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Editorial: Multiple levels of analysis

DANTE CICCHETTI[a] AND GERALDINE DAWSON[b]
[a]*Mt. Hope Family Center, University of Rochester; and* [b]*University of Washington*

In a recent article, Cowan, Harter, and Kandel (2000) concluded that much of the success and excitement engendered by modern neuroscience can be attributed to the incorporation of several previously independent disciplines into one intellectual framework. During the 1950s and 1960s, neuroanatomy, neurochemistry, neuropharmacology, and neurophysiology, disciplines that had largely functioned in a separate and distinct fashion, gradually merged into a unified field of neuroscience. The penultimate step in the coalescence of neuroscience occurred in the early 1980s, when neuroscience integrated with molecular biology and molecular genetics. The confluence of these fields enabled scientists to understand the genetic basis of neurological diseases for the first time without requiring foreknowledge of the underlying biochemical abnormalities. The final phase of the merger of neuroscience into a single discipline took place in the mid-1980s, when cognitive psychology joined with neuroscience, leading to the formation of cognitive neuroscience.

Over the course of the past several decades, it has become increasingly acknowledged that the investigation of developmental processes, both normal and atypical, is an inherently interdisciplinary enterprise (e.g., see the papers in this issue; also see Caccioppo, Berntson, Sheridan, & McClintock, 2000; Cicchetti, 1990; Gottlieb, Wahlsten, & Lickliter, 1998). Scientists must utilize different levels and methods of analysis (e.g., molecular, cellular, behavioral, and macrosystem levels), depending on the questions being addressed in their research. The movement toward a multiple levels of analysis perspective is exemplified by work conducted in contemporary neuroscience. Neuroscientists have increasingly changed their emphasis from a focus on examining single neurons to investigating how the individual neurons that comprise the brain work together in specialized groups. Systems neuroscience is devoted to the study of these neural systems (Albright, Jessell, Kandel, & Posner, 2000; Cicchetti & Cannon, 1999; Johnson, 1998).

According to this dynamic, neural systems viewpoint, the brain is conceptualized as operating in a plastic, self-organizing fashion and being less constrained by predetermined boundaries than previously thought (Posner, Rothbart, Farah, & Bruer, 2001). Information in the brain is represented and processed by distributed groups of neurons that maintain a functional interconnection based on experiential demands rather than by a strictly genetically determined scheme (Cicchetti & Tucker, 1994; Courchesne, Chisum, & Townsend, 1994; Dawson & Fischer, 1994; Eisenberg, 1995). From this framework, not only do molecular and neural processes impact behavior, social experiences modify the structure and function of the brain, as well as affect gene expression (Cicchetti & Tucker, 1994; Dawson & Fischer, 1994; Dawson, Hessl, & Frey, 1994; Francis, DiOrio, Liu, & Meaney, 1999;

Address correspondence and reprint requests to: Dante Cicchetti, PhD, Shirley Cox Kearns Professor of Psychology, Psychiatry, and Pediatrics, University of Rochester, Rochester, NY 14608, and Director, Mt. Hope Family Center, 187 Edinburgh Street, Rochester, NY 14610, or Geraldine Dawson, PhD, Professor of Psychology, Director, University of Washington Autism Center and Child Clinical Psychology Program, Center on Human Development and Disability, Box 357920, University of Washington, Seattle, WA 98195.

Gottlieb, 1992; Kandel, 1998; Meaney, DiOrio, Francis, Widdowson, LaPlante, Caldji, Sharma, Seckl, & Plotsky, 1996).

Albright and colleagues (2000) attributed the ascendance and coalescence of contemporary systems neuroscience, in part, to the convergence of five critical subdisciplines, each of which made major conceptual or technical contributions to this new field. Collectively, the research armamentarium in the areas of neuropsychology, neuroanatomy, neurophysiology, psychophysics, and computational modeling has contributed to an enhanced understanding of the structure, operational mechanisms, and functions of neural systems (Albright et al., 2000).

Relatedly, since its emergence as a new discipline, developmental psychopathology has been an interdisciplinary science (Cicchetti, 1984, 1990). Work conducted within a developmental psychopathology perspective incorporates theory and research from the fields of normal and abnormal development and advocates multidisciplinary approaches that examine the biological, psychological, and social–contextual aspects of development (Institute of Medicine, 1989). Risk and protective factors cut across multiple levels of analysis, from the molecular and cellular through the psychological and social systems levels. Within individuals, single risk processes may not have sufficient power to eventuate in problems on their own. Collectively, however, multiple risk processes may operate additively, amassing increasingly greater probabilities that maladaptation and psychopathology will ensue. In addition, risk processes may co-act synergistically with an exponential rather than additive impact on increasing the likelihood of negative outcomes. Moreover, risk factors tend to occur together rather than in isolation (Rutter, 1987). Furthermore, some risk factors may contribute to the emergence of problems that, in turn, become risk factors for other problems as development proceeds.

