Grossberg & Schmajuk 1987; 1989). My remaining comments summarize aspects of the models that develop Lewis's goals.

The START (Spectrally Timed Adaptive Resonance Theory) model (Grossberg & Merrill 1996) synthesizes three models: a CogEM model, an ART model, and a Spectral Timing model. The CogEM model describes how cognitive and emotional processes learn through reciprocal interactions to focus attention on motivationally desired goals, and to release appropriate actions to realize them. The ART model describes how sensory and cognitive representations are learned, focus attention on expected events, and drive adaptive memory searches in response to unexpected events. The Spectral Timing model describes how learning can release actions at times that are appropriate to a given behavioral context. The START model embodies many of the properties that Lewis seeks.

"Positive-feedback and self-amplification" combined with "self-maintaining (negative) feedback" (sect. 3.2.2) are key elements in these nonlinear models. The assertion that "a coherent, higher-order form or function *causes* a particular pattern of coupling among lower-order elements, while this pattern simultaneously *causes* the higher-order form" (sect. 3.2.4, emphasis in original) is a key hypothesis of ART since its introduction in 1976 (Grossberg 1976b; 1978; 1980; 1995; 1999a; 1999b). Indeed, ART clarifies how these different levels code complementary types of information (cf. Grossberg 2000a) which, by themselves, are insufficient to control behavior. ART also proposes how resonant feedback states can lead to "temporal synchronization . . . corresponding to attentional states of expectancy or focused perception" (sect. 5.1, para. 10; cf. Grossberg 1976b; Grossberg & Somers 1991) and how "attentional and evaluative processes . . . must remain integrated for some period of time for [. . .] learning to take place" (sect. 5.5.1). Indeed, this is the main idea of ART: that resonance drives learning. ART also introduces a concept of "vigilance" that can explain "vigilant attention to strangers" (sect. 6.1) (cf. Carpenter & Grossberg 1987; 1991). Finally, ART mechanizes concepts of "intentionality and consciousness" (sect. 3.2.4) and predicts that "all conscious states are resonant states" (Grossberg 1995; 1999b).

Cognitive-emotional resonances of the CogEM model preceded the introduction of ART (Grossberg 1975) and give mechanistic meaning to Lewis's assertions about "a self-amplifying interaction among appraisal and emotion elements" (sect. 3.3.1) so that "emotions guide the focus of attention . . . to those features that are emotionally relevant (sect. 3.3.2). Indeed, CogEM models how attentional blocking can filter out emotionally irrelevant cues and focus motivated attention upon motivationally relevant ones (Grossberg 1982a; 1982b; 1984b; Grossberg & Levine 1987; Grossberg & Merrill 1996), clarifying how motivated attention provides a "beam of attention . . . focused on whatever is emotionally compelling" (sect. 4.3.3). Lewis cites Damasio's (1999) book to describe the "affective feeling of emotion" (sect. 4.3.4). The Damasio model is a heuristic version of CogEM (Grossberg 2000b). As in ART's sensory/cognitive resonances, CogEM cognitive/emotional resonances provide the "enduring couplings [that] seem necessary to strengthen the connections responsible for learning" (sect. 3.3), notably connections underlying conditioned reinforcer and incentive motivational learning (e.g., Grossberg, 2000a; 2000b). Orbitofrontal cortex and amygdala (cf. sect. 4.2.2) are highlighted in CogEM learning processes (Grossberg 2000b), which clarify how "ongoing emotion regulation implies continual recruitment of orbitofrontal evaluation by amygdala associations, thus stabilizing the activities of both structures" (sect. 6.2) and settling into "a lasting mood-like state" (sect. 6.2). In both ART and CogEM, several different types of nonspecific arousal and neuromodulatory functions are described that are consistent with Lewis's review. Finally, the claim that "emotion theorists restrict their analysis to the effects of clinical traits on emotion and appraisal" (sect. 6.3) is not correct. The reverse direction has been used to clarify symptoms of mental disorders such as schizophrenia and attention deficit disorder (Grossberg 1984a; 2000b).

These long-standing results contradict Lewis's claim that, concerning "self-organizing states of coherence, there is as yet no mechanism to relate that coherence back to component interactions" (sect. 5.3), or that "the mechanism of this meta-integration is unknown" (sect. 5.3). I would argue, instead, that convergent psychological and neurobiological data are starting to confirm long-standing predictions about how these mechanisms work; see, for example, Raizada and Grossberg (2003).

