



Neuroanthropology: evolution and emotional embodiment

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The Decade of the Mind is a proposal for a research initiative focused on four areas of neuroscience, including mental health, high-level cognitive function, education, and computational applications. Organizing efforts to date have primarily included cognitive scientists, computer scientists, and engineers, as well as physicians. At the same time anthropologists have started to explore the implications of neuroscience for understanding culture. Here we suggest that evolutionary neuroscience can be used to bridge knowledge obtained by social scientists with that obtained in the neurosciences for a more complete appreciation of the mind. We consider such a perspective as neuroanthropology. We use embodiment, an anthropological concept that has been substantiated by recent findings in neuroscience, to illustrate an integrative biocultural approach within neuroanthropology and suggest future possible directions for research.

Keywords: embodiment, insula, evolution, cultural neuroscience, biological anthropology

INTRODUCTION

The past few years have seen a call for interdisciplinary research on the brain, including Decade of the Mind (DOM), an international initiative for basic neuroscience research on the mind including mental health, high-level cognitive function, education, and intelligent machines (Albus et al., 2007). Despite DOM's interest in moving brain research beyond the clinic, to date anthropological research has not been well represented in such interdisciplinary discussions. At the same time, however, there has been growing interest in incorporating neuroscience perspectives into anthropology, as exemplified by the Encultured Brain Conference, Oct 8th 2009 at Notre Dame University.

Biological anthropology, with its concern for human brain evolution (Falk, 2004; Holloway, 2008), has embraced the insights of neuroscience into the origins of human cultural capacities (Deacon, 1998; Rilling, 2008). Social anthropology, on the other hand, with its focus on cultural variation in human experience, has been a philosophical holdout against "reductionist" neuroscience. However, recent research has made it clear that these three fields have much to offer one another in creating a holistic conception of the role of the evolved brain in human culture – welcome the heading of neuroanthropology.

Here we suggest that evolutionary neuroscience can be used to bridge knowledge obtained by social scientists with that obtained in the neurosciences for a more complete appreciation of the mind. More specifically, neuroscience can bring information about neurological mechanisms, evolutionary processes and primate context to enrich more traditional anthropological perspectives on human experience. To demonstrate this point, we provide an example of how our understanding of embodiment, a term used by anthropologists to denote the subjective experience of the body, can

be complemented by evolutionary neuroscience. As shown below, far from reducing embodiment to neural processes, a neurological and evolutionary perspective on embodiment open up new vistas for neuroanthropologists to explore in studying cultural variation in human experience.

EMBODIMENT

As defined by anthropologists, embodiment is the subjective experience of the body, but not the physiological body (Csordas, 1990). As such, embodiment is generally considered to represent a culturally generated experience of the body and has been approached ethnographically (Csordas, 1990, 1994), including its expression in ritual (Strathern and Stewart, 2008). However, because ethnography relies largely on verbal description, the term embodiment has traditionally been limited to philosophical and/or ethnographic discourse, and carries post-modern connotations for many neuroscientists.

From the perspective of the neurosciences, the subjective experience of the body must logically be instantiated in the brain. The neural questions underlying embodiment are clear: where is the subjective representation of body located and functionally processed in the brain? And is such a representation highly integrative? A highly integrative representation of subjective somatic experience would make the neurological contribution to embodiment more compelling, yet still require environmentally-specific explanation in terms of variable expression.

Understanding embodiment in terms of its neurological correlates allows for more holistic investigation into both internal psychological and external socio-cultural factors. Thus, neuroanthropology becomes a truly consilient perspective by which to tackle the cultural context of our evolved human brain. The infusion of evolutionary principles into areas of

neuroscientific investigation have spurred intellectually rewarding theoretical and predictive study, as demonstrated by Platek, et al. (2007) work on evolutionary cognitive neuroscience as a new and emerging field of inquiry. Similarly, neuroanthropology combines input from evolutionary biology, behavioral neuroscience, and cultural anthropology, to attempt a deeper appreciation of how the cultural context of the evolved brain can influence individual experience.

