The Human Affectome

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Abstract

We present here a unifying framework for affective phenomena: the Human Affectome. By synthesizing a large body of literature, we have converged on definitions that disambiguate the commonly used terms—affect, feeling, emotion, and mood. Based on this definitional foundation, and under the premise that affective states reflect allostatic concerns, we take a goal-directed, enactive perspective. The human affectome is comprised of allostatic features (valence, motivation, and arousal) and allostatic concerns, which differ in the amount of action required to alleviate allostatic load. Allostatic concerns often fall into three ranges: physiological (the most immediate), operational (intermediate to distal), and global. Global concerns involve summations of overall trajectory, general wellbeing, and self-identity. Within this organizational scheme, the human affectome allows vastly different scientific interests to reside within the same theoretical framework and relate to each other. We hope this framework serves as a common focal point for affective research.

Key Words: Feeling; Emotion; Mood; Affect; Valence; Motivation; Arousal; Allostasis; Physiology

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Introduction

In the 1990s, seminal books by Antonio Damasio (Descartes' Error, 1994), Joseph LeDoux (The Emotional Brain, 1996), and Jaak Panksepp (Affective Neuroscience, 1998) came to signify the modern neuroscientific study of emotion in the brain. From this beginning, what is now called 'affective neuroscience' encompasses an interdisciplinary field that combines cognitive neuroscience with the psychological study of affective experience, such as feeling, emotion, and mood, to investigate how these constructs are linked to behavior, personality, and disorder. As cognitivism fulfilled the mission of combatting behaviorism, we no longer underestimate the value of studying mental states, and we no longer limit research solely to the observable (Dukes et al., 2021). Yet, we are left with a gaping conundrum: how do we study an experience that is private in nature? While cognitive processes, such as perception, reasoning, memory, and attention, are investigable by means of behavioral tasks and other objective measures, affective experience proves to be more difficult to study for several reasons. First, terminology surrounding constructs such as feeling, emotion, and mood, has been vague and inconsistent. Second, despite extensive research, both academic and colloquial understanding of affective experience is still under debate. Third, without a definitive understanding guiding the design of behavioral tasks and measurements, we lack consensus on how to study affective experience systematically. Lastly, introspective verbal report—the gold standard for accessing subjective experience—is inconsistent

and context-dependent, as often seen in individual differences, empirical manipulations, and cultural variations (Barrett, 2011a; Dehaene et al., 2003; Ericsson and Simon, 1993; Harmon-Jones et al., 2016; Kahneman, 1999; Lindquist et al., 2013a; Mauss and Robinson, 2009; Robinson and Clore, 2002; Rosenthal, 2019; Wilson, 1994).

This capstone paper attempts to address these challenges. This work is authored by the entire taskforce of a global interdisciplinary working group (173 scientists from 26 countries) that has collaborated on a project titled '*The Human Affectome Project*'. The project united diverse research areas and comprehensively surveyed and categorized feeling words of major affective phenomena. A computational linguistic approach identified over three-thousand feeling words in the English language, and an expert coding process assigned each word to a feeling category (Siddharthan et al., 2018). Divided into teams, the taskforce then produced twelve reviews (published in this issue), each summarizing much of what is currently known about affective neuroscience.

At the outset of this endeavor, we defined the Human Affectome as a conceptual umbrella that encompasses all aspects of human affective experience. To describe the Human Affectome, we provide an overview of an integrative theoretical framework. The framework delineates the major affective constructs within this realm—affect, feeling, emotion, and mood—and we propose a unified model that explains how these concepts are related to one another and ultimately tie to human behavior. In the following sections, we first define the major affective constructs within the human affectome, and then provide a theoretical model that carves up a functional taxonomy of felt experience. By doing so, we wish to provide a useful rhetorical framework for studying the affective aspect of mental experience. We hope this framework serves as a common focal point for affective research.

Terms & Theory: A Foundation

The terms feeling, affect, emotion, and mood, have been largely used interchangeably and inconsistently, which has led to much confusion. We hope to clear up this ambiguity by building a coherent synthesis of the theoretical background of these terms, ultimately, aiming to propose distinctions and definitions for these concepts for common interdisciplinary use. Specifically, we consolidate an ontology—a set of affective categories with specifications of their definitions and relations to each other. In untangling the theory surrounding this terminology and synthesizing consistent conceptualization, we build the foundation for the approach we take in the subsequent integrative framework: the Human Affectome. Thus, along the way, we also leverage this review of terminology to clarify our theoretical assumptions.

Affect

Affective states have three fundamental features (i.e., the qualitative aspects that mark affective experiences; Anderson and Adolphs, 2014). The first is valence—an evaluation of the goodness or badness of a state, or the quality of an experience on a positive-to-negative spectrum**.** The second is motivation—implying the directional intensity of an action tendency along the approach-to-avoidance spectrum. The third is arousal, defined as the physiological activation of the autonomic nervous system. High arousal often corresponds to high valence and motivation, just as

motivational direction often corresponds to valence (e.g., approach to positive valence). Nevertheless, these features are independent since the location on one of these dimensions does not always signify location on the other dimensions (e.g., Kuppens et al., 2013).

Affective states are relative to a comfort zone—a stable but dynamic organismic state. Two complementary processes are presumed to maintain a balanced organismic state: homeostasis—a regulatory error-correcting process that protects an internal 'set-point' based on physiological feedback (Cannon, 1932; Cooper, 2008; McEwen and Wingfield, 2003; Schulkin and Sterling, 2019); and allostasis—a regulatory error-anticipating process that meets predicted needs using feed-forward signals (Sennesh et al., 2022b; Sterling and Eyer, 1988). Homeostasis is a local regulatory process of individual parameters (e.g., correcting calcium levels to a set-point), whereas allostasis is a centralized process that orchestrates multiple parameters based on anticipated needs. The two processes are complementary because allostasis aims at preventing errors that would require a homeostatic response, but homeostasis is needed when errors occur.

Allostasis, as the etymology indicates ('stability through change'), is advantageous in unstable environments by adjusting internal parameters as needed rather than maintaining a fixed preset value. Allostasis can also be viewed as subsuming homeostasis: organizing the agent's regulation and behavior to make sure that homeostasis can keep protecting the basic elements required to navigate the world in order to sustain life (Carpenter, 2004; Sterling, 2012, 2020; Sterling and Eyer, 1988). Both homeostasis and allostasis arise from autopoiesis: the necessity for an organism to self-organize and self-generate. To self-organize, the organism must remain an operationally closed system (i.e., functionally separate) as it will otherwise dissipate into environment. To self-generate, the organism must keep generating its own material.

Based on these regulatory processes, affective states are inherently allostatic: affective experience indicates the current allostatic state of the organism and its trajectory in the ongoing environment—how at risk are we from leaving the comfort zone and how to alleviate that risk. Allostatic information may reach consciousness and coalesce (with additional processes such as memory and perception, and utilizing multimodal information) into subjective experience, signaling the individual's evaluation and readiness to act in the world as an agent that regulates needs (Frijda, 1986, 2004). Individuals narrate and verbalize affective states using linguistically and culturally designated terms.

Embodied & Enactive

Finally, affective states might be considered through the lens of embodied and enactive cognition. Affect is embodied in the sense that it is not presumed to be encoded by non-physical symbolic entities manipulated in the brain, but rather encoded in the material of the entire nervous system, both central and peripheral (Shapiro, 2019). Affect is enactive by virtue of its role in making sense of an environment through sensorimotor bodily activity (Di Paolo and Thompson, 2014). Rather than passively registering sensory information into an internal symbolic representation, organisms actively exercise sensorimotor processes to make sense of, and bring about, their environment. Affective states, therefore, can be viewed as inherently geared towards allostatically-driven action (Dennett, 1987; Frijda, 2004; Newen et al., 2018; Thompson, 2010; Varela et al., 1991), reflecting changes in action readiness (Frijda et al., 2014) This process can be formalized as a prediction or

modeling of the internal and external environment for the sake of action (e.g., Barrett and Simmons, 2015; Clark, 2015; Frijda, 2004; Friston et al., 2017; Seth and Friston, 2016).[1]

In sum, we converge on the following working definition of affect:

1. Affect is characterized by metrics of valence, motivation, and arousal, and is inherently about action tendency.
2. Affect is anchored to an organismic comfort zone, and signifies impending departure from it and actions needed to mitigate resulting risks.
3. Affect is an embodied and enactive process.