Focusing on the area of drug abuse, the neuroscientist Bloom (1993) advocated the combination of research at the molecular, cellular, and behavioral levels as the most effective strategy for addressing questions on drug addiction. Bloom (1993) emphasized the criticality of examining two temporal phases in the ontogenesis of drug addiction. Specifically, he underscored the importance of investigating the neuronal and behavioral changes that take place with multiple drug exposures over extended time periods and how these contribute to the development of the altered drug sensitivities of tolerance and sensitization. Further, Bloom stressed the need to study the residual changes that persist even after prolonged periods of drug abstinence and that contribute to the phenomenon of drug craving.

Most of what is known about the causes, correlates, course, and consequences of psychopathology was gleaned from investigations that focused on relatively narrow domains of variables. Yet it is apparent from the questions addressed by developmental psychopathologists that progress toward a process-level understanding of mental disorder will require research designs and strategies that call for the simultaneous assessment of multiple domains of variables both within and outside of the developing person. Similarly, research in the area of resilience must follow these interdisciplinary multiple levels of analysis perspectives (Cicchetti, in press). In some instances, reference to variables measured in other domains is essential to clarify the role(s) of variables of interest; for other questions, variables from other domains are necessary to consider as competing explanations for postulated causal paths. Psychopathology cannot be understood fully unless all levels are examined and integrated. Each level both informs and constrains all other levels of analysis. Moreover, the influence of levels on one another is almost always bidirectional.

Because different levels of analysis constrain other levels, as scientists learn more about multiple levels of analysis, researchers conducting their work at each level will need to develop theories that are consistent across all levels. When disciplines function in isolation, they run the risk of creating theories that ultimately will be incorrect because vital information from other disciplines has either been ignored or is unknown. Just as is the case in systems neuroscience, it is critical that

there be an integrative framework that incorporates all levels of analysis about complex systems in the development of psychopathology.

In this Special Issue of *Development and Psychopathology,* contributors provide illustrations from investigations carried out within their own laboratories, as well as in those of their colleagues, to demonstrate the scientific gains that can be achieved from a multiple levels of analysis perspective. The papers range from an examination of self-regulatory processes in early personality and behavioral adjustment, to how the construction of relatively homogeneous profiles that include physiological and behavioral data can more clearly reveal the temperamental origins of individuals categorized as having similar phenotypes based solely on self-report information, through investigations that examine high risk conditions and serious mental disorders.

Notably, a number of the contributors discuss the need for new approaches to the training of graduate students and postdoctoral trainees in developmental psychopathology. One of the major challenges confronting scientific progress involves establishing communication systems among disciplines. For example, despite tremendous technological advances that have occurred in neuroimaging and molecular genetics, great knowledge gaps remain between scientists who possess competence with the technologies and methods of brain imaging and genetics and those who are comfortable with the complex issues inherent in the investigation of development and psychopathology. Consequently, the field has not yet made optimal use of the advances in technology that have taken place (Posner et al., 2001).

It is rare for individuals to fully comprehend the breadth of the phenomena associated with areas that they are studying, except in the rare cases of persons who have developed expertise in multiple fields. For example, in order to investigate the role that genetic factors play in the emergence of mental disorders, a scientific team should minimally comprise a molecular biologist, a methodologist who possesses competence in sophisticated statistical techniques, and a psychopathologist. If communication is to take place among professionals who do not necessarily speak the same scientific language and if the divisions and schisms that commonly prevent an in-depth understanding of normal and abnormal development from occurring are to be eroded, then graduate and postdoctoral training programs will need to be modified. Those conducting multidisciplinary research will profit from possessing substantial knowledge in more than one discipline. Additionally, being trained in multiple disciplines should facilitate communication between scientists specializing in different areas of research. Such efforts will necessitate not only interdisciplinary collaborations but also a move to a more interdisciplinary training of developmental scientists (Cicchetti & Toth, 1991; Pellmar & Eisenberg, 2000; Singer & Ryff, 2000). Further, because it is impossible to learn everything that there is to know while in graduate school and the knowledge base changes over time, all scientists must be committed to developing new competencies far beyond the attainment of their degrees.

In closing, it is essential that research in developmental psychopathology increasingly strives to investigate multiple levels of analysis. To date, most efforts have sought to obtain a comprehensive understanding of functioning by integrating information available across studies. Ideally, investigators must direct their energies toward an examination of multiple levels of analysis within the same individual. The sophisticated and comprehensive portrayals of adaptation and maladaptation that will ensue will serve not only to advance scientific understanding but also to inform efforts to prevent and ameliorate psychopathology.

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