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Introduction

DANIEL P. KEATING

For developmental scientists, the nature versus nurture debate has been settled for some time. Neither nature nor nurture alone provides the answer. It is always nature *and* nurture in concert that shape developmental pathways and outcomes, from health to behavior to competence. In recent years, this insight has moved far beyond the commonplace assertion that both nature and nurture matter, progressing into the far more complicated and fascinating terrain of understanding how they interact over the course of development. This research arena has benefited from the emergence of new tools and techniques, enabling the field to gather information on the biological processes underlying child development and to analyze more complex information in more sophisticated ways that enable a clearer view of nature-nurture interactions in operation. Another significant change has been the steady accumulation of longitudinal data sets that permit the study of developmental trajectories from birth, or even prenatally, to adolescence and into adulthood.

A NEW PARADIGM FOR EARLY CHILD DEVELOPMENT

The convergence of these factors – the uptake of a nature-and-nurture model into research endeavors on many fronts, the emergence of new research tools and techniques, and the accumulation of developmental databases to which they can be applied – has set the stage for a major expansion of knowledge about human development. Much of this work has focused the field's attention on early child development as a key period within which many of these important interactions are occurring, with significant influences on the subsequent developmental trajectories for which they provide the foundation. This is to be distinguished from infant determinism, with its claims that all-important developmental pathways have

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been set by age three or five years. There are contingencies that operate throughout the life course, affecting eventual outcomes in all areas in important ways, both positively and negatively. However, some important pathways are heavily tilted toward nature-nurture interactions in early child development, establishing foundations that will enable or constrain a host of future pathways.

There are a number of ways in which these newly dominant models and perspectives have not been taken up fully among students, practitioners, policy thinkers and analysts, or the public at large. Clearly, moving beyond the nature versus nurture polemics of an earlier era will take some time. Nevertheless, for students, practitioners, and others with a serious interest in human development, it is crucial to provide the opportunity to learn what is transpiring at the cutting edge of the new paradigm.

THE GOAL OF THIS VOLUME

The goal of this volume is to provide such an opportunity. It aims to achieve this goal in two ways. The first is to learn from the developmental scientists who are themselves working at this cutting edge, in a range of critical areas of early child development from neural mechanisms to population studies, and from basic laboratory science to clinical interventions. Owing to the fast-moving nature of work in this area, it is important to learn from those who are generating the new knowledge and confronting the complexities that arise in doing so. As the reader will discover, this volume benefits from the willingness of these scientists to communicate effectively the excitement, challenge, and implications of this new paradigm in action.

In addition, these authors accepted an additional challenge. Without watering down the key scientific progress in their fields, they have made every effort to make the science accessible to a wide audience, from students to practitioners to policy thinkers to the interested public at large. Readers will judge how well this dual challenge – conveying the cutting edge in an accessible way – has been met, and there is no doubt that some of the material requires more careful, rather than casual, reading. In any case, the significance and the timeliness of the work deserve sound reporting from the frontlines of the new paradigm, which this volume aims to provide.

THE NEW PARADIGM IN POLICY AND PRACTICE

In addition to the mandates of explaining how the new paradigm is yielding new findings in developmental science, and of doing so in an accessible way,

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a third mandate was undertaken by the contributors to this volume: to call attention wherever possible to the implications for both policy and practice. The full range of these implications is beyond the scope of this volume, and in any case will continue to emerge as the new paradigm takes firmer hold in the field and in public discourse. One of the barriers is that nature-and-nurture is inherently more complex than single accounts from either perspective, but the routes to overcoming this barrier are to understand better both the science and its implications. The intent of this volume is to move that dual agenda forward. As Rutter notes in Chapter 1 of this volume:

> In summary, there can be no serious doubting of the importance of genetic influences on both normal and abnormal psychological functioning. Nevertheless, knowing that there is a genetic influence does not tell one anything very useful on its own, with respect to risk or protective causal pathways. That is because genetic influences may operate in such a diversity of ways, both direct and indirect, and the implications will vary as to the details of the mode of operation.

