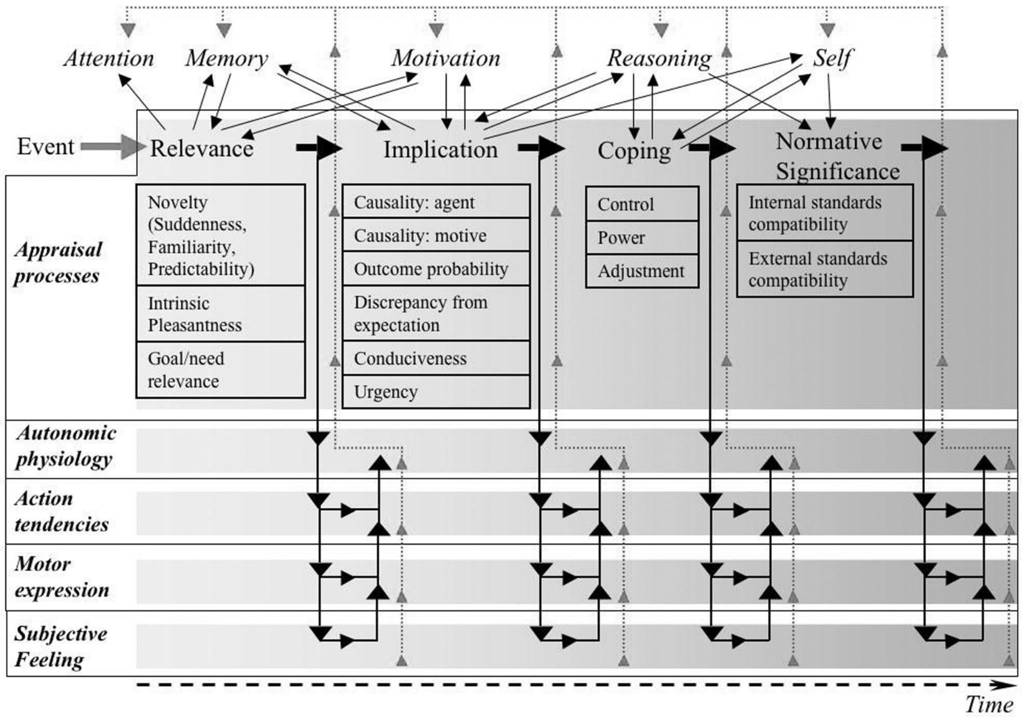

Figure 1 (Sander & Scherer). Comprehensive illustration of the Component Process Model of Emotion (adapted from Scherer 2001).

other cognitive processes and (ii) an effect of particular *emotion components* on these cognitive processes. Moreover, *direct versus indirect* types of emotional effects on appraisal criteria can be distinguished. Direct effects would consist in the modulation of appraisal criteria by other emotion components. Indirect effects would consist in an effect of these components on particular cognitive processes that, in turn, can influence appraisal criteria (see Figure 1). It can be expected that most effects are indirect – in the sense of individual emotion components affecting attention, memory, and other cognitive processes or representations.

4. The role of the underlying neural architecture. Identifying the neural mechanisms subserving emotional processes serves to constrain and inform models of emotion (see Davidson 2000; Sander & Koenig 2002). Unfortunately, Lewis's extensive review of the vast literature concerning the cerebral basis of major cognitive functions and other psychological processes is of limited use for this purpose because the information is often too general to allow inferences concerning specific functional architectures. The treatment of the amygdala is a good example: According to Lewis, the role of the amygdala in the evaluative component of appraisal consists of a "basic pattern-matching function" (sect. 4.2.2). However, a more specific account of the function of the amygdala, as based on recent research, is required to constrain and inform models of emotion. Contrary to the assumption that the amygdala is central to a "fear module" (Öhman & Mineka 2001), presumably supporting a discrete emotion model, patient data and brain imaging studies clearly demonstrate that this structure contributes to the processing of a much wider range of negative affective stimuli (for a review, see Sander et al. 2003). As the amygdala seems also involved in the processing of positive events, it was suggested that it modulates arousal, independently of the valence of the elicitor (e.g., Anderson et al. 2003) – potentially supporting dimensional theories of emotion. However, it has been shown that equally intense stimuli differentially activate the dorsal amygdala (e.g., Whalen et al. 2001), and that arousal ratings in a patient with an amygdala lesion are impaired for negative, but not positive, emotions (Adolphs et al. 1999). These results seem to contradict the view that the amygdala codes arousal irrespective of valence. Converging evidence supports the view that the computational profile of the human amygdala meets the core appraisal concept of *relevance detection* (for a detailed analysis, see Sander et al. 2003), a view which integrates established findings on the amygdala and suggests that it may be central in processing self-relevant information. Although this type of neural architecture can be directly integrated into appraisal models like the one shown in our Figure 1, it is difficult to see how it informs very general models like the one presented by Lewis.

