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Systems theory and cascades in developmental psychopathology

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Abstract

In the wake of prominent theoreticians in developmental science, whose contributions we review in this article, many developmental psychologists came to endorse a systems approach to understanding how the individual, as it develops, establishes functional relationships to social ecological contexts that from birth to school entry rapidly increase in complexity. The concept of developmental cascade has been introduced in this context to describe lawful processes by which antecedent conditions may be related with varying probabilities to specified outcomes. These are understood as processes by which function at one level or in one domain of behavior affect the organization of competency in later developing domains of general adaptation. Here we propose a developmental sequence by which the developing child acquires regulative capacities that are key to adjustment to a society that demands considerable control of emotional and cognitive functions early in life. We report empirical evidence showing that the acquisition of regulative capacities may be understood as a cascade of shifts in control parameters induced by the progressive integration of biological, transactional, and socioaffective systems over development. We conclude by suggesting how the developmental process may be accessed for effective intervention in populations deemed "at risk" for later problems of psychosocial adjustment.

For a number of years, the term cascades has been used in developmental psychology to describe processes by which function at one level or in one domain of behavior affects function at higher levels or the organization of competency in later developing domains of general adaptation. As observed by Masten et al. (2005), these processes have been variously described as implicating phenomena of amplification, snowballing, transactional, or progressive effects, depending on the theoretical orientations of their investigators. Because the students of these phenomena have generally endorsed a systemic approach, our goal in this article is to examine how developmental cascades may be understood with reference to the basic tenets of this approach. Informed by this perspective we report empirical evidence showing that the acquisition of emotion regulation capacities by the young child may be understood as a cascade of shifts in control parameters induced by the progressive integration of biological, transactional, and socioaffective systems over development. We conclude by suggesting avenues by which the developmental process may be accessed for timely and effective intervention.

Systems Theories, Mechanistic, and Organismic Metaphors of Development

Systems theories have been evolving in developmental science for the last three decades (Cox & Paley, 1997, 2003; Gottlieb, 2007; Magnusson & Cairns, 1996; Sroufe, Egeland, Carlson, & Collins, 2005). Advances in embryology provided the first empirical evidence to support this view of development (Cairns, 1983; Sameroff, 1983). A prominent biologist, Ludwig von Bertalanffy (1968) was among the first to introduce a general systems theory in response to efforts in classical science to understand better the behavior of complex systems. He argued that in such cases one needs to understand not only the elements of a system but also their interrelations, which is more important (Sameroff, 1983). With regard to biological systems, in particular, von Bertalanffy argued that the Cartesian "machine metaphor" did not render justice to the special properties of living systems, that it conceived of organisms as passive and merely responding to external stimuli through simple causation, and that it ignored the contribution of the organism as a whole to the construction of its relation to a structured environment. He argued that an "organismic metaphor" would allow for the construction of a more accurate framework for studying phenomena of biological development and adaptation.

Sameroff (1983) noted that "it is in the balance between individual and collection, part and whole, that the organismic model derives its metaphor. By examining embryological development in detail, it is possible to see how a wholistic emphasis is necessary to understand living systems" (p. 252). A key observation of embryology illustrates this assertion: the process of cell differentiation proceeds through an integration of both internal and external controls. In this process, each cell does not commit to a specific developmental path via a blueprint but in accordance with its surrounds, which is understood as a network of distributed information (Gephardt & Kirshner, 1999). Extending this principle to the developmental process in general, Gottlieb, Wahlsten, and Lickliter (2006) proposed a definition of epigenesis stating ". . . that individual development is characterized by an increase in novelty and complexity of organization over time—the sequential emergence of new structural and functional properties

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and competencies—at all levels of analysis as a consequence of horizontal and vertical coactions among its parts, including organismic–environmental coactions" (p. 211).

Thus, the organismic metaphor in systems theory has clear implications for our goals in research on development (Lerner, 2002). As Thelen and Smith (2006, p. 263) note,

> The larger lesson from embryology for psychology is this: the stable regularities we see in developed organisms—the phenomena we seek as psychologists to explain—might not have specific causes that can be demarcated and isolated but rather may be understood only as a dynamic cascade of many processes operating over time. This idea challenges the usual notions of science that we understand by analysis, by isolating things—ingredients and components—until we arrive at the essential stuff. Explanations in terms of complex and cascading processes as opposed to explanations in terms of list of parts is difficult even for scientists.

The nature of this cascade of processes is understood to be toward more complexity of organization and yielding novel forms as proposed by Gottlieb and colleagues (2006). Understanding the emergence of increasingly complex as well as novel patterns of behavior from precursors that did not contain those patterns is central to developmental science. However, it is often neglected in developmental analysis that organismic activity brings an essential contribution to this cascade and for social species such as humans this activity takes place primarily in a social context. To emphasize these aspects, Cairns (1983, p. 80) wrote the following:

> It required only a modest conceptual leap to consider behavior to be an essential component of the organismic system, and behavioral development to be understood in terms of biological and social features of the system. Hence the "system" in which the organism developed is not merely under the skin. The concept of "organization" is thus broadened to include feedback from other organisms and from the social network in which development occurred.

It follows from these ideas that there are bidirectional influences between persons and social contexts, which, over time, give rise to increased synchrony between the individual and progressively larger aspects of the social environment (Magnusson & Cairns, 1996). In this progression, new sources of influence enter the developmental scene from within and from without, and understanding the new complexity of organized functioning that emerges as a result requires attention to how the developing person at any one point transacts with current challenges and supports (Sroufe, 2005) and to the transformations personal experience undergoes in this process (Sameroff, 2000). The organismic metaphor sees the individual through this cascade of changes as active, purposeful, and as part of an integrated, complex, and dynamic person–environment system. This last point, emphasizing as it does, the active role of the organism in its own construction requires attention to an important characteristic of living systems, namely, their capacity for self-organization and adaptive reorganization.

Von Bertalanffy (1968) observed that inert systems are "closed systems" in the thermodynamic sense that they contain a finite amount of energy that they gradually dissipate in the environment. That is, the behavior of inorganic matter is subordinated to the law of entropy. By contrast, organisms are "open systems" because they have a capacity to maintain and even augment their internal organization by extracting energy from the environment through their activity. In this sense, living systems are characterized by a degree of "negative entropy." It is important that energy extraction from the environment requires the active establishment, by the organism, of an instrumental relationship to the environment so that the recurrence and continued availability of vital resources is assured to a significant degree. However, in the face of an environment that is constantly decaying with respect to their needs, organisms maintain their homeostatic balance by constantly renegotiating their relation to the environment. In this context, organisms are self-organizing to the extent that maintaining this relation requires new behaviors and a continued reorganization of the internal biological and cognitive structures that support them. As Thelen and Smith (2006) observed, however, there is no explicitly given rule to guide this process.