HOW TO USE THIS VOLUME

How could this book best be used by different audiences? It is ideally suited for graduate and advanced undergraduate courses and seminars that focus on understanding how biology, behavior, and society interact in the generation of developmental pathways in infancy and early childhood. For courses with a particular focus on early child development, this volume provides a substantial overview of most of the core issues. For courses with a broader overview of human development, it can provide an important basis for understanding the earliest processes and influences on child development. As the following overview indicates in more detail, the organization of the volume is generally from more micro to more macro, and from more basic to more applied – although these levels and approaches are intermixed throughout the volume.

For practitioners working in early child development, in settings from childcare to clinical intervention, this volume provides an important view into the underlying developmental mechanisms, a view that can be essential for grounding practice in a fully realized nature-and-nurture paradigm. It also encourages a new perspective on, and creative reworking of, some long-standing practices in the field.

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For policy thinkers and analysts, the new paradigm will be challenging. Entrenched arguments arising from either perspective are hard to move, and these arguments are frequently deeply embedded in policy or even institutions. Educating the public will make easier the revamping of policies in line with the newly discovered realities of early child development. Of course, for research, policy, and practice, having a clear conceptual framework to organize the complex information arising from the new paradigm will be essential, and this volume seeks to provide a framework that can be widely used.

THE ORGANIZATION OF THIS VOLUME

There were many ways that this volume could have been organized. Each chapter deals with the nature-and-nurture perspective by considering gene-environment and biology-context interactions; each provides an overview of a broad area of the field, overlapping to some extent with all other chapters; and each chapter identifies important implications for research, policy, and practice. Accordingly, instructors and the general reader can productively read the volume in any order, or sample among the chapters on topics of the greatest interest.

Nonetheless, the sequence of the chapters was ordered to lead the reader generally from molecular processes and mechanisms toward more complex behaviors and contexts, and from more basic to more applied developmental science. The opening chapter by Rutter provides a comprehensive overview of the topics that arise as one considers the joint influence of biology and experience, from which the reader will obtain a succinct and workable framework for the key issues in the rest of the volume. In Chapter 2, Nelson provides a compelling introduction to early brain development, including the implications of the nature of those developments for lifelong growth and plasticity. It can be read productively as a primer on early brain development, laying out the major stages from conception through early child development.

In the two chapters that follow, Barr, and Gunnar and Loman take up some of the most important early experiences for lifelong behavior and health. Barr focuses especially on the nature of the most important early relationship, between infant and caregiver, most often the mother. He reports on an elegant series of studies that illuminate the complex ways in which caregiving serves as support and regulation of the infant's distress, sleep, and memory. Gunnar and Loman take up the core issue of the early

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development and function of the stress response system, especially as they affect the formation and later function of that system.

Boyce, and Jenkins and Bisceglia, in the two chapters that follow, focus on the specific features of the interaction of biology and context. Boyce describes an elegant overall formulation of that interaction, employing to good use the metaphor of a symphony, in order to draw our attention to the promise and the challenges of building a developmental science on the complex interaction of biology and context. Jenkins and Bisceglia address an aspect of one of the longest-lived issues in the old paradigm: how to assess environmental influences on early child development. Earlier analyses looked only at the shared environment until it was recognized that the within-family environment was quite variable between siblings. This topic is taken up by Jenkins and Bisceglia in a positive research agenda, examining in some detail the effects of differential experience by siblings within families.

In the two chapters that follow, Tremblay, and Lieberman and Ippen explore how the new perspective can be used to shape developmentally guided interventions that address early vulnerabilities through an understanding of the basic developmental processes underlying social relationships, from attachment to aggression. From these chapters, it is clear that although greater complexity is introduced by taking up the new paradigm and the importance of early experience, there are also a range of new tools and approaches that can be deployed to maximize the effectiveness of early interventions, through timing that is more appropriate and a focus on more precise targets of intervention.

In the two concluding chapters, Hertzman and Keating consider the influence of the new paradigm for understanding population patterns, and the societal responses that may be most effective in light of the new knowledge. Hertzman describes a comprehensive community-level approach to these issues, ranging from biodevelopment to population studies. Keating addresses similar issues, focusing on the persistent issue of social disparities in important developmental health outcomes, and presents a model for understanding those disparities in terms of the underlying causal pathways that run through early child development.