Developmental affective neuroscience describes mechanisms at the core of dynamic systems theory

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Abstract: Lewis describes the developmental core of dynamic systems theory. I offer recent data from developmental neuroscience on the sequential experience-dependent maturation of components of the limbic system over the stages of infancy. Increasing interconnectivity within the vertically integrated limbic system allows for more complex appraisals of emotional value. The earliest organization of limbic structures has an enduring impact on all later emotional processing.

In this target article, as in all of his writings, Marc Lewis describes the essential developmental core of self-organization theory, a theory that fundamentally models the emergence of novel patterns or structures, and the appearance of new levels of integration and organization in existing structures. In light of his contributions and research in developmental psychology, it is curious that he offers little in the way of data from developmental psychology or developmental affective neuroscience that may bear directly upon his model of self-organizing emotional appraisals. In his neurobiology he emphasizes the roles of the amygdala, anterior cingulate, and orbitofrontal cortex. These same structures are also central to Adolphs' (2001) neurobiology of social cognition and Schore's (1997; 2000; 2001) and Davidson et al.'s (2000) circuits of emotion regulation. In two recent books (Schore 2003a; 2003b), I have documented a growing body of research on the experience-dependent maturation of these three limbic structures over early stages of development, which ontogenetically evolve in a subcortical to cortical sequence over discrete critical periods of postnatal brain development. These studies demonstrate that increasingly complex emotional communications embedded in attachment experiences imprint a fixed ontogenetic sequence of early maturing amygdala, then ventral anterior cingulate, and finally orbitofrontal levels of the limbic system (Helmeke et al. 2001; Nair et al. 2001; Neddens et al. 2001; Poeggel et al. 2003; Ziabreva et al. 2003). The organization and increasing interconnectivity of these limbic structures over the stages of postnatal development (the first 2 years in humans) allows for the appearance of more complex systems for appraising emotional value and regulating psychobiological states.

Lewis's fertile model brings the following questions to mind. Could this developmental information about the sequential-stage, experience-dependent maturation of a three-tiered limbic system offer clues about the sequence of psychoneurobiological operations of the trigger phase, self-amplification phase, and self-stabilization phases of self-organizing emotional appraisals in the adult human brain? Could these three amygdala, cingulate, and orbitofrontal limbic levels produce separate subcortical-cortical implicit appraisals (and visceral responses), and would their vertical integration across multiple levels of the vertical limbic neuraxis be involved in what Lewis calls "emergent wholes"? Could "flows of activation" among these subcortical and cortical systems be linking energetic (excitatory and inhibitory synaptic) pathways that are originally sequentially imprinted in critical periods of development of these corticolimbic structures? Would these patterns of energy flow follow the rostral-to-caudal development of expanded arousal-energy systems in the maturing brain? Could each component level process a trigger, self-amplification, and self-stabilization phase, with information reciprocally moving bottom-up and top-down between and within levels of the neuraxis, with such synchronized dynamic adjustments allowing for what Lewis calls "an ongoing state of engagement with the world." Does this mechanism describe Lewis's "vertical integration," and could this more complex interconnectivity of higher and lower components of the limbic system optimally adapt on a moment-to-moment basis to a rapidly changing environment?