To begin to appreciate the physiology of embodiment, Craig refers to embodiment in terms of recent findings demonstrating the integration of somatosensory, homeostatic, and emotional information within the insula – suggesting a specific location for a global somatic representation (Craig, 2002, 2009). The insula cortex is part of the cerebral cortex and lies deep within the lateral sulcus, overlain by the opercula. The insula is at the base of the parietal lobe with important inputs from other sub-cortical structures including the thalamus, anterior cingulate cortex, and amygdala (Craig, 2002).

Such bodily representation is not to be confused with Penfield's famous homunculus map of the body represented in the cortex. Rather, embodiment may be best thought of as somatic mood, a feeling that is not closely tied to language, perhaps helping to account for the subjective and elusive nature of its linguistic description. In its positive form, it may be thought of as well-being. We will use the term emotional embodiment to distinguish the insular representation from the use of embodiment in conjunction with language and cognition (see for instance Clark, 2006).

EMBODIMENT AND RITUAL PRACTICES

The insula and anterior cingulate cortex have been implicated in recent studies of ritual spiritual practices, including meditation (Lazar et al., 2005; Lutz et al., 2009), yoga (Kakigi et al., 2005), and shamanism (Riba et al., 2006). Thus the neural correlates of emotional embodiment not only reflect our evolutionary heritage, but have become an object of cultural practice. In fact, findings showing that individuals who are more aware of their own heart beat exhibit greater activation in the insula and experience stronger emotions (Critchley et al., 2004), suggest that some individuals may be more intrinsically skilled at such practices than others.

Recent findings indicate that the relationship between emotion, the insula, anterior cingulate cortex, and autonomic nervous system function is central to meditation. For instance, experienced compassion meditators showed greater activation of the insula to negative sounds (Lutz et al., 2008) and such activation was more strongly tied to heartbeat relative to novices (Lutz et al., 2009). Lazar et al. (2005) report increased thickness of the insula among meditators who focused on internal awareness, suggesting long-term internal awareness can lead to increased development of the neural structures of embodiment.

In a more exotic example, Kakigi et al. (2005) investigated brain activity in a Japanese yoga master who claimed to be impervious to pain while meditating. They report decreased activity in the insula and anterior cingulate cortex during meditation relative to a non-meditative state, regions already mentioned to be central to the emotional aspects of pain (Singer et al., 2004; Jackson et al., 2006). More such studies are needed to see if such findings are common among yogis who claim similar powers.

The anterior cingulate and insula have been implicated in other ritual healing practices as well. Ayahuasca, a South American psychoactive plant tea, is known to have dramatic effects on bodily and emotional perceptions (Riba et al., 2001). Riba et al. (2006) report that the ingestion of ayahuasca is associated with increased brain activity in the right anterior insula and the anterior cingulate cortex, consistent with previous findings on the neural correlates of emotional embodiment, and empathy. Thus the ingestion of ayahuasca by traditional shaman may be important in generating an empathetic state that allows them to experience the feelings of afflicted individuals during their spirit journey and facilitate healing (Dobkin de Rios, 1984).

Interestingly, the involvement of the anterior cingulate cortex and insula in meditation, yoga, and shamanic practices appears to be mirrored by the activation of both structures in long-term romantic relationships. This investigation is consistent with Jankowiak and Fischer's landmark study showing that romantic love, although culturally and idiosyncratically variable, is a cross-cultural and human universal (Jankowiak and Fischer, 1992). Among individuals who reported being romantically in love, the anterior cingulate cortex and insula cortex were not very active during the first 8 months (Aron et al., 2005), but become more active from 8 to 17 months (Aron et al., 2005; Fisher et al., 2005). Further, Bartels and Zeki (2000) found that activation of the anterior cingulate and insula cortex were clearly involved in feelings of romantic love among individuals who reported being in love for an average of over 2 years. Alcorde and Sosis (2005) argue that one defining experience of ritual is a feeling of intense joy (ritual can also invoke powerful negative feelings as well), a feature they associate with dopaminergic neurotransmission. Given activation of insula and anterior cingulate cortex in meditation, yoga, ingestion of ayahuasca, as well as romantic love, spiritual healing practices may, in fact, as many of them claim, draw on the positive neurological experience of love.