Feeling

Feelings are first-person conscious mental states that have qualitative character that is experienced (Chalmers, 1996; Locke, 1690; Nagel, 1974; Siewert, 1998). In this broad sense of 'felt'—as the raw qualitative aspect that marks all experience—one might define 'feeling' as *anything* experienced, i.e., any first-person conscious mental state, such as thoughts and bodily sensations (Bayne and Montague, 2011; James, 1890; Siewert, 1998), that evolved for maintaining organismic imbalance (Damasio and Carvalho, 2013). Feelings are characterized by internal consistency, organized structure, and functional richness (Brentano, 1874; Chalmers, 1996; Husserl, 1929). That is, feelings have some structure to them and are non-random, which allows some interpretation based on semantics and meaning (Chalmers, 2012; Dretske, 1995, 1998; Fodor, 1975; Hardin, 2011; Newell and Simon, 1972b; Putnam, 1976; Sellars, 1956; Sellars, 1967).

Intentional

Feelings can be translatable into 'propositional attitudes': an attitude one has toward a state of affairs (Frege, 1892; Russell, 1948). These propositional attitudes, expressed in feeling words, can be used to interpret and communicate mental states. The expression "I feel…" indicates that an individual is having an experience that has valence, motivation, and arousal, reflecting the individual's action tendency toward the object of that feeling. Felt experience thus has meaning and logical structure, reflected in linguistic expression. If assigning content to an organism's state and explaining and predicting its behavior based on that content makes sense, then the organism acts intentionally, and the assignment of feeling content is true: the system is not arbitrary and there is structure to it. This is the role linguistic expressions of feeling may play: adopting an 'intentional stance' toward a system or an organism (Dennett, 1987). Note that we do not mean to say that mental states are, themselves, linguistic—merely that such abstraction can be helpful in identifying and communicating about the neurocomputational mechanisms of feelings (Egan, 2018b, 2020). Based on the assumption that felt experience has systematicity, we can construct a model of felt experience and the relationship between its components (Schoemaker, 2011). Thus,

[1] There is another, more radical, claim that we do not take up here: minds extend beyond our bodies into the external world if they are sufficiently incorporated into our cognitive system (Clark, A., Chalmers, D., 1998. The Extended Mind. Analysis 58, 7-19.)

we can outline structure to affective linguistic expressions, and a foundation for scientific inquiry using verbal report (Scarantino, 2017).[2]

In sum, feeling can be defined as a conscious mental representation that:

1. emerges from physiological bodily states, central neural activation, and environmental circumstances;
2. varies along dimensions of valence, arousal, and motivation;
3. and is related to allostatic aspects of survival and life regulation, reflecting the individual's action tendency toward the object of that feeling.

As we discuss in the following sections, emotion and mood are both encompassed within affect and can be regarded as types of feelings, affective states, or affective experiences. Additional feeling types, which do not fall under emotion or mood, are physiological states induced by sensory stimuli (sights, sounds, smells, tastes, touch, and visual aesthetics), which also have the features of valence, motivation, and arousal.

Emotion

Given that all conscious experiences are 'felt' in a broad sense, the term 'emotion' usually refers to a subset of feeling, or a certain set of felt experiences (Lambie and Marcel, 2002b; Leighton, 1985; Pugmire, 1998b). The breadth of affective experiences within that subset, however, varies a great deal. Some use 'emotion' and 'feeling' interchangeably but exclude physiological feelings (e.g., hunger, thirst) when considering emotions per se (e.g., MacCormack and Lindquist, 2019). In other cases, emotion is used more narrowly to denote affective experiences only on the higher end of the valence and motivational scale, with high demand for allostatic regulation. For instance, fear, anger, or surprise are considered emotions that signal significant departure from the comfort zone; but calmness, serenity, or pensiveness lack these characteristics and may not be considered 'emotions' in this narrow sense of the term.

Given the wide range of perspectives on emotion (Dixon, 2012) this section does not aim to be a comprehensive review, but instead attempts to sort two broad classes of emotion theories based on their explanatory goals and consequent methodologies: philosophical (*what* emotion is) and scientific (*how* emotion works). In doing so, we hope to emphasize points of pragmatic convergence among these classes, and to situate them within the framework of the Human Affectome.

Philosophical: the 'what' of emotion

The first class of theories that we consider are philosophical theories of emotion. Having proliferated since ancient times, these accounts aim to understand the metaphysics of emotion, or *what* emotion is (Dixon, 2003, 2012; Scarantino, 2016; Solomon, 2008). In contemporary philosophy of emotion, this definitional effort has primarily relied on tools of conceptual analysis (Jackson, 1998), which aim to give charitable interpretation of folk theory in an explicit, reasoned, and parsimonious manner, while adjusting those intuitions when they fail to be systematic (Farr

[2] For an overview of the debate on mental representation, see Pitt, D., 2020. Mental Representation, in: Zalta, E.N. (Ed.), The Stanford Encyclopedia of Philosophy, Spring 2020 ed. and Lycan, W., 2019. Representational Theories of Consciousness, in: Zalta, E.N. (Ed.)ibid., Fall 2019 ed..

and Ivanova, 2020). Often, this analytical approach has focused not only on distinguishing emotion from other affective kinds, but also providing ground to individuate emotion types (Deonna et al., 2015; Deonna and Teroni, 2012a; Goldie, 2000a; Scarantino and de Sousa, 2021; Teroni, 2017).

Philosophers of the mind ask whether emotions are in essence conscious or felt at all (Lambie and Marcel, 2002a; Pugmire, 1998a; Stocker, 1983). While unconscious emotions have been considered (Hatzimoysis, 2007; Lacewing, 2007), there is widespread consensus that emotions are *episodes of experience*, that is, they are consciously experienced over a duration of time (Goldie, 2000a; Wollheim, 1999).[3] Some assert that it is this felt aspect that constitutes an emotion (e.g., James, 1890; Lange, 1885). Considering emotions as episodes helps distinguish them from affective dispositions such as being an angry person, rather than being angry in the moment in reaction to a specific trigger (Broad, 1954 ; Deonna and Teroni, 2020; Deonna and Teroni, 2009; Lyons, 1980; Mulligan, 1998; Ryle, 1949).

Philosophy of mind and philosophy of language consider 'intentionality': whether emotions are *about* or represent something ('particular object') and, if so, which properties ('formal objects') are ascribed to that object by virtue of having an emotion directed at it (Bedford, 1956; Brentano, 1874; De Sousa, 1987; Kenny, 1963; Leighton, 1985; Pitcher, 1965). For example, you might be angry at a car [particular object] on your morning drive by deeming it an obstacle [formal object]. To some, whether emotions are representational (i.e., about something) distinguishes them from moods, which are not about anything in particular (see section on *Mood* below). If emotions confer properties to objects, then they are subject to the 'epistemological constraint of correctness': whether the knowledge that emotion conveys about an object's properties is justified or fits the facts (Searle, 1983). For example, you might be angry at a person who turned out to do no harm, which is a case where the property conferred to that person is incorrect. Some assert that these evaluative beliefs are what defines emotion, rather than their felt quality (Furley and Nehamas, 1994; Goldie, 2000a; Goldstein, 2002; Gordon, 1987; Green, 1992; Lyons, 1985; Marks, 1982; Neu, 2000; Nussbaum, 2001; Solomon, 1980; Whiting, 2011).

Considering the correctness of emotion also facilitates differentiating between types of emotion—an idea embraced by some psychological theories (Teroni, 2007). For example, wading into ethics and moral psychology, beliefs conferring adherence or violation of ethical standards may characterize moral emotions, such as disgust or pride (D'Arms and Jacobson, 2000; Rabinowicz et al., 2004; Tappolet, 2012). Others, however, still disregard belief as the central aspect of emotion, designating it as important but auxiliary, arguing that perception (e.g., (De Sousa, 1987; Prinz, 2004; Roberts, 2003; Tappolet, 2016)) or feeling (e.g., (Goldie, 2000b; Helm, 2009)) of such beliefs are at the heart emotion.

Another candidate for the essence of emotion is readiness for action (Dewey, 1895; Frijda, 1986; King, 2009). These theories define emotion as feeling one's body prepared for action as an evaluative attitude toward an object (Deonna et al., 2015; Deonna and Teroni, 2012a), or the change in potential for behavior itself, without the necessity for feeling (Scarantino, 2014, 2015).

[3] There is further, notoriously unsettled, debate concerning what consciousness is. The point of this paper is not to debate about the essence of consciousness, but to organize the contents of consciousness.

Finally, enactivist theories follow from the motivational approach, but instead emphasize that this is not unique to emotion: the entire cognition of a self-generating organism prepares that organism for action in order to keep self-sustaining (Varela et al., 1974). According to this view, emotion might be considered a dynamic process in the continuous effort to self-organize by making sense of an external world (e.g., Colombetti and Thompson, 2008; Shargel and Prinz, 2017; Slaby and Wüschner, 2014)). By situating action as the teleological purpose for cognition, emotion may not need representational beliefs as proxies in defining its nature (Hufendiek, 2018; Hutto, 2012).

