Visualize a businessman whose car has been scratched by an arrogant teenager, or a soldier ordered to cross an open field under enemy fire, or a mystic anticipating communion with an angel, or any emotional situation. We see facial blanching or flushing, widened eyes, rumpled hair, heavy breathing, limbs trembling – all the musculoskeletal, autonomic, and neuroendocrine manifestations (Cannon 1939) of bodily preparation by the brain for action. These accompaniments may well be the medium for awareness of emotional states as postulated in the James-Lange theory (cf. James 1890). Neuropsychologists debate how many kinds of emotion there are; novelists show that emotions are in variety not subject to enumeration, and that commonly in schemata they are alloys: grief, for example, combines pain of loss with survivor guilt, nostalgia, anger at betrayal by abandonment, fleeting joy at being rid of an impediment, guilt about that, and so on.

Despite their infinite range, all emotions have four features in common that relate directly to their neurobiology. First is the capacity for rapid onsets and terminations (sect. 2.3 of the target article, "Process models of appraisal"). A single word can precipitate instant rage; another word can transform rage to shame, fear, or guilt. Intracranial and scalp EEG recordings from animals and humans have shown that neocortex operates by sequential state transitions (sect. 3.2.7, "Phase transitions"). Oliver Sacks (2004) concluded: "The mechanism of our ordinary knowledge is of a cinematographical kind." EEG shows that state transitions occur in sequences at rates in theta and alpha ranges (see discussion of theta in sect. 5.1.1), each state lasting about one-tenth of a second (Freeman et al. 2003a). States are expressed by spatial patterns of phase and amplitude modulation of beta and gamma oscillations (sect. 5.1, "Nested feedback loops and self-synchronization"). Each transition begins with a discontinuity in phase by which the oscillations are re-initialized. Resynchronization follows within a few milliseconds, and a new spatial pattern emerges and stabilizes. Then within 25–35 msec of onset the intensity of the pattern increases dramatically (sect. 3.2.2, "Positive feedback and self-amplification"). These phenomena demonstrate the capacity of neural populations for virtually instant reorganization of spatiotemporal patterns (Freeman 2003b; 2004a).

The second feature in common to all emotions is their globality. The entire musculoskeletal, autonomic, and neuromodulatory systems are orchestrated. These associated signs and movements have obvious secondary survival value in providing for reliable communication of emotional states among individuals in societies (Darwin 1872). Multichannel EEG recording from high-density electrode arrays in rabbits and cats provide evidence (Freeman & Rogers 2003; Freeman et al. 2003b; 2003c) that large areas of neocortex in each cerebral hemisphere generate intermittent spatial patterns of synchronized oscillations that are statistically related to intentional behaviors. The fractal distributions of the parameters of phase measurements (Freeman 2004b), the power-law "$1/f$" distributions of spectral energy, and the rapidity of global changes all indicate (Freeman et al. 2003a) that each hemisphere maintains a scale-free network that resembles major airline routings (Wang & Chen 2003) in which a small number of critical nodes have exceptionally high levels of connectivity at which damage can be catastrophic. These nodes in brains may easily be identified inter alia with the thalamus, amygdaloid, entorhinal cortex, and midbrain reticular formation. The impact of an expected conditioned stimulus induces a local state transition in the pertinent primary sensory area, with formation of a local field of neural activity having a reproducible spatial pattern, which is engulfed 200 msec later by a global field (Freeman 2005) established by a global state transition that integrates by multiple interactions (sect. 3.1, "Cognition as self-organization") the several sensory areas with the limbic system (sect. 5.3, "Vertical integration"; Freeman & Burke 2003).

A third feature common to all emotions is dependence of brain states on expectancy. An off-hand remark or gesture by one person can be perceived by another as a compliment or as an insult, irrespective of intent. This property reflects the fact that the overwhelming input to every cortical neuron comes from other cortical neurons and not from sensory pathways. EEG pattern analysis has shown that the chaotic dynamics manifested in background activity in the waking brain elaborates landscapes of chaotic attractors (Skarda & Freeman 1987), each of which constitutes a hypothesis (sect. 3.2.6, "Multistability and stochasticity") about the environment inside and outside the body (Freeman 2003a). The incoming sensory information selects an attractor by placing the local trajectory of the sensory area into its basin of attraction. In the aftermath of the ensuing state transition, the sensory information, having done its work, is washed away in the processes of abstraction, generalization, and classification. The mechanism is the cortical broadcast by divergent-convergent transmission pathways, which extract the newly constructed activity that provides the meaning of information (Freeman 2003a; 2005), not processed information. The meaning is private and may or may not match others' realities. For this reason the hypothesis-testing model from dynamic systems (DS) is superior to information-processing model from artificial neural networks (ANN) in explaining emotion.

