CHILD DEVELOPMENT PERSPECTIVES

Reassessing Emotion Regulation

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ABSTRACT—***Developmental research on emotion regulation is increasingly advancing toward a systems view that integrates behavioral and biological constituents of emotional self-control. However, this view poses fundamental challenges to prevailing conceptualizations of emotion regulation. In portraying emotion regulation as a network of multilevel processes characterized by feedback and interaction between higher and lower systems, it becomes increasingly apparent that emotion regulation is a component of (rather than a response to) emotional activation, that it derives from the mutual influence of multiple emotion-related systems (rather than the maturation of higher control processes alone), and that it sometimes contributes to maladaptive behavioral outcomes, especially in conditions of environmental adversity. The implications of this perspective for the developmental study of emotion regulation are discussed.***

KEYWORDS—*emotion regulation; systems theory; brain-behavior relations*

REASSESSING EMOTION REGULATION

Emotion regulation is a compelling but challenging issue in developmental science. It is compelling because the association of developing self-regulatory skills with social and emotional competence promises to enhance therapeutic approaches to emotion-related disorders of many kinds. It is challenging because emotion regulation is a broadly inclusive construct whose definition, empirical operationalization, development, and outcomes are complex and poorly defined (Cole, Martin, & Dennis, 2004). Although most conceptualizations of emotion regulation focus on the processes by which emotional responses are modified to accomplish individual goals, developmental researchers continue to disagree over core features of emotion regulation and its definition (cf. Bridges, Denham, & Ganiban, 2004; Campos, Frankel, & Camras, 2004; Cole et al., 2004; Gross & Thompson, 2007; Thompson, 1990, 1994). Much of this disagreement centers on the association of self-regulatory processes with other influences on emotion, and the implications of this association for the constructive, adaptive functions that emotion regulation may provide.

Research efforts to incorporate developmental neuroscience and psychobiology into the study of emotion regulation may help to resolve a number of these conceptual problems. Biological formulations favor a multidirectional systemic view that encourages researchers to understand, in concert, the component processes of emotion regulation at multiple levels. But the integration of behavioral and biological approaches is also likely to present further challenges for current conceptualizations of emotion regulation. In particular, it challenges the view that self-regulatory processes follow from (rather than being integrated with) activated emotion, that emotion self-regulation results in adaptive (rather than sometimes maladaptive) behavioral outcomes, and that it derives from the influence of higher levels of control over lower emotive processes (rather than from their mutual influence). Our purpose here is to profile these conceptual challenges and to suggest several ways they can be addressed in the next generation of research on the development of emotion regulation.

DEVELOPING CONSTITUENTS OF EMOTION REGULATION

In developmental research, the breadth of the concept of "emotion regulation" means that scientists are studying a multifaceted phenomenon whose development arises from the growth and integration of many behavioral and biological processes (Thompson & Goodvin, 2007). Some of these processes are regulatory and emotion-specific, but others are not. Early in infancy, for example, self-regulation of emotional arousal is tied

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to the growth of executive attentional control, with the redirection of attention enabling the infant to disengage from emotionally arousing stimuli (Posner & Rothbart, 2000; Rothbart, Posner, & Boylan, 1990; Ruff & Rothbart, 1999). Developing language ability subsequently becomes incorporated into emotion regulation as self-management develops through extrinsic talk (which can also be used to solicit assistance from another) and, later, internal speech (Bloom, 1993; Bloom & Tinker, 2001; Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986). In early to middle childhood, executive function progressively fosters emotion self-management through processes such as self-directed inhibition, self-distraction, reappraisal, and action monitoring, which are also enlisted into broader forms of strategic control (Zelazo & Cunningham, 2007; Zelazo & Mueller, 2002). Emotion self-regulation is also enhanced by growth in episodic and semantic memory, causal reasoning, and advances in perceived self-efficacy (Kopp, 2008). With increasing age, emotion regulation is influenced by growth in theory of mind, emotion understanding, and developing knowledge of sociocultural display rules (Bartsch & Wellman, 1995; Saarni, 1999; Thompson & Lagattuta, 2006). A variety of biological processes are associated with these developmental acquisitions, and we consider them in some detail in the next sections of this article.

