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Imaging Brain Systems in Normality and Psychopathology

Kathleen M. Thomas and **Dante Cicchetti**
Institute of Child Development, University of Minnesota

Neurobiological development is a complex process that originates at conception and extends throughout the lifespan (Casey, Tottenham, Liston, & Durston, 2005; Cicchetti & Cannon, 1999; Nowakowski, 1987; Rakic, 1996; Thompson & Nelson, 2001). The course of brain development can be altered by a host of factors, ranging from genetic liabilities to psychosocial stressors, and mental disorders are thought to eventuate from etiologic factors that modify the normal progression of brain development.

Perturbations that take place in the developing brain can trigger a cascade of growth and function changes that lead the neural system down a pathway that deviates from that taken in normal neurobiological development (Cicchetti & Tucker, 1994). Accordingly, abnormal perturbations at one stage of brain development likely impede the creation of some new structures and functions, distort the form of later-emerging ones, bring about the construction of structures and functions that would never become manifest, and hinder or limit the elaboration and usage of ones that had appeared earlier (Cicchetti, 2002; Courchesne, Chisum, & Townsend, 1994). Subsequently, abnormal neural network configurations and operations likely develop that may cause aberrant connections to be retained or created (Courchesne et al., 1994). Such early developmental abnormalities may eventuate in the development of aberrant neurocircuity and often compound themselves into enduring forms of psychopathology (Cicchetti & Cannon, 1999; Nowakowski & Hayes, 1999).

An outgrowth of systems theorizing in neuroscience has been a growing acceptance that neurobiological development and experience are mutually influencing (Cicchetti & Tucker, 1994; Eisenberg, 1995; Greenough, Black, & Wallace, 1987; Kandel, 1998; Nelson & Bloom, 1997). Pathological experience may become part of a vicious cycle, as the pathology induced in the brain structure may distort the child's experience, with subsequent alterations in cognition or social interactions causing additional pathological experience and added brain pathology (Black, Jones, Nelson, & Greenough, 1998). Because experience-expectant and experience-dependent processes may continue to operate during psychopathological states, children who incorporate pathological experience during these processes may add neuropathological connections into their developing brains instead of functional neuronal connections (Black et al., 1998; Cicchetti & Tucker, 1994).

Basic research in neuroscience has begun to elucidate the neural events that mediate the relation between experience and behavior. Researchers in the field of developmental psychopathology have begun to use this knowledge base to inform their investigations aimed at uncovering the neural mechanisms that might subserve the dynamic, multiple-level interactions that exist among genes, brain, behavior, and experience (Gottlieb, 2002; Gottlieb & Willoughby, 2006).

Correspondence: Please address reprint requests to either Kathleen M. Thomas, Ph.D., thoma114@umn.edu or Dante Cicchetti, Ph.D., cicchett@umn.edu, Institute of Child Development, University of Minnesota, Minneapolis, MN 55455.

Despite the major influence that embryology exerted upon the leading systematizers in the field of developmental psychology (Fishbein, 1976; Sameroff, 1983; Waddington, 1957; Weiss, 1961, 1969), the majority of the classic theories of normal development that were prominent throughout much of the twentieth century accorded little attention to neurobiological processes (Cicchetti, 2002; Goldman-Rakic, 1987; Johnson, 1998; Nelson, Thomas, & de Haan, 2006; Segalowitz, 1994). Undoubtedly, the paucity of information that existed about the structural and functional organization of the brain contributed to the relative neglect of neurobiology in the formulation of developmental theorizing on the ontogenesis and epigenesis of behavior (Goldman-Rakic, 1987; Johnson, 1998; Kandel, 1998, 1999).

Although extant knowledge of the nature of the relations between neurobiology and behavior in both normal and abnormal development across the lifespan is far from complete, in recent decades a number of technological advances have emerged that have greatly enhanced the ability of neuroscientists and psychopathologists to discover normal and abnormal pathological processes in the brain (Amso & Casey, 2006; Casey, Giedd, & Thomas, 2000; Casey, Tottenham, Liston, & Durston, 2005; Durston et al., 2006; Johnson, Halit, Grice, & Karmiloff-Smith, 2002). This rapid growth in the development of sophisticated techniques that permit the anatomical and physiological imaging of the nervous system has enabled researchers to uncover diverse information about the brain, including brain metabolic processes, glucose metabolic rate, the ability to distinguish between cerebrospinal fluid and white and gray matter, the capacity to detect biochemical changes within brain cells, such as changes in neurotransmitter receptors, and the examination of brain connectivity through tracing white matter tracts and detecting brain functional connectivity (Hunt & Thomas, this issue; Thomas, 2003).

Because developmental psychopathology and neuroscience share fundamental principles, the connection between neuroscience and developmental psychopathology can provide a compelling framework to support the study of normal and abnormal neurobiological development (Cicchetti & Posner, 2005). For example, one of the central principles of developmental psychopathology – that the study of normality and pathology are mutually informative – also is embraced by developmental neuroscientists (Goldman-Rakic, 1987; Johnson, 1998). Scientists in each of these disciplines believe that a firm knowledge base of normative developmental processes is essential for understanding both psychopatholgy and resilient functioning (Cicchetti, 1993; Sroufe, 1990). Moreover, scientists in these two fields have long asserted that one can gain valuable information about an organism's normal functioning by investigating its abnormal condition (Cicchetti & Cannon, 1999; Goldman-Rakic, 1987; Johnson, 1998; Nelson, Thomas, & de Haan, 2006).