Extending from general systems theory, Thelen and Smith (2006) proposed a developmental systems theory to explain the *emergence* of novel forms of behavioral patterns through processes of self-organization. "By self-organization we mean that pattern and order emerge from the interaction of the components of a complex system without explicit instruction, either in the organism itself or from the environment. Self-organization—processes that by their own activity change themselves—is a fundamental property of living things" (Thelen & Smith, 2006, p. 259). Thus, pattern and order, these regularities that emerge with development, come from multiple contributing influences each with its own history. Behavioral development is here conceived as an epigenetic, stochastic process that is historically constructed through system-wide activity (for a discussion of the early contributions of Kuo, 1967, and Schneirla, 1957, in a history of these ideas, see Gottlieb, 1976; Thelen & Smith, 2006).

In the same vein, but with a specific reference to social behaviors, Magnusson and Cairns (1996) proposed that organismic activity has "distinctive properties in adaptation because [it] organize[s] the space between the organism and the environment, and thereby promote[s] rapid, selective, and novel adaptations" (p. 5). More broadly, they suggested that the function of behavior is to bring into functional alignment person and environment systems (Gariépy, 1996). The establishment of this alignment involves a process whereby behavioral patterns are internally supported by correlations among biological and cognitive systems and through their external validatation via the instrumental access to the environmental resource they promote. Cairns, McGuire, and Gariépy (1993, p. 110) illustrated this process in the following quote:

> It should not be surprising to find hot-tempered, impulsive children growing up with family members who themselves exhibit and reward these traits, or subcultures of aggressive adolescents in which

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aggressive behavior is viewed as an asset rather than a liability. More broadly, social systems are usually formed in ways that are correlated with and support bio-behavioral dispositions. The biological forces that operate to enhance adaptation should typically operate in the same direction as the environmental experiences so that nature–nurture competition should be the exception rather than the rule.

One implication of this proposal is that the functional relations established over time between systems within and systems without tend to constitute a "system of correlated constraints" on behavioral organization and, for better or for worse, to promote *continuity* in patterns of social adjustment (Cairns et al., 1993). Note that this conception of development leaves open the possibility of behavioral reorganization because an environment in flux or a natural change in biological system (e.g., as induced by puberty) would naturally promote new patterns of person–environment alignment and new behaviors to support them. In this view, patterns of adaptive activity are not fixed by genes, early experience, or a personal history of rewards and punishment but remain eminently open to reorganization when the internal or the external environment cease to support or validate them.

Note also that this conception of development is entirely consistent with Thelen and Smith (1998), who suggested that although there is overall bidirectionality among systems, differential rates of change among them cause certain coactions to become "control parameters" that at certain points in development become overdeterministic and may reside alternatively within the person or in the social environment. Whereas the instrumental relations established by the person with his or her social environment over time impose inertia and favor stable adaptations, developmental systems theories also postulate that person–context relations are "softly" assembled (Sameroff, 1983; Thelen & Smith, 1998) and remain open to both consolidation and reorganization over ontogeny (Cairns et al., 1993).

Shifting Loci of Control in the Acquisition of Self-Regulation Over the First Years of Life: From Genes to Socioaffective Systems

The organismic metaphor suggests specific questions regarding cascades in child development and heuristics for their interpretation. Consider, for example, that during the early years social and emotional behaviors undergo rapid changes with the emergence of clear novelties in expressive forms. Of special importance for subsequent development is the gradual acquisition of emotion regulation capacities during this period (Calkins, 1994; Calkins & Hill, 2007; Thompson, 1994). In the first years of life, the child changes from a passive and reactive newborn to a child who self-initiates behaviors that serve a regulatory function (Calkins, 1994; Calkins & Hill, 2007; Kopp, 1982; Sroufe, 1996). The emergence of this ability is critical for later competence and/or the development of psychopathology. As argued by Sroufe (1995), during early childhood a "self" or "personality" must develop so that in interactions with others the child can manage frustration, accept delays and disappointment, operate in the environment autonomously and effectively, and cooperate and coordinate in give and take with others. Without the acquisition of this competence, adjustment to tasks in school and to interactions with peers may be compromised. More recently, Blair and Diamond (2008) defined the capacity for self-regulation as ". . . primarily volitional cognitive and behavioral process through which an individual maintains levels of emotional, motivational, and cognitive arousal that are conducive to positive adjustment and adaptation, as reflected in positive social relationships, productivity, achievement, and a positive sense of self" (p. 900).

There is ample evidence to support the view that the early acquisition of emotion regulation skills is important for subsequent adaptation. A recent report that used data from the NICHD Study of Early Childcare (NICHD Early Care Research Network, 2008) showed that higher self-regulation (as indexed by effortful control) during the late preschool years is associated with greater self-reliant behavior in the classroom and is predictive of better academic achievement gains over the first 4 years of school. Using the same data set, Caughy, Owen, Hurst, and Melhado (April, 2009) reported that children raised in families with chronic poverty had significantly lower vocabulary skills at school entry than those never in poverty or experiencing transient poverty. However, chronically poor children with higher self-regulation (as indexed by delay of gratification) were significantly more likely to close the gap in these skills with nonpoor children by the fifth grade than children lower in self-regulation from the same poor background. Similarly, Lengua, Bush, Long, Kovacs, and Trancik (2008) found that although socioeconomic risk was associated with higher behavior problems among 8-year-olds, children with the same risk but with high effortful control scores were more likely to show a decrease in behavior problems over a period of 3 years in contrast to children exposed to the same risk who were lower in effortful control. The latter children were more likely to maintain high levels of problems. This work is consistent with a small but growing body of research that suggests an association between low emotion regulation skills in childhood, later disinhibitory problems such as attention-deficit/hyperactivity disorder, and some forms of antisocial behavior (Mullin & Hinshaw, 2007).

The above findings demonstrate significant associations between regulatory skills and adjustment. However, as Cole, Michel, and Teti (1994) have noted, we have incomplete knowledge about the processes by which self-regulatory skills are acquired during childhood. Given the relatively late onset of these skills, are there psychological or behavioral domains whose earlier organization could affect the subsequent emergence of self-regulatory skills? If so, are there transactional processes among biological and other interpersonal factors that may amplify and/or minimize the trace effects of early development? Finally, are there specific pathways involving social transactions among personological and environmental factors that lead to developmental psychopathology? Clearly, the expression of temperamental differences early in development is important in this respect, but research shows

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that children with similar reactive temperament, a propensity that has been associated with self-regulation difficulties, show a variety of outcomes later in childhood (Calkins, 1994). Alternatively, children may start at different places and end in the same place or start at the same place with the same end, but through different processes (i.e., equifinality as proposed by Spemann, 1927; see also Gottlieb et al., 2006). More generally, it appears that different processes may be important for different children, as different configurations of person–environment factors bring to the fore different control parameters that may gain salience at different points in ontogeny.

