

## Are basic emotions ingrained in the brain's architecture?

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*Abstract* – Emotions are a series of functional states that promote specific action tendencies. Phenomenologically, they were thought to be associated with a specific set of mental, behavioral, and physiological manifestations. Ontologically, however, inconsistencies in these patterns have led some researchers to question whether emotions are simply *perceived* as distinct experiences. On one hand, classical theorists defend that humans have a set of basic emotions which are underpinned by biologically distinguishable functional states; on the other, social constructionists argue that these biological differences are limited to broad dimensions of affect such as valence and arousal – broadly known as core affect – and that emotions are better described as mentalisations of such core affect. Are emotions ingrained in the brain's architecture, or does the neurological evidence suggest that all emotions are fundamentally similar? In this essay, I take stock of neurological research on basic emotions and evaluate the extent to which current theory can help us answer this question. To do this, I first outline the classical and the social-constructionist views of emotion, then discuss a lesion case study and review neuroimaging evidence, and finally integrate these findings to shed light on the conceptual and empirical complexities underpinning the nature of emotions. Ultimately, I conclude that there is enough evidence to suggest that emotion states are fundamentally distinct.

*Keywords:* emotion, basic emotions, social constructionism, lesion, neuroimaging

### Introduction

Every day, humans automatically combine stimuli, life experience and billions of years of evolution to satisfy their biological and psychological needs. During infancy, reflexes guide reactions to basic stimuli that human evolution has determined beneficial or harmful, and during childhood and adolescence, ambiguous or neutral stimuli become associated with positive or negative outcomes (e.g. Skinner, 1984). Some automatic behaviours remain primarily determined by non-conditioned information in the nervous system, but over time, humans develop increasingly nuanced emotional responses and gain the ability to act volitionally (Bullock & Lütkenhaus, 1988; Izard,

2007; Simms, 2006). Yet, we never decide how to behave in a vacuum. We perceive the world in relation to our needs, and from the moment we are born, functional emotional states create evolutionarily adapted tendencies that help us to navigate complex environments in need of fast, self-relevant decisions (Frijda, 1986).

Initially, these basic emotional states were hypothesised to be ontologically different, but mounting evidence of overlapping phenomenological properties has led some researchers to hypothesise that this might not be the case. Specifically, scales that were built to measure basic emotions showed high correlations between similar affective states (e.g. anger and fear; Barret, 2006); the behavioral characteristics that were previously thought to universally represent individual emotions seemed to be impacted by cultural differences (Gendron et al., 2014); the autonomic manifestations of basic emotions reveal no clear patterns<sup>1</sup> (Kreibig, 2010); and initial meta-analyses of neurological bases of basic emotions proved to be inconsistent (e.g. Murphy et al., 2003 vs Phan et al., 2002). Altogether, the inability to differentiate emotions on the basis of mental, behavioral, and physiological properties led some researchers (e.g. Barrett, 2006) to depart from the classical view of emotion and question whether there are any bases to believe that individual emotions are biologically different.

## Two Perspectives

The classical view of emotion posits that emotions are discrete, functional states that can be differentiated through sets of recognisable, observable properties (Adolphs, 2017). According to this perspective, emotions are biologically driven affective states (Frijda, 1986) that provide intermediate flexibility for complex behavior (Adolphs, 2017). Unlike reflexes, which create a direct connection between input and output, and volitional behavior, in which motor output is independent from sensory input, emotions allow us to deal with environmental challenges in an efficient and context-sensitive manner by encouraging evolutionarily adapted action tendencies that influence cognition and predispose certain behavioral outputs (Adolphs & Anderson, 2018, Izard, 1992).