Lewis also discusses how emotional processing may mediate the learning of plans and actions, including the role of dopamine (e.g., sect. 5.4), but does not note that action processes may obey laws that are complementary to those of perception, cognition, and emotion (Grossberg 2000a). Progress towards quantitatively explaining behavioral and neurobiological data about how animals and humans learn actions under the guidance of reinforcing events has also been made (e.g., Brown et al. 1999, 2004; Fiala et al. 1996).

In summary, Lewis provides an excellent introduction to a useful direction for emotion research to follow. He regrettably misses the most-developed models that realize his stated goals, and therefore the brain design principles and mechanisms that can turn his goals into working science. I hope his article will help readers to better understand such models.

Brain, emotions, and emotion-cognition relations

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Abstract: Lewis makes a strong case for the interdependence and integration of emotion and cognitive processes. Yet, these processes exhibit considerable independence in early life, as well as in certain psychopathological conditions, suggesting that the capacity for their integration emerges as a function of development. In some circumstances, the concept of highly interactive emotion and cognitive systems seems a viable alternative hypothesis to the idea of systems integration.

Lewis's significant target article shows the usefulness of dynamic systems theory (DS), particularly the principle of self-organization, in linking emotion theory to the neurobiology of emotions. His exposition of the processes that link emotion feelings and cognition resembles that described by other theories (Izard 1977; 1993; Magai & McFadden 1995). However, he advances recent research and theory by explicating interactions at the neural, affective, and cognitive levels and by treating the gamut of issues relating to emotion-cognition relations. His analysis of the neural systems of emotions and appraisal helps to explain the coupling and veritable integration of thought/memories, emotions, and actions or action tendencies into personality traits. Yet, significant questions remain.

Contextual restraints on integration. When Lewis asserts that emotion and cognition are "parts" that become integrated through interaction, he implies that they become a whole, a unity. Indeed, it does appear that emotion and cognition act in unison in behavior driven by dispositional emotionality. Dispositional emotionality is exemplified in enduring affective-cognitive structures or emotion traits in which a particular emotion feeling and a particular set of thoughts have become functionally integrated (Izard 1977; Magai & McFadden 1995). Functional integration means that the feeling and the associated pattern of thoughts coexist, operate, and interact harmoniously and in synchrony. It is exemplified in the happiness-prone individual who even in difficult situations typically thinks optimistically, expresses hope, and engages in decisions and actions commensurate with a happy feeling-thought pattern. However, such integration does not produce a gestalt in which emotion has lost its distinctive qualities. The individual still experiences both the feeling of happiness and the positive thinking characterized by optimism and hope, albeit in apparent synchrony. This outcome of the harmonious interaction and reciprocal influences of emotion and cognition appears consistent with the concept of the functional integration of the two types of systems.

However, situations in everyday life often elicit appraisals and emotions which do not cohere and operate synchronously through adaptive emotion traits or other mechanisms. In these situations cognitive appraisal and emotion operate as separate systems that may or may not interact harmoniously to produce desirable outcomes. Lewis seems to have implicitly acknowledged this point when he refers to the end product of emotion-cognition interactions as an amalgam. In an amalgam, the parts retain their separate identities and functions. Moreover, inter-system interactions may prove effective without leading to systems integration. Fear-regulating thoughts (and speech) to help conceal the signs of fear from threatening and dangerous individuals illustrates an effective interaction of emotion and cognition without integration. In such a situation, an integration of emotion and cognition in which fear feelings color speech and other forms of expressive behavior may prove maladaptive.

Emotion-cognition integration as a function of development. Evidence suggests that the emotion system involved in emotion-cognition interactions may in certain situations have privileged communication lines that enable it to exclude or override cognitive input and preempt action systems. Data from studies of developmental changes in emotions and emotion-cognition relations in early development suggest that emotions and cognition operate with considerable independence during early development. For example, infants lack the ability to exercise cognitive control of emotions in stressful situations. Pain or separation activates negative emotions that continue at high levels of intensity, despite parental efforts at comforting (Izard et al. 1987; Shiller et al. 1986).

