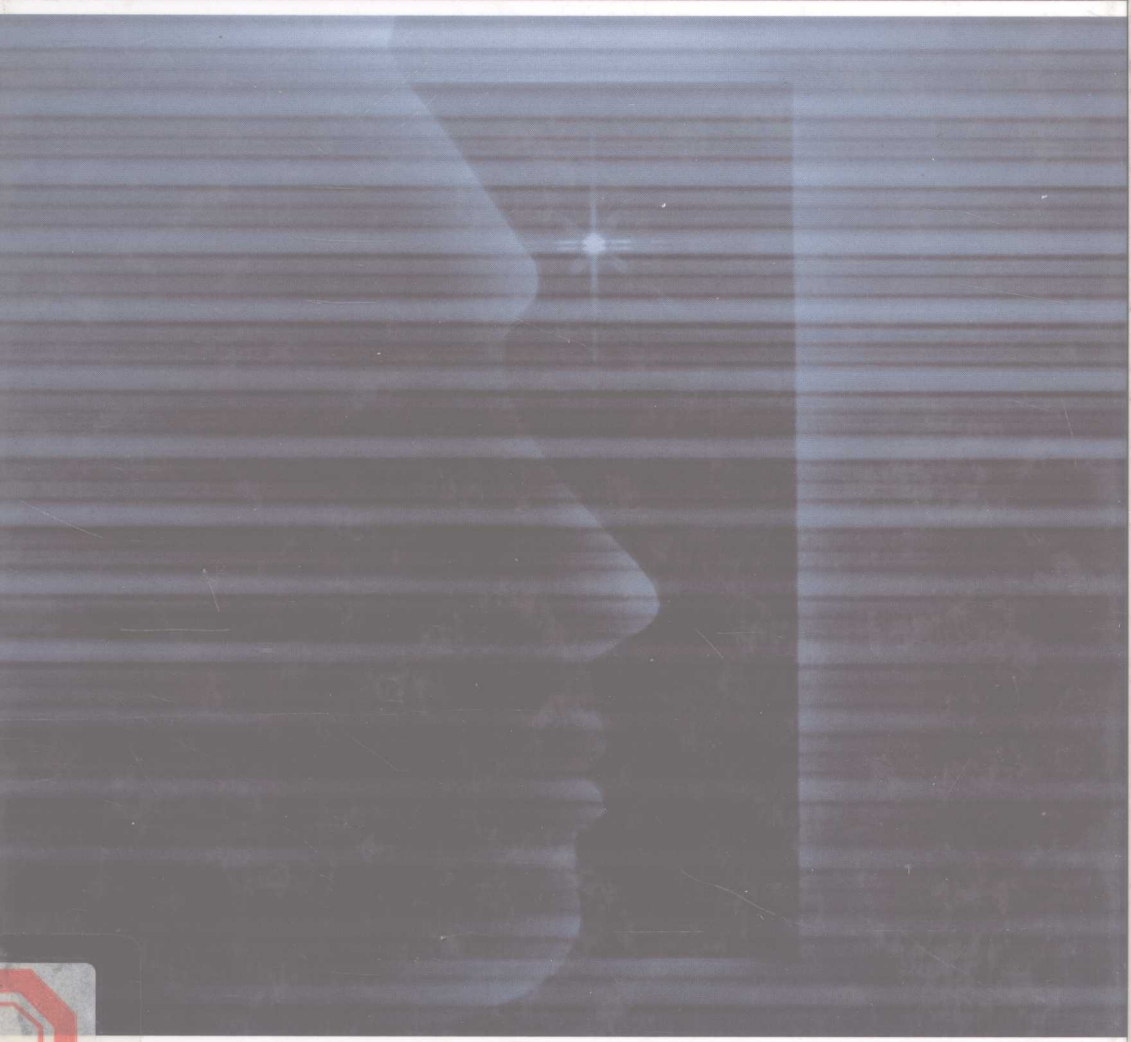
EARLY EXPERIENCE, THE BRAIN, AND CONSCIOUSNESS