All in all, the debate is far from settled, but philosophical theories of emotions converge in that they seek to explain the nature of emotion: what makes emotion what it is.

Scientific: the 'how' of emotion

The second class of theories—scientific theories of emotion—are found at the intersection of scientific disciplines, whether with special interest in the brain ('affective neuroscience', (Panksepp, 1998) or under a broader interdisciplinary umbrella akin to cognitive science ('affective science'; Gross and Barrett, 2013). While these theories may assume metaphysical claims about what emotion is, they ultimately gravitate in their central explanandum—the phenomenon they aim to explain—toward *how* emotion unfolds mechanistically (Hempel and Oppenheim, 1948). Scientific theories infer phenomena by construing scientific explanations for empirical data, aiming to predict future effects (Glennan, 1996; Hempel, 1965b; Hempel and Oppenheim, 1948; Kauffman, 1971). As such, the main emotion phenomena of interest often concern characterizing emotion in relation to attainable types of data, as well as providing a mechanistic causal structure of emotion by relating it to upstream influences or downstream effects (Bechtel and Abrahamsen, 2005; Glennan, 2002; Machamer et al., 2000). These approaches fall into the following overlapping domains: individual differences in experience and awareness of emotion; influence of, or effect on, related features of emotion (e.g., evaluative beliefs, motivation, physiology, subjective experience); social perception and expression; effects of context (e.g., development, cognition, language, relationships, culture), and the role of emotions in behavior and clinical disorders (Barrett et al., 2016).

Although often implicit. definitions of emotion provide the theoretical foundation necessary for the scientific process (Azzouni, 2004; Chang, 2005; Farr and Ivanova, 2020; Mill, 1843; Whewell, 1858). A scientist must defer to a theoretical construct referring to a state of affairs, such as emotion, to explain observable data (Carnap, 1966; Hempel, 1965a; Hempel, 1952; Lewis, 1970; Lewis, 1972). The methodological approach that scientists take to interpret empirical data reveals those underlying metaphysical assumptions, which are subject to the scientist's individual and contextual biases (Fox, 2018; Morganti and Tahko, 2017; Scarantino, 2016). When empirical methods cannot arbitrate between equivalent hypotheses, non-empirical considerations, such as parsimony (Occam's razor), are necessary to evaluate whether one metaphysical claim applies better than another (Achinstein, 1983; Duhem, 1954; Farr and Ivanova, 2020; Ivanova, 2010, 2017; Ladyman, 2012; Lowe, 2002; Paul, 2012; Poincar et al., 2018; Van Fraassen Bas, 1980; Van Fraassen, 1990).

From a pragmatic perspective, we can cluster scientific theories of emotion by the metaphysical assumptions that scientists embrace (whether explicitly or implicitly):

Basic emotion theories claim that there are specific sets of emotion types that are natural kinds: different types of emotions are identified and distinguished by biologically basic programs, consisting of innate and universal causal mechanisms and responses (Adolphs, 2017; Ekman and Cordaro, 2011; Izard, 2007; Levenson, 2011; Panksepp, 2011). Under this assumption, basic emotion researchers study specific physiological, neural, cognitive, and experiential markers, as indicative of specific basic emotion types (Ekman, 1999). The assumption that emotion types can be individuated by natural markers, however, received theoretical pushback (Barrett, 2006a; Griffiths, 2004; LeDoux, 2022; Machery, 2005; Ortony and Turner, 1990).

Appraisal theories claim that emotion results from evaluations occurring across a hierarchy of information processing (Arnold, 1960; Lazarus, 1984; Scherer et al., 2001). Different appraisal theories differ in their claims about how the appraisal process individuates emotions (Moors, 2014; Moors et al., 2013; Scarantino, 2016; Smith and Lazarus, 1990). One approach assumes that the output from all appraisals is integrated into a master appraisal, which is the unique cause of discrete emotion types. For instance, appraisal ingredients may result in the appraisal of loss, which will pick out sadness (Lazarus, 2001; Roseman and Smith, 2001). The second approach does not claim integration into a discrete appraisal, but instead assumes that appraisal dimensions narrow down into infinite combinations that causally differentiate infinite types of emotion (Grandjean and Scherer, 2008; Scherer, 2009; Scherer and Moors, 2019). Computational models may pin down the nuanced dynamics of these dimensional appraisal processes (Cunningham et al., 2013; Sander et al., 2005; Scherer, 2021). The last approach of appraisal theories presents a stronger metaphysical claim, closer to evaluative philosophical theories: that appraisal does not cause emotion—it constitutes emotion (Clore and Ortony, 2000, 2013; Ortony et al., 1988).

Constructionist theories counter the assumptions and methodologies of both basic and appraisal theories (Barrett, 2011b). Opposing basic and discrete appraisal (first approach) theories, constructionist theorists argue that boundaries around emotion types are not universal, innate, or fixed in cause, citing evidence that the associations between markers and emotion types are variable and context-based (Barrett et al., 2019; Cordaro et al., 2015; Gendron et al., 2018; Gendron et al., 2014a; Gendron et al., 2014b; Lindquist et al., 2013b; Russell et al., 2003). Based on this counterevidence, the range of constructionist theories share the claim that emotion types are variable constructions of lower-level ingredients—often more basic feelings or dimensions in feeling—even if they differ in which ingredients are involved and what 'construction' means (Scarantino, 2016).

For example, one theory argues that emotions are felt states that are accumulations of lower-level bodily changes (Damasio, 2003; Damasio, 1994). Most other 'psychological constructionists', instead, steer away from commitment to bodily markers and home in on generic dimensions of neural activity (Gendron and Barrett, 2009; Russell, 2009). These theories often posit two specific dimensions of non-specific affective ingredients that are present as 'core affect' across all cognitive experiences, whether emotional and not: valence and arousal (Russell, 2003). Similar to dimensional appraisal (second approach) theories, these have been studied through self-report measures mapping various emotion labels along these two dimensions (Barrett and Russell, 2015). These constructionist theories, however, oppose the assumption of causality in appraisal theories. Rather, they construe the dimensions of valence and arousal as emergent characteristics of emotions, rather than causal precursors (Russell, 2003). In earlier constructionist theories, one

theory studied processes associated with those components at the reportable psychological level, without attempting to track relations between precursor mechanisms leading up to specific emotion types, or even identifying a set of mechanisms that unify the construct of emotion (Russell, 2012a; Russell, 2015). Another similar earlier theory, instead, studied the variable categorizations of those dimensions, often using operationalizations of semantic knowledge, such as emotion labels, affective images, or videos (Barrett, 2006b; Barrett et al., 2015).

This latter theory morphed into one with stronger opposition to the causal appraisal cluster, denying emotions to be responses at all, and thus, closer in metaphysical assumption to the constituent (third approach) appraisal theory (Barrett, 2017a). This resulted from a rising predictive view of the nervous system instead of the traditional stimulus-response conception of cognition (Hohwy, 2013). This perspective presumes that neural organization is a probabilistic model among deep cortical layers that anticipate incoming sensory signals in order to infer explanations for new neural information (such as through 'approximate Bayesian conditional probability'; Bastos et al., 2012; Knill and Pouget, 2004b). Learning consists of updating this model according to its error in prediction, such that synaptic plasticity encodes strengthening of certain parameters in the model across updates (Friston, 2003; Schultz et al., 1997; Schultz and Dickinson, 2000).

A particular thread of the predictive view—active inference—makes a strong enactive commitment (Constant et al., 2021; Ramstead et al., 2020). Active inference proposes that consideration of what might be the best subsequent action drives learning. Here, action choice is guided by an underlying principle that the organism should minimize global information entropy among prediction errors, across all levels in a self-generating and self-organizing system (Friston, 2010; Friston et al., 2016; Friston et al., 2017). In order to motivate the hypothesis that emotion types are mutable and variable, the most recent strand of constructionist theory suggests that emotions are constructions in virtue of being learned inferences of what incoming sensory data means in terms of allostatic action (Barrett, 2017b). This semantic commitment to a particular formal framework invites the application of computational models to constructionist methodologies.

Yet, according to psychological constructionist theories, the mechanism for emotion is presumably that for all cognition, and thus the ontological question of what distinguishes emotion from other affective kinds remains unaddressed. Indeed, what unites the psychological constructionism cluster of theories is that they do not seek to provide one process as *the* explanation for emotion (Russell, 2012b; Russell, 2015). All in all, the metaphysical assumption among all constructionist theories, psychological and not, is that emotion is primarily an emergent feeling. The mechanistic hypothesis of constructionist theories has given rise to a rich literature of research characterizing the variability in emotional experience and concepts, dependence on bodily and external context, and mutability across development and training (Barrett, 2009; Gendron et al., 2012; Hoemann et al., 2021; Hoemann et al., 2020; Hoemann et al., 2019; Lindquist et al., 2015a; Lindquist et al., 2015b; Nook and Somerville, 2019).