The fourth feature in common is the future-orientation of emotion: "What will I do?" Even nostalgia nests in the necessity for coping with a deteriorating environment contrasting with a perceived golden age. Brains are designed by evolution to form goals, act to achieve them, hypothesize the changes in sensory input that follow test action, and assimilate to the consequences of their test by learning. All that brains can know are their hypotheses and the cumulative results of their tests. Emotion is an integral aspect of the predictive, preparatory phase of the action-perception-assimilation cycle, whereas consciousness (sect. 4.3.4, "Feeling and consciousness") is an aspect of the judgmental phase of evaluation of the consequences of action – and therefore is past-oriented: "What have I done?" Perhaps this disjunction between future- and past-orientation is responsible for much of the obscurity that attends our grasp of the nature of emotion – and consciousness.

My hypothesis is that brain dynamics is governed by an adaptive order parameter that regulates everywhere neocortical mean neural firing rates at the microscopic level, and which finds expression in maintenance of a global state of self-organized criticality (Freeman 2004a). Under perturbation by environmental input (including that from the body), brain dynamics moves away from its basal attractor and generates repeated state transitions in its attempt to regain balance. These local states form chaotic itinerant trajectories (Tsuda 2001) that constitute a search for a course of action that can be predicted to restore balance. Selection of an action constitutes closure (sect. 5, "DS mechanisms of neural integration"). If the intensity of the chaotic background activity overwhelms the search trajectories, then closure is premature, and the action chosen is suboptimal and may appear to be irrational and short-sighted – that is, "emotional" in the colloquial sense of the term (Freeman 1995; 1999). Strong self-control is required to reign in a torrent of chaotic discharge to reach optimal closure; from this point of view, Plato's metaphor is valid still.

Dynamic appraisals: A paper with promises

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Abstract: The proposed dynamic systems model of emotion generation indeed appears considerably more plausible and descriptively adequate than traditional linear models. It also comes much closer to the complex interactions observed in neurobiological research. The proposals regarding self-organization in emerging appraisal-emotion interactions are thought-provoking and attractive. Yet, at this point they are more in the nature of promises than findings, and are clearly in need of corroborating psychological evidence or demonstrated theoretical desirability.

The target article makes several impressive contributions to the study of emotion. First, it corrects the common schema of the

https://doi.org/10.1017/S0140525X05340040 Published online by Cambridge University Press

emotion process in which events lead to appraisals leading to emotional responses. Instead, it presents an appealing model of emotion generation as a process over time that allows for the many things that can happen during that time, and in which a triggering phase, a self-amplification phase, and a self-stabilization phase can be meaningfully distinguished. Each phase is described as guided by ongoing processes that the triggering event impinged upon, by the effects of those processes on subsequent processes, and by the self-organizing interactions between the various outcomes that augment, counteract, dampen, or stabilize the processes that caused them. The article thus sets the agenda for research on the time course of emotion arousal. In fact, considerable research is emerging that substantiates the hypothesis that many things do happen when an emotion is aroused, and before it obtains its distinct contours. Examples are the evidence produced by varying prime exposure times in priming experiments (e.g., Murphy & Zajonc 1993; Stapel & Koomen 2000), and by changes in responses to emotional stimuli over exposure time, which led to the defensive cascade model (e.g., Bradley & Lang 2000).

Second, the target article beautifully describes the processes of emotion generation as an intimate intertwining of appraisal and response generation sub-processes rather than of appraisals preceding emotions. Feedback from intermediate action components steers appraisal processes, but, in addition, appraisals are steered to support ongoing action components and may well be shaped and augmented by what would be needed to select from among available response options. A primary example comes from the impact of one of the major appraisal components in appraisal theory, that of appraised coping competence, which appears as a result of ongoing interactions rather than of prior appraisal. Also, appraisals often reflect accessed action modules rather than determining such access: many stimuli (e.g., human faces) are appraised as attractive or frightening because they happen to elicit an approach or avoidance tendency. One may well hypothesize (I do) that appraisal patterns are shaped and stabilized by what the action modes happen to be responsive to, which responsiveness thus filters out (and makes demands on) the available information. For this intertwining, too, evidence of various sorts exists, both from self-reports and from experimentally shown effects of ongoing emotional responses upon information pick-up and interpretation. I am of the opinion that both the temporal development and the appraisal-response-reciprocities should become elements of any standard account of emotion generation.