Understanding what processes initiate, maintain, and consolidate adjustment for different groups of children is certainly important but notoriously difficult to achieve in developmental investigations. Systems theory suggests that the intrinsic qualities of very young children are important, but that so are the transactions with the specific qualities of the environment of care that structure early experiences and lay down the trace effects[1] seen later in the internal representations the child forms of these experiences (i.e., working models of the self and others; see Hofer, 1996). On this point, Magnusson and Cairns (1996) note that "in the accommodations of human development, the actions and counteractions of other people constitute major extraorganismic sources of behavioral organization" (p. 15). Informed by this rich theoretical background, a growing body of research now investigates, with a specific focus on parent–child interactions, how genetic and environmental coactions within the family system, from genetic to behavioral activity, influence the development of self-regulative capacities in the young child (Propper & Moore, 2006). Another group of researchers also addresses questions pertaining to the intergenerational processes that account for the transfer of these self-regulative capacities in progeny (see, e.g., research led by S. Suomi at NIH, M. Meaney at McGill University, and C. Champagne at Columbia University).

The cascade of events that accounts for individual differences in self-regulation and its eventual intergenerational transfer begins at conception with the transmission of genetic material from parents to offspring. Clearly, experience in the prenatal environment differentially interacts with the fetal genotype to influence prenatal and postnatal developmental trajectories (Wiebe et al., 2009), but in the current discussion, we focus on the postnatal environment shared by the mother and her newborn child. Although the study of this cascade is just beginning, it seems that behaviors in this shared environment allow for experience-dependent changes in both mothers and children that promote *differential* shifts in control parameters across individuals (and domains within individuals) that ultimately impact the acquisition of self-regulatory abilities. A *general* cascade of control parameters in this case is likely to (a) begin with the child's genotype, then to shift in succession to (b) the caregiving environment, (c) the mother–child attachment relationship, and ultimately (d), to find its source within the child with the emergent organization of socioaffective representations of the self and others in early childhood.

Genes as early control parameters

A long history of research has documented individual differences in neonatal and infant temperament (e.g., Buss, Plomin & Wilerman, 1973; Rothbart, Ahadi, & Evans, 2000) and the evocative effects between child temperament and parenting behavior (Belsky, 1984; Pluess & Belsky, 2009). Twin and adoption studies provide evidence in support of a genetic basis for individual differences (Emde, Plomin, Robinson, & Corley, 1992; Goldsmith & Gottesman, 1981; Plomin & Rowe, 1977). Moreover, new research in molecular genetics has begun to identify polymorphic variations in candidate genes that may be responsible for some early behavioral predispositions (Auerbach et al., 1999; Auerbach, Faroy, Ebstein, Kahana, & Levine, 2001; Ebstein et al., 1998). Given these findings, it seems likely that maternal genotype contributes two paths of influence on early child development. First, there is evidence for direct genetic effects (Bakermans-Kranenburg & van IJzendoorn, 2008) as well as gene–environment (G × E) interaction effects (van IJzendoorn, Bakermans-Kranenburg & Mesman, 2008) on maternal early caregiving behaviors. Second, mothers pass on a portion of their genotype to their offspring, the manifestation of which may be responsible for early variations in temperamental behavior (see Rutter, Moffitt, & Caspi, 2005). Of interest, the infant genotype also appears to contribute two paths of influence in this developmental cascade. First, it provides a set of predispositions that biases how infants first perceive and react to their environments that may lay the foundation for future cognitive and behavioral adaptations (Izard, Schultz, Fine, Youngstrom, & Ackerman, 1999). Second, consistent with the evocative effects of early child temperament there is a potential for the elicitation of differences in parental behavior. In support of this assertion, there is recent evidence suggesting that the child genotype is predictive of sensitive caregiving (a G × E correlation) that is independent of the effects of the mother's genotype (Mills-Koonce et al., 2007; O'Connor, Deater-Deckard, Fulker, Rutter, & Plomin, 1998; Propper, Willoughby, Halpern, Carbone, & Cox, 2007).

Although behavior during the neonatal period is quite likely influenced by genetic factors, early experiences do accumulate, patterns of interactions between parents and children stabilize, and, as those effects take place, the locus of the control parameters in psychological development may shift from intrinsic (genetic) to extrinsic (environmental) factors. Because the scope of much of infants' exposure to the outside world is defined and limited by interactions with their caregivers, the quality of those interactions become overde-

1. Schneirla introduced this notion in 1966 to refer to the fact that higher functions inevitably reflect in their current structures and functions the "trace effects" of the conditions that prevailed during the organization of the foundational biological systems out of which these more advanced systems emerged.

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terminative in child development and quite likely initiates a new point in the cascade leading to the acquisition of self-regulation (Cassidy 1994; Field, 1994; Fox & Calkins, 2003; Thompson, 1994).

The emergence of caregiving as a moderator of genetic effects

Because of their limited cognitive, motor, and social capacities, infants are unable to regulate their own behavioral and physiological arousal without the help of others (Sroufe, 2000). Maternal sensitivity to infants' signals and affective expressions during the first year of life is known to play a crucial role in the formation of an ability to regulate emotions (Crockenberg & Leerkes, 2000). Studies have found that infants with more sensitive and responsive parents showed greater behavioral and physiological regulation during a challenge task when compared to those with less sensitive parents (Haley & Stansbury, 2003; Moore et al., 2009). Thus, with the parent serving as an external regulator, and the acquisition by the child of a capacity to use this source of regulation, a shift from genetic predispositions to extrinsic sources of regulation takes place.

Propper et al. (2008) documented such a shift as they identified early genetic effects in vagal functioning in infancy that gave way to a G × E interaction by the end of the first year of life. She and her colleagues compared physiological regulation at 3, 6, and 12 months of age between infants who carried the taq1 A1 polymorphism of the dopamine D2 receptor (*DRD2*) gene to those who did not. This polymorphism has been associated in adolescents and adults with impulse control problems and sensation seeking behaviors. Propper and colleagues found that at 3 and 6 months of age infants with the taq1 A1 polymorphism were significantly less likely to exhibit normal vagal reactivity (i.e., decrease in respiratory sinus arrhythmia [RSA]) during an age-appropriate stressful situation (i.e., "still face" where mothers' facial expression remained neutral or nonresponsive to the infant for a 2-min period) compared to infants without this polymorphism. However, they also found that infants with the taq1 A1 polymorphism exposed to sensitive maternal caregiving over the first year of life were as likely as those without this polymorphism to exhibit the expected RSA response to stress at 12 months of age. By this age, infants with the taq1 A1 polymorphism but with sensitive mothers no longer differed in RSA reactivity from those infants without the taq1 A1 polymorphism. This finding provides a clear example of a shift from early genetic influence to environmental control of a basic physiological response during infancy.