The theme of this Special Issue, "Imaging Brain Systems in Normality and Psychopathology," addresses a timely and important topic that has the potential to augment the understanding of the etiology, developmental course, and pathogenesis of high-risk conditions and mental disorders across the lifespan. Furthermore, in the present era, where interdisciplinary and multiple-levels-of-analysis perspectives are receiving increased attention and emphasis (see, e.g., Cacioppo et al., 2007; Cicchetti & Posner, 2005; Gottlieb, Wahlsten, & Lickliter, 2006; Masten, 2007; Pellmar & Eisenberg, 2000), the incorporation of neuroimaging into the research armamentarium of developmental psychopathologists may contribute to an increased comprehension of the mechanisms underlying maladaptive, psychopathological, and resilient adaptation (Cicchetti & Curtis, 2007). Furthermore, because psychopathology and resilience cannot be understood fully unless all levels of analysis are examined, the integration of neuroimaging into basic multi-level empirical investigations will be critical to suggesting future opportunities for translational research in neuroscience and developmental psychopathology (Cicchetti & Gunnar, 2008; Gunnar & Cicchetti, in press).

As illustrated through the contributions to this Special Issue, neuroimaging methods are being used by neuroscientists and developmental psychopathologists to enhance the understanding of normal and abnormal neurobiological development and to augment knowledge concerning the processes and pathways linking neurodevelopment and outcomes, typical and disordered (Casey et al., 2005; Giedd, Shaw, Wallace, Gogtay, & Lenroot, 2006; Nelson & Bloom, 1997). For example, it is now thought that the increasing cognitive capacities that emerge in childhood may take place concurrently with a gradual loss rather than with the formation of new synapses and a presumed strengthening of the synaptic connections that remain (Casey, Giedd, & Thomas, 2000). Moreover, regions of the brain that are associated with basic functions (e.g., sensory and motor processes) have been shown to mature earliest, followed by maturation of the association regions that are involved in the top-down control of behavior (Casey et al., 2005). In addition, as cortical systems undergo a fine-tuning, it has been shown that there is a corresponding enhancement of connectivity with cortical and subcortical circuitry (Amso & Casey, 2006). Thus, neuroimaging research has helped the field of cognitive development transcend the questions of what develops and when, to how these transformations in cognition across time may take place (Amso & Casey, 2005; Casey et al., 2000). Furthermore, neuroimaging research has aided in the discovery of the underlying neural mechanisms of a number of psychopathological conditions.

These scientific gains may allow us to develop therapeutic strategies that may lead to advances in the treatment, and even in the prevention of, behavioral and emotional symptoms, as well as coping strategies, that may have been adaptive in their initial context, but proved to be ultimately maladaptive. Through investigating brain structure and function developmentally, we may get closer to specifying etiological pathways or a set of necessary precursors for the development of symptoms associated with various mental disorders. Regional differences in structural brain development or patterns of brain activity may serve as an endophenotype (Gottesman & Gould, 2003), providing an alternate means of identifying those individuals who are more likely to respond positively to various treatments, those whose symptoms may be more refractory to intervention, or even those at risk for developing disorder. Moreover, the use of neuroimaging methods may allow for more precise subclassification of behavioral symptoms and syndromes. In addition, examination of the brain systems associated with specific cognitive, emotional, and social behaviors across development may aid in identifying key symptoms that are common among individuals with different behavioral or emotional profiles. Neuroimaging may indicate previously unstudied overlap between seemingly disparate symptoms.

Further investigating the activity of brain systems associated with disrupted behavior or emotion dysregulation can aid in understanding typical individual variability in brain function and organization, and in comprehending processes of risk and resilience. Neuroimaging also provides a unique method for examining the impact of various environmental and experiential factors on brain development and biological instantiations of behavior. In the future, emphasis should be placed on longitudinal data, especially on functional neuroimaging. In order to truly comprehend the emergence of behavioral and affective symptoms, it is critical for the field to conduct prospective longitudinal investigations. The prohibitive financial cost of neuroimaging research and the vast amount of human effort expended on coding and data analysis have thus far rendered the accumulation of prospective data to be a challenging goal.

Clearly, however, brain imaging technology cannot solve the complex issues inherent to the relation between typical and atypical development alone. Sound theory, in conjunction with experimental paradigms that permit the investigation of cognitive, emotional, and social behavior, has enabled research on neuroimaging to enhance the understanding of the relation between typical and atypical development across multiple levels of analysis. Since individual levels of analysis constrain other levels, researchers conducting their work at each level will need to develop theories that are consistent across all levels. Interdisciplinary research will become increasingly prevalent, necessitating that the challenge of establishing communication between scientists from different fields be confronted and solved (Gunnar & Cicchetti, in press; Pellmar & Eisenberg, 2000). This will enable the field of developmental psychopathology to make optimal use of the advances in technology that have occurred. If disciplines function in isolation, then it is likely that the theories they promulgate will ultimately prove to be incorrect because existing vital information from other disciplines will either have been unknown or have been ignored. Just as has been witnessed in the development of the discipline of systems neuroscience (Kandel & Squire, 2000), it is essential that we strive to develop an integrative framework that incorporates all levels of analysis about complex systems in typical development, as well as the development of psychopathology, and resilience. The sophisticated and comprehensive portrayals of adaptation, maladaptation, and resilience that ensue will serve not only to advance scientific understanding, but also to inform efforts to prevent, ameliorate, and, ultimately, develop cures for, mental disorders (Insel & Scolnick, 2006).

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