely relevant body region, which is however only marginally considered by researchers in the field of neuroscience.

The unique nature of the tongue is determined by the fact that this muscle is also a two-fold sensory organ, as it hosts gustatory (taste buds), as well as somatosensory receptors. This implies that the tongue can be seen as a hub of complex innervations involving large portions of interconnected brain regions, including the primary motor cortex, the origin of the motor neurons that control its movement, the somatosensory cortex, which contains neurons that processes somatosensory information originating from the tongue, and the insular cortex, which includes (together with the operculum) the primary gustatory cortex that processes taste information delivered by the taste buds of the tongue. Further relevant sensori-motor regions include sectors of the thalamus, cerebellum (in humans) and the cingulate cortex (in non-human primates) (Bono et al., 2022).

In paragraph 3.5 of their article, the authors provide some information about the non-motor properties of tongue motor cortex. As a complement to the interesting work of Bono et al. (2022), in this commentary we focus on this aspect by addressing the link of the tongue motor cortex to the reward system, and its relevance for emotion processing, social cognition and psychopathology via connections of tongue motor area with other brain structures.

Prior neuroanatomical and neurophysiological studies in primates have shown specific patterns of connectivity (e.g., Alipour et al., 2002) between neurons of the tongue motor cortex and several cortical and subcortical regions involved in reward processing. This complex network of connected regions includes the striatum (i.e., ventral putamen and caudate nucleus), which is crucial for linking action and reward processing; the orbitofrontal cortex, essential for detecting the value of an object and mediating complex forms of decision-making (e.g. moral decisions, at least in humans); the amygdala, which represents the current desirability of a reward according to the internal state (Passingham, 2021), and is involved in the processing of fear and other emotional signals; the insula (i.e., granular and agranular portions), which encodes internal states (i.e., interoception) and mediates the experience of disgust and its social and moral aspects (Vicario et al., 2022); the anterior cingulate cortex, which is involved in the choice between alternative resources while foraging, in encoding the value that a monkey attributes to its conspecifics and in the respective perceived interest to interact with them (Passingham, 2021).

These patterns of connectivity suggest a potential involvement of tongue motor cortical neurons in the processing, evaluation, and reaction to stimuli along the reward-punishment continuum, including

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processes related to affective experiences (e.g., disgust, fear) and social behavior (e.g., moral decision making), as well as processes associated with to psychopathology (e.g., substance dependence).

Investigations conducted in healthy humans, in which we explored tongue motor cortex excitability via transcranial magnetic stimulation-elicited tongue motor-evoked potentials, have shown that the excitability of this area responds to manipulations of factors that affect the activity of the reward system, and may be directly relevant to psychopathology. This is suggested by investigations showing that the induction of a state of physiological withdrawal from nicotine in smokers increases the excitability of tongue motor cortex (Vicario et al., 2014), whereas the exposure to potentially disgusting stimuli in healthy individuals reduces it (Vicario et al., 2017, 2022). Furthermore, the same group of authors have recently shown that modulation of the activity of tongue motor cortical neurons through transcranial direct current stimulation reduces appetite in healthy individuals (Vicario et al., 2020).

These results highlight the relevance of the tongue motor cortex for the response to reward-related properties of stimuli and internal states. In line with results of earlier investigations (Alipour et al., 2002), this suggests a direct connection between the motor cortical neurons of the tongue and the reward circuit even in human primates. Furthermore, the evidence for the modulation of appetite following non-invasive stimulation of the tongue motor cortex (Vicario et al., 2020) suggests that this area can serve as a cortical target to modulate the reward circuit via non-invasive brain stimulation, most probably due to its strong connection with the OFC and the insula, which are not easily reached directly by these intervention tools. Crucially, such connections are not commonly reported for the hand, arm, and leg areas of the motor cortex, and thus represent a fundamental difference that distinguishes the motor tongue area projections from other motor projections, and makes this area unique (Alipour et al., 2002). In many species, the tongue muscle is an essential tool – if not the primary means of interacting with the world – as it contributes to swallowing food, detecting, and preventing potential threats such as the ingestion of contaminated food. Evidence that the tongue motor cortex responds and is connected with neural structures involved in gustatory processing, affective processing and social behavior suggests that tongue motor neurons may be the remnant of an ancestral brain structure that may have evolved from the reward system.

Data availability

No data was used for the research described in the article.

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