"Emotion regulation" is thus a conceptual rubric for a diffuse network of allied processes, from within and outside the child, that contribute to emotional self-management. Consequently, the nature of developmental change in emotion regulation is also multifaceted. Children become more competent at emotional self-control as they acquire a greater variety of self-initiated strategies of emotion management that rely less on external support. In addition to behavioral tactics, these strategies increasingly entail mental regulators of emotion (including attentional, linguistic, and representational influences), are more flexibly applied to specific contextual demands, and gradually incorporate cultural expectations. Children also enlist emotion regulatory skills to accomplish increasingly complex social and personal goals. In light of these multifaceted developmental changes, it should not be surprising that early-emerging individual differences in emotion regulation are not very stable over time because they are based on a changing constellation of behavioral and neurobiological capacities with different maturational timetables and origins (see Calkins, Gill, Johnson, & Smith, 1999; Grolnick, Bridges, & Connell, 1996).

The complexity of these developmental constituents of emotion regulation argues for a systems perspective involving reciprocal influences among multiple control processes. Such a systems perspective should lead to research questions focused specifically on these components and how they interact. In behavioral research, for example, one could assess how increases in executive function contribute to the child's use of other self-regulatory capacities (such as language) in emotion management, or one could assess the association between response inhibition and the use of emotional displays in social situations. Moreover, as we illustrate below, biological research can also elucidate the interactions among multiple components of emotion regulation. By emphasizing the emergence of emotion regulatory competence from a constellation of emerging capacities at many levels of analysis rather than from the maturation of higher order regulatory functions alone, developmental researchers are in a better position to understand how regulation occurs in different contexts and at different ages and what exactly is being regulated when emotions arise.

Emotion regulation is multifaceted not only in its constituents but also in its manifestations. Children in supportive contexts who are overwhelmed with uncontrollable emotions that undermine competent functioning are usually understood as deficient in emotion regulation. However, children may appear to be emotionally dysregulated in situations where they are functioning quite well as emotional tacticians (e.g., a toddler fussing for candy, an adolescent becoming moody to gain attention from sympathetic friends) because their goals for managing emotion are different from those of an adult observer. In these circumstances, emotions are managed in ways that may lead to socially inappropriate conduct.

For children who are not in supportive contexts, such as those facing severe environmental stresses or biological vulnerability to emotional problems, emotion regulation often entails inherent trade-offs that can increase rather than diminish affective problems (Thompson & Calkins, 1996; Thompson, Flood, & Lundquist, 1995). In families with significant marital conflict, for example, children may employ a variety of strategies for managing their emotions, such as maintaining hypervigilance to signs of impending conflict so that they can avoid exposure to it or act to head it off (Cummings & Davies, 1994; Davies & Forman, 2002). Such strategies are problematic because although they may sometimes provide immediate safety or relief, they leave the child emotionally vulnerable in the long run. But there may be no more adaptive manner of regulating emotion in these circumstances. In a similar manner, children who live with a depressed parent, or who are behaviorally inhibited, or who are biologically prone to anxious affect have also been found to enlist strategies of emotion regulation that buffer against immediate stresses while increasing their emotional vulnerability in other ways (see reviews by Calkins & Hill, 2007; Thompson, 2000; Thompson & Calkins, 1996). That their efforts at emotion regulation do not result in psychologically healthy outcomes derives from the emotionally impossible circumstances they face more than from their lack of emotional regulatory skill or effort. Emotion regulation can, in short, contribute outcomes that may not be psychologically healthy or adaptive in an overarching sense.

