

## Letter

## Embodied Simulation: Beyond the Expression/Experience Dualism of Emotions

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In their recent review, Wood *et al.* [1] argue that emotion recognition is supported by an automatic sensorimotor simulation of the observed expression in one's own motor system. This proposal recaps the 'reverse simulation' model, previously discussed by simulation theorists [2], in assuming that emotion recognition depends on multistep serial processing. First, the agent expression is simulated in the perceiver's motor system. Subsequently, feedback from the motor system triggers a cascade of neural activations in other brain regions involved in the emotional experience, eliciting the correspondent experience in the perceiver. Finally, this first-personal experience is employed to infer the agent's emotional state, which is not observable otherwise. A problem with this model is that it assumes a dualism between the neural underpinnings of emotional experience and expression, leading to the view that 'we cannot directly access another's experience' ([1], see p. 236) and that emotion recognition is a probabilistic 'game of prediction'. We will briefly make a case for the notion that this phenomenological shortcoming could be avoided by rejecting the experience/expression dualism characterizing the proposal by Wood *et al.*

The experience/expression dualism maintains that the sensory and motor components of emotions are processed by distinct neural circuits. Wood *et al.* present data concerning the neural basis of emotion recognition but they do not present data concerning the neural basis underlying the production of emotional expressions.

However, the authors should not be blamed for this omission. Indeed, the production of emotional expressions has been studied in a restricted number of studies. Electrical stimulation studies prove that social emotional facial expressions can be directly elicited by stimulating a very wide set of brain regions, extending beyond the classic motor system. Moreover, what these studies also show is that distinguishing between sensory and motor emotional regions in the brain is problematic for two reasons. First, positive emotional expressions can be elicited by stimulating regions involved in emotional awareness and semantic memory, such as the ventral insula [3] and the basal temporal cortex [4], respectively. Second, emotional experiences such as mirth and merriment can be evoked by stimulating frontal areas traditionally deemed to control motor output, including the pregenual anterior cingulate cortex, the supplementary motor area, and the inferior frontal gyrus (see [5]). It follows that the neural systems supporting emotional production and experience largely overlap, thus defusing the experience/expression dualism and nullifying the need for serial processing in the emotional brain [6,7].

Evidence shows that recognizing others' emotion triggers activity in a network largely overlapping with the one from which emotional expressions/experiences are elicited by stimulation [8]; lesions of these brain centers impair emotion recognition and social behavior [9,10]. This shows that embodied simulation is not confined to the sensorimotor system and that emotion recognition is carried out in shared w-centric space distributed in the brain [11]. Our suggestion is in accord with the view that emotional states are relational properties of an individual within a given social context more than inaccessible intrinsic psychological properties of a subject, as suggested by Wood *et al.*

The view that emotions are a multifaceted phenomenon constituted by independent sensory and motor components is an old

idea that has been formalized in two different versions. Some scholars advised that emotional responses follow the emotional experiences, in line with the early suggestions by Darwin. Some others run the serial processing in the opposite direction, considering emotional responses to be the trigger of the emotional experience, echoing a perspective dating back to William James. Wood *et al.*'s model capitalizes on both stances. The literature reviewed above, by contrast, encourages one to abandon this dichotomous interpretation, retracing the original criticism that John Dewey [12] moved against both Darwin's and James's perspectives: agency is a core feature of emotional experience and its behavioral expression is part of the ontology of some emotions.

In conclusion, while we agree that embodied simulation is a critical tool for understanding others' emotion, we disagree with narrowing its role to the very first steps of the recognition process. Embodied simulation occurs in a wider network than the one hypothesized by the authors, not restricted to the sensorimotor system and likely sufficient to support intersubjective recognition without explicit inferential reasoning. In rejecting the expression/experience dualism and situating agency as a core feature of emotional experience, we rejoin with early theoretical attempts to uphold the continuity between sensory, motor, and social aspects of emotions.

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<http://dx.doi.org/10.1016/j.tics.2016.03.010>

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## Letter

# The Perils of Boxes and Arrows: Reply to Gallese and Caruana

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We recently [1] reviewed evidence indicating that sensorimotor simulation, and sometimes resulting facial mimicry, accompanies and supports the perception of facial expressions of emotion. In their comment (this issue), Gallese and Caruana [2] challenge the concept of what they call 'expression/experience dualism' and suggest that emotion experience, expression production, and expression recognition are inseparable processes that take place in a unified brain network that encompasses but is not restricted to sensorimotor systems. We are grateful for their comment, primarily because Gallese and colleagues' own work [3,4] has

inspired much of our thinking on embodied simulation [5]. It also provides us with the opportunity to clarify our original claims and findings, which is the goal of this reply.

Gallese and Caruana's interpretation of our model of the recognition of facial expression as relying on 'multistep serial processing' motivated their comment. However, this is a misinterpretation. When developing a specific mechanistic theory, the linear nature of language sometimes requires conceptually serial and modular descriptions. Our Figure 1 may be misleading because it comprises boxes and arrows, suggesting functional and anatomical separation as well as serial processing. In fact, we do not assume that these processes are independent (i.e., encapsulated) or serial in nature. This view is expressed in the figure legend itself, where, rather than a dual process, we indicate that we are illustrating the 'distributed and recursive nature of the emotion perception process, which iteratively recruits visual, somatosensory, motor, and premotor cortices, as well as, subcortically, parts of the limbic system and brainstem' ([1], see p. 232). We are grateful for the opportunity to make this view clearer.

Indeed, we agree with Gallese and Caruana that emotion production and perception cannot be reduced to a few cognitive processes or circumscribed brain areas. Facial expression recognition is a multifaceted phenomenon that calls into play a great number of psychological processes [6]. It requires a wide and distributed neural network, going beyond the areas classically implicated in the production of facial expressions [7] or in the processing of facial feedback. We also agree that emotional expressions and behaviors are inextricably linked to emotional experience (e.g., see the section beginning on p. 230 of our review [1]). Nevertheless, we do find it useful to conceptually separate the neural systems that plan and execute motor programs and receive somatosensory feedback from those involved in other

components of emotion. We deliberately chose not to collapse across the two phenomena.

Certainly, a feeling and/or a facial expression can be generated by electrical stimulation (ES) of extrasensorimotor cortices implicated in emotion processing [8–10], and this fits with our model. However, the co-occurrence of the two phenomena during ES is not convincing evidence that they are part of a single circuit. Arguably, some of the reported effects [8–10] do not arise from the stimulated area (the insula and basal temporal cortex) itself but from the effects of ES on more distant areas, being part of a widespread and highly interconnected network. Consistent with this, and as supported by the commenters' own research, the macaque insula is likely involved not in the core emotional response but rather in 'a more complex elaboration of emotional stimuli' [8]. As a hub of higher-level integration, the insula thus seems perfectly suited to draw on basic emotion centers such as the hypothalamus and amygdala on the one hand and expression-producing and -monitoring motor and somatosensory areas on the other.

It should also be noted that the authors of one of the cited studies [9] do not postulate an overlap of emotional experience (mirth) and smile production in the basal temporal cortex (which they identify as involved in semantic and language processes). Instead, they speculate that ES of this area may have been transmitted to the facial motor nuclei via a multisynaptic tract running through the amygdala and the limbic system. Furthermore, in their study smiling preceded feelings of mirth, suggesting that sensorimotor activity was induced first and subsequently activated areas underlying the subjective experience of mirth. This could also explain why, for many patients, smiling was initiated on the contralateral side from ES in the anterior cingulate cortex [10]. The observed asymmetry would be unlikely if smiling were the result of felt affect. Finally,