EVOLUTION, SOCIALITY, AND THE PRIMATE BRAIN

Rilling (2008) has suggested that anthropologists might make their best contribution to a deeper understanding of the human brain by concentrating on the neural basis of behaviors uniquely developed in humans and critical to the evolution of the human brain, including language (Deacon, 1998), tool making (Stout and Chaminade, 2007; Stout et al., 2008), mental perspective-taking (Amodio and Frith, 2006), and altruism (Moll et al., 2006). We suggest that emotional embodiment, that is the global representation of bodily status as somatic mood, is also critical to the evolution of the human brain and deserves special focus from neuroscientists and anthropologists alike.

Bodily awareness has been argued by numerous philosophers and neuroscientists, including William James and Antonio Damasio, as the basis of human consciousness (see Prinz, 2004 for a more recent example). The insula and anterior cortex is not only central to elements of somatic awareness, such as pain (Singer et al., 2004; Jackson et al., 2006) but also to empathy (Lamm et al., 2009), racial group identity (Xu et al., 2009), social norm violation (King-Casas et al., 2008), and moral intuitions (Woodward and Allman, 2007), thus linking somatic awareness to social emotions.

Based on anatomical evidence, Craig (2002) argues that the incorporation of C and A δ nerve fibers into the spinothalamic lamina I tract provides primates with an integrated representation of physiological status not found in other mammals. Such fibers arise from nearly every cell of the body, including some that respond to lactic acid in muscle and provide information about peripheral metabolism processes. Furthermore, among primates, the termination of the tract in the posterior ventromedial nucleus with the thalamus (VMpo) means that all such information is integrated in a single location providing a global emotional representation of the body (Craig, 2002).

Compared to anthropoid primates however, the representation of somatic status appears to be elaborated in humans. Humans exhibit a relatively larger VMpo. While in non-human primates some of the spinothalamic lamina I neurons go directly to the orbitofrontal cortex, in humans, they all pass through the insula, in particular the right anterior insula (Craig, 2002). This allows for a fuller representation of somatic status, which is then passed on to the orbital frontal cortex where it serves as an hedonic input for decision-making (Wallis, 2007).

The social brain hypothesis holds that it is the demands of complex social interactions in groups that have spurred the adaptive increase in brain size across the biological order Primates (Dunbar, 1998, 2009), a relationship not found in other mammalian orders (Shultz and Dunbar, 2007). The importance of bonding among primates would explain why affiliation through physical touch initiates a neurochemical cascade, involving oxytocin and opiates, that is positively reinforcing and fundamental to effective social cohesion (Dunbar, 2010). While such neuroendocrine mechanisms remain important in human social interaction, they do not appear sufficient to explain group cohesion among humans for whom language and technology form the foundation for greatly expanded spheres of social interaction.

Humans and the great apes (*Hominidae*), but not other primates, exhibit Von Economo neurons (VENs) linking both the fronto-insular and anterior cingulate cortex (ACC) to other areas of the prefrontal cortex (Nimchinsky et al., 1999). The density of VENs is related to the degree of sociality exhibited across the four genera of great apes – orangutans (*Pongo*), gorillas (*Gorilla*), chimpanzees (*Pan*), and humans (*Homo*). These findings suggest a potentially similar role for emotional embodiment in complex social behavior, together with similarities in the prefrontal cortex, between humans and the other great apes (Semendeferi et al., 2002).

In humans, the neural correlates of emotional embodiment appear to be particularly well developed. Along with a large and well developed insula (Craig, 2009), humans demonstrate both greater density of VEN linking the ACC and insula relative to the apes (Nimchinsky et al., 1999) as well as the presence of VEN in the dorsolateral prefrontal cortex (Fajardo et al., 2008). Allman and colleagues (Allman et al., 2001; Woodward and Allman, 2007) suggest that limbic/cortical connections through VENs provide a neural pathway for rapid processing of complex social information which they argue underlies so-called moral intuition (Woodward and Allman, 2007).