Other studies of early G × E interactions involving dopaminergic genes and maternal sensitivity have yielded similar findings. For example, Mills-Koonce et al. (2007) reported that children with the taq1 A1 polymorphism of *DRD2* were more susceptible to the early influence of maternal sensitivity on later affective problems than those without this polymorphism. Studies involving other dopaminergic genes, like the dopamine D4 receptor (*DRD4*), and early caregiving found similar G × E effects on behavioral development. For example, Bakermans-Kranenburg and van IJzendoorn (2006) reported an interaction between the 7-repeat *DRD4* allele and insensitive maternal caregiving during infancy that predicted a higher probability of externalizing behaviors in preschool-age children compared to children with the 7-repeat allele and sensitive caregiving or children without this allele. In a replication of this study, Propper et al. (2007) found that it was the interaction of *S-DRD4* and higher maternal sensitivity that predicted lower externalizing behavior, but only for African American children. Clearly, the molecular basis of these G × E processes is not fully understood (but see Meaney & Szyfe, 2005); however, each of these studies suggests that early environmental factors do affect development both independently and in conjunction with the child's genotype.

It is interesting that G×E interaction effects are also evident in the development of early attachment relationships. For instance, there is evidence suggestive of interactive effects involving the *DRD4* gene (7-repeat allele), as well as the serotonin transporter gene, and early caregiving in the formation of infant–mother attachment. Van IJzendoorn and Bakermans-Kranenburg (2006) showed that maternal unresolved loss or trauma was related to infant attachment disorganization with a significantly higher probability for infants who carried the long versus short *DRD4* allele. However, a study by Gervai et al. (2007) indicated that infant attachment disorganization was related to disrupted forms of maternal affective communication with a significantly higher probability for infants *without* the 7-repeat allele; infant disorganization classification was not significantly related to maternal disrupted communication if infants carried the 7-repeat allele. Another polymorphism involving variations of the serotonin transporter linked polymorphic region gene (*5-HTTLPR*) has been implicated in a similar interaction. Children homozygous for the short allele who are reared with insensitive mothers were more likely to be classified as disorganized in one study (Spangler & Zimmermann, 2007) or as insecure (but organized) in another (Barry, Kochansak, & Philibert, 2008) compared to children with the same short allele but reared by a sensitive mother, who were more likely to form secure attachments. Given the importance of early relationships in the transition from other-supported to self-regulatory capacities, we see another critical step in the developmental cascade: the social-interactive basis for a return to intrinsic control parameters, but of a different order, in that the new locus no longer resides at the genetic level but in the socioaffective domain of internal representations.

Emergence of attachment relationships as moderators of genetic effects on the emergence of self-regulative capacities

Attachment relationships in infancy have been described as mechanisms for the social regulation of stress (Kobak, 1999). The development of secure attachment relationships thus appears to mark a transition from extrinsic control (par-

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enting) to dyadic control (the emerging attachment relationship). To this effect, Bowlby (1969) proposed that early attachments in infancy serve as a "psychic organizer" of the ability to cope with and regulate internal and external demands (see also Gunnar & Donzella, 2002). This may be especially true for children at heightened genetic risk, as proposed by Suomi (2006): "secure attachment relationships somehow confer resilience to individuals who carry alleles that may otherwise increase their risk for adverse developmental outcomes" (p. 57). Evidence for this effect has been demonstrated by Kochanska, Philibert, and Barry (2009), who reported that infants with the short *5-HTTLPR* allele (ss/sl) who were insecurely attached to their mother were less likely to develop good regulatory capacities as toddlers and preschoolers when compared to children with the short *5-HTTLPR* allele who were securely attached or to children with the long allele. Consistent with previous research, these findings highlight the role of secure early attachment relationships in the development of effective and adaptive self-regulatory abilities (Cole, Martin, & Dennis, 2004; Schore, 2001; Sroufe, 1996; 2005), specifically for children at elevated risk for maladaptive development.

It is in the context of these early attachment relationships that parenting behaviors affect infants' interpretation and alleviation of negative emotions, reinforce positive emotions and experiences, and appropriately structure the environment for these experiences (Thompson, 1994). Not only has attachment quality been demonstrated to moderate genetic effects on development, but it also has the potential to moderate the effects of parenting on developmental outcomes. Findings of a recent study revealed that attachment security moderated the association between a maladaptive cycle of parent–child behavior and future child antisocial outcomes (Kochanska et al., 2009). Early attachment security acted as a protective factor against such outcomes by making less probable one known pathway (i.e., parental power assertion, child opposition, antisocial outcomes) that leads to the development of antisocial conduct. As expected, this pathway was associated with a higher probability of antisocial outcomes for children of insecure dyads, but not for children of secure dyads. Thus, as children progress along this cascade and transition from complete reliance on caregiver to greater autonomy and self-regulation, security of attachment (Berlin & Cassidy, 2003; Diener, Mengelsdorf, McHale, & Frosch, 2002; Schore, 2001) as well as caregiver support (Fox & Calkins, 2003; Smith, Calkins, & Keane, 2006) are undoubtedly of great importance.

Shift from dyadic to a more intrinsic self-regulation

The toddlerhood years are marked by a shift from an almost complete reliance on caregivers and attachment relationships to a more internalized set of regulatory strategies (Fox & Calkins, 2003). Just as children adapt to a specific caregiving environment by developing and organizing specific types of attachment relationships (Cassidy, 1994), over time the behavioral strategies inherent to attachment styles become internalized and may function on both conscious and unconscious levels (Main, 1990). As such, early attachment relationships may serve as the foundation for developing self-regulatory abilities (Cassidy, 1994; Isabella, 1993; Sroufe, 1996). Different patterns of coregulation of emotional experiences that occur across different attachment relationships in infancy should ultimately give rise to different and predictable patterns of self-regulation in toddlerhood (Thompson, 1994; Weinfield, Sroufe, Egeland, & Carlson, 2008). In comparison to insecurely attached children, those with secure attachment histories are better able to recognize the types and intensity of emotional experiences in themselves and others (Steele, Steele, & Croft, 2008) and are better able to modulate their own levels of arousal using flexible self-regulation strategies (Cassidy, 1994; Sroufe, Egeland, Carlson, & Collins, 2005). A growing number of empirical studies have demonstrated that children with secure attachment histories are more effective at self-regulation than children with insecure attachments (Berlin & Cassidy, 2003; Denham, Blair, Schmidt, & DeMulder, 2002; Diener, Mandelsdorf, McHale, & Frosch, 2002; NICHD Early Child Care Research Network, 2004).

The development of these self-regulatory abilities during the first years of life is critical for the emergence of autonomy and the development of later social and behavioral competencies or problems (Fox & Calkins, 2003), as well as continued success through preschool (Calkins & Fox, 2002) into adolescence (Bell & Calkins, 2000). It should be noted, however, that the proposed cascade represents merely a strand of the equifinal possibilities leading to self-regulation and the multifinal outcomes associated with each stage of the cascade. Nonetheless, it is a clear example of how shifting sources of influence over time, in conjunction with new abilities made possible by development and maturation, result in the dramatic change from a purely reactive organism to a self-regulated and autonomously functioning individual.

