facilitated CRH-gene expression versus testosterone-potentiated amygdalar vasopressin gene-expression results in the expected reversed shift in the balance between the sensitivity for punishment and reward (DeVries et al. 1995; Schulkin 2003). Concurring antagonistic effects of cortisol and testosterone have been observed in humans during implicit or unconscious measures of approach- and withdrawal-related emotions that predominantly depend on subcortical processing (Van Honk et al. 1998; 1999; 2003; 2004). (2) Although the steroids primarily target subcortical affective regions, there is evidence for a relationship between cortisol and dominant right-sided *cortical* asymmetry in young children and nonhuman primates, which accompanies punishment-sensitive characteristics of behavioral inhibition (Buss et al. 2003; Kalin et al. 1998). Contrariwise, recently we found that testosterone administration induces reward-associated left prefrontal cortex activation during the display of erotic movies (unpublished observation). (3) Our *subcortical-cortical* evidence builds on a theory wherein the phylogenetically different brain systems relate to the subcortically generated delta (1–3 Hz) and cortically generated beta (13–30 Hz) oscillations in the electroencephalogram (EEG). Relative increases or decreases in subcortical-cortical cross-talk are computed by correlating the change in power between these bands, and it has repeatedly been demonstrated that elevated subcortical-cortical cross-talk as indexed by EEG is accompanied by elevated punishment sensitivity (Knyazev & Slobodskaya 2003; Knyazev et al. 2004). On the endocrinological level, increased levels of cortisol have been associated with enhanced punishment relative to reward sensitivity and are evidently accompanied by increased subcortical-cortical cross-talk (Schutter & Van Honk 2005). In an opposite fashion, reductions in subcortical-cortical cross-talk after administration of testosterone have been observed in healthy volunteers (Schutter & Van Honk 2004). This *decoupling* of subcortical and cortical processing is argued to indicate a shift in motivational balance from punishment towards reward sensitivity (Schutter & Van Honk 2004).

In sum, an increasing body of evidence suggests that the steroid hormones cortisol and testosterone are antagonistically involved in the modulation of emotional homeostasis on the different phylogenetic levels of the brain. Importantly, this emotional homeostasis is not only subcortically controlled by bottom-up inter- and intra-axes negative feedback mechanisms, but also cortically through top-down psychological regulatory processes (Mazur & Booth 1998). This dynamic steroid hormone regulation of social emotional behavior provides a bridging principle between the psychological and biological domains, and might well prove to be an important neurobiological mechanism in motivation and emotion.

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A dynamic duo: Emotion and development

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Abstract: A dynamic systems (DS) approach uncovers important connections between emotion and neurophysiology. It is critical, however, to include a developmental perspective. Strides in the understanding of emotional development, as well as the present use of DS in developmental science, add significantly to the study of emotion. Examples include stranger fear during infancy, intermodal perception of emotion, and development of individual emotional systems.

Lewis presents a dynamic systems approach to emotion with an emphasis on self-organization of small neurological units and larger social wholes. As is typical of self-organizing systems, he proposes that large complex emotion systems arise from oscillating interactions among smaller and often simpler forms that may have emotional potential. We also have argued that the study of emotion must not veer into a barren, reductionist landscape in which a set of boxes fixed in a linearly organized fashion sit waiting to be opened. We wish only to add some examples from our work that expand Lewis's call and also reintroduce the critical need to include development in any study of emotion, and especially in a dynamic systems (DS) approach to emotion (see also Lewis 2000b). Some of the most outstanding research on emotion is developmental (Izard et al. 1995; Malatesta & Izard 1984; Nwokah and Fogel 1993; Witherington et al. 2001), as is some of the best work using DS principles (Magai & Haviland-Jones 2002; Thelen & Smith 1994). This is no accident: During particular age periods of rapid change (e.g., infancy), one can observe the coaction of a number of systems in real time within a reasonable research time frame. However, across a life span the DS principles are applicable.