Emotions could have evolved from reflexes as action tendencies due to their utility in addressing recurring problems faced by our ancestors (Frijda, 1986; Tooby & Cosmides, 1990). Basic emotions motivate and regulate both cognition and action in order to achieve an adaptive advantage (e.g. Ekman, 1994; Ohman & Mineka, 2002). Joak Panksepp (1998) found that all mammals share seven innate 'primary emotional

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<sup>1</sup> For instance, anger, disgust and fear (three of the six basic emotions) share similar changes in most psychophysiological measures (i.e. heart rate, heart rate variability, systolic and diastolic blood pressure, electrodermal activity, respiratory rate, and even the adrenergic receptors they activate). Aggravatingly, happiness and anticipatory sadness (theoretically very different emotions) share more changes in common (heart rate, heart rate variability, respiration rate, systolic and diastolic blood pressure, skin conductance level, alpha adrenergic receptors) than anticipatory and acute sadness (different states of the same emotion; only respiratory rate; cf. Kreibig et al., 2010).

systems' that predispose action related to competence, reproduction, or self-preservation. The neurobiological systems responsible for such affective expression appear early in development (Buck, 1999), and many of these systems become functional during the first few years of age (Camras et al., 1998). Indeed, the existence and early development of a neurobiological system that fosters emotional reactions before higher cognition matures is a strong indicator that we have a basic set of evolutionarily determined affective responses.

On the other hand, the theory of socially constructed emotion postulates that our brains and bodies evolved to experience broad dimensions of affect, and discrete emotions emerge from the internal interpretation of this core affect (Barrett, 2006). As an analogy, we might think of emotions as colours: our eyes and brain work in tandem to sense varying wavelengths of light, but we interpret and communicate our appraisal of a particular wavelength by categorising colours on the basis of our previous experience and cultural preferences (Davidoff, 2001). Similarly, Barrett (2006) proposes that we can interoceptively sense varying degrees of an affective predisposition to certain events, but we classify these experiences into discrete emotions on the basis of past experience, cognitive schemas, and culture. Being exposed to similar categories of events throughout our lifespan and experiencing similar affective responses to those events may promote the view that all humans experience discrete categories of similar emotions, but—according to social constructionist theory—emotions *per se* do not have evolutionarily pre-determined neural circuits responsible for producing specific emotional experiences. Instead, social constructionists propose that emotions are more akin to cognitive concepts such as money (Barrett, 2017).

Indeed, it is also possible that nature selected for a more elementary affective system in the brain. Approaching what benefits us, and shunning away from what harms us, are the guiding principles of all human behaviour (Schneirla, 1959), so rather than discrete emotional states, evolution could have promoted the development of *broad affective systems* that use sensory systems and mental schemas to inform the organism whether a stimulus is harmful (i.e. good or bad; valence) and to prepare the organism for action if an immediate response is required (i.e. arousal; cf. Russel, 1980; cf. Chikazoe et al., 2014). According to this view, the behavioural direction of the action could be informed by both *behavioural inhibitory systems* (BIS), responsible for sensitivity to punishment and avoidance motivation, and *behavioural approach systems* (BAS), responsible for sensitivity to reward and approach motivation (Gray, 1981, 1982). In line with this perspective, Barrett (2006) proposes that the affective-state component of an emotion is best captured not by distinct emotion-states, but by broad dimensions of core affect such as valence, arousal, and BIS/BAS.

Specifically, Barrett (2017) proposes that self-referential systems transform core affect into individual emotions. To accomplish this, the default mode network forms an interoceptive sensation in the form of valence and arousal, the salience system matches our current goals with relevant sensory information about the world, and the

frontoparietal control network sustains a simulation of the expected sensations as well as the best action plan to maintain physical and psychological equilibrium. Together, these systems create individual mental states that drive specific action plans, and with experience, Barrett argues, we learn to categorise these mental states into distinct emotions.

The fundamental difference between these two perspectives is that classical theorists see emotions as *adaptive functional states* that arise in response to specific events, whilst constructionists assume that emotions are *predictive concepts* that prospectively regulate behaviour in the service of allostasis. The former seeks to find deep-seated affective states that are objectively shared by all humans; the latter provides a strong framework that successfully explains differences in emotion schemas, but rebuts the existence of naturally distinct emotion-states. In the next sections, I will discuss a lesion case study and review recent neuroimaging evidence to shed some light on the conceptual and empirical complexities underpinning this foundational debate.