An Historical and Interdisciplinary Synthesis



Thomas C. Dalton • Victor W. Bergenn

EARLY EXPERIENCE, THE BRAIN, AND CONSCIOUSNESS

An Historical and Interdisciplinary Synthesis

Thomas C. Dalton • Victor W. Bergenn

LEA Lawrence Erlbaum Associates
Taylor & Francis Group
New York London

Lawrence Erlbaum Associates
Taylor & Francis Group
270 Madison Avenue
New York, NY 10016

Lawrence Erlbaum Associates
Taylor & Francis Group
2 Park Square
Milton Park, Abingdon
Oxon OX14 4RN

Lawrence Erlbaum Associates is an imprint of Taylor & Francis Group, an Informa business

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-13: 978-0-8058-4085-8 (Softcover) 978-0-8058-4084-1 (Hardcover)

Library of Congress Cataloging-in-Publication Data

Dalton, Thomas Carlyle.
Early experience, the brain, and consciousness : an historical and interdisciplinary synthesis / Thomas C. Dalton, Victor W. Bergenn.
p. cm.
Includes bibliographical references and index.
ISBN 0-8058-4084-2 (cloth : alk. paper) -- ISBN 0-8058-4085-0 (pbk. : alk. paper)
1. Developmental psychology. 2. Experience. I. Bergenn, Victor W. II. Title.

BF719.6.D35 2007
155.4'13--dc22 2006027106

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the LEA Web site at
http://www.erlbaum.com

Preface

There is a growing interest and demand among developmental scientists and practitioners across disciplines to put the burgeoning knowledge of the brain, mind, and behavior in historical and contemporary contexts. This book shows how different lines of inquiry intersect to afford a more coherent and comprehensive understanding of the relationship between brain development and experience. Historically significant events that contributed to the scientific study of the brain and consciousness are described, and an interdisciplinary body of literature is synthesized regarding what we know about the relationship between early experience and the brain. Recent theories about the relationship between motor and perceptual development are critically assessed in light of neuroscientific evidence. An alternative theory is proposed that the acquisition of behavioral, cognitive, and linguistic functions during early childhood is governed by mechanisms of selection, variation, complexity, and integration characteristic of emergent biological systems.

The neuroscientific revolution has forced developmental scientists to reexamine assumptions about the causes of human behavior. The persistent tendency among psychologists to understand the phenomena of development in terms of nature versus nurture is a dichotomy that has outlived its usefulness as a theoretical construct. Over the last decade, there have been enormous advances in the theories and methods employed by scientists to understand how genetic and environmental factors interact during the processes of human growth and development. Developmental scientists no longer view development as if it could be neatly partitioned along a continuum in which the earliest events reflect largely genetic influences and the later events are shaped by environment and culture. Instead they see individual growth in terms of a reciprocal interaction of biological, behavioral, and cultural events that occur throughout an individual's lifetime. Together over time, these interactions contribute cumulatively to small but important changes in the human phenotype.

Scientific knowledge about the effects of experience on neural growth and brain function has been limited, until recently, to experimental

behavioral, electrophysiological, and surgical interventions in nonhuman primates and other animals. These animal studies have been enormously useful in generating knowledge about the probable effects of experience in human neurobehavioral development. Although these studies continue to furnish new insights about brain-behavior relationships, newer, noninvasive techniques have significantly enlarged our understanding of how different regions of the human brain are functionally integrated during development. Functional magnetic resonance imaging (fMRI) now makes it possible to isolate brain regions that show the largest increase in metabolic activity and trace their interaction in response to stimulation. The authors describe what investigators have learned about the development of motor, perceptual, and cognitive skills by experimentally manipulating these processes. Readers find out why information is processed differently by persons with normal and dysfunctional brains and why individuals learn about and experience their world in contrasting ways.

These and other methods for recording brain activity also suggest that consciousness is a tool that infants acquire early on to integrate multiple sensory and motor experiences, communicate, attain a sense of self, and acquire knowledge of other minds. Neither mind nor consciousness are entities confined to cortical or prefrontal regions, but involve the functional integration of neurobiological and neurobehavioral processes that include the whole brain and involve experiential influences at every phase of development.