Importantly, both the insula and ACC are active in response to the perception of fairness in social interactions (Hsu et al., 2008; Tabibnia et al., 2008; Chiao et al., 2009). While the notion of

fairness may seem a long step from bodily awareness, it represents a logical extension of threats to bodily awareness into the social sphere, or “social embodiment” (Singer, 2007). To the extent that others’ actions threaten bodily survival they are unlikely to be experienced as “fair”. Activation of the ACC under laboratory conditions of social exclusion (Eisenberger et al., 2003) suggests that fairness may be linked to survival because group exclusion is perceived as potentially threatening to survival.

The salience of the neural correlates of emotional embodiment extends to vocalization, language, and music, all important elements in ritual. Recent studies indicate that the insula is active in the response to the prosody or emotional content of language (Dietrich et al., 2008; Quadflieg et al., 2008; Ethofer et al., 2009), laughing and crying (Sander and Scheich, 2005), and music listening (Brown et al., 2004). In fact, music and speech perception overlap in the insula (Brown et al. 2006), and the dorsal anterior insula may be specific for processing language and auditory information (Mutschler et al., 2009). While language may facilitate social communication among larger human groups, its role in social cohesion is linked to emotional elements of vocalization clearly expressed in laughing, crying, and music.

EMBODIMENT AND BRAIN DEVELOPMENT

Biological anthropologists are particularly attuned to substantial population variation in somatic growth based on energy balance (the difference between consumption and output) related to subsistence patterns and cultural consumption practices (Stinson, 2000). However, much less attention has been given to the potential impact of energetics for population variation specifically in terms of brain development. This reflects an assumption that the brain is prioritized for energy (Fehm et al., 2006) and hence should suffer little from variation in energy supply (Campbell, in press).

However, given that the development of the prefrontal cortex during the first 15 years of life is directly related to glucose utilization (Chugani, 1998), and that cortical development is a sequential hierarchical process (Gogtay et al., 2004; Shaw et al., 2008), brain development may be more sensitive to fluctuations in energy availability than currently considered (Vaynman and Gomez-Pinilla, 2006). More specifically, given that the insula and ACC exhibit elevated glucose utilization relative to the prefrontal cortex from the age of 6 years into the 20’s (Van Bogaert et al., 1998), food availability may have important implications for the development of emotional embodiment and hence empathy, notions of fairness, and artistic development.

There is relatively little evidence linking chronic undernutrition to specific aspects of brain development in humans. However, recent findings demonstrate altered insula activity in anorexia nervosa (Nunn et al., 2008; Kaye et al., 2009). Altered insula activity is related not only to changes in the taste of food, but also distorted self-body perception (Sachdev et al., 2008). In addition, the size of the ACC is reduced in AN (Mühlau et al., 2007; McCormick et al., 2008), an effect that appears to reflect the degree of weight loss (Mühlau et al., 2007) and is reversible with weight gain (McCormick et al., 2008). Importantly, both the ability to identify emotions (Miyake et al., 2009), and impaired cognitive set shifting (Zastrow et al., 2009) among individuals with AN have been related

to alteration in the ACC, among other structures. Together these findings implicate the ACC and insula in body perception, emotion, and intellectual performance, a combination of traits suggestive of emotional embodiment.

AN is a chronic pathological condition and hence represents an extreme case for the potential malleability of the insula and ACC in brain development. However, Kar et al. (2008) recently reported that a small sample of chronically un-nourished children aged 5 to 10 years from India show reduced cognitive function. Deficits included attention, working memory, learning and memory, and visuospatial ability but not motor speed and coordination. Furthermore, while attention scores increased with age among the malnourished children, those of design fluency, working memory, visual construction, learning and memory did not. The authors conclude that chronic malnutrition specifically underlies deficits in higher cognitive functions.

These results are especially important because the ages of 5 to 10 years coincide with middle childhood, a time of elevated glucose utilization and overall brain plasticity (Chugani, 1998), as well as important changes in social, emotional, and intellectual skills (Piaget, 1963), including the development of reason and responsibility (White, 1996). Thus given the hierarchical and sequential nature of cortical maturation (Gogtay et al., 2004; Shaw et al., 2008), alterations in brain development during this stage may have important consequences for the long-term maturation of emotion, social emotion, and morality.