## A Case Study

Patient S.M. is a woman born with a particularly severe case of Urbach-Wiethe disease, an extremely rare genetic condition in which hyaline deposits build up on skin, mucosa and internal organs (Hofer, 1973). One of the mysterious effects of this mutation is the selective calcification and consequent bilateral destruction of the amygdala, which—alongside S.M.'s willingness to collaborate with researchers—has enabled the scientific community to expand our understanding of the amygdala's role in experiencing fear (Feinstein, et al., 2016).

S.M.'s condition developed throughout her childhood; she claims to have autobiographical memories of being afraid as a child (before the disease had fully affected her amygdala), but now, as an adult, the only way she can experience an emotional state similar to fear is by breathing in air with higher concentrations of carbon dioxide (Feinstein et al., 2011, 2013). S.M. has accumulated a wealth of conceptual knowledge of fear through books, movies and conversations to the point where she can recognise fear in bodies and voices, correctly use the concept of fear in conversation, and tell you about the causes and manifestations of experiencing fear (Feinstein et al., 2016); yet despite exhibiting normal skin conductance responses to unexpectedly loud noises, her brain does not use arousal as a learning cue in fear-learning paradigms, nor show loss aversion when gambling, nor indeed show any of the normal manifestations of fear (Feinstein et al., 2011, 2016). S.M. appears to have successfully developed a *concept* of fear, but her ability to experience *emotion-state* fear as an adult is, at least, extremely limited.

There are, however, some facets of fear that S.M. might be able to experience without the amygdala. For instance, after a traumatically painful visit to the dentist, S.M. experienced anticipatory anxiety and strong feelings of worry at the thought of

experiencing similar pain upon returning to repeat the procedure (Feinstein et al., 2016). Additionally, she asked the experimenters not to repeat the CO<sub>2</sub> experiment because she had experienced a very unpleasant flashback to the time her ex-husband choked her after she tried to confront him about an infidelity (Feinstein et al., 2016). In both situations, she denied feeling scared both during the events (instead experiencing pain or anger, respectively) and at the prospect of repeating the procedures. However, the fact that she exhibited avoidance behavior to highly arousing, negatively valenced events shows that she could in fact experience key properties of emotion state fear, even if she did not associate those properties with her concept of experiencing fear.

Evidence from S.M. reveals three important facts:

1. First, state-fear is distinct from other emotional states. It appears that the complete calcification of S.M.'s amygdala prevented her from experiencing fear, but it did not impact her ability to experience any other emotions.
2. Second, state-fear is distinct from the concept of fear. S.M. had no trouble *understanding* the concept of fear, identifying it in others and even mentalising it, but her experience with state-fear is anecdotally limited to memories from her early life.
3. Finally, fear can be divided into different components. S.M. seems to experience fear-related schemas and feelings, but even if she is in a highly aroused, negatively valenced state, she does not consciously experience fear.

Hence, it seems that while fear cannot be subjectively experienced as a proper emotional state without the amygdala, the absence of the amygdala does not prevent someone from articulating the concept of fear, or experiencing the broader dimensions of affect that form part of a fearful response.

## Neuroimaging Debate

Interpreting neurological data can be tricky. Even if scientists ignore limitations in resolution and in sporadic correlations inherent to the physics of current neuroimaging technology (Bennet et al., 2009; LeDeux, 2012), they are left with the task of making sense of the most complex organ in the human body using fully correlational data. Early theorists hypothesised that emotions lay within specific regions of the limbic system (e.g. MacLean, 1952) but it was later accepted that no specific brain region is uniquely activated for each emotion (c.f. Murphy et al., 2003; Vytal & Hamann, 2010). Some theorists claim that the lack of one-to-one correspondence between brain regions and emotions violates one of the main characteristics of basic emotions (Barrett, 2017; cf. Ekman, 1999), but this argument does not appear to be entirely consistent. Classical and constructionist theorists agree that the word 'emotion' should be used in the same way we use the words 'vision' or 'memory' (Barrett, 2017; Aldolphs, 2017), yet, there is no strict one-to-one relationship between brain regions and vision (Hubel & Wiesel, 1979;