Implications of the Organismic Metaphor in Systems Theories for Research Methodology

Clearly, a developmental orientation implies that to identify developmental pathways formed among persons and contexts during ontogeny and over generations, to pinpoint the mechanisms involved and the time frames over which they operate, observations should be extended over both life times and generations (Magnusson & Cairns, 1996, p. 7). Thus, longitudinal designs involving parents and progeny are central to capturing cascading processes in development. Although such designs are powerful approaches for suggesting key parameters in developmental cascades, clarifying mechanisms of development necessitates manipulation of those parameters most amenable to experimental testing.

Consistent with the assumption that development arises from the dynamic interaction of systems within and without the person over time, conceptualization and measurement of multiple levels of systems requires methods from multiple disciplines. It is unlikely that any one scientist is trained to concep-

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tualize and measure critical processes that operate from genes to culture. Collaboration across disciplines becomes important to adequately measure these processes at multiple levels. For example, we have noted that sensitive and responsive caregiving provides the young infant with the experience of regulation. It is tempting to think of sensitivity of the caregiver as a fixed trait in caregivers, but sensitivity is also a dynamic quality in caregivers that is responsive to the child's behavioral characteristics as well as supported or not supported by the relationships and beliefs in the broader family, community, and culture (Cox & Paley, 1997). By limiting the study of the development of self-regulation to the child and the parent–child caregiving relationship, we may miss important control parameters that could suggest effective interventions to influence cascades. Thus, the broader context of the family system and the neighborhoods, communities, and cultures in which families are embedded should be considered, but often scholars who study family relationships lack the expertise to adequately conceptualize and measure critical processes that involve these phenomena at the neighborhood, community, and cultural levels.

Longitudinal research approaches are not without limitations. They require a significant investment of research funds and individual subject's time. Data quality and subject retention are major challenges (Magnusson & Bergman, 1990). The most difficult subjects to retain may be those from the most chaotic and risky environments, so that longitudinal samples often become biased over time. Subject burden is a challenging issue. Especially in samples where subjects do not have a high degree of literacy, overuse of questionnaires to tap key phenomena may be problematic. Investigators undertaking large longitudinal studies often find it necessary to use questionnaire measurement because the cost of other approaches is too high, but this may lead to inappropriate measurement. For example, if the interactions between caregivers and infants are deemed important in providing experience of regulation for young infants, as suggested here, observations, although expensive and imperfect, are more likely to capture the child's experience than parent's reports of their parenting behavior or attitudes.

Finally, Masten et al. (2005) have noted that to demonstrate a cascade effect, one must show a causal relation over time from one domain to a later developing one, ruling out continuity within focal constructs as well as covariance among measures of those domains. Thus, controls are often needed for within-time covariance among domains and across-time continuity within construct domains. Without these controls, studies that purport demonstrating mediating or cascade effects could be faulted for merely reporting uncontrolled preexisting covariance among the domains of interest (Masten et al., 2005). This is a challenge for longitudinal studies. In responding to this challenge, investigators may feel compelled to measure the same relevant variables at all time points. However, because the developmental phenomena we seek to understand often involve behavioral novelty, it may not be possible to truly measure the same variables at all time points (Magnusson & Cairns, 1996). The optimal solution to such a problem is strong conceptualization of a proposed cascade, awareness of alternate mechanisms by which it may be obtained, and the inclusion of measurements that allow testing of those alternatives. Ideally, longitudinal studies should be coupled also to experimentally induced changes in parameters believed to control a cascade to test more rigorously the mechanisms we think explain it.

Implications of the Organismic Metaphor in Systems Theories for Intervention

Intervention programs aim at imparting significant change in developmental trajectories when they constitute a path likely to lead to problematic outcomes for the person, society, or both. Developmental psychologists are mandated to provide a basic understanding of how problematic trajectories form, to clarify mechanisms that link past histories of development to predictable outcomes, to offer counsel regarding the optimal timing for intervention, and to specify the personological, environmental, or relational elements that should be targeted for maximal effectiveness. Given the probabilistic nature of development, this is a formidable task. However, probabilistic does not mean chaotic, as there are lawful processes by which antecedent conditions may be related with varying probabilities to specified outcomes. As developmental psychology came to embrace an organismic metaphor for development, our scientific ideal shifted from one of prediction and control to the more modest (but more daunting) goal of understanding processes by which those probabilities may be affected. At this juncture, a cascade metaphor of developmental continuities should inform intervention strategies with a solid knowledge of how person–context systems, differentially assembled early on, affect the possibility of later reorganization, the control parameters most likely to promote reorganization, and at what point during development that their manipulation should be most effective.

Because most intervention programs target populations deemed "at risk" for later problems of psychosocial adjustment, it is important first to appreciate how having adopted an organismic–philosophical framework changed our understanding of what constitutes "being at risk." We have moved in this respect from an understanding of risk as residing squarely within the individual or his environment, that is, from a "deficit model," to one that defines risk in relational terms, personological resources, and environmental opportunities. In addition, contemporaneous contexts are now recognized as key players in the process by which antecedent attributes *become* risk factors. To illustrate, Entwisle and Alexander (1993) pointed out that poverty in a supportive family context is not necessarily a risk factor for the developing child, but becomes so with school entry at a time when poverty imposes clear constraints on the acquisition of academic competencies. The authors further observe that the societal expectation of "school readiness" may place poor African American children at even greater risk, as they are more likely than European American children to experience during this transition a shift from *who you are* as a basis for constructing a personal identity to one that places in the forefront *how you perform.* For these children risk arises as previ-

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ously neutral, or even adaptive factors (in a nurturing family context), acquire new meaning and new functions in the changed person–context system predicated by formal schooling.

That risk is best understood in relational terms is also illustrated by the reverse situation where an earlier association between a person factor and pathological behavior is lost with a change in environmental conditions. Bold, surgent children tend to be impulsive and to have poor regulatory capacities. They are prone to externalizing problems, and these characteristics have been deemed stronger predictors of poor school adjustment than the lack of basic literacy skills at school entry. Rimm-Kaufman et al. (2002), however, showed that this trait constitutes a risk for classroom disturbance behavior *only* when bold children are exposed to disengaged teachers who are insensitive to their students' personal needs. It is worth noting in this light that the cascade described by Masten et al. (2005) that linked adolescent externalizing problems to internalizing problems in adulthood via academic failure may be averted for some individuals given enough exposure over adolescence to sensitive classroom environments.

Just like individuals and their environments, genes have long been regarded as loci where "risk" may potentially reside. Following the stress-diathesis model, so-called "risk alleles" or "candidate genes" confer risk to their carriers by making them vulnerable to develop pathologies when certain adverse conditions are encountered. Noncarriers under the same conditions would be less likely to develop the disorder. In a critical assessment of this view, Belsky and Pluess (2009) reported compelling evidence from the recent literature showing that, although the carriers of those genes are more affected by adverse conditions, they may also be poised to benefit *more* from favorable conditions, to the point of showing less pathological outcomes than noncarriers when the environment is a favorable one. On this basis, the authors suggest that such genes might best be regarded as "susceptibility genes" because what they contribute is simply a higher susceptibility to environmental effects, whether positive or negative. The implications for intervention programs are not trivial as shown by Brody, Beach, Philibert, Chen, and Murry (2009, cited in Belsky et al., 2009). These authors instilled nurturant-involved parenting practices among parents of rural African American children with the goal of reducing risk-taking behavior later in adolescence. They were paying special attention to children who carried the short polymorphic variant of the *5-HTLLPR* gene because of its strong association with this kind of behavior. They unexpectedly found that those explicitly labeled "at genetic risk" were those who were more likely to benefit from the intervention.