Nevertheless, infants show individual differences in the amount of negative emotion they display during stress, and 1.5-year-old toddlers' negative emotion expression during stress predicted their scores on the personality trait of Neuroticism at age 3.5 (Abe & Izard 1999). In both children and adults, negative emotions essentially constitute the trait of Neuroticism (Izard et al. 1993; Watson & Clark 1992). Data like these raise the question of whether emotion is dominant in such traits. They also raise the question of whether these traits can drive behavior mainly with emotion motivation and involve little or no cognitive control. In general, the socialization of emotion and the development of self-regulation of emotion, which appear to be deficient in individuals high on trait Neuroticism, are the keys to the child's transition to a greater capacity to exercise cognitive control of mood and behavior.

Psychopathological conditions and the functional dissociation of emotions and cognitive control. Both autism spectrum disorders and psychopathy have empathy-related deficits as primary characteristics, and, therefore, are logical candidates for an investigation of the dissociation of emotion and cognitive systems. In attempting to explain autism spectrum disorders, researchers have proposed a theory in which systemizing is dominant and empathizing is severely underdeveloped (Baron-Cohen 2003). In support of this possibility, a recent brain imaging study shows that autistic patients showed less activation of the amygdala and more activation of temporal lobe structures during an emotion recognition task (Baron-Cohen et al. 1999). This study and other evidence of amygdala processing deficits in autism suggest that emotion processing systems are less well-developed in autistic patients, and higher order cognitive processing is used as a compensatory systemizing strategy.

Amygdala deficits are also primary in psychopathy, and psychopaths appear unable to pair stimuli in the environment that are generally considered distressing with cognitive representations of moral behavior (see Blair 2003). However, unlike people with autistic spectrum disorders, psychopaths do appear able to succeed at theory of mind tasks, likely because they can master the cognitive aspects of empathy (Richell et al. 2003). Thus, the dissociation of cognitive and emotional systems is especially striking in psychopathy because cognitive processing of others' emotions is intact, and this ability is often used for personal gain. However, the cognitive understanding of others' emotions is not integrated with emotion-related autonomic responses and empathic behaviors, and this dissociation is clear in neurological measurements of intact (orbital prefrontal cortex) versus impaired (amygdala) brain regions. Are the separability and relatively independent functioning of emotion and cognitive processes that characterize autism and psychopathy categorically different from those of other psychopathological and normative conditions, or different in degree?

Brain injury and the dissociation of emotion and cognition. Research with brain injured patients reveals with remarkable clarity that emotion and cognitive systems have distinct functions in learning, decision making, and actions, and that emotion does not merely add color or tone to cognitive processes (Bechara et al. 1995). Emotions determine choices and actions on some occasions and no amount of cognition can replace the functions of emotions in decision making. Bechara et al. (1997) compared the performance of patients with lesions in the orbitofrontal cortex and normal controls on a card game that offered options of conservative and risky decisions. Conservative decisions (choosing cards from the "good decks") led eventually to a positive outcome (winning game money) and risky decisions (choosing from the "bad decks") led to negative outcomes (big losses of game money). Even after the orbitofrontal patients fully comprehended the consequences of their actions, they still made disadvantageous choices that resulted in losses, presumably for lack of anticipatory arousal and emotion information. Control participants experienced emotion arousal on a number of trials before they fully ciphered emotion information into the decision-making process, suggesting that the emotion and cognitive systems of the normal controls operated quite independently for a while. Also, normal participants who never acquired an understanding of the game (or reached the "conceptual level") still made advantageous choices. Presumably, they did that on the basis of emotion information that was not integrated with cognition at the conscious level. Results for the patients and controls taken together suggest that on a given occasion, emotion and cognitive systems may first operate independently and then interactively or integrally. The concept of highly interactive systems seems to explain the end result for the normal controls (mainly conservative and advantageous decisions). At the least, this study shows that in the course of acquiring a response strategy for risky situations, the integration of cognitive and emotion systems does not occur immediately or simply as a function of emotion arousal. It takes time. During this time emotion and cognition interact and influence each other reciprocally.

In another experiment, patients with orbitofrontal damage not only failed to anticipate the consequences of disadvantageous choices, they demonstrated the firmness of the separation of cognitive and emotion systems by not reporting regret following feedback about their mistakes or poor choices (Camille et al. 2004). Evidence also suggests that the anterior cingulate cortex makes preconscious decisions about the desirability of outcomes (Gehring & Willoughby 2002). One could argue that emotion drives such decisions. No one has shown how they could result from the influence of cognitive control when the decisions occur at the nonconscious level.

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