BIOLOGICAL CONSTITUENTS OF EMOTION REGULATION

Emotion regulation is multifaceted biologically as well as behaviorally. Many neural constituents, including functioning of the autonomic nervous system (ANS), underlie the generation and regulation of emotion and, as we shall argue, interact with each other through feedback processes. This makes it difficult and potentially misleading to map onto the developing nervous system the behavioral distinction between emotion activation and emotion regulation: Higher and lower neural processes that influence the course of emotion at any point must be regarded, in some sense, as regulatory in nature. This is exemplified at the neurobiological level, where the function of emotion regulatory processes is not necessarily the fostering of subjective well-being but the stabilizing of organismic activity through reciprocal coordination and consolidation, in a process often referred to as self-organization (Lewis & Todd, 2007). In this respect, the "individual goals" incorporated into most functionalist conceptualizations of emotion regulation must be significantly broadened to include biological and neurobiological functions (such as achieving coherent organization), as well as, or instead of, psychological health and well-being. Consistent with this view and with the processes of behavioral development outlined above, research on the neuroscience and psychobiology of emotion regulation also demonstrates that self-regulation develops systemically through the interaction of multiple constituents, not just as the maturation of higher order control mechanisms.

Parasympathetic Control of Arousal: A Self-Regulating System

The ANS functions as a complex system of afferent and efferent feedback pathways that are integrated with other neurophysiological and neuroanatomical processes, reciprocally linking cardiac activity with central nervous system processes (Chambers & Allen, 2007). Pathways of the parasympathetic nervous system in particular are implicated in these processes and, consequently, play a key role in the regulation of state, motor activity, and emotion (Porges, 2003). Specifically, the myelinated vagus nerve, originating in the brainstem nucleus ambiguous, provides input to the sinoatrial node of the heart, producing dynamic changes in cardiac activity that allow the organism to transition between sustaining metabolic processes and generating more complex responses to environmental events (Porges, 2007). This central–peripheral neurochemical feedback loop is functional relatively early in development (Porges, 2007). There is good evidence that individual differences in the integrity of these processes are a consequence of both organic characteristics and postnatal experiences (Calkins & Hill, 2007).

Parasympathetic influences on heart rate can be easily quantified in young humans. Variability in heart rate that occurs at the frequency of spontaneous respiration (respiratory sinus arrhythmia [RSA]) can be measured noninvasively and is considered a good estimate of parasympathetic influence on cardiac variability via the vagus nerve. Porges and colleagues developed a method that measures the amplitude and period of the oscillations associated with inhalation and exhalation, called vagal tone (Porges, 1985, 1991, 1996; Porges & Byrne, 1992). Of particular interest to researchers studying emotion regulation has been the measurement of vagal regulation of the heart when the organism is challenged. Such regulation is indexed by a decrease in RSA or vagal tone (vagal withdrawal) during situations where coping or emotional and behavioral regulation is required (Porges, 2003, 2007). Vagal regulation in the form of decreases in RSA is often described as the functioning of "the vagal brake" because a decrease, or withdrawal, in vagal input to the heart has the effect of stimulating increases in heart rate. During demanding tasks, such a response reflects physiological processes that allow the child to shift focus from internal homeostatic demands to demands that require internal processing or the generation of coping strategies to control affective or behavioral arousal. Thus, vagal withdrawal is thought to be a physiological strategy that results in greater cardiac output in the form of heart rate acceleration and that contributes (together with other influences) to behaviors indicative of active coping (Porges, 1991, 1996; Wilson & Gottman, 1996).

Considerable research suggests that vagal withdrawal is linked to a range of behavioral processes that are regulatory in nature. They can begin to be observed quite early in development. Greater RSA decreases during challenging situations are related to better state regulation, greater self-soothing, and more attentional control in infancy (DeGangi, DiPietro, Greenspan, & Porges, 1991; Huffman et al., 1998), fewer behavior problems and more appropriate emotion regulation in preschool (Calkins, 1997; Calkins & Dedmon, 2000; Calkins & Keane, 2004; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996), and sustained attention in school-age children (Suess, Porges, & Plude, 1994). While vagal withdrawal is related to complex responses involving the regulation of attention, emotion, and behavior, the magnitude of this response is an individual difference that is moderately stable across early development and that predicts a range of indicators of adaptive functioning (Calkins, Graziano, & Keane, 2007; Calkins & Keane, 2004; El-Sheikh, 2005). For example, the control of physiological arousal, which is achieved during early infancy, eventually becomes integrated into the processes of attentional engagement and disengagement (Porges, 1996; Richards, 1985, 1987), emotional regulation (Calkins, 1997), and the behavioral and cognitive control processes characteristic of early childhood (Belsky, Friedman, & Hsieh, 2001; Rothbart et al., 1990; Sethi, Mischel, Aber, Shoda, & Rodriguez, 2000).

