CHAPTER 1

Reflections on Cognitive Development

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The study of cognitive development has itself developed significantly since the first edition of this *Handbook* appeared in 1946. Early scholars often tried to catalogue which factors could account for what outcomes, and even when they identified multiple factors, they attempted to quantify the relative contributions of each. The term "independent variable" was perhaps overinterpreted to mean that variables could, indeed, be independent of one another. As well-reflected in all four volumes of this new edition of the *Handbook*, contemporary developmental scientists recognize the problems associated with reductionist models and with the failure to consider the role of the broader context in addition to the role of an individual's self-directive processes. The alternative model, described elsewhere in this *Handbook,* first in brief (Lerner, Preface) and then in detail (Overton, Chapter 1, Volume 1), is a relational-systems view that examines any particular topic such as cognitive development within the broader biological and sociocultural context.

Given their relational perspectives, authors of this volume's chapters reject models that argue for singular unidirectional effects (for instance, from action to cognition or from social context to cognition). Similarly, authors make it clear that one cannot divorce so-called peripheral from so-called central processes. As such, what were earlier viewed as "lower level" processes are no longer seen as automatic and overdetermined. They are instead conceptualized as integrated within the developmental system, and investigated as part of a more inclusive and conjoint range of biological and sociocultural processes.

Although each chapter in this volume is titled to name its focus on a relatively constrained topic, many chapters actually address shared issues. Illustrative are the importance of symbols (e.g., see chapters on concepts, language, literacy, mathematical reasoning, gesture, symbolic representation, play, and artistic development); the role of context in human development (e.g., see chapters on artistic development, gender development, atypical cognitive development, cognitive development and culture, and media and cognitive development); the power and pervasiveness of inferential or logical processes (e.g., see chapters on reasoning, conceptual development, memory, temporal cognition, mathematical reasoning, and scientific thinking); connections between cognition and emotion (e.g., see chapters on gender, executive function, and social understanding); and the importance of diversity, both in individuals' own characteristics and in the cultural contexts that surround them (e.g., see chapters on artistic development, culture, scientific thinking, and atypical development). The importance of the human body, whether approached from the perspective of neuroscience or embodiment, does not end with the first chapter on the brain and cognitive development, but rather is threaded throughout discussions of virtually all the chapters in the volume.

In short, then, while focusing on the richness and importance of their assigned topics, authors nevertheless reflect a relational perspective in conceptualizing the role of their focal cognitive-developmental process within an integrated developmental system.

If one begins from a relational systems approach to developmental science, one of the greatest editorial challenges is rooted in the linear nature of books. Pages necessarily follow one another, and it is far too easy for readers to infer that what comes first is meant to be thought of as foundational, and that the order of the chapters that follow is meant to convey a message about the conceptual layering of topics such that each builds, in turn, on the preceding more-fundamental one. As editors, we thus begin by explicitly rejecting these as intended messages. In our attempt to find a way to avoid this implication we considered multiple possible chapter sequences. In the end, though, we simply selected one, recognizing that our commitment to a relational perspective meant that there could, in fact, be no single best order. There are simply too many simultaneous and reciprocal connections among topics and processes. Fortunately, the authors have avoided presenting their substantive topics as if they were isolated, materialist, independent causal explanations of developmental outcomes. In the remainder of this introduction to Volume 2, we briefly highlight the focus of each chapter. Of course, a few lines of text cannot begin to do justice to the depth of these contributions and thus they are intended only to whet readers' appetites rather than to substitute for careful readings of the chapters themselves.

In the first chapter, Stiles, Brown, Haist, and Jernigan examine current knowledge about the links between the brain and cognitive development. They point out that as knowledge about brain development has increased, models of brain development have changed. Whereas several decades ago the dominant belief was that brain development is innately determined, current models hold that brain development proceeds as a result of the complex and dynamic interplay of molecular, cellular, and environmental systems. Stiles et al. describe the different imaging technologies used to study the brain and its development, appraising the specific strengths and weaknesses in terms of the informational detail each offers. They next summarize basics of pre- and postnatal brain development. The section on *Brain and Cognitive Development in the Postnatal Period* constitutes the heart of the chapter. Here Stiles and colleagues examine the relations between brain development and cognitive development in three domains: visuospatial processing, cognitive control, and language. The authors synthesize the data in a neurocognitive model of brain-behavior relations in a way that captures the dynamic changes in brain and behavioral systems, aligning theory and data from developmental neurobiology and developmental neuropsychology. The core idea of this model is that neurobehavioral development involves a dynamic series of interactions between biological and environmental factors. The chapter ends with a series of reflections on themes, trends, and future directions that emerge from the reviewed work.