Over the years, scientific theories of emotion have proliferated within these three broad clusters as well as between and beyond, but this diversity has only increased without movement to consensus on which theory reigns supreme. This is likely due to the differences in metaphysical assumptions

(and the following translation to methodologies), which empirical data cannot settle (Deonna and Scherer, 2009), since the metaphysical tenets of these theories are, themselves, unfalsifiable. Such theoretical frameworks can only guide research programs, which will then encompass more specific testable theories (Ormerod, 2009; Popper, 1963). Although each of these frameworks' metaphysical stance on 'what is emotion' can be inferred from their methodologies, they are often philosophically unclear—making the attempt of parsing them intractable (Deonna and Scherer, 2009; Mulligan and Scherer, 2012; Scarantino, 2016) and prone to biases (Achinstein, 1983; Frappier et al., 2017; Van Fraassen Bas, 1980; Van Fraassen, 1990).

This history is remarkably akin to the disparate proliferation in scientific frameworks of neural correlates of consciousness (Doerig et al., 2021), which has resulted in an adversarial collaboration aimed at organizing each framework's metaphysical claims, deriving consequent falsifiable hypotheses, and testing those empirical consequents (Crick and Koch, 1990; Melloni et al., 2021). It remains to be seen whether this careful and systematic mobilization of scientific theorists of consciousness help situate their metaphysical claims in relation to each other, if not succeed in settling the competition between their claims (Yaron et al., 2021). The similarity between the trajectory of these two academic fields is not surprising given the close, albeit unsettled, ties between emotion and conscious experience (Izard, 2009; James, 1890; Lange, 1885; Teroni and Deonna, 2017). While the academic discussion about consciousness may be unsolvable in principle (Chalmers, 1995), scientific frameworks of emotion may have better prospects in converging on the same metaphysical assumptions by clearly defining the metaphysical claim of emotion at use, outlining consequent testable theories, and comparing and integrating theories where they might be compatible with the same metaphysical claim (Deonna and Scherer, 2009; Doerig et al., 2021). Note that, while we do not make a strong commitment to a metaphysical claim about what consciousness is—we do assume that organisms, including animals, babies, and adults, have some form of conscious experience, which enables 'feelings' to be felt or have some quality of subjective experience.

Such comparative and integrative efforts have emerged. The basic emotion framework and the discrete approach of the appraisal framework may be compatible with dimensional appraisal and constructionist research programs, if basic emotion types are considered common clusters of feeling with shared biological mechanisms (LeDoux, 2020; LeDoux et al., 2015; Panksepp and Watt, 2011; Scarantino, 2015; Scarantino and Griffiths, 2011). Dimensional appraisal and constructionist frameworks might merge by encompassing their separate claims in a single, parsimonious claim of goal-directedness (Moors, 2017). In the following section, we will synthesize a proposal for how philosophical claims about *what* emotion is might guide scientific research programs motivating testable theories that investigate the mechanisms, or the *how*, of emotion and related phenomena.

In conclusion, despite differing theoretical perspectives on emotion, there is at least consensus that:

1. Emotions are first-person conscious organismic states that are rooted in evolution and implemented in physiological and neural circuits (either specific or general-purpose mechanisms).
2. Emotions are driven by external or internal stimuli and inferred based on biological and/or psychological significance.

3. The function of emotions subserves survival needs via allostatic regulation.

However, not only should we, as researchers of emotion as well as other affective types, be aware of these different theoretical perspectives—our work should be cognizant of the assumptions that each perspective carries.

Pragmatic: the 'why' motivating the study of 'what' and 'how'

Philosophical and scientific classes of emotion theories differ depending on the discipline or theoretical interest. From a pragmatic perspective, this may be due to the context-dependent interests of different subfields (Achinstein, 1983; Bromberger, 1966; De Regt and Dieks, 2005; Scriven, 1962; Van Fraassen Bas, 1980). Epistemologists might be interested in whether emotions can be defined as carriers of beliefs because of their wider interests in explaining knowledge. Philosophers of mind care about consciousness, and so strive to situate the definition for emotion in relation to it. A scientist with a background in animal models may assume universality in emotion types to study mechanisms that differentiate those types in animals whose experiences are inaccessible. Discrete appraisal theorists are more concerned with attitudes that might delineate emotion types rather than mechanisms, due to their interest in cognitive causes of emotion. Dictating what scholars are interested in and what they will accept as explanation, seem to hinge on *why* they ask those questions in the first place.

Therefore, to muster a research program that confronts emotion with the utmost consistency and coherence in conceptualization, it must be collaborative and integrative of a comprehensive sampling of perspectives on why inquiries into emotion should be made and answered. To compare and integrate not just theories, but their overarching metaphysical frameworks in a non-adversarial manner, will help wading through the labyrinth of emotion theories (Bechtel, 2009; Tabery, 2014).

Formalism, computation, and algorithm are ripe tools for crossing theories, frameworks, and disciplines (Cartwright, 1983; Suppes, 1962). While formalism and computation involve describing a phenomenon in mathematical equations and programming code, respectively, algorithm refers to the sequence or structure of abstract entities aimed at a particular goal or purpose (Hill, 2016; Marr, 1982; Rapaport, 2012; Vardi, 2012). Given that we take algorithm here to mean the abstract configuration of affairs, an algorithm can be referred to and described in several ways, including mathematical equations, code, and propositional statements. Although these explicit tools are not always necessary, they can be powerful in anchoring the algorithms implicit in semantic theories, situating them in relation to each other on the same plane or in a hierarchical manner using concrete terms (Bechtel, 2009; Browning et al., 2020; Craver, 2007; de Chadarevian and Hopwood, 2004; Downes, 1992; Egan, 2018a; Johnson-Laird, 1987; Kindermann and Egan, 2019; Marr, 1982; Newell and Simon, 1972a; Pylyshyn, 1984; Suárez and Pero, 2019). However, these explicit methods can also benefit from the explanatory work of descriptive theories, which aid in characterizing the metaphysical significance of explicit equations, computations, or algorithms—an important endeavor when constructing a broad coherent and collaborative, yet parsimonious, framework (Egan, 2020; Moor, 1978; Naur, 1985; Ryle, 1950).

Historically, computational approaches to emotion and, more broadly, affect, have been aimed at the ontological question of differentiating between affective types (e.g., emotion vs. mood) or within types (e.g., anger vs. sad; Cowen and Keltner, 2021; Hoque et al., 2011; Picard, 1997; Poria

et al., 2017; Tao and Tan, 2005)). However, these approaches (usually types of machine learning of existing data) do minimal metaphysical work to describe affective mechanisms—the algorithmic manipulations of information that are in the service of allostasis. As we will see below, the Human Affectome is an endeavor to present a principled organization approach that describes and delineates algorithms across interdisciplinary descriptive theories of affective mechanisms, ultimately, lending itself to—though not necessitating—the explicit tools of formalism and computation. Next, we will touch upon another case of construct ambiguity that can benefit from these explicit methods, before turning to the integrative synthesis of the Human Affectome itself.

Mood

Finally, we consider 'mood'. According to some philosophical (Deonna and Teroni, 2012a; Kind, 2013; Searle, 1983) and psychological (Averill, 1980; Bollnow, 1956; Frijda, 1993; Gendolla, 2000) views, mood is construed as not being *about* anything in particular, unlike emotions, which are about particulars such as being "afraid *of*" or "happy *about*" something. Other philosophers deem mood to be about everything as a whole (Crane, 1998; Goldie, 2000a; Seager, 1999; Solomon, 1976). Further views consider whether or not moods are directed at certain abstract, free-floating properties, unbound to any object, and perhaps projected onto new incoming objects (De Sousa, 1987; Mendelovici, 2013; Tye, 1995).