This biological response is also sensitive to elements of the context in which regulatory challenges are being met. For example, recent research comparing the magnitude of RSA response to different types of challenging tasks indicates that children display significantly greater decreases in RSA when provided with parental support than when they are not (Calkins & Keane, 2004; Calkins et al., 2007). This finding is consistent with other evidence indicating that parental support also helps to buffer toddlers' cortisol responses during challenging situations (e.g., Nachmias, Gunnar, Mangelsdorf, Parritz, & Buss, 1996). These data demonstrate how relational influences interact with psychobiological systems in the process of emotional coping.

The physiological strategy of vagal withdrawal to facilitate active coping may also create outcomes that are less adaptive, however, even as children appear to be actively regulating themselves. For example, children with elevated symptoms of anxiety or depression appear to be very "well regulated" physiologically, displaying a greater degree of vagal withdrawal to emotional challenge than do children with externalizing behavior problems or children with few or no symptoms of behavior problems (Calkins et al., 2007). Adults with depression and anxiety have shown the same pattern of responding in some studies and the opposite pattern in other studies (Beauchaine, 2001). However, the data on depressed individuals are difficult to interpret across studies due to variations in the tasks used to elicit cardiac responding. Nevertheless, one interpretation of an apparently well-regulated physiological response is that although the vagal system is acting to facilitate increases in cardiac output to meet the challenge, the physiological response is exaggerated, perhaps in an effort to maintain control of emotions that are quite labile or intense (Beauchaine, 2001; Calkins et al., 2007). One consequence of such a strategy, at least at a physiological level, is that the greater cardiac output that is needed might in and of itself be disruptive to functioning. The feedback processes of this system, much like the behavioral processes of emotion regulation, can be both adaptive and disruptive depending on at what point in the emotion process the physiological response is activated.

Research on the developmental psychobiology of stress and coping illustrates the systemic nature of emotion regulation, therefore, by demonstrating how cardiac activity is reciprocally linked both to central nervous system processes and to the support of close relationships. Importantly, none of these affective, physiological, or social mechanisms is the source of emotion regulation or coping. Rather, each interacts with the other in specific situations from early in life in an integrated feedback system to guide the organism's response to stresses in increasingly complex ways.

Feedback and Coordination in the Neurobiology of Emotion Regulation

Another complex integrated feedback system related to emotion regulation is the brain itself. A number of investigators view the brain as a set of nested feedback loops (e.g., Edelman & Tononi, 1997; Freeman, 1999; Grossberg & Merrill, 1992; Lewis, 2005), in which multiple brain structures interact with each other as the brain shifts from one state to another, continuously modifying perceptions and interpretations of events while emotional responses self-organize (Lewis, 2005). This sort of modeling can be taken one step further by assigning brain structures to higher or lower levels of the neuroaxis (see also Tucker, Derryberry, & Luu, 2000, for a similar general model; see Kocsis, Viana Di Prisco, & Vertes, 2001, for the specification of neurophysiological mechanisms of feedback). We can identify four major levels: the brain stem, the diencephalon (thalamus and hypothalamus), the standard limbic structures (e.g., hippocampus and amygdala), and finally the cerebral cortex. Whereas higher levels are often assumed to regulate lower levels of the neuroaxis, regulatory influences actually travel in both directions and regulatory activities can be identified at all levels (Lewis & Todd, 2007).