In the next chapter, Johnson and Hannon discuss perceptual development. They emphasize that infants' perceptual systems are the primary means for acquiring and interpreting knowledge about events, objects, and people in the world around them. The chapter begins with a discussion of theories of perceptual development and its consequences for children's cognitive and social development. The authors then discuss neural foundations of perception and the emergence and development of sensory systems before and after birth, followed by detailed sections on audition, vision, and intermodal perception. Throughout, they focus on questions of how the developing child extracts meaningful information from the sensory array—that is, how the observer detects, synthesizes, and interprets sensory input so as to yield perceptions of structured events and objects—and how effects of experience on perceptual development interact with developmental timing and what had already been acquired earlier. They focus also on developmental processes—growth, experience, and learning—and examine as well the malleability, or plasticity, of perceptual systems during development. The chapter concludes with a discussion of how different theoretical views may be reconciled in light of the fact that the child is developing in a wider context.

In the chapter on motor development, Adolph and Robinson suggest that the study of motor development provides an opportunity to integrate developmental domains that are typically studied in isolation. This substantive domain is particularly conducive to an integrative framing because motor development is a physical (embodied) phenomenon that occurs through the child's activities within particular physical environments, is intertwined with social interactions, and is affected by the larger sociocultural context. Adolph and Robinson examine motor development through the lens of 10 general developmental issues: (1) the function of incidental activity and its consequences for motor development; (2) the relation between similar behavior patterns that are displayed at different ages; (3) the role of intraindividual variability in motor development; (4) the way in which the passage of time contributes to developmental change; (5) the challenge that the ever-changing body poses for adaptation and developmental diversity; (6) the active contribution of children to their motor development; (7) the importance of prospective control for

motor behavior; (8) the role of perceiving and generalizing affordances for action in choosing the appropriate course of action; (9) the ways in which the social and cultural context affects motor development; and (10) the influence of motor development on perceptual, cognitive, and social development. Reflecting the fact that motor development is a biopsychosocial (and cultural) phenomenon, the issues are loosely organized into framing sections on embodied movement, embedded action, and enculturated interaction.

Ristic and Enns begin their chapter on attentional development by arguing that the field has undergone a seismic shift over the past decade with respect to first, the content of the empirical data being collected, and second, the theoretical ideas used to understand these data. They begin their description of this paradigm shift by first examining research during the latter half of the 20th century. Specifically, they argue that work at this time was dominated by the information-processing framework, which views attention as a localizable, domain-general, and situation-invariant cognitive faculty for which the primary role is filtering sensory information in the service of task goals. However, more recently, researchers have begun to study how individual, emotional, and social aspects of life influence everyday attentional behavior. Mounting evidence from those studies revealed that the classic information-processing framework could not provide a complete account of attentional development. Thus, at present, attention is viewed as a concept that cannot be isolated from social and emotional aspects of development. With regard to future directions, they outline a dynamic view of attention in which attention is conceptualized as a cognitive facility, integrating the demands of "cool" cognition (i.e., information processing capacities) with "hot" functions that span temperament, emotion, social communication, individual histories, and cultural context. The authors note that if this trend continues, attentional development in the next decade will be studied as the outcome of complex interactions among an individual's biology, life history, and social environment.

In the following chapter on memory development, Howe begins with a brief review of 20th-century views about memory development and then turns to three issues that have been attracting attention in the early 21st century. The first moves the theoretical focus away from questions about the structure of memory and its development and towards questions about the adaptive function of memory. Research shows that at least some of the functional attributes of memory include extracting meaning, binding information into regular patterns, and using these patterns

to predict future outcomes. The second issue concerns how these adaptive memory systems develop. To address this issue, Howe reviews recent research examining correlated changes in neurobiological and cognitive functioning. The final question he raises concerns whether humans share adaptive memory development with other animals, which he addresses by reviewing the comparative literature on memory development. Howe argues for the adaptive view of memory, which holds that memory's function is not simply to remember the past, but also to understand the present and to anticipate the future.