In affective science, there is general consensus that mood is an extended felt episode marked by positive or negative valence that provides some information relevant to well-being—even if it is unclear for which allostatic concern (Eldar et al., 2016; Pears, 1975; Schwarz and Clore, 1983; Schwarz and Clore, 2007). Unlike emotions, which are relatively short, specific, and object-related states, that suggest action goals through physiological adjustments, moods do not have such specific motivational functions. Compared to emotions, they are not only more prolonged in duration, but are far more variable and context-dependent in their behavioral manifestations (e.g., (Cunningham and Sterling, 1988; Thayer et al., 1994)). While moods do not suggest specific action repertoires, they still inform action tendency such as avoiding a certain environment as a whole, thus carry aspects of motivation. Moreover, moods themselves—in contrast to emotions—do not involve autonomic nervous system adjustments related to the preparation and execution of actions (for overview see, Gendolla, 2012; Gendolla et al., 2005). Nevertheless, moods can systematically influence self-regulated action through their informational impact on behavior-related judgments, such as estimates of subjective task demand (e.g., Gendolla and Krusken, 2001) or decisions about stopping or continuing an action (e.g., Martin et al., 1993).

Despite the debate concerning the 'aboutness' of mood (Kriegel, 2019), it is at least widely accepted that moods tend to last for more extended periods of time than emotional episodes. Due to this duration of experience, mood has been difficult to distinguish from momentary valence in the characterizing of affective experience via subjective report. For example, various iterations of the valence component of the Self-Assessment Manikin (SAM; Betella and Verschure, 2016; Bradley and Lang, 1994) have often been used to measure global affect—how globally good or bad a participant feels in a moment of inquiry. However, this measure equates broad mood experience with a momentary emotional episode being positively or negatively valenced due to a recent stimulus. Similarly, the Positive and Negative Affect Schedule (Watson et al., 1988) has been often used to measure mood as having felt positive and negative emotions, but allows the instructions for retrospective report to be customized across any stretch of time, ranging from

momentary to within the past year. The PANAS also defines mood as having certain clusters of emotions. Based on these operationalizes alone, it is unclear whether mood is moment-to-moment goodness or badness or the presence of certain emotions. Perhaps, further operationalization might suggest a different allostatically informative construct altogether, such as a more cumulative, prolonged affective experience, as described in the following section.

Formal, Computational, & Algorithmic

The ambiguity surrounding mood provides an exemplar case of how semantic theories, and the operationalizations they accept, might be anchored by formal, computational, and algorithmic descriptions—to pin down a mechanistic account more precisely. For example, an account that has arisen in computational neuroscience reflects the philosophical view that moods represent the increased likelihood of certain occurrences (Price, 2006; Railton, 2017). In reinforcement learning, mood has been operationalized as the momentum or trajectory of unexpected good (reward) or bad (punishment) outcomes (i.e., prediction errors), across time (Eldar et al., 2016). Accordingly, mood corresponds to how recent experienced history of unexpected outcomes influences an organism's valuation of an incoming stimulus.

These computations indicate the function of mood: generalization and momentum. When there are several positive occurrences in an environment, for instance, instead of learning each one individually, mood will generalize to all sources of reward in the environment, assuming interdependence between those sources (i.e., the environment seems generally positive). In addition to generalization, mood can also function to indicate that current outcomes predict changes in future outcomes. For example, experiencing only few positive surprises is a signal that more positive outcomes are likely to follow. This will bias perception of subsequent rewards upward, expectations would be updated more quickly, eventually catching up with the rising rewards in an increasingly positive environment. In this case, positive mood is an inference of positive momentum, and similarly, it can occur in the opposite direction where negative mood represents diminishing reward availability (Eldar et al., 2016)

To capture the temporal dynamics of mood, rather than static one-off measurements, studies have used repeated, momentary subjective reports of valence across time through experience sampling methods (Csikszentmihalyi and Larson, 1987), or ecological momentary assessment (Stone and Shiffman, 1994). Such observations of affective predictions over time can be informative in describing affective algorithms, especially if paired with reinforcement learning or probabilistic analyses (Gu et al., 2019). In the case of mood, these dynamics help us define this construct as a concrete parameter of the propelling effect of collective emotional experience, rather than the individual instances of emotion episodes or even their sum.

To summarize:

1. Mood is a prolonged felt experience marked by valence, motivation, and arousal.
2. It can be formally defined as the statistical average of reward, punishment, and their momentum.
3. Mood does not pertain to any object in particular, but rather reflects the cumulative impact of multiple events, or everything as a whole.

4. The primary function of mood seems to be informational—generalizing from one event to other related occurrences, and as capturing the momentum of the environment.

Grounding the definition of mood in an explicit account is just one case in which affective mechanism can be clarified by mathematics and code: where the analysis of collected data can be abstracted into mathematical symbols that are calculable and programmable—ultimately, for rendering one interpretation of allostatic significance (Hill, 2016; Marr, 1982; Rapaport, 2012; Vardi, 2012). These tools, paired with semantic framing, can help us clarify what affective constructs might be. As such, the Human Affectome presented here assumes that affective mechanisms have allostatic purpose, such that those individual algorithms can be described and perhaps better grounded by not only semantic, but also formal and computational terms.

The Present Approach

According to our synthesis of an ontology of working definitions of affective terms:

1. **Affect** reflects metrics of allostasis, including valence, motivation, and arousal, that indicate actionable deviations from an organismic comfort zone.
2. All **feelings** are affective in that they are allostatic mechanisms. Thus, emotion and mood are feelings, in the sense that they are subjective, first-person, conscious experiences, each denoting a certain class of affective experiences.
3. **Emotion** is a subset of feeling, or affective experience. Emotion is typically an evaluation of a particular object in relation to specific actions concerning the allostatic comfort zone—where allostatic implication is learned and, thus, varies across experiences, people, and groups. This subset tends to exclude physiological feelings.
4. **Mood**, also a subset of feeling, is more temporally extended compared to emotion, and it is not directed at a particular event or trigger. Rather, it is the cumulative momentum of momentary judgments, resulting in an extended affective experience.

In addition, these working definitions are based on the following metaphysical assumptions:

1. Affect is **embodied** and **enactive**.
2. Feelings have **intentionality**.
3. A theoretical framework of affective types must be not only **philosophical** and **scientific**, but **pragmatic** by integrating across interdisciplinary perspectives and incorporating differing academic motivations.
4. Affective mechanisms that are of interest in semantic theories are **algorithms** that can be concretely grounded in **formalism** and **computation**.

This foundation, we hope, not only has set the scene for the semantic discussion surrounding the constructs of affect, feeling, emotion, and mood—but also discloses our own academic motivations for construing this metaphysical framework.

The Human Affectome: A Theoretical Framework

As we have seen thus far, metaphysical assumptions ruling philosophical and scientific research into emotion have been tangled and discussed in insulated pockets of inquiry, each field, subfield, and researcher, with its or their own explanatory motives. Here, we present the Human Affectome as an attempt at a synthesis of a comprehensive sampling of academic perspectives on emotion and nearby affective explananda. To truly address the richness of valid scholar motivations would require a full research program's worth of time and work, spanning years, decades, or more. What we proffer here is but a multidisciplinary theoretical launchpad for many threads of inquiry. Theories that have existed and are familiar to the reader (depending on background) now might be situated in congruence with each other.

Based on the metaphysical assumptions we have presented above, we have synthesized the perspective that the organism is an agent operating in the environment to alleviate allostatic concerns. We propose this to be a parsimonious explanation that unifies across aspects of affect. As such, we distinguish between:

(1) **Allostatic features**: the experiential qualities of affective states—valence, motivation, and arousal—that provide information about how to regulate.
(2) **Allostatic concerns**: what is of interest in experience—the felt implications of sensory objects that are inferred to be allostatically relevant and actionable.

Allostatic Features

Valence, motivation, and arousal are features of affective experience: each of the affective states pertaining to fundamental organismic needs are inherently imbued with those features. Given that affective states reflect allostatic tendency, each state is inherently positive or negative in relation to organismic balance (i.e., deficit or surplus). Even within the comfort zone, where organismic needs are balanced, there is never a fixed state with zero or neutral valence, motivation, and arousal. The organism is constantly self-generating, and the maintenance of homeostasis is an active fluctuating process (Cannon, 1932; Cooper, 2008; McEwen and Wingfield, 2003; Schulkin and Sterling, 2019). Individuals may also be aware of the experience of those features, thus subjectively experience hedonic, motivational, and arousal related feelings. Based on our synthesis, these three features are what we, as researchers, tend to consider to be affect. Below we discuss the explicit accounts of each of these features, including how formal, computational, or algorithmic evaluation of allostatic concerns might give rise to these allostatic metrics.

Valence

Valence-related or hedonic feelings—awareness of the valence of an experience—capture the spectrum of feelings from pleasure to displeasure (Becker et al., 2019). This range includes feelings of enjoyment in response to the presence of a desired state (e.g., delighted) or the removal of an aversive one (e.g., relieved); and feelings of dissatisfaction in response to an undesired state, such as punishment or omission of reward (e.g., unpleasant). The experience of pleasure and displeasure accompanies bodily states and feelings (e.g., experiencing pleasure from a soft touch, or displeasure when feeling rejected).