Pitzalis et al., 2018), and the nature of vision has not been questioned. Consequently, there is no reason why lack of one-to-one correspondence between emotions and brain regions should preclude emotions from being considered 'natural kinds' (cf. Anderson, 2016). Therefore, to identify whether basic affective operations are best represented by basic emotions or broad affective dimensions in the brain, we must look beyond the phrenological study of emotion, and seek consistently to identify unique *patterns* in neural activation that may represent functional emotional states.

Multi-voxel pattern analysis (MVPA) techniques have made great progress in finding such patterns (Celeghin et al., 2017; Kirby & Robinson; 2017; Saarimäki et al., 2016; Vytal & Hamann, 2010). By comparing data from more than one voxel at a time, MVPA has the power to analyse broader patterns of activity and can achieve a higher sensitivity than conventional univariate analysis (Mahmoudi et al., 2012). A significant problem in the study of the neural bases of emotion is that the methodologies used to induce emotions were responsible for a significant amount of variability across studies (Barrett & Wager, 2006), but studies using MVPA techniques have found unique neural signatures for each emotion that are independent from how the emotions were induced (Bush et al., 2018; Celeghin et al., 2017; Saarimäki et al., 2016). Through the lens of MVPA, the initially surprising findings that the amygdala is not only related to fear but also to anger, disgust, sadness and joy (Sergerie et al., 2008; Lindquist et al., 2012; Tettamanti et al., 2012; Kirby & Robinson, 2017) can be explained by the idea that emotions reside not in specific regions, but in specific *interactions* between regions (Pessoa, 2014). In line with this hypothesis, amygdala activity has been found to correlate with posterior visual areas during the processing of fear and with the dorsomedial prefrontal cortex (dmPFC) during the processing of happiness (Diano et al., 2017). Such idea of emotions residing in *networks* of regions as opposed to specific regions in the brain has opened up the door to new possibilities, and is already helping us make sense of previously incongruent findings.

However, Clark-Polner, Johnson and Barret (2016) interpret this evidence differently. They argue that biological categories involve highly variable individuals, and statistical patterns that distinguish one category member from another do not necessarily exist in nature. They take the lack of one-to-one consistency between categories and their members to mean that emotions are highly variable across individuals, and while categorising emotions in networks can provide a valid statistical summary, it does not prove that emotions are naturally distinct. In fact, the authors argue that this view aligns best with Barrett's theory of constructed emotion. Barrett hypothesised that the medial prefrontal and posterior cingulate cortices worked alongside limbic regions to produce allostatic predictions that we interoceptively perceive as emotions (see the Embodied Predictive Interoception Coding model; Barrett, 2012; Barrett & Simmon, 2015). Saarimäki et al.'s (2016) findings reinforce Barrett's hypotheses by showing that there are cortical and subcortical interactions during the experience of emotion, and that the medial prefrontal and posterior

cingulate cortices are two key regions for the subjective experiences of most emotional states. Thus, instead of interpreting Saarimäki et al.'s results as evidence that basic emotions lie within specific interactions, constructionists argue that these data reflect a *combination* of neural networks involved in affective interoception and emotion concepts rather than specific networks that represent basic emotions (Clark-Polner et al., 2016).