Callaghan and Corbit focus their chapter on symbolic representations. They view these as communicative behaviors that set humans apart from other species, and that bind people together in communities and other social groups. More specifically, they focus on the developmental use of external symbols to communicate with others. They begin the chapter by considering the varieties of definitions, theoretical approaches, and recurring themes that have emerged from classic and contemporary work. They then use dominant themes from contemporary work to guide their review of the empirical findings from studies of language (including gesture), pretense, and material artifacts (including scale models, pictures, video, and maps). They argue that comparative research and cultural developmental studies provide important ways to deepen understanding of the origin of human symbolic representation, and thus they review such studies in their chapter. They end by discussing challenges faced by researchers who would like to move beyond offering insightful descriptions of symbolic development to providing process accounts of symbolic development.

In the next chapter on language development, MacWhinney observes that the modern study of children's language is influenced by two contrasting perspectives. The first, the theory of Universal Grammar, emphasizes the role of innate abilities in a core language module. The second, Emergentism, instead views language learning as the result of processes of variation, competition, and generalization that operate across a diverse set of space-time scales ranging from online processing to long-term patterns of social and genetic consolidation. MacWhinney reviews language development on seven levels of emergent structure: articulatory phonology, auditory phonology, lexicon, morphology, syntax, mental models, and conversation, with the analysis for each addressing the role of input language structure, neural processes, and social mechanisms. On each level, MacWhinney articulates ways in which the initial learning of specific items gives rise to

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subsequent pattern extraction and generalization and then examines the neuronal basis of language control in terms of structures and methods that allow highly interactive online processing among the seven components. This model provides developmental science with ways of understanding both developmental language disorders and the learning of multiple languages at different stages in development.

Goldin-Meadow addresses the topic of gesture and cognitive development, arguing that one important feature of gesture is that it has the potential to reveal information about how speakers think, information that may not be evident in their words. A central claim of the chapter is that gesture not only provides information that might not otherwise be revealed about the speaker's state of mind, it also plays a central role in the development of communication and cognition. The chapter begins by discussing the relation between gesture and other nonverbal behaviors. The next sections describe the development of gesture in children who acquire language following the typical course, as well as in children whose course is atypical. These sections demonstrate that gesture is instrumental in language acquisition and that it can take on many different forms and functions. The next section shows that gesture continues to play a role in promoting skill learning even after language is developed, and provides a window into the learner's thoughts. The final sections examine the mechanisms that underlie gesturing and the functions of gesturing.

Carpendale and Lewis discuss the development of social understanding, emphasizing that understanding others is an essential aspect of being human. They review research and theory on the development of a range of skills constituting social understanding, beginning in infancy with gaze-following and gestures such as pointing. Given the importance attributed to false belief understanding in preschoolers, they review accounts of this development and criticisms of these accounts. Likewise, they discuss debates about claims of infants' understanding of false beliefs—claims that raise questions about the nature and origins of social awareness. Carpendale and Lewis also discuss later-developing social skills that are still relatively neglected in the literature as well as contributions of neuroscience to the study of social cognitive development. Noting that there are many links between social cognition and children's social relations, the authors explicitly focus on the key role of language in social cognitive development. They also review ways in which social understanding may influence social conduct, issues of trust and deception, and cooperation and moral development. Throughout the

chapter, the authors highlight ways that research traditions are influenced by worldviews or preconceptions about the nature of mind, meaning, and knowledge, and emphasize the interconnections between social understanding and all other aspects of human life.

To begin her chapter on play, Lillard notes that children spend a significant amount of time engaged in play, and illustrates the broad range of play activities. Despite its pervasiveness, play's role in development is not well understood. After discussing and evaluating the various definitions of play that have been used, Lillard reviews major theories of play, and then overviews the developmental course of various types of play (sensorimotor play, physical play, rough and tumble play, exploratory play, construction play, symbolic play). Lillard next covers some contemporary debates in play research that concern the relation between pretend play and theory of mind and symbolic understanding, children's ability to discriminate between fantasy and reality, the role of pretend play in promoting development, and the ways that children are initiated into the practice of pretend play. In the next section she reviews gender and cultural differences in play, and discusses play in atypically developing children. She closes by highlighting particularly important issues that remain in need of further research.