How should we characterize these different regulatory mechanisms? Higher levels such as the prefrontal cortex (PFC) and anterior cingulate cortex (ACC) mediate voluntary, executive control mechanisms, including response inhibition, selection among competing responses, reappraisal, judgment, and self-monitoring (e.g., Rolls, 1999; Van Veen & Carter, 2002; Zelazo & Cunningham, 2007). Lower level structures mediate processes that are automatic rather than deliberate and that proceed without consciousness. For example, the hypothalamus regulates activity by tuning corticolimbic systems to basic mammalian agendas such as mating, nurturance, and aggression. Even the amygdala, often considered a target of emotion regulation, also has regulatory influence itself (Lewis & Todd, 2007). The amygdala constrains the cortex to perceive and appraise events according to emotional meanings that have been previously established through associative learning (LeDoux, 1995; Ohman, 1993; Rolls, 1999). In sum, higher levels of the neuroaxis regulate through the application of deliberate cognitive activity, whereas lower levels regulate by tuning perception and cognition to emotional cues, needs, drives, and organismic requirements. As long as we conceptualize *regulation* in terms of constraints on one structure by another, emotion regulation occurs at both levels. (Such a view overlaps with the psychological model of Ochsner and Gross, 2007—who emphasize the interplay between emotional generation and reappraisal processes in emotion regulation—and the developmental approach of Gross and Thompson, 2007.)

If each level of the neuroaxis contributes to emotion regulation, it is important to describe how these levels interact in real time and how they develop. On the basis of event-related potential and magnetoencephalographic responses to different kinds of cues, some authors conceptualize component processes in emotion as working in a particular sequence (see review and synthesis by Adolphs, 2003). However, the fact that various components enter the picture early does not mean that they disengage early. Thus, our approach focuses on the ongoing reciprocal interactions that take place among these component elements—or, in a word, feedback—fashioning highly coherent, stable configurations of neural dynamics. The concept of feedback is very helpful in assessing both normative and individual features of emotion regulation. For example, higher cortical structures such as the ACC (which is closely connected to several regions of the PFC) can be described as regulating or suppressing amygdala activity (Critchley et al., 2003; Ochsner et al., 2004; Poremba & Gabriel, 1997) while, at the same time, the amygdala tunes ACC activation according to its emotional associations (e.g., Surguladze et al., 2003). Within this feedback loop, the balance of these two directions of regulation—top-down and bottom-up—determines many aspects of a person's response to challenge (Lewis & Todd, 2007).

To take a ubiquitous and dramatic example, depressed or anxious individuals show increased ventral ACC activity, elevated amygdala arousal, and sometimes reduced dorsal ACC and PFC activity (see Drevets, 2000, for a review). These individuals are also more likely to show a genetic anomaly in a serotonin transporter gene, suggesting the underutilization of serotonin in ACC neurons (Pezawas et al., 2005). Thus, susceptibility to depression may be determined by the character of feedback relations in a network of interacting structures during the processing of negative emotion. In a neurobiological sense, it is not that these individuals are underregulated, overregulated, or dysregulated. Rather, the neurobiological mechanisms involved in their self-regulation have achieved a specific (and many would say "maladaptive") pattern of interaction that is stable and coherent from one episode to the next. Furthermore, depression facilitates ruminations about the self as bad or blameworthy. Such ruminations can be understood as deriving from a constrained set of cognitive operations designed to protect against unpredicted rejection by others. Rumination is likely mediated by prefrontal cortical activities under the influence of a highly active and attuned amygdala. Thus, emotion regulation can be achieved by lower structures as well as higher structures, and in ways that would not be described as *adaptive* from a superordinate perspective on social functioning.

The complexity of multiple interacting neural components in emotion regulation challenges researchers to differentiate the developmental trajectories of different systems. Consider, for example, the development of PFC and ACC systems mediating executive control in comparison with the development of associations in the amygdala. Recent longitudinal neuroimaging studies show that more dorsal and lateral regions of the PFC continue to mature from late infancy through adolescence (Crone, Donohue, Honomichl, Wendelken, & Bunge, 2006; Giedd et al., 2004; Gogtay et al., 2004). Correspondingly, the capacity for effortful and deliberate self-regulation and rule-use strategies also develops across these years. This developmental trajectory is not entirely linear, however. For example, although there are few direct data on the neural correlates of effortful control in very young children, this skill is thought to be mediated by dorsal ACC networks that come on line between ages 3 and 6 years (Posner & Rothbart, 2000). During this period, children become better able to delay gratification (Prencipe & Zelazo, 2005; Thompson, Barresi, & Moore, 1997), deliberately control impulsive behavior (Jones, Rothbart, & Posner, 2003), use higher order rule systems for decision making (Zelazo & Mueller, 2002), and achieve higher levels of explicit emotional awareness (Lane & McRae, 2004). Another period of qualitative change is seen in adolescence, when enhanced cognitive control appears to derive from increased proliferation, pruning, and myelination of activity-based connections across wide regions of cortex (Luna & Sweeney, 2004; Zelazo & Cunningham, 2007).

Development of the amygdala is less well understood. However, a handful of fMRI studies have examined anxious or inhibited children 8 years old and older and showed exaggerated amygdala responses to fear-eliciting situations (Perez-Edgar et al., 2007; Thomas et al., 2001). And in a study that used cortical source models constructed from dense-array EEG data from 9- to 12-year-olds who had experienced a negative mood induction, Lewis, Lamm, Segalowitz, Stieben, and Zelazo (2006) observed activity in ventral cortical regions known to be closely linked with the amygdala. Thus, there is reason to conclude that the amygdala is online and modulating emotional responses from an early age, gradually shaping emotional content across the life span. In fact, because the amygdala modulates thought, perception, planning, and decision-making activities in the cortex, it must provide a repertoire of emotional appraisals that can be further analyzed by the deliberate, executive, regulatory processes mediated by cortical systems such as the ACC and PFC (see also Davidson, 2004; Ochsner & Gross, 2007).

In sum, the development of emotion regulation capabilities depends on the interaction of multiple cortical and subcortical systems, mirroring the complexity of multiple, interacting psychological processes. Each of these systems has its own developmental trajectory, which helps to explain the complex, heterogeneous development of emotion regulation demonstrated by behavioral research. Finally, each can influence the course of emotion in ways that may or may not foster subjective well-being. There is good evidence that different neural systems become effective according to different timetables and interact with each other in unique ways as children develop. The outcomes of these interactions supply children with a repertoire of habits of emotional appraisal, emotional self-control, and emotional response, fashioning individual personality pathways and, sometimes, setting the stage for developing psychopathologies.

CONCLUSION

Our portrayal of the development of biological and behavioral components of emotion regulation illustrates why a systems view of emotion regulation is gaining momentum, despite the challenges it poses for longstanding conceptualizations of emotion management. Consistent with a view of emotion regulation as a systemic process, developmental study must focus not only on the emergence of higher order emotional control processes but also on the developing constituents of emotion regulation in both behavioral and neurobiological systems. These systems can be parsed into higher and lower level constituent processes in both behavioral and neurobiological domains (e.g., language and executive function, mediated by cortical and cingulate systems vs. attention switching and species-specific action routines, mediated by limbic and brainstem systems). However, each level assumes a role in the ongoing regulation of emotional arousal. Emotions are managed as emotions are generated, not always afterward, and thus emotion regulation must be studied as a component of emotion itself. In developmental analysis, emotion regulation becomes more complex—behaviorally and biologically—with increasing age as multiple component processes of emotion management mature, higher control processes develop, and emotion regulation becomes increasingly enlisted to accomplish more complex psychological goals. In this sense, the phenomenon of emotion regulation evolves as the systems on which it is based mature, but much remains to be understood about how these constituents of emotion regulation shape each other as they develop. Adding further complexity to this systems view is the realization that emotion regulation processes do not always result in adaptive or positive outcomes, especially for individuals in conditions of environmental stress and those with intrinsic vulnerabilities.

Our analysis of the development of emotion regulation has some similarities to recent critiques of the construct (e.g., Campos et al., 2004), but we do not conclude that, owing to these complexities, emotion regulation cannot be studied as a distinct developmental process. The reason is illustrated in the research reviewed in this article. Consistent with empirical inquiry into any complex biobehavioral system, it is possible (indeed necessary) to elucidate the reciprocal influences of multiple components of the system without having to specify which are exclusively "activational" and which are specifically "regulatory." We expect that this will become increasingly apparent in other domains as developmental scientists work across multiple levels of analysis in their efforts to understand the functioning and development of emotion, cognition, and other complex psychological processes. In these and other areas, moreover, understanding the integration of influences from molecular genetics, central and peripheral nervous system processes, the sociocultural context, and behavioral control systems will inspire models based on concepts of mutual feedback systems, multilevel control processes, and integrated behavioral functions.

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