One explicit account of valence formalizes momentary goodness or badness as dynamics of better-than-expected rewards and worse-than-expected judgments in reinforcement learning (Rutledge

Robb et al., 2014). An alternative account formalizes valence as an organism's evaluation of its own adaptiveness, as a model based on preparedness for its environment according to approximate Bayesian predictions (Hesp et al., 2021a). While both accounts highlight the importance of trajectory across multiple predictions, the latter proposes that minimal metacognition is at play when an organism assesses its own adaptiveness (Van de Cruys, 2017). Later, we will touch on how this formalism of valence can be used as information for global well-being, wherein an organism assesses whether it has optimized its adaptiveness (see *Global Optimization* section; Miller et al., 2022).

Motivation

The motivational aspect of feeling, such as attraction and repulsion, depicts the direction of action tendency (Cromwell et al., 2020). Motivations of approaching or avoiding a goal, and the mobilization of the necessary resources to do so behaviorally, can occur in the pursuit of conscious or unconscious goals, and are often directed by the presence of various emotions. Attraction and Repulsion feelings can draw attention to unaccomplished goals (e.g., allure), heighten the urgency for accomplishing a goal (e.g., yearn), and amplify behavioral actions (e.g., admire, tempted).

In reinforcement learning, motivation can be computationalized as an extra parameter or variable of action or control in addition to the typical reward or punishment parameters (e.g., control-as-inference; Attias, 2003; Botvinick and Toussaint, 2012; Grahek et al., 2020; Levine, 2018; Sutton and Barto, 2018b). This approach provides incentive and direction for action by increasing or decreasing the probabilities of actions and outcomes. Alternatively, if action is assumed to be inherent in all cognition, probabilistic inferences about the world can be conditioned on the predictions about what particular actions mean for returning to a comfort zone (Friston et al., 2017; Millidge et al., 2020; Parr et al., 2022; Smith et al., 2022). Consequently, perception and decision, such as those at play in affective mechanisms, can be formally and computationally biased or subjective on the basis of allostatic action.

Arousal

Arousal is defined as the activity of the autonomic nervous system. It usually refers to sympathetic activation that places the organism in a state of high alert and readiness for action, indicating the intensity of an experience (Anderson and Adolphs, 2014). Arousal-related feelings are the subjective experience or awareness of arousal levels (e.g., aroused, edgy, calm). Although arousal often corresponds to valence, such that high arousal accompanies negatively or positively valenced states (V-shaped relationship), this relationship is not static, and there are individual differences and various ways in which valence and arousal co-occur (Kuppens et al., 2013). Motivation also interacts with valence and motivation with a non-static relationship, evincing the independence of these features.

While, to our knowledge, arousal has yet to be formalized in the context of affect, this construct has been formally linked to cognitive processes, such as arousal-related adjustments of perceptual biases (Krishnamurthy et al., 2017) or arousal-driven regulation of learning dynamics (Nassar et al., 2012) among others. In enactive approaches, the mechanism of arousal might be formalized as changes in an organism's self-assessed preparedness for the environment, wherein this evaluation is based on the predicted impact of possible actions (Barrett and Simmons, 2015; Hesp et al., 2021b; Seth and Friston, 2016).

Allostatic Concerns

Based on the assumption of intentionality, affective experiences are *about* or are *directed at* intentional objects—the things that are being evaluated (Teroni, 2007; Deonna and Teroni, 2012b). These objects are important to an organism based on the allostatic orientation toward that object—the allostatic concern (**Figure 1**). An affective state's allostatic concern demands action to address that concern in the service of restoring organismic balance (Frijda, 1986). In keeping with enactivism, this actionable implication is inherent to affective cognition itself (Di Paolo and Thompson, 2014). Although we will not give a full explicit account here, one way this can be formalized is as 'hidden conditional probabilistic states' that an organism needs to infer based on sensory data, whether that be through exteroceptive modalities, such as vision, audition, etc., or interoceptive modalities (Barrett, 2017b; Dayan et al., 1995; Doya, 2007; Knill and Pouget, 2004b; Lee and Mumford, 2003; Seth, 2013; Seth and Friston, 2016; Smith et al., 2019; Wolpert et al., 1995). In other words, an organism must use observable sensory data to infer the non-observable allostatic meaning of that sensory data (Friston et al., 2016; Neal, 1996).

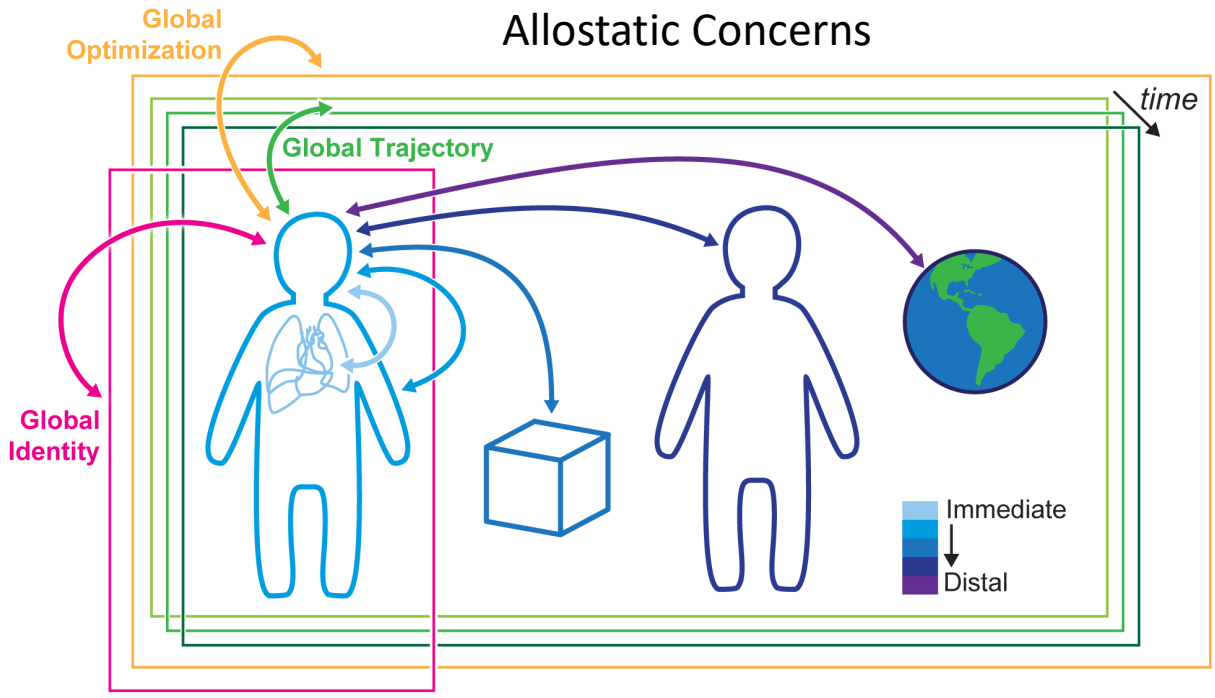

Figure 1. Allostatic Concerns. We organize allostatic concerns by the distance from homeostatic impact that the actions suggested by the concerns would have. Physiological concerns (light blue arrow pointing to inner organs) are the most immediate and concrete (e.g., getting food alleviates hunger); intermediate to distal concerns arise when an organism operates in the environment and interacts with things and other people. These concerns can be concrete (light blue arrow), i.e., directed toward specific objects (e.g., feeling curious about a book, angry at the printer, afraid of the dog); or more abstract, i.e., involve more causal steps to reach allostatic impact, such as social feelings of guilt, shame, or pride (dark blue arrow), or feelings related to more distal concepts such as concerns about climate change (purple arrow). Finally, there are global concerns, which do not pertain to any specific object. These are concerns about, 1) global trajectory—whether things are heading in the right direction (green arrow and green frames indicating movement in time); 2) global optimization—the overall wellbeing of the organism, or the dynamic

optimization of the overall organismic state (orange arrow and frame); and 3) global identity—the stable states that characterize the organism (pink arrow and frame).

To synthesize a principled structure **(Figure 1)**, we organize the allostatic concerns into:

1. Distance from homeostatic impact of the actions indicated by an affective state (if that state takes some object to be actionable).
2. Dimension of evaluation (if that state makes a comprehensive evaluation of the environment or its own allostatic performance).

Immediate to Distal Concerns

Immediate to distal concerns provide a gradient or scale pertaining to things in the environment one can have affective states about, which can be interpreted as the complexity of actions needed to address the allostatic concern, the timescale necessary to achieve homeostatic impact, or its abstractness and semantic meaning (McEwen and Seeman, 1999; Pezzulo, 2012; Pezzulo et al., 2015). In formal and computational terms, this can be construed as hierarchical depth (Pezzulo et al., 2022). Immediate concerns, such as physiological ones, are hidden states inferred at a lowest level (i.e., shortest timescale, fewest number of calculations, closest mappings to one-to-one between prediction and sensory data) in a hierarchy of allostasis. Distal concerns, such as moral concerns, are those at the highest (Scherer, 1982). Below, we organize ranges of concerns on the continuum of allostatic impact.

Physiological Concerns

The most immediate or concrete actions required to maintain organismic balance pertain to physiological needs. This set of concerns requires actions that affect the immediate internal environment of one's own body, therefore dealing with the allostatic process in the most direct manner, given that the organism has to perform action to address it. Physiological affective states arise from interoceptive sensations, and typically reflect the integration of many interoceptive sources (Hutcherson et al., 2008; Pace-Schott et al., 2019; Seth, 2013; Seth and Friston, 2016). For example, in the expression "I feel hungry"—the target (or intentional object) is some edible object, and the property (value, quality) placed on the object is 'valuable for nourishment'. The allostatic features of this state could be, for instance, positive valence and approach motivation. This process can also recruit other feelings with different, even higher-level, concerns, such as interest (Ombrato and Phillips, 2020).

The different feeling words along this dimension typically capture the intensity or degree of departure from the comfort zone of organismic physiological balance (e.g., full, famished, starving). Physiological affective states may pertain to action-based drives (e.g., thirsty), energy levels (e.g., rejuvenated), and internal bodily states (e.g., nauseous), among others. When these physiological concerns cross into intermediate to distal concerns, such as operational ones (elaborated on below), these might be regarded as emotions beyond physiological feelings, such as feeling 'hangry'—angry due to hunger (MacCormack and Lindquist, 2019). Physiological feelings as immediate concerns can be formalized using reinforcement learning (Sutton and Barto, 2018b) as parameters that might influence reflexive decision-making (i.e., 'model-free') but not planned decision-making (i.e., 'model-based'), which may recruit estimates of higher-level allostatic implications (van Swieten et al., 2021).

Operational Concerns

These are a broad scope of concerns ranging from intermediate to distal, wherein an organism has a feeling toward an object that, if acted upon, has proximal to eventual impact on organismic balance. We consider these to be operational given that the organism must act as a unit to interact with the environment, and can usually only do so if lower-level concerns, such as physiological ones, have been addressed. Under this broad definition, various concerns differ in the type of objects they pertain to and their overall action-relevant implications. Some examples of subtypes of operational concerns are:

- ***Safety Concerns****:* Concerns about dangers and objects that put the organism in harm's way (Raber et al., 2019; Stefanova et al., 2020). For example, a feeling is fear if it assigns the property of 'being a threat' to an object, implying a set of actions such as running away from that object.
- ***Obstruction Concerns****:* Concerns about obstacles and violation of the organism's dispositions and goals (Alia-Klein et al., 2020). For example, a feeling is anger if it assigns the property of 'being an obstacle' to an object, implying actions such as removing the object.
- ***Epistemic Concerns****:* Concerns about acquisition of vital and useful knowledge (Dolcos et al., 2020). For example, a feeling is curiosity if acting upon it provides the organism with information. In this case, assigning the value of 'being informative' to an object implies actions to obtain information from that object.
- ***Social Concerns****:* Concerns about the quality and outcome of interactions with others (Eslinger et al., 2021). For example, a feeling is belonging, if it assigns the value of 'being in a relationship with' to an object. In this case, "I feel I belong" indicates sharing experiences with that object.
    - ***Moral Concerns*** are a subset of social concerns that pertain to moral behavior and norms. e.g., a feeling is shame if it applies the property of 'being immoral' to an object.

These examples highlight just a few of many possible operational concerns. Although typically studied in separate fields, these concerns share a common structure whereby an organism operates in the environment and assigns properties to things and beings, implicating proximal, but not immediate, allostatic impact. These feelings imply a complex set of actions over a period of time to ultimately return to a balanced organismic state. These concerns vary in the degree of complexity and abstractness, such as being angry at an object (concrete) or being afraid of climate change (abstract). The more distal and abstract the concern is, the more causal steps would be required for achieving allostatic impact.

The affective mechanism that evaluates operational concerns seems to be what we tend to refer to as *emotions*. Accordingly, many proposals and explicit accounts of emotion converge on the mechanistic role of an organism making considered evaluations in order to best operate in an environment with regard to its comfort zone. Historically, akin to basic and discrete appraisal emotion theories, these approaches tend to allocate different evaluations to specific emotion types in order to differentiate between them (Marsella et al., 2010; Poria et al., 2017 ; Scherer et al., 2010). More recently, formal and computational accounts using combined reinforcement learning and Bayesian approaches—both standard and enactive—have arisen (Gratch and Marsella, 2004;

Lee et al., 2021; Marsella and Gratch, 2006; Sennesh et al., 2022a; Smith et al., 2019). These approaches model emotions as an organism's flexible learning of operational concerns, intermediate to distal in nature, wherein sensory data might have varying allostatic implications depending on the organism's prior experiences.

Global Concerns

Global concerns pertain to summative agential allostatic states over trajectory, wellbeing, and identity. These concerns are not about particular objects but rather summations that inform an overall state. This is the difference, for example, between feeling afraid *of* the dog, disgusted *by* violation, or glad *about* an award (all of which relate to a particular object), versus being in a bad mood, feeling happiness in life, and feeling smart or accomplished (which are an overall summary state). Formally speaking, these might be made explicit through inferences of not just certain objects in an environment, but collectives of either objects or the organism's own allostatic processes. As such, there are three dimensions of global concerns which we outline below: trajectory, optimization, and identity.

Trajectory Concerns

These concerns are about the global direction, or momentum, that the experience in the environment points towards. For example, an environment can have a 'positive slope' if few instances of positive outcomes imply further positive outcomes from many additional similar sources, or further and larger positive outcomes in the future. As reviewed above, trajectory concerns can be seen as formalism of *mood*. For example, when you are in a good mood, the environment can be said to have been heading in a positive direction (Eldar et al., 2016).

Optimization Concerns

As the environment may allow for many combinations of positive slopes (i.e., various ways by which things could be heading in the right direction), optimization concerns are about the optimal match between the organism and the environment. These concerns apply to feelings related to wellbeing, self-actualization, fulfillment, and authenticity (Alexander et al., 2021; Arias et al., 2020). This is a dynamic optimization process assessing how the organism is doing overall, or faring in the quest for survival, and implicating actions to optimize the overall organismic state. As discussed above, this can be formalized as maximizing momentary valence, such that the organism's allostatic system deems itself an optimal match for the swathe of environments it has encountered (Miller et al., 2022). Optimization concerns seem to be what we refer to as *global wellbeing*, such that an organism uses momentary judgments of its adaptiveness to evaluate whether it is globally optimal in navigating the world.

Identity Concerns

Self-related feelings reflect concerns about one's global identity (Frewen et al., 2020). In this case, values or properties are attributed to the self rather than to objects that are separate from the organism. Feeling words that refer to the self as an object could reference bodily dimensions such as size, weight, age, and gender (e.g., "I feel young", "I feel masculine"), but could also relate to the appraisals of the self on domains such as mental capacities (e.g., wise, smart), social aspects (e.g., humble, admired), or one's social grouping (e.g., devout). Self-related feelings may also pertain to the 'spiritual-self' dimension, such as feeling words related to self-determination or

autonomy (e.g., free), self-esteem (e.g., capable) and personal growth (e.g., improved). These concerns tend to withstand time or trajectory—when an organism comes to a conclusion about itself as an adaptive thing as a whole. Although there has been minimal formalism of identity concerns in the context of affect, these comprehensive concerns can be viewed as lasting self-evaluations, or probabilistic predictions about the self, that have staying power because they are confirmed again and again by an organism's encounters with the environment.

Putting it all together: An Integrative Model of the Human Affectome

Several principles arise from this synthesis:

1. Each affective state has the features of valence, motivation, and arousal, which in themselves may be experienced as a feeling.
2. Affective states are anchored to allostasis and reflect allostatic concerns.
3. Allostatic concerns vary from immediate to distal, or concrete to abstract. The immediacy or concreteness is measured by distance to allostatic impact: how many actions, or causal steps, are required to achieve organismic balance.
4. Immediate concerns relate to one's physiological and bodily needs.
5. Intermediate to distal concerns relate to the organism's operations in the environment, or one's interactions with concrete or abstract objects including social others. These operational concerns are what we typically regard as emotions.
6. Global concerns do not pertain to specific objects, but rather to the organism's overall trajectory (i.e., mood), optimization (i.e., general wellbeing), and identity (i.e., self-referential feelings).