In combination, these chapters provide the reader with the opportunity to arrive rather quickly at the cutting edge of new research on early child development across a full range of central topics, to do so with the guidance of leading active researchers in each of these fields, and to consider some of the most significant implications of this new paradigm for policy and

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practice. This effort is, of course, an early contribution to what will no doubt become an ongoing and lengthy dialogue as the new paradigm grows into the mainstream not only among researchers but also eventually among the public at large, and as its implications become more apparent for how we see our children, our society, and ourselves.

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1

Biological and Experiential Influences on Psychological Development

MICHAEL RUTTER

INTRODUCTION

Over recent decades there have been major developments in our understanding of the various ways in which biological and experiential factors influence psychological development (Rutter & Rutter, 1993; Rutter 2000a, 2006a; Shonkoff & Phillips, 2000). In this chapter, I focus on the conceptual issues that are involved, on possible causal mechanisms, on effects on abnormal or suboptimal functioning, and on implications for intervention. Throughout, the arguments are based on empirical research findings (placing most emphasis on those that have been replicated by independent research groups) and, when dealing with causal mechanisms, reference is made to studies in biology and medicine, as well as in psychology, to draw conclusions on likely processes.

DEVELOPMENT

In much of the literature, there has been a tendency to seek to partition influences into those that are genetic (G) and those that are environmental (E), as if between them they accounted for all possibilities. This is a seriously misleading oversimplification because it focuses exclusively on individual differences without taking account of the universals of development (see Rutter, 2002). Also, it wrongly assumes that G and E are separate and involve no co-action (see Rutter, 2006a) and ignores the role of chance. Accordingly, I start with a consideration of some of the key features of developmental processes.

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Neural Development

Several features of brain development warrant particular emphasis (Greenough et al., 1987; Greenough & Black, 1992; Nelson, this volume; Nelson & Bloom, 1997, Nelson et al., 2006). It is well established that the process comprises an initial proliferation of neurons and neuronal connections, accompanied by neuronal migration, and later by myelinization of nerve fibers. This phase of overproduction of nerve cells (which takes place during the first few years of life in humans) is followed by a selective pruning resulting in a loss of nerve cells. This phased development is a consequence of the fact that brain development, like development as a whole, is probabilistic. In other words, there is a genetic programming of the pattern of development but this provides a general set of instructions, as it were, rather than a specific instruction as to what should happen to each individual neuron. This means that the phase of pruning can be used to fine-tune brain organization. This process is partially driven by neuron-neuron interaction so that the organization is shaped by the ways in which neurons fire together. This leads to the establishment of neuronal networks on the general principle of neurons that "fire together wire together."

It is also partially driven by experiential input. Another way of thinking about this process of brain development is to recognize that a key feature of biological development is that it is organized to be adaptive to circumstances. From an evolutionary viewpoint, it is important that the organism be able to develop normally in a wide range of environments (Bateson & Martin, 1999; Bateson et al., 2004). It would not "work" for there to be an undue reliance on specific environmental conditions that would apply only to some individuals. Nevertheless, within a wide range of expectable environments, there is a need for sensory input if brain development is to proceed normally. This was shown most dramatically by Hubel and Wiesel (2005) with respect to the dependence of the growth and functioning of the visual cortex on appropriate visual input during the early years. This has been amply confirmed by numerous investigators since then. The practical consequence is that, if there is not coordinated binocular visual input in the first few years, normal binocular vision at a later age is not likely. That is the reason why it is important for children's squints (strabismus) to be corrected early in life.

The most rapid and most radical period of brain growth takes place during the early years of life, but it is important to recognize that brain maturation continues throughout childhood and into early adult life (Giedd, Lalonde, Celano, White et al., 2009; Gogtay et al., 2004; Huttenlocher, 2002; Toga, Thompson, & Sowell, 2006). It used to be thought that no new

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neurons could be produced after the first few years but it is now apparent that new nerve cells can be produced, even in adult life, at least in the hippocampus (Baringa, 2003; Gross, 2000). It is certainly the case that brain plasticity is greatest in early life but a degree of plasticity is evident even at later ages (Nelson, this volume; Nelson et al., 2006; Roder & Neville, 2003; Stiles, 2000).