Although Lewis makes an important contribution emphasizing lower subcortical mechanisms that regulate the arousal (and energy metabolism) of the higher cortex, I suggest the current appraisal literature has largely overlooked a key contributor to bottom-up emotion processes, the energy-expending sympathetic and energy-conserving parasympathetic components of the autonomic nervous system, and thereby the body. In other words, vertical circuits also include "limbic-autonomic circuits" (Schore 2001). Craig (2002) provides evidence that the right orbitofrontal cortex, the hierarchical apex of the right limbic system, processes information from the ANS and generates the most complex subjective evaluation of interoceptive state, the highest representation of the sense of the physiological condition of the body. This line of research suggests that the higher corticolimbic centers appraise not just exteroceptive information, but also interoceptive information that is critical to adaptive function (see Schore 2003a; 2003b). Furthermore, studies indicate that this same right frontal area is dominant for the appraisal of biologically meaningful exteroceptive and interoceptive self-related information in contexts of threat (Sullivan & Gratton 2002). These data clearly suggest that appraisal mechanisms need to be studied in more than the non-stressed or artificially stressed state, and in states of low and high arousal.

In the target article Lewis also offers some brief thoughts on the roles of the right and left hemispheres in appraisal processes. There is now compelling evidence that the right hemisphere develops in early infancy, before the left, and that the rapid emotional communications and appraisals embedded in attachment transactions imprint the right limbic system (Schore 2003b). I agree with Lewis's conclusion that right hemisphere processing of somatic-affective information precedes left hemisphere semantic processing. In recent work (Schore 2003a; 2003b) I suggest this may reflect early implicit appraisals of the ventral processing stream dominant in the right hemisphere, antecedent to the explicit appraisals of the dorsal stream dominant in the left. This left lateralized (dorsolateral prefrontal cortex) processed explicit information may then be callosally fed back to right orbitofrontal implicit systems. The right orbitofrontal cortex, centrally involved in affect regulation, may then top-down relay this information to lower levels of the right limbic-autonomic neuraxis to cingulate and amygdalar limbic structures and to monoaminergic arousal and hypothalamic motivational centers, which in turn alter CNS arousal and ANS autonomic arousal. This bottom-up adjusted arousal state and somatic-affective information can then be fed back up the neuraxis, altering higher cortical processing. Resonance between the higher and lower levels of the right brain may then allow it to self-organize to an optimal level of complexity and act as "an emergent whole." The right brain has been suggested to be dominant for the ability to maintain a coherent, continuous, and unified sense of self (Devinsky 2000; Schore 1994).

The dynamic systems perspective of emotional processes presented by Lewis also suggests that longitudinal studies of a single system dynamically moving through state spaces may be of more value than averaging group measures. This experimental approach may offer a deeper understanding of emotion psychopathogenesis. Self-organization concepts can also be applied to the field of emotion communication and brain-to-brain intersubjectivity. This integration can lead to an emotion theory that can shift between a one-person and a two-person psychology.

The importance of inhibition in dynamical systems models of emotion and neurobiology

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Abstract: Lewis makes a compelling case for a dynamical systems approach to emotion and neurobiology. These models involve both excitatory and inhibitory processes. It appears that a critical role for inhibitory processes is implied but not emphasized in Lewis's model. We suggest that a greater understanding of inhibitory processes both at the psychological and neurobiological levels might further enhance Lewis's model.

Lewis has made a very important contribution by arguing that antecedent and consequent processes are one and the same. For too long appraisal processes and cognitive consequences of emotional arousal have been considered separate academic domains. It is refreshing to reevaluate this long-held assumption in light of modern neurobiology and to consider the implications of this insight for future research. Lewis's framework also incorporates individual differences within a single model that addresses antecedent and consequent processes. This unifying vision has great potential for expanding our understanding of emotional processes.

A major conclusion of this target article is that traditional distinctions between cognition and emotion break down and no longer appear valid when one considers the neural substrates and the dynamic interactions of the processes in question. This was in fact the fundamental thesis of the volume *Cognitive Neuroscience of Emotion* (Lane & Nadel 2000). It is refreshing to see this fun-

https://doi.org/10.1017/S0140525X05460045 Published online by Cambridge University Press