A decade ago, we proposed a multicomponent systems approach for understanding the origins and development of emotion (Haviland & Walker-Andrews 1992). Our primary focus was on the socialization of emotion, and our primary example was the emergence of fear of strangers. We argued that stranger fear was not an additive growth function built with "more" cognition, but, in DS terminology, a phase. Further, stranger fear is expressed (or not) due to a number of initial conditions, including the typical infant-caregiver communication patterns that have emerged over time. Since that first article we have added other examples that could both benefit from a DS perspective and contribute support to DS principles.

One example arises from research on infants and their self-organizing patterns of emotion perception. The environment is replete with multimodal and co-occurring information for objects, events, and personal experience. An observer moving through the world sees occluding surfaces, hears transient sounds, may touch rigid objects, and smell and taste various substances concurrently. Information for emotion is available multimodally as well. An angry person may scowl, raise his voice, gesture abruptly, and tense his muscles. The perception of the emotional expression is not merely the sum of each of these components. Rather, the observer perceives a unified multimodal pattern that has unique communicative affordances. Moreover, the presence of multimodal information may facilitate the perception of an event (Bahrick & Lickliter 2000; Walker-Andrews & Lennon 1991). The detection of meaning in an expression develops as the observer's perceptual skills develop, as she gains experience, as she becomes more familiar with a particular person and eliciting situations. Consequently, an adult may recognize that someone is angry by observing gestures alone or attending to the situation, but the young infant appears to need the redundant, extended information. Similarly, the experience of emotion is multifaceted, including kinesthetic, somatosensory, and other modality-specific information. According to Stern (1985), such experience may provide for infants a feeling of deja vue that allows the infant to develop a sense of self as an extended emotional agent. The perception of multimodal information for emotions of the self and of others is an example of how "individual elements or groups of elements lose their independence and become embedded in a larger regime" (sect. 3.2.3 of the target article).

In a second example, fractal patterns have emerged in studies of life-span emotional development (Magai & Haviland-Jones 2002). The social-cognitive emotion system at a point in time shows features of fractal geometry or self-similarity of emotion pattern replicated at lower and higher orders of magnification. Individuals reproduce their unique emotion organizations psychologically. Without examining long-term development of individual change, as is required by DS, such fractal structures would not become apparent. Once established, the fractal patterns tend to organize new sensory information to form a "growing" system that is subject to phase shifts. This newer work on individual development of emotion systems is related to the model described above (Haviland & Walker-Andrews 1992) and a more mathematical visualization of emotion patterns emerging from small and potentially chaotic events – dependent also on initial neurological conditions (Haviland-Jones et al. 2001).

Given our work and that of many others, Lewis may have overstated the case for social emotions systems to be linear rather than self-organizing or dynamic. It is certainly true that, historically, approaches to research on emotion are linear and normative, but developmental theory even in its own infancy dating from Vygotsky or Piaget has been built upon the emerging principles of individual change and self-organization.

Dynamics of cognition-emotion interface: Coherence breeds familiarity and liking, and does it fast

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Abstract: We present a dynamical model of interaction between recognition memory and affect, focusing on the phenomenon of "warm glow of familiarity." In our model, both familiarity and affect reflect quick monitoring of coherence in an attractor neural network. This model parsimoniously explains a variety of empirical phenomena, including mere-exposure and beauty-in-averages effects, and the speed of familiarity and affect judgments.

In the target article, Lewis argues for conceptualizing the interplay between cognition and emotion in dynamical terms. His proposed framework highlights bidirectional links and multiple feedback loops between cognitive and emotional processes. The framework's focus on comprehensiveness and abstract principles spanning different levels of analysis is valuable. However, as a result of this focus, the framework specifies few concrete mechanisms that perform the postulated integration of cognition and emotion. In our commentary, we illustrate the value of the dynamical systems approach by discussing specific mechanisms linking recognition memory and affect.

Titchener (1910) noticed that familiar stimuli elicit a "warm glow." Nearly a century later, a host of studies show that variables that enhance familiarity also enhance positive affect (Reber et al. 1998; Winkielman & Cacioppo 2001; Winkielman et al. 2002). Thus, both familiarity and liking are enhanced by (1) repeated exposure to a stimulus (mere-exposure effect), (2) exposure to category exemplars that converge on a prototype (beauty-in-averages effect), (3) presenting the target with higher clarity or at longer durations, or (4) preceding the target with perceptual or semantic primes. In addition to these commonalities, familiarity and affect are both fast processes. Familiarity judgments are often faster than recognition judgments (Mandler 1980) and liking judgments are often faster than judgments about descriptive attributes (Zajonc 1980).