In addition to modulating environmental effects genes can also affect the type of intervention different individuals may be most responsive to, as well as the developmental window when intervention might be expected to be most effective. To illustrate, one of the authors on this article used mouse lines selectively bred over 30 generations for high and low levels of intraspecific aggression to examine how maternal care, subsequent housing conditions, and genetic background interact over ontogeny to impact adult hypothalamic–pituitary–adrenal activity. Gariépy, Rodriquiz, and Jones (2002) identified two pathways by which low-aggressive mice achieve optimal regulation of this system as adults: an augmentation of the frequency and quality of maternal care during infancy, and social interactions with low-aggressive peers during adolescence. In this low-aggressive line these two factors had similar (and additive) effects on adult hypothalamic–pituitary–adrenal reactivity to stress. By contrast, in the high aggressive line only maternal care during the first few weeks of life was found to affect the organization of this physiological system. Exposure to the characteristically aggressive social ecology of this mouse line during adolescence slightly reduced the beneficial effects of early care. These results illustrate the principle of equifinality showing as they do that different organism–environment systems, configured at different points in development and via different environmental influences may lead to similar developmental end points, albeit through different pathways.

The examples cited in this section were chosen with the goal of showing that the establishment of person–environment systems, although quite sensitive to conditions arising from within and from without early on, retain a significant capacity for reorganization later on for the better of for worse. This is what we should expect, given the concept of correlated constraints (Cairns et al., 1993), namely, that developmental continuities arise in a large measures because of *continuity in patterns of alignment* among system within and systems without and their mutual functional validation. A relaxation of the conditions that maintain this alignment, either from within (e.g., because of maturational change in physiological or cognitive systems) or from without (a fortuitous change in environmental conditions, or deliberate change through intervention) reveals the intrinsic malleability of the developmental process. We do not develop just to grow bigger. We do so because this is the very process that makes possible continued adjustments to changing demands and circumstances through the life span. Finally, with those examples we wanted to show that how, when, and by what means established patterns of adaptation may be open to reorganization is likely to involve different cascades for different groups of individuals given differences in biological endowment, rearing histories, stochastic effects in the construction of person–environment systems, and the subsequent interactions of these systems with age- and culture-specific societal expectations.

References

Auerbach, J., Faroy, M., Ebstein, R., Kahana, M., & Levine, J. 2001. The association of the dopamine D4 receptor (*DRD4*) gene and the serotonin transporter promoter gene (*5-HTTLPR*) with temperament in 12-month-old infants. *Journal of Child Psychology and Psychiatry*, *42*, 777–783.

Auerbach, J., Geller, V., Letzer, S., Shinwell, R., Belmaker, R., Levine, J., et al. (1999). Dopamine D4 receptor (*D4DR*) and serotonin transporter promoter (*5-HTTLPR*) polymorphisms in the determination of temperament in two month old infants. *Molecular Psychiatry*, *4*, 369–373.

https://doi.org/10.1017/S0954579410000234 Published online by Cambridge University Press

Bakermans-Kranenburg, M., & van IJzendoorn, M. (2006). Gene–environment interaction of the dopamine D4 receptor (*DRD4*) and observed maternal insensitivity predicting externalizing behavior in preschoolers. *Developmental Psychobiology*, *48*, 406–409.

Bakermans-Kranenburg, M., & van IJzendoorn, M. (2008). Oxytocin receptor (OXTR) and serotonin transporter (*5-HTT*) genes associated with observed parenting. *Social Cognitive and Affective Neuroscience*, *3*, 128–134.

Barry, R., Kochanska, G., & Philibert, R. (2008). G × E interaction in the organization of attachment: Mothers' responsiveness as a moderator of children's genotypes. *Journal of Child Psychology and Psychiatry*, *49*, 1313–1320.

Bell, K., & Calkins, S. (2000). Relationships as inputs and outputs of emotion regulation. *Psychological Inquiry*, *11*, 160–163.

Belsky, J. (1984). The determinants of parenting: A process model. *Child Development*, *55*, 83–96.

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin*, *135*, 885–908.

Berlin, L., & Cassidy, J. (2003). Mothers' self-reported control of their preschool children's emotional expressiveness: A longitudinal study of associations with infant–mother attachment and children's emotion regulation. *Social Development*, *12*, 477–495.

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology*, *20*, 899–911.

Bowlby, J. (1969). Disruption of affectional bonds and its effects on behavior. *Canada's Mental Health Supplement*, *59*, 12.

Brody, G., Beach, S., Philibert, R., Chen, Y., & Murry, V. (2009). Prevention effects moderate the association of *5-HTTLPR* and youth risk behavior initiation: Gene × Environment hypotheses tested via a randomized prevention design. *Child Development*, *80*, 645–661.

Buss, A., Plomin, R., & Willerman, L. (1973). The inheritance of temperaments. *Journal of Personality*, *41*, 513–524.

Cairns, R. B. (1983). The emergence of developmental psychology. In P. H. Mussen (Ed. & Vol. Ed.), *Handbook of child psychology: Vol. 1. History, theory, and methods* (4th ed., pp. 41–102). New York: Wiley.

Cairns, R. B., McGuire, A., & Gariépy, J. L. (1993). Genetics and behavior: Fusion, correlated constraints and timing. In D. Hay & A. Angold (Eds.), *Precursors and causes of development and psychopathology* (pp. 87–122). Chichester: Wiley.

Calkins, S. (1994). Origins and outcomes of individual differences in emotion regulation. *Monographs of the Society for Research in Child Development*, *59*, 53–72.

Calkins, S., & Fox, N. (2002). Self-regulatory processes in early personality development: A multilevel approach to the study of childhood social withdrawal and aggression. *Development and Psychopathology*, *14*, 477–498.

Calkins, S., & Hill, A. (2007). Caregiver influences on emerging emotion regulation: Biological and environmental transactions in early development. In *Handbook of emotion regulation* (pp. 229–248). New York: Guilford Press.

Cassidy, J. (1994). Emotion regulation: Influences of attachment relationships. *Monographs of the Society for Research in Child Development*, *59*, 228–283.

Caughy, M. O., Owen, M. T., & Hurst, J. R. (2009, April). *Early poverty experience and the growth of academic skills in elementary school: The modifying role of self-regulatory capacity.* Paper presented at the biennial meeting of the Society for Research in Child Development, Denver, CO.

Cole, P., Martin, S., & Dennis, T. (2004). Emotion regulation as a scientific construct: Methodological challenges and directions for child development research. *Child Development*, *75*, 317–333.