Surprisingly, the role of physical activity in brain development may be particularly relevant in our own society. Recent work pointing to the importance of motor activity in the early development of the brain (Diamond, 2001) as well as the impact of physical exercise on learning in both school age children and adults (Ploughman, 2008) are consistent with the continued importance of elevated levels of physical exercise thought to characterize our hunting and gathering ancestors (Vaynman and Gomez-Pinilla, 2006). Thus the simple recognition of the importance of physical activity for learning and the detrimental effects of a sedentary lifestyle as associated with video games and heavy use of the internet may do more for reviving our education and health care systems than any other single brain based pedagogical programs.

FUTURE RESEARCH DIRECTIONS

Cultural neuroscience is already revealing important dichotomies in the activation of brain regions for such basic behaviors as response to fear faces (Chao et al., 2008) as well the valuation of dominant and subordinate behaviors (Freeman et al., 2009) based on differences between Western and Eastern cultures. Such results demonstrate that cultural conditions can lead to discernable differences in the specific cues that activate fundamental brain structures such as the amygdala and mesolimbic reward pathways. We expect that similar comparisons of Western and Eastern cultures directed toward understanding the role of the ACC and insula in such topics, as ritual, group identity, and romantic love will reveal similar differences based on habitual experience.

Extending such studies directly to traditional societies in which undernutrition, habitual levels of physical exercise, and even parasitic infections may represent important inputs in somatic mood, is

much more difficult, because of a lack of brain imaging techniques that can be used in the field. Thus much of the investigation of emotional embodiment in traditional societies will have to rely on indirect methods, including questionnaires, neuropsychological tests, genetic and hormonal markers, and inferences from laboratory based brain imaging studies.

For instance, among male Arrial pastoralists from northern Kenya, self-reported quality of life, which may be thought of as a measure of well-being, is predicted by the number of male supporters as well as amount of body fat (Campbell unpublished data). Other findings demonstrate that DRD4 7R+ is positively related to BMI among nomadic Arrial males (Eisenberg et al. 2008) while salivary T is positively related to measures of body fat in the same men (Campbell et al., 2007). Whether such biomarkers are also related to quality of life through their association with somatic status deserves more a detailed investigation of health, well-being and subjective mood among Arrial men based on genetic variation in neurotransmitters and salivary steroids, as well as cultural ideals.

SUMMARY

There is growing excitement among neuroscientists and social scientists alike about the possibility of investigating the brain processes underlying those capacities for culture that seem uniquely human. We suggest here that an evolutionary framework for such a neurological perspective on the human brain highlights a pre-existing primate neural system of emotional embodiment as a key element in human sociality. The phylogenetic elaboration of bodily awareness helps to suggest the elaboration of human romantic love into a wider set of positive social emotions and moral sentiments that act to maintain the cohesion of larger groups. In addition, it suggests that practices such as meditation, yoga, and shamanism are based on activating the neurological mechanisms associated with such positive social emotions.

The investigation of cultural variation's influence on neuroplasticity is in its infancy. An evolutionary approach suggests that the role of culture in human neuroplasticity is not a recent event, but extends throughout human brain evolution (Deacon, 1998). Hence the role of metabolic constraints (Fehm et al., 2006) is crucial to an evolutionary understanding of the way in which empathy and other social emotions are linked to somatic states. Thus the investigation of traditional cultures with deeply engrained cultural practices, high levels of habitual physical activity, and low caloric intake, has a critical role to play in neuroanthropology. However, the lack of suitable brain imaging methods for the field means that such investigations, for now, will have to rely on indirect methods and courageous attempts at interdisciplinarity.

ACKNOWLEDGMENTS

The authors thank Leslie Heywood for supportive discussion and comments, along with Paul Brodwin and two anonymous reviewers for helpful comments on an earlier draft of this article. We also thank our Neuroanthropology colleagues for valuable discussion (see <http://neuroanthropology.net/>).

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. Both Benjamin C. Campbell and Justin R. Garcia conceived of and wrote this article.

Received: 21 June 2009; paper pending published: 24 July 2009; accepted: 10 November 2009; published online: 24 November 2009.
 Citation: Campbell BC and Garcia JR (2009) *Neuroanthropology: Evolution and Emotional Embodiment*. *Front. Evol. Neurosci.* 1:4. doi: 10.3389/neuro.18.004.2009
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