Part of this analysis is the view that "emotions" are not considered as wholes but as more or less integrated sets of components, each of which can be separately influenced by appraisal, and can separately act upon appraisal. I agree with Lewis that this is the only viable viewpoint in any process analysis; it is, I think, shared by most current emotion researchers. Emotion words – fear, joy, anger, and so forth – should be avoided unless it is simultaneously specified which component or combination of components in the given analysis they refer to.

The dynamic systems perspective is obviously a third major aspect of Lewis's treatment. Appraisal components presumably organize into "whole appraisals"; appraisal-emotion amalgams somehow tend to stabilize; and higher-level states or structures emerge that constrain the more elementary processes. Lewis proposes that order in the entire domain of emotional phenomena and appraisal-emotion relationships is much more a function of self-organization than of prewired or even of learned structures. The proposal is enticing. It can accommodate salient structure in the phenomena as well as deviations from such salient structures, and phase transitions from one structure to another. It is a promising perspective, considering its achievements in, for example, shedding light on the variability of facial expressions (Camras 2000) and the emergence of patterns in interactional behaviors (Fogel 1985), and in considering the possibility of self-stabilizing in parallel constraint satisfaction networks. Yet, with regard to appraisal and emotion relationships, the dynamic systems perspective still remains mainly a promise. The notion of "whole appraisals" in Lewis's target article is not defined or substantiated. Whether an appraisal of "threat" is more than a linear combination of its constituent components (except when mediated by the word "threat") remains to be demonstrated, though studies by Lazarus and Smith (1988) and Chwelos and Oatley (1994) represent efforts in that direction. Whether actually occurring appraisal patterns indeed form only a small subset of theoretically possible patterns (as Lewis asserts they do), has, to my knowledge, not yet been examined. Whether appraisals indeed stabilize, and if they do, for what reasons, also awaits evidence. Probably, evidence in these regards is not too difficult to come by. So far, little effort has been devoted to analyzing the variability of appraisal patterns linked to a given emotion class. De Boeck and his colleagues (Kuppens et al. 2003) have recently begun work on that issue.

That these proposals are mostly promises does not detract from their plausibility. Certain appraisal patterns may have more internal coherence than others, or their components may be more related; they do, as patterns, have meaningful relationships to particular action readiness modes because they represent precisely what the action readiness modes aim to modify. Action readiness also may well entrain particular actions and physiological activations, and may even form coordinative structures. Attractors may be shaped on those grounds. The dynamic systems approach thus points to focused research in those directions. But appeal and plausibility are dampened by the question that emerges upon reading the article: What are the phenomena that make analysis in terms of self-organization notions desirable?

The fourth contribution of this target article is its detailed review of neurobiological findings that are relevant to emotion processes. The complex neurobiological interactions parallel the complex interactions described at the psychological level. The analysis arrives at three plausible high-level neurophysiological loops. Surprisingly, considering the author's reservations regarding the appraisal–response distinction (confusingly termed the appraisal–emotion distinction), the loops identify appraisal (here called "object evaluation") and action as distinguishable major functional circuits, together with process monitoring.

Exploring psychological complexity through dynamic systems theory: A complement to reductionism

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Abstract: Dynamic systems theory (DS) provides tools for exploring how simpler elements can interact to produce complex psychological configurations. It may, as Lewis demonstrates, provide means for explicating relationships between two reductionist approaches to overlapping sets of phenomena. The result is a description of psychological phenomena at a level that begins to achieve the richness we would hope to achieve in examining psychological life as it is experienced and explored in psychoanalysis.

It has long been evident that the clarity and testablity reached through the reduction of complex psychological phenomena is achieved at the price of the loss of the richness people hope for from psychological explanations. Whether in terms of emotion theory, neuroscience, psychoanalytic theory, or any number of other efforts to reduce personal experience to underlying mechanisms, it is rare for individuals to feel that the theory has achieved an explanatory power adequate to their own experience. One result has been an ongoing tension between the psychological theories and experiential descriptions. This tension is especially evident in clinical work, where the ever-present search for the bases for complex particular psychological states rapidly comes up

https://doi.org/10.1017/S0140525X05340040 Published online by Cambridge University Press