Cole, P., Michel, M., & Teti, L. (1994). The development of emotion regulation and dysregulation: A clinical perspective. *Monographs of the Society for Research in Child Development*, *59*, 73.

Cox, M. J., & Paley, B. (1997). Families as systems. *Annual Review of Psychology*, *48*, 243–267.

Cox, M. J., & Paley, B. (2003). Understanding families as systems. *Current Directions in Psychological Science*, *12*, 193–196.

Crockenberg, S., & Leerkes, E. (2000). Infant social and emotional development in family context. In C. H. Zeenah, Jr. (Ed.), *Handbook of infant mental health* (2nd ed., pp. 60–90). New York: Guilford Press.

Denham, S., Blair, K., Schmidt, M., & DeMulder, E. (2002). Compromised emotional competence: Seeds of violence sown early? *American Journal of Orthopsychiatry*, *72*, 70–82.

Diener, M., Mengelsdorf, S., McHale, J., & Frosch, C. (2002). Infants' behavioral strategies for emotion regulation with fathers and mothers: Associations with emotional expressions and attachment quality. *Infancy*, *3*, 153–174.

Ebstein, R. P., Levine, J., Geller, V., Auerbach, J., Gritsenko, I., & Belmaker, R. H. (1998). Dopamine D4 receptor and serotonin transporter promoter in the determination of neonatal temperament. *Molecular Psychiatry*, *3*, 238–246.

Emde, R., Plomin, R., Robinson, J., & Corley, R. (1992). Temperament, emotion, and cognition at fourteen months: The MacArthur Longitudinal Twin Study. *Child Development*, *63*, 1437–1455.

Entwisle, D. R., & Alexander, K. L. (1993). Entry to school: The beginning school transition and the educational stratification in the United States. *Annual Review of Sociology*, *19*, 401–422.

Field, T. (1994). The effects of mother's physical and emotional unavailability on emotion regulation. *Monographs of the Society for Research in Child Development*, *59*, 208.

Fox, N., & Calkins, S. (2003). The development of self-control of emotion: Intrinsic and extrinsic influences. *Motivation and Emotion*, *27*, 7–26.

Gerhart, J., & Kirshner, M. (1997). *Cells, embryos, and evolution: Toward a cellular and developmental understanding of phenotypic variation and evolutionary adaptability.* Malden, MA: Blackwell.

Gariepy, J. L. (1996). The question of continuity and change in development. In R. B. Cairns, G. H. Elder, Jr., & E. J. Costello (Eds.), *Developmental science* (pp. 78–96). Cambridge: Cambridge University Press.

Gariépy, J.-L., Rodriguiz, R. M., & Jones, B. D. (2002). Handling, genetic, and housing effects on the mouse stress system, behavior, and dopamine function. *Pharmacology, Biochemistry, and Behavior*, *73*, 7–17.

Gervai, J., Novak, A., Lakatos, K., Toth, I., Danis, I., Ronai, Z., et al. (2007). Infant genotype may moderate sensitivity to maternal affective communications: Attachment disorganization, quality of care, and the *DRD4* polymorphism. *Social Neuroscience*, *2*, 307–319.

Goldsmith, H., & Gottesman, I. (1981). Origins of variation in behavioral style: A longitudinal study of temperament in young twins. *Child Development*, *52*, 91–103.

Gottlieb, G. (1976). Conceptions of prenatal development: Behavioral embryology. *Psychological Review*, *83*, 215–234.

Gottlieb, G. (2007). Probabilistic epigenesis. *Developmental Science*, *10*, 1–11.

Gottlieb, G., Wahlsten, D., & Lickliter, R. (2006). The significance of biology for human development: A developmental psychobiological systems view. In R. M. Lerner (Ed.), *Handbook of child psychology: Theoretical models of human development* (Vol. 1, 6th ed., pp. 210–257). Hoboken, NJ: Wiley.

Gunnar, M., & Donzella, B. (2002). Social regulation of the cortisol levels in early human development. *Psychoneuroendocrinology*, *27*, 199–220.

Haley, D., & Stansbury, K. (2003). Infant stress and parent responsiveness: Regulation of physiology and behavior during still-face and reunion. *Child Development*, *74*, 1534–1546.

Hofer, M. A. (1994). Early relationships as regulators of infant physiology and behavior. *Acta Paediatrica Supplements*, *397*, 9–18.

Isabella, R. (1993). Origins of attachment: Maternal interactive behavior across the first year. *Child Development*, *64*, 605–621.

Izard, C. E., Schultz, D., Fine, S. E., Youngstrom, E., & Ackerman, B. P. (1999/2000). Temperament, cognitive ability, emotion knowledge, and adaptive social behavior. *Imagination, Cognition, and Personality*, *19*, 305–330.

Kobak, R. (1999). The emotional dynamics of disruptions in attachment relationships: Implications for theory, research, and clinical intervention. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (pp. 21–43). New York: Guilford Press.

Kochanska, G., Philibert, R. A., & Barry, R. A. (2009). Interplay of genes and early mother–child relationship in the development of self-regulation from toddler to preschool age. *Journal of Child Psychology and Psychiatry*, *50*, 1331–1338.

Kopp, C. B. (1982). Antecedents of self-regulation: A developmental perspective. *Developmental Psychology*, *18*, 199–214.

Kuo, Z. Y. (1967). *The dynamics of behavior development*. New York: Random House.

Lengua, L. J., Bush, N. R., Long, A. C., Kovacs, E. A., & Trancik, A. M. (2008). Effortful control as a moderator of the relation between contextual risk factors and growth in adjustment problems. *Development and Psychopathology*, *20*, 509–528.

https://doi.org/10.1017/S0954579410000234 Published online by Cambridge University Press