Nevertheless, there is a significant limitation to Barrett's arguments. The claim that statistical patterns do not reflect natural entities supports the idea that the classic view of emotion may have fallen into essentialism, but it neglects alternative explanations. For instance, it is possible that the lack of one-to-one consistency observed in neuroimaging studies is related to individual differences in the emotional schemas that are automatically activated alongside emotions (Damasio, 1999; Panksepp, 1994, Izard, 2007). While constructionists group together emotions and emotion concepts, classical theorists respond that in the same way 'concepts of planets are not planets, concepts of emotions are not emotions' (Adolphs, 2017); the two phenomena are distinct. Indeed, most inconsistencies between emotion categories are primarily distributed across cognitive or perceptual areas commonly associated with emotional schemas. Thus, given that modern technologies such as magnetoencephalography (MEG) and MVPA are only beginning to help us disentangle the seemingly overlapping patterns of activity in the limbic system, and disassociate emotion states from schemas in the brain, it would be premature to preclude the existence of individual emotion-states within broader affective networks (Izard, 2007; c.f. Saarimäki et al., 2015; c.f. Wager et al., 2015).

## Discussion

Emotion is a rapidly evolving concept. Neuroimaging technology has shown us that emotions have more dynamic neural representations than had we previously envisioned, but evidence from lesion studies continues to show us that certain brain regions are fundamental for experiencing certain emotions. Although all of this understanding has outdated Ekman's (1999) definition of basic emotions, neither classical theorists nor social constructionists have provided an accurate definition of emotion that encompasses extant evidence. Contrary to the classical view of emotion, it seems that basic emotions can be dissociated into more elementary facets of those emotions (cf. Adolphs, 2017), and contrary to social constructionist views, there is enough evidence to suggest that emotions are mental states that are neurologically different from each other and altogether qualitatively different from mental concepts that can be compared to 'money' (Barrett, 2017).

Lesion studies provide strong evidence for the classical view of emotion. S.M. is a clear example of 1) the extent to which fear schemas are different from state-fear; 2) the fact that fear is distinct from other emotions; and 3) that fear can be separated into different sub-components. If we considered concepts as emotions, we could argue that

the fear-related schemas S.M. has acquired throughout the years constitute an emotional experience, but electrophysiological data from fear-learning paradigms, behavioral data in loss-aversion tasks, and self-report data clearly indicate that she does not experience many of the markers that differentiate fear from other emotions (Feinstein, 2016). To be sure, the fact that she can experience negative valence, high arousal, and avoidance behaviors (e.g. at the prospect of going to the dentist, or breathing air rich in carbon dioxide) indicates she can still experience some of its physiological aspects, but the fact that in those scenarios S.M. misidentifies her emotional experience (as pain, or anger, respectively), speaks to the importance of the amygdala in producing *state* fear. Thus, because a lesion to the amygdala prevents S.M. from experiencing state fear, but not other aspects of fear or indeed other emotions, it is likely that at least the most primal component of individual emotions is a 'natural kind'.

Other non-neuroimaging approaches also support the importance of specific neural regions to emotion. S.M.'s case study is unique in that she suffers from a particularly severe case of a rare disease, but the data from this study are only part of the broader literature showing the importance of specific brain regions in relation to emotions. For instance, researchers have found that other lesions in specific brain regions can impact the recognition of individual emotions (Calder et al., 2001); specific neural populations can produce specific-emotion behavior (Lin et al., 2011); fear does not rely on cognitive processes for its activation (Öhman & Mineka, 2001; Mineka & Öhman, 2002); and direct brain stimulation can elicit discrete emotions (e.g. Krack et al., 2001; Okun et al., 2004). Together, these non-neuroimaging findings suggest that there is indeed a strong relationship between brain regions and individual emotions, and that—in theory—if we mapped all of these regions and stimulated the appropriate areas, we should be able to artificially induce the functional state that underpins emotional experiences.