For his chapter on conceptual development, Sloutsky guides his review by using the following five principles: (1) There are diverse conceptual behaviors that range from simple and universal to complex and uniquely human; (2) simpler forms are more universal and exhibit earlier onset in the course of individual development; more complex forms are later appearing and depend on other aspects of cognitive development, including the development of attention and memory; (3) the development of more complex forms of conceptual behavior is more likely to be affected by language and instruction than is the development of simpler forms; (4) the age at which conceptual categories are acquired is affected by the structure of the input; and (5) conceptual development progresses from less-structured representations to more-structured representations.

Using these principles as a framework, Sloutsky reviews the history of the study of concepts and of theoretical approaches to concepts. Next, he discusses the multiplicity of conceptual behavior and its biological foundations. In the remainder of the chapter he addresses conceptual development in human infancy, the role of language in conceptual development, acquisition of semantic knowledge and of conceptual hierarchies, and the role of concepts

in reasoning. In the concluding section, Sloutsky revisits the principles of conceptual development outlined at the beginning of the chapter.

Ricco's chapter on the development of reasoning begins with a review of the course of development for deductive and inductive forms of reasoning across childhood and adolescence, followed by a critique of key theoretical accounts of that developmental course. The development of deduction is considered primarily with respect to syllogistic and conditional reasoning. Mental-logic, metacognitive, and mental-model accounts of deduction are contrasted and compared and the potential for rapprochement is identified. The development of inductive reasoning is discussed with respect to three primary types of induction—category-based induction, causal induction, and inductive processes in scientific thinking. The discussion of the development of reasoning provided in this chapter is situated within a dual systems or dual process account of cognition. According to this account, human cognition consists of two distinct systems (1 and 2) or types of processing, with the primary basis for the distinction being the engagement of working-memory resources. By adopting this framework, it becomes possible to shed light on the processes that underlie deductive and inductive reasoning and to trace how the development of each type of reasoning is related to changes in these underlying processes. Among the key conclusions of the chapter is that while the development of certain aspects of system 1 processing contributes to age-related changes in performance on reasoning tasks, the most significant changes in both deductive and inductive reasoning result from key developments in system 2 processing.

In the next chapter, on the development of executive function, Müller and Kerns examine theories of and empirical research on executive function. They show that research on executive function has grown dramatically over the last three decades. Even though the term emerged only 40 years ago, the concept of executive function can be traced back to far earlier clinical and empirical research on the frontal lobes. Müller and Kerns review influential theories of executive function, working memory, inhibition, computational modeling, and hierarchical accounts. They next review the development of the prefrontal cortex, which is considered the neural basis of executive function, and summarize research on particular component processes of executive function. In the next sections they address, in turn, the methodological challenges in research on executive function; sources of the development of executive function, with particular emphasis on the

ways in which social factors and language facilitate its development; and summaries of research of executive function in two other domains of functioning—social understanding and academic achievement. They conclude the chapter with the suggestion that executive function should be studied as a distributed process that develops as a result of the child's embodied interactions within a social context.

McCormack divides her chapter on the development of temporal cognition into two major sections, reflective of two basic ways in which time features in everyday thought and action, and in cognitive-developmental psychology. The first section addresses time as duration (i.e., time as a dimension of stimuli or events). In this section McCormack describes methods that are used to assess the accuracy of processing duration at different ages. She also reviews developmental changes in the accuracy of duration-processing across infancy and childhood, and discusses models and theories proposed to explain its development. The second part of the chapter deals with time as a framework within which events can be located, that is, as a framework that allows one to locate events in the past, present, or future and to recognize the systematic before–after relations inherent in the temporal locations of events. McCormack examines empirical research addressing the origin and development of children's understanding of time as a framework and summarizes the theoretical approaches that have been proposed to explain these developmental progressions.