On the surface, there are no obvious reasons for these commonalities between familiarity and liking. However, things become clearer when memory and affect are conceptualized in dynamical terms as processes occurring in a neural network. In such a network, representations (learned patterns) correspond to attractors, that is, states to which the network dynamics converges (Hopfield 1982; O'Reilly & Munakata 2000). During the stimulus recognition process, each neuron of the network adjusts to the signal coming from other neurons until the network gradually approaches a stable state, an attractor. Typically, the behavior of a network is characterized by a degree of match between the input and output pattern. However, the network can also be characterized by its "volatility" – a number of neurons changing state and the coherence of signals arriving at each neuron. Simulations show that such volatility is different when the network is recognizing known versus novel patterns. When the network is close to its attractor, relatively few neurons change their state because most neurons already match the attractor. When the incoming pattern is novel, however, a large number of neurons change their state. Based on this observation, Lewenstein and Nowak (1989) proposed that the network uses its volatility signal to determine a global familiarity of the incoming pattern. Remarkably, such estimation of whether a pattern is generally "new" or "old" (i.e., proximity to its closest attractor) can occur within the first moments of processing, long before the pattern is actually recognized (sometimes in as little as 3% of the time needed for full recognition). Now, what about affect? Note that the volatility signal also allows the network to quickly estimate the potential valence of the pattern. This is because novelty is a cue to a potential danger whereas familiarity is a cue to positivity – after all, familiar objects have not eaten us yet. It is also important that this rough valence estimate is obtained fast, before the network fully knows what it is dealing with, as it helps prepare immediate avoidance-approach actions.

The proposed conceptualization nicely accommodates the empirical phenomena listed earlier. In the mere-exposure effect, many prior encounters establish a strong memory for a pattern, whereas few prior exposures establish a relatively weak memory. Later, a test pattern with a relatively stronger memory (i.e., stronger attractor) elicits little volatility, and thus is more familiar and liked (Drogosz & Nowak, in press). In the beauty-in-averages effect, converging exemplars create a strong attractor for a prototype, which is recognized with less volatility. Patterns presented with longer duration or with higher clarity are represented by more extreme values of activation, and result in less volatility. Finally, priming pre-activates neurons that encode the pattern, which add up to the activation from the actual target, resulting in more extreme values of activation and less volatility. In sum, according to the proposed computational model, repetition, prototypicality, duration, contrast, clarity, and priming enhance familiarity and liking because all these manipulations reduce the network's volatility and increase its coherence. These changes in volatility manifest early, long before the full completion of the recognition process, thereby accounting for the fast nature of familiarity and affect.

In addition to quick feedback about the valence of the incoming stimulus, the early pre-recognition of familiarity may be used to control the recognition process, so that known stimuli are processed differently than new ones. This may be achieved by linking the outcome of pre-recognition based on monitoring the system dynamics to a control parameter (e.g., network's overall noise level) that influences the later stages of the recognition process. A number of specific models that involve a feedback loop between pre-recognition and the noise level have been proposed. For example, in the original model by Lewenstein and Nowak (1989), unknown patterns raised the noise level, preventing false "recognition" of unfamiliar patterns – a common problem for neural networks. In another example, by monitoring its own early dynamics a network can switch between recognizing known patterns and learning novel patterns (Zochowski et al. 1995). Yet another implementation of this control mechanism allows a network to recognize the emotional quality of the stimulus in the pre-recognition process and use this emotional pre-recognition to facilitate the recognition of stimuli that are relevant to this emotion (Zochowski et al. 1993). This is a concrete exemplification of one of the main feedback loops proposed in Lewis's model: that the early cognitive processes elicit emotion that control further cognitive processing. For an extensive model of how such loops are used in self-regulation, see Nowak and Vallacher (1998) and also Vallacher and Nowak (1999).