The Role of Chance

One of the consequences of the probabilistic process of development is that chance, as well as genetic and environmental influences, plays a role (Molenaar, Boomsma, & Dolan, 1993; Jensen, 1997; Goodman, 1991). Thus, females inherit two X chromosomes but one is always inactivated. It appears that it is largely a matter of chance which X chromosome is suppressed. There are numerous other examples in biology where it is evident that chance is operative. In thinking about the role of chance, however, it is necessary to differentiate between group effects and individual effects. One of the consequences of probabilistic development is that it is very common for development to go slightly awry in one way or another. This is evident, for example, in the high frequency with which individuals show minor congenital anomalies. There are predictable group effects on the frequency with which such anomalies occur. For example, they are more common in babies born to older mothers, and they are more common in twins (especially monozygotic twins) than in singletons (Vogel & Motulsky, 1997). To that extent, the occurrence of anomalies is predictable at a group level. However, the particular anomalies seen in any one individual do seem to be determined by chance to a considerable extent. Because of the importance of such chance effects, it is desirable to have some measure of the extent to which any particular individual shows developmental perturbations. One way in which this matter has been approached has been to focus on dermatoglyphic asymmetry (Naugler & Ludman, 1996), but the validity of this approach remains uncertain. Such asymmetry, measured as differences between left versus right fingerprint ridge counts, has been found in one study to increase because of increased maternal stress during prenatal weeks 14–22 (King, Mancini-Marïe, Brunet, Meaney et al., 2009).

ADAPTATION TO THE ENVIRONMENT

The notion that biological development proceeds in a way that is adapted to the environments experienced at the time is often considered under the general concept of *developmental programming*. This term has also been

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used to refer to the experience-expectant sculpting of brain development in relation, for example, to visual input, as outlined earlier (Greenough, Black, & Wallace, 1987). However, this type of sculpting that is contingent on an average expectable environment (hence the descriptor experience-expectant) only goes awry if the environments experienced are outside a very broad range.

The experience-adaptive notion of developmental programming is different in two key respects (Bateson et al., 2004; Barker, 1999; O'Brien et al., 1999; Rutter, 2006b). First, it deals with variations within (as well as outside) a normal range and, second, it has to be viewed in relative terms. The early experiences prepare the organism, biologically speaking, to be particularly well prepared to cope with a specific type of environment, rather than to develop optimally in some absolute sense. It is unlikely that the biological processes involve a single mechanism but there are parallels across systems. For example, initially babies across the world all show much the same skills in phonological discrimination. However, during the course of the first year discriminatory abilities become increasingly shaped by the language input experienced (Maye, Werker, & Gerken, 2002; Kuhl et al., 1997; Werker, 2003). Later on, children show phonological discriminations that are adapted to the language with which they have been brought up, and they find it quite difficult to pick up discriminations that are important in other languages, but not in their own. In somewhat comparable fashion, the early vocalizations of completely deaf children are normal, but as auditory input becomes increasingly important during the middle and latter part of the first year, sound productions become progressively distorted.

Before turning to a more detailed consideration of biological programming, it is necessary to note that there is a third variety of neural effects of experiences – what have been termed experience-dependent brain effects (Greenough, Black, & Wallace, 1987) – meaning that there are effects of experience on brain structure and function that can occur at any age and that do not involve effects on ordinary brain growth. Thus, animal studies have shown that environmental enrichment/deprivation has brain effects in adult as well as juvenile animals. Human brain imaging studies have shown the effects of psychological as well as pharmacological intervention (Goldapple et al., 2004). Other brain imaging studies have also shown variations in brain structure associated with intensive experiences in adult life (Rutter, 2009). This should not be surprising because learning has to involve the brain in some way. What is important, however, is to recognize that there are different types of brain effects resulting from experiences, and

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