In the next chapter, which discusses the development of scientific thinking, Lehrer and Schauble introduce three views of science that ground research and education on the development of scientific thinking: science-as-reasoning, science-as-conceptual change, and science-as-practice. They observe that there is now increasing emphasis on science as an integrated set of epistemic practices. For example, new science education standards in the United States highlight the importance of students' participation in scientific practices—communally recognized and supported ways of generating, revising, and critiquing scientific knowledge. Based on reviews of the history, philosophy, and psychology of science, Lehrer and Schauble argue that the defining practice of science is modeling, and that it is useful to conceive of other scientific practices in relation to this foundational one. Accordingly, they trace the ontogeny of representational and material practices of modeling and summarize the development of seven scientific practices (e.g., constructing and interpreting data; developing explanations and arguments) that are

intimately related to modeling. This perspective identifies fruitful areas for additional research that can inform ways of describing and supporting the development of scientific thinking.

In their chapter on the development of children's mathematical reasoning, Nunes and Bryant note that psychological research on this topic has focused either on children's understanding of quantities or on their knowledge of number. A synthesis of these two foci can be achieved by acknowledging that numbers have two meanings: a representational meaning, defined by their use as signs for quantities or relations between quantities, and an analytical meaning, defined by the conventions in the number system. In the introduction, the authors explicate these two meanings of numbers and explore the connections between them. In subsequent sections they analyze how children's mathematical knowledge develops in terms of an increasing ability to use different numerical representations (e.g., from the use of fingers to represent quantities to the use of conventional signs), a growing understanding of invariant relations between quantities (e.g., realizing that, given a fixed number of cookies, the more people sharing the cookies the fewer cookies each receives), and an increasing awareness of the relevance of specific concepts to different situations (e.g., understanding the relevance of division to solving problems connected to multiplication). Throughout the chapter, the connection between the nature of quantities and their numerical representations is explored. In the final section, Nunes and Bryant focus on the use of numbers to quantify space and relations between spatial dimensions, arguing that understanding relations among different dimensions in space (e.g., length and width) is crucial to quantifying space. They end their chapter with a brief discussion of directions for future research.

In the chapter on literacy development, Lonigan argues that the acquisition of literacy skills (i.e., reading and writing) is the most important educational attainment because it constitutes the foundation on which the acquisition of knowledge in multiple domains is built in school and throughout life. Lonigan begins by defining reading, and then details the skills and processes required for successful reading, including decoding skills and linguistic comprehension skills. He next reviews developmental changes in and influences on reading skills. In the next section he describes emergent literacy skills, the developmental precursors to conventional forms of reading and writing, and the types of reading problems children experience

and the methods used to identify reading impairments. He concludes the chapter with a discussion of historical perspectives, current approaches, and empirical evidence concerning reading instruction.

In the next chapter, Leaper presents contemporary theory and research on children's gender development from a social-cognitive perspective. First, he examines contemporary social-cognitive theories and conceptual models pertinent to the study of gender development. These include cognitive-developmental, information-processing, intergroup, and motivational approaches. Second, he summarizes the development of children's gender cognitions and examines their ramifications for a variety of areas, including gender stereotyping, attitudes, prejudice, self-concepts, and gender as a social identity. Third, he considers possible causes and consequences of gender-typed play. In the fourth section, Leaper reviews research on gender similarities and differences in children's competencies in academic achievement (including verbal, spatial, mathematical, science, and artistic domains), athletic achievement, interpersonal competence, and intrapersonal competence, among others. Fifth, he highlights some of the individual and social-relational influences on gender-related variations in performance and achievement. Leaper closes the chapter by advocating for future work that offers more theory-bridging and replications of prior empirical research.

Gauvain and Perez discuss cognitive development and culture, noting that cognitive development always occurs in cultural context. Accordingly, they describe the complex and multifaceted connections between culture and cognitive development and how these unfold across child development. Sociocultural theory, which is unique in its focus on cognitive development in relation to culture, provides the conceptual foundation of the chapter. Following discussion of the historical foundations of contemporary research on culture and cognitive development, the authors describe how culture has been studied in psychological research, the importance of a developmental approach for understanding culture-cognition connections, and some considerations in studying the sociocultural basis of cognitive development. They discuss capacities that human beings have that underlie participation in culture, reviewing current understanding of relevant neural functioning and brain development, and the social-cognitive capabilities through which children learn from others. To illustrate the defining role of culture in human cognition, the authors describe empirical research in four areas of cognitive development: memory, executive functions, spatial

cognition, and problem solving. They offer general conclusions on theory and research about culture and cognitive development and suggestions for future research.