We have chosen to focus on attention and memory in this book because these mechanisms of consciousness appear to play a crucial role in the perceptual judgments that infants form and the motor strategies they undertake to learn about and change their world. These mechanisms enable the coupling between sensory inputs and motor actions through a series of developmental events needed to gain perceptual access and control of the meaning and significance of situations encountered through personal experience. Attention and memory are complex functional mechanisms that reflect continuous changes in neural, behavioral, and emotional states. The efficacy of attention and memory can be temporarily or even seriously impaired if the normal interaction between brain regions is impeded by persisting states of behavioral redundancy and/or restricted sensory or emotional variability. Evidence from such episodes is presented in the chapters that follow to explain how small deviations from the expected trajectory of neurobehavioral development can compromise the mechanisms that infants rely on to gain conscious access to their world and control of the consequences of their behavior.

This book also features the discoveries of pioneers and contemporary innovators who have made important contributions to our knowledge of the relationship between brain growth and early development. This seminal knowledge has come from several fields, including philosophy, embryology, ethology, neurology, neurobiology, cognitive neuroscience, developmental psychology, and the nascent field of mind and consciousness studies. Experimental research with animals and humans, including individuals with normal and damaged or dysfunctional brains, indicates that the brain is remarkably plastic and resilient, and that the neural mechanisms supporting attention and memory play equally important roles in learning in both humans and animals.

The beliefs that developmental outcomes are strongly influenced by the timing of stimulation and its duration remain controversial. The contention has been that there are critical periods in early development during which sensorimotor functions must be acquired that, if delayed, result in permanent impairment. Nevertheless, researchers are increasingly divided about the effects of early experience in later childhood. Researchers who track the influence of developmental events over time are finding more complex and variable patterns that reduce the probability that adult personality, behavioral traits, or cognitive abilities can be accurately predicted by any one factor or influence occurring in early development. Moreover, children with learning disorders, such as attention deficits or dyslexia, possess compensatory, brain-based strategies to mitigate these deficits. Alternative sites for neural processing provide windows of opportunity for children and adults to acquire new skills long after the earliest formative years. The brain's plasticity, interactivity, and structural redundancy enable individuals to attain sensorimotor integration in different ways that support diverse but comparable modes of learning.

Developmental psychologists who do experimental or clinical work with infants and young children should find this book useful. In addition, this book will be of considerable interest to neurobiologists, cognitive neuroscientists, pediatricians, educators, and parents with infants and young children. We believe that developmental scientists will find this volume appealing because it furnishes to their students the conceptual tools to critically assess and put into historical context scientific knowledge about experience and the brain. Students will become familiar with the latest theories about how development has evolved and will better understand how the sequence of early development is susceptible to variations introduced by the contingencies of experience. They will also learn about the biological processes that contribute to the plasticity of the human brain,

and they will be better able to assess the competing arguments about how the brain is organized and becomes integrated through experience.

Chapter 1 addresses several issues regarding the brain and mind from historical and neuroscientific perspectives. Philosophical speculation about the mind and soul dominated the discourse about human nature for centuries until scientists sought more knowledge about the biological foundations of human thought and behavior. The American pragmatists William James and John Dewey decisively contributed to the ascendancy of psychological science by showing how the brain generates thoughts whose value does not require certitude that they represent some indisputable truth about nature or our perceptions of the world. Instead, they believed that the brain and mind evolved to furnish new capabilities to respond effectively to the uncertainties and contingencies of nature that depend less on certain knowledge than on the accumulation of experience.

Developmental psychologists are generally divided on how best to characterize what infants know and how they use their brains to gain knowledge about their world. That is why developmental scientists have increasingly adopted neuroscientific techniques, described in Chapter 1, to better understand the relationship between brain development and the acquisition of motor and cognitive functions. Neurobiologist Gerald Edelman advances a useful theory that brain development can be best explained by processes of Darwinian selection that exploit the enormous diversity of alternative patterns of interaction to satisfy