These components and their relations converge into an integrative model of the human affectome (**Figure 2**).

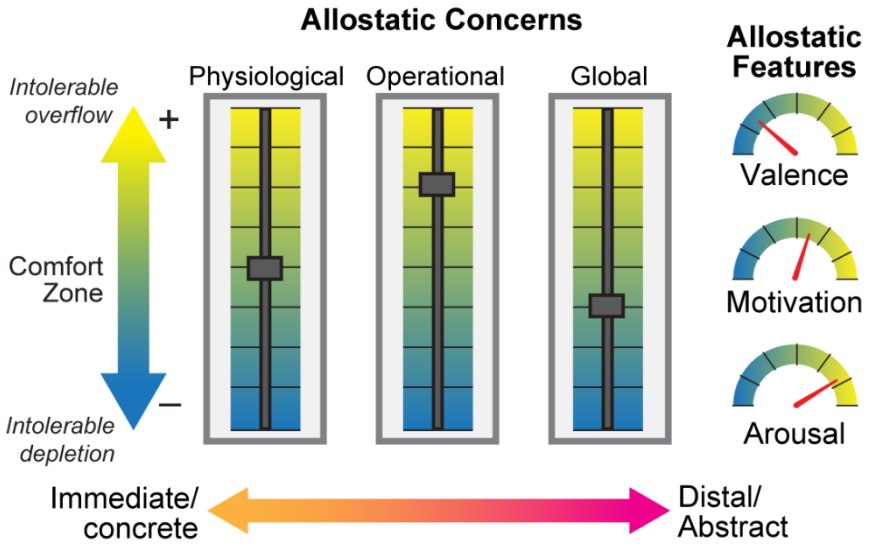

Figure 2 – A model of the human affectome. The human affectome is depicted schematically as a console board. Allostatic concerns are represented as sliders, where the indicators mark the allostatic state of the organism relative to a comfort zone, or organismic balance (vertical arrow on the left). Each slider represents a family or domain of concerns (i.e., there are multiple sliders within domain). Physiological concerns are the most immediate (e.g., hunger, thirst, temperature). Operational concerns are intermediate to distal, reflecting the organism's interaction with things (concrete or abstract) and people in the environment. Examples of such concerns are safety (e.g., afraid), obstruction (e.g., angry), or social (e.g., respected). Global concerns are the most distal and abstract, and do not pertain to any object in particular. These concerns are derived from summation of the overall state of the organism, reflecting the trajectory (i.e., mood), optimization (i.e., wellbeing), and identity of the organism as a whole (i.e., self-identity). Affective states (commonly referred to as feeling, emotion, and mood) reflect those allostatic concerns, by assigning value to an object (or an overall global state), that if acted upon, would restore allostatic balance. Each affective state has the features of valence, motivation, and arousal (depicted as dials that apply to all sliders), which in themselves can be subjectively experienced.

Conclusion: The Human Affectome as a Research Program

We presented here a unifying metaphysical framework for affective phenomena: the Human Affectome. By synthesizing a large body of literature, we have converged on definitions that disambiguate the commonly used terms—affect, feeling, emotion, and mood. Based on this definitional foundation, and under the premise that affective states reflect allostatic concerns, we propose to take a goal-directed, enactive perspective to describe the aspects of the human affectome. When an organism experiences an affective state, it infers value of an object, which might be a physical entity, a concept, or an overall state of affairs. This value implies an action that will alleviate the allostatic concern. Different concerns differ in the amount of action, or causal steps, that would lead to allostatic balance. Considering this scale of concrete to abstract, or immediate to distal, allostatic concerns often fall into two common ranges: physiological (the most immediate and concrete) and operational (intermediate to distal concerns that apply to objects that the organism acts upon). On the other hand, global concerns, which are the most abstract, involve collective metrics of allostatic importance (summations of overall trajectory, wellbeing, and self-identity). Each affective state has three features: valence, motivation, and arousal. Within this organizational scheme, each affective state, or subjective feeling, is a location in this three-dimensional space, while orthogonal affective concerns can add further dimensions contingent on the quality of actionability a situation calls for.

The elements we have synthesized are semantic descriptions of the levels and features of goal-directedness an organism might have—but they also outline empirical hypotheses for the types of formal and computational algorithms at play in the allostatic mechanisms of affective states. Considering subjective feelings as one's attitude and action tendency toward a state of affairs, we can operationalize feelings based on the computational function they imply. This approach gives a basis for the use of subjective verbal self-report as a computational description in scientific inquiry and part of the affective process (Satpute et al., 2020). Verbal report of propositional attitudes can thus be described parametrically: inform a 'feeling' parameter (e.g., mood, craving, fear) within an algorithm that captures a computational process (e.g., valuation, decision making, planning).

There are, however, a few caveats to formalizing an interdisciplinary, integrative theoretical framework of affect such as this one. First, we do not present an explicit formal or computational model, in part, to allow for multiple interpretations of this framework. Second, the computational methods discussed here, variants of reinforcement learning (Sutton and Barto, 2018a) and Bayesian approaches (Doya et al., 2007; Griffiths et al., 2008; Knill and Pouget, 2004a) make the prevailing scientific assumption of optimality: organisms are rational agents searching for best (minimal or maximal) solutions to their computational problems which, in this case, are allostatic concerns (Schoemaker, 2011). Third, of the computational methods reviewed, only the variant of approximate Bayesian approaches called 'active inference' formally accounts for an enactive perspective (see *Motivation* section). In this approach, action is assumed in the inference of these concerns, rather than being added as a supplementary variable within a cognitive process (Friston et al., 2009; Millidge et al., 2020; Ramstead et al., 2019; Sajid et al., 2021).

The framework as a whole also presents more general caveats. Primarily, discussion of neural mechanisms of affective phenomena has not been included here but rather presented separately (see the other reviews in this issue). However, much integrative work can be done to address the question of 'where' or how these affective algorithms manifest dynamically in the nervous system (e.g., Armony and Vuilleumier, 2013; Barrett and Satpute, 2019; Kragel and LaBar, 2016; Lindquist et al., 2012; Panksepp, 1992; Polley and Schiller, 2022). In addition, clinical perspectives on how these affective mechanisms may go awry have not been integrated into this framework but remain essential in translating these definitions and structures to the real world (Browning et al., 2020). Another major caveat is that, as interdisciplinary and integrative as this framework is, only Western academic perspectives have been considered, while Eastern ones have not been breached (e.g., Mercado et al., 1994; Reyes, 2015; Rošker, 2021; Sundararajan, 2015; Tuske, 2021; Zhou et al., 2021)—a significant drawback given the metaphysically categorical approach to affect that is taken in the West. In addition, areas of academic and industry perspectives in affective research beyond philosophy and science have not been touched upon, such as design and architecture (Desmet et al., 2021; Hassenzahl and Tractinsky, 2006; Norman, 2007). Lastly, what we present is *not* a theory as it is not falsifiable—what we present is a framework that we aim to be parsimonious explanation across many proposed frameworks and theories, a metaphysical research program that can be broken down into testable theories (Popper, 1962).

Despite these caveats, we ultimately propose this metaphysical research program in order to motivate a scientific strategy: a unified framework for testable scientific theories (Sporns et al., 2005). Synthesizing the various, non-testable, metaphysical assumptions ruling different fields, would allow us to compare and test scientific findings, by considering their explanatory motives. Researchers interested in interoception, for example, would focus on the physiological domain of the human affectome. Researchers interested in fear, anger, disgust, or social feelings (among many others), are located on the operational arm of the human affectome—these researchers focus on the value that an organism puts on different categories of objects within the environment in which the organism operates. Researchers who wish to investigate mood, wellbeing, or self-identify, share the focus on global concerns but ask different questions: What is the trajectory of an environment enacted by the organism? How does the organism dynamically assess its overall wellbeing? When does self-identity emerge? We hope that this framework not only instigates principled theoretical discourse and empirical collaboration within existing camps, but also

provides a bridge and medium of communication across proponents of different perspectives. This may be through informal communication or more structured discourse in existing avenues.

Considering our explanatory motives, the Human Affectome allows vastly different scientific interests to reside within the same theoretical framework and relate to each other. The fields of affective research have long felt fragmented, vaguely defined, and contested by competing camps. Yet, affective states can neatly map onto organismic needs, feelings can be put into formulas, and many theoretical arguments are complementary rather than conflicting. We put forward the human affectome as a unifying framework across seemingly disparate fields, to facilitate collaboration, translation, and application of affective research domains.

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