The next chapter focuses on artistic development in both the visual arts and music. The authors, Milbrath, McPherson, and Osborne, begin by presenting archaeological evidence that indicates that modern humans have been making music, portable art, and cave-wall paintings as far back as 35,000 years ago. Drawing and song are also the first two art forms in which young children take an active part. The authors review what is known about children's artistic development in the visual arts and music, focusing on the historical and theoretical grounding of artistic development, the psychological and physical attributes of the developing child that play a role in children's artistry, and the sociocultural contexts in which child art and development occur. In each of the two major sections—one on the visual arts and the second on music—the authors begin by describing the known inceptions of the art form and the historical and contemporary approaches to children's development in them, and then review research on children's developmental achievements and competencies in the domain. They also present studies of atypically developing children and inquiries into children's understanding and aesthetic experience of the art form. They conclude each major section with a discussion of cultural differences in artistic practice and the influences these different practices have on children's artistic outcomes.

Anderson and Kirkorian discuss media and cognitive development, noting that by the time children reach adulthood, they will have spent more time using electronic screen media than in formal school settings. Thus screen media have enormous potential to influence cognitive development, for good or ill. The authors describe popular concerns about media impact, using *Sesame Street* as a case study. They provide current estimates of children's use of media and discuss data on engagement in multitasking behavior. They review empirical research on children's cognition during media use and then outline potential direct and indirect pathways of longer-term media influences on cognitive development, focusing on effects on cognitive skills and academic achievement. The authors conclude the chapter with a critical analysis of extant research and identify areas that are especially in need of further study.

In the final chapter of the volume, Pennington discusses atypical cognitive development. In addition to reviewing the history of earlier research, he reviews current issues and findings in the study of atypical cognitive development organized around the following five key questions: (1) How general versus specific are mechanisms of cognitive development and individual differences in cognition? (2) What is the etiology of cognitive development and of individual cognitive differences? (3) How do these etiologies act on structural and functional brain development? (4) How malleable are developmental and individual cognitive outcomes? (5) Does age moderate the answers to these questions, and if so, how? A key issue that runs through the chapter is the role of nature versus nurture in the development of physical and psychological forms. Pennington argues that the resolution to this issue is found in the principles of probabilistic epigenesis, constructivism, and complex systems that self-organize to yield emergent properties. The chapter uses a multilevel, interdisciplinary approach to understanding atypical cognitive development. In addition to behavioral and cognitive development, these levels include consideration of etiology (genetic and environmental influences and their interplay) and brain mechanisms. Specific examples of atypical cognitive development (e.g., amblyopia, orphanage rearing, genetic syndromes) are described to illustrate these levels of analysis and to address key issues. The chapter concludes with a summary of current answers to the five key questions and implications for future research.

Collectively, the contributions to this volume offer convincing evidence that the complexity of cognitive development cannot be captured adequately by studying particular aspects of cognition in isolation as if they were encapsulated modules unfolding along a genetically predetermined timetable. Different cognitive processes are intrinsically linked to one another and to emotional processes. Thus, advances in the domain of cognitive development are of interest not only to those who are fascinated with cognitive development per se, but also to those whose major interests lie elsewhere. Connections among different aspects of cognitive development, in turn, must be examined in the context of biological, physical, social, and cultural contexts. Even though taking such complexity into account may at first appear daunting, in the long run, only relational approaches can produce a satisfactory and useful understanding of cognitive development.

Authors who contributed to this volume have demonstrated important continuities with work from earlier eras while simultaneously offering exciting new methodologies and findings that escort us into the future. As captured in the concluding sections of each chapter, the field has

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made important strides in understanding key domains of cognitive development. Theoretical and methodological advances should allow developmental scientists to become increasingly adept in describing, explaining, and optimizing developmental outcomes in the years to come. We invite readers to taste or devour the chapters that follow. They offer much food for thought, not only about individual topics traditionally studied under the umbrella of cognitive development, but also about broader ideas that must be considered as developmental science continues to grapple with theoretical, empirical, and applied pursuits.