Neuroimaging evidence presents a slightly different picture. Based on current data, Barrett (2017) builds a compelling case that limbic regions govern elementary functions related to arousal, saliency, and relevance, and cortical regions help shape these emotional states into emotions (Barrett, 2017). However, her argument falters when she interprets this as evidence that emotions do not have specific neurological underpinnings. Neuroimaging evidence does suggest that becoming cognitively aware of our emotion-states involves interoceptive processes that make use of systems such as the default mode, salience, and frontoparietal control networks (Barrett, 2017; Damasio & Carvalho, 2013; Kragel & LaBar, 2014), but there is little evidence indicating that emotion states do not have distinguishable neural systems beneath the neural representations of these emotion-concepts. In fact, there is some evidence from MVPA studies suggesting that emotion states lie *within* specific interactions in the brain (Bush et al., 2018; Celeghin et al., 2017; Saarimäki et al., 2016). Additionally, there is also nascent evidence from a MEG study using MVPA that different emotions exhibit unique

temporal dynamics (Grootswagers et al., 2021), which suggests that the nature of these interactions may not only be physical, but also temporal. As things stand, constructionists have interpreted the current lack of one-to-one consistency found in neuroimaging studies as proof that significant findings are but statistical summaries, and that emotions are not to be found in nature. However, given that most interpersonal differences are found in cortical regions that are also associated with emotion schemas, and that different physical and temporal interactions of the same neural regions elicit different emotion states, it is possible that emotion states (but not emotion schemas) consistently rely on unique patterns of neurological activity.

Together, neuroimaging and lesion studies stress the importance of individual brain regions for emotion-states while highlighting the relevance of emotion schemas in shaping the subjective experience of emotion. Classical theorists propose that basic emotions are the fundamental reality of the brain's affective architecture, and constructionists counter this by arguing that broad affective systems are in fact the irreducible reality in the brain, and that emotions are better described as mentalisations of core affective states. The constructionist view is compatible with neuroimaging evidence in the sense that if broad affective systems were damaged, people would not be able to mentalise core affects and therefore struggle to subjectively experience emotion, but this view is incompatible with lesion evidence in that it predicts that individual emotions (e.g., fear, disgust) cannot be selectively cut. Indeed, if broad affective systems were the fundamental reality of the brain, and a lesion damaged one of these systems, the repercussions should impact at least whole clusters of similar emotions, but this is not what the data show. There is strong evidence that lesions to the amygdala can prevent people from selectively experiencing state-fear (Feinstein et al., 2016), and lesions to the insula and basal ganglia prevent people from selectively experiencing state-disgust (Calder et al., 2000), while the opposite is not true. Moreover, even though the amygdala and insula are closely associated with the salience and default mode networks, respectively, selective damage to one of these regions does not prevent people from mentalising other emotions—even if they are closely related (i.e. both anger and disgust are highly arousing, negatively valenced emotion). Thus, given that there are key regions without which people can experience all emotion states but one, but no such relationship exists between brain regions and emotion schemas, it seems likely that emotion states are affective experiences qualitatively different from emotion schemas that merit individual distinction.

## Conclusion

Early theorists postulated that emotions are evolutionarily adapted affective states that promote specific action tendencies, but inconsistent evidence concerning their neurological underpinnings prompted some theorists to hypothesise that perhaps emotions were better construed as mentalisations of core affective states. Based on neuroimaging data, Barrett (2006, 2017) makes a compelling argument that subcortical

regions might govern elementary aspects of emotion such as arousal, saliency, and relevance while cortical regions help to shape these emotional states into the emotion concepts we experience. However, more recent neuroimaging findings indicate that emotions are underpinned by unique physical and temporal patterns of region-activation, and lesion evidence indicates that certain subcortical brain regions are vital to the proper experiencing of emotion states. Thus, it is possible that individual regions are responsible for different *aspects* of the emotion, and that basic emotion states are found within unique but overlapping networks of regions. In this manner, our emotional experiences could arise from a unique collection of properties, with emotion-states eliciting consistently distinct combinations of neural networks, and emotion concepts activating highly variable representations in cortical regions that allow us to create, update, and implement allostatic schemas. Future research should aim to elucidate the exact relationship between emotion concepts and emotion states, but as things currently stand, there is enough evidence to suggest that emotion states are grounded in the brain's architecture.

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