Lerner, R. M. (2002). *Concepts and theories of human development*. New York: Erlbaum.
Magnusson, D., & Bergman, L. R. (1990). A pattern approach to the study of pathways from childhood to adulthood. In L. N. Robins & M. Rutter (Eds.), *Straight and devious pathways from childhood to adulthood* (pp. 101–115). Cambridge: Cambridge University Press.
Magnusson, D., & Cairns, R. B. (1996). Developmental science: Toward a unified framework. In R. B. Cairns, G. H. Elder, Jr., & E. J. Costello (Eds.), *Developmental science* (pp. 7–30). Cambridge: Cambridge University Press.
Main, M. (1990). Cross-cultural studies of attachment organization: Recent studies, changing methodologies, and the concept of conditional strategies. *Human Development*, *33*, 48–61.
Masten, A. S., Roisman, G. I., Long, J. D., Burt, K. B., Obradovic, J., Roley, J. R., et al. (2005). Developmental cascades: Linking academic achievement and externalizing and internalizing symptoms over 20 years. *Developmental Psychology*, *41*, 733–746.
Meaney, M., & Szyfe, M. (2005). Environmental programming of stress responses through DNA methylation: Life at the interface of a dynamic environment and a fixed genome. *Dialogues in Neuroscience*, *7*, 103–123.
Mills-Koonce, W. R., Propper, C., Gariépy, J. L., Blair, C., Garrett-Peters, P., & Cox, M. J. (2007). Bidirectional genetic and environmental influence on mother and child behavior: The family system as the unit of analyses. *Development and Psychopathology*, *19*, 1073–1087.
Moore, G. A., Hill, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother–infant vagal regulation in the face-to-face still-face paradigm is moderated by maternal sensitivity. *Child Development*, *82*, 209–223.
Mullin, B. C., & Hinshaw, S. P. (2007). Emotion regulation and externalizing disorders in children and adolescents. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 523–541). New York: Guilford Press.
NICHD Early Child Care Research Network. (2004). Affect dysregulation in the mother–child relationship in the toddler years: Antecedents and consequences. *Development and Psychopathology*, *16*, 43–68.
NICHD Early Child Care Research Network. (2008). Mothers' and fathers' support for child autonomy and early school achievement. *Developmental Psychology*, *44*, 895–907.
O'Connor, T., Deater-Deckard, K., Fulker, D., Rutter, M., & Plomin, R. (1998). Genotype–environment correlations in late childhood and early adolescence: Antisocial behavioral problems and coercive parenting. *Developmental Psychology*, *34*, 970–981.
Plomin, R., & Rowe, D. (1977). A twin study of temperament in young children. *Journal of Psychology: Interdisciplinary and Applied*, *97*, 107–113.
Pluess, M., & Belsky, J. (2009). Differential susceptibility to parenting and quality child care. *Developmental Psychology*, *46*, 379–390.
Propper, C., & Moore, G. (2006). The influence of parenting on infant emotionality: A multi-level psychobiological perspective. *Developmental Review*, *26*, 427–460.
Propper, C., Moore, G. A., Mills-Koonce, W. R., Halpern, C. T., Hill-Soderlund, A. L., Calkins, S. D., et al. (2008). Gene–environment contributions to the development of infant vagal reactivity: The interaction of dopamine and maternal sensitivity. *Child Development*, *79*, 1378–1395.
Propper, C., Willoughby, M., Halpern, C., Carbone, M., & Cox, M. (2007). Parenting quality, *DRD4*, and the prediction of externalizing and internalizing behaviors in early childhood. *Developmental Psychobiology*, *49*, 619–632.
Rimm-Kaufman, S. E., Early, D. M., Cox, M. J., Gitanjali, S., Pianta, R. C., Bradley, R.H., et al. (2002). Early behavioral attributes and teachers' sensitivity as predictors of competent behavior in the kindergarten classroom. *Applied Developmental Psychology*, *23*, 451–470.
Rothbart, M., Ahadi, S., & Evans, D. (2000). Temperament and personality: Origins and outcomes. *Journal of Personality and Social Psychology*, *78*, 122–135.
Rutter, M., Moffitt, T. E., & Caspi, A. (2005). Gene–environment interplay and psychopathology: Multiple varieties but real effects. *Journal of Child Psychology and Psychiatry*, *47*, 226–261.
Sameroff, A. J. (1983). Developmental systems: Context and evolution. In P. H. Mussen (Ed.) & W. Kessen (Vol. Ed.), *Handbook of child psychology: Vol. 1. History, theory, and methods* (4th ed., pp. 237–294). New York: Wiley.
Sameroff, A. J. (2000). Developmental systems and psychopathology. *Development and Psychopathology*, *12*, 297–312.
Schneirla, T. C. (1957). The concept of development in comparative psychology. In D. B. Harris (Ed.), *The concept of development* (pp. 78–108). Minneapolis, MN: University of Minnesota Press.
Schore, A. (2001). Effects of a secure attachment relationship on right brain development, affect regulation, and infant mental health. *Infant Mental Health Journal*, *22*, 7–66.
Smith, C., Calkins, S., & Keane, S. (2006). The relation of maternal behavior and attachment security to toddlers' emotions and emotion regulation. *Research in Human Development*, *3*, 21–31.
Spangler, G., & Zimmermann, P. (2007, March 30). *Genetic contribution to attachment disorganization and temperament.* Paper presented at the 2007 Meeting of the Society for Research in Child Development.
Spemann, H. (1927). Organizers in animal development. *Proceedings of the Royal Society of London*, *102*, 177–187.
Sroufe, L. (1996). *Emotional development: The organization of emotional life in the early years*. New York: Cambridge University Press.
Sroufe, L. (2000). Early relationships and the development of children. *Infant Mental Health Journal*, *21*, 67–74.
Sroufe, L. (2005). Attachment and development: A prospective, longitudinal study from birth to adulthood. *Attachment & Human Development*, *7*, 349–367.
Sroufe, L., Egeland, B., Carlson, E., & Collins, W. (2005). *The development of the person: The Minnesota study of risk and adaptation from birth to adulthood*. New York: Guilford Press.
Steele, H., Steele, M., & Croft, C. (2008). Early attachment predicts emotion recognition at 6 and 11 years old. *Attachment & Human Development*, *10*, 379–393.
Suomi, S. J. (2006). Risk, resilience, and Gene × Environment interactions in rhesus monkeys. *Annals of the New York Academy of Sciences*, *1094*, 52–62.
Thelen, E., & Smith, L. B. (1998). Dynamic systems theories. In W. Damon (Ed. & Series Ed.), *Handbook of child psychology: Vol. 1. Theoretical models of human development* (pp. 595–625). New York: Wiley.
Thelen, E., & Smith, L. (2006). Dynamic systems theories. In R. M. Lerner (Ed.), *Handbook of child psychology: Vol. 1. Theoretical models of human development* (6th ed., pp. 258–312), Hoboken, NJ: Wiley.
Thompson, R. (1994). Emotion regulation: A theme in search of definition. *Monographs of the Society for Research in Child Development*, *59*, 25–52.
van IJzendoorn, M., & Bakermans-Kranenburg, M. (2006). *DRD4* 7-repeat polymorphism moderates the association between maternal unresolved loss or trauma and infant disorganization. *Attachment & Human Development*, *8*, 291–307.
van IJzendoorn, M., Bakermans- Kranenburg, M., & Mesman, J. (2008). Dopamine system genes associated with parenting in the context of daily hassles. *Genes, Brain & Behavior*, *7*, 403–410.
von Bertalanffy, L. (1968). *General systems theory*. New York: Braziller.
Weinfield, N., Sroufe, L., Egeland, B., & Carlson, E. (1999). The nature of individual differences in infant–caregiver attachment. In *Handbook of attachment: Theory, research, and clinical applications* (pp. 68–88). New York: Guilford Press.
Wiebe, S., Espy, K., Stopp, C., Respass, J., Stewart, P., Jameson, T., et al. (2009). Gene–environment interactions across development: Exploring *DRD2* genotype and prenatal smoking effects on self-regulation. *Developmental Psychology*, *45*, 31–44.

https://doi.org/10.1017/S0954579410000234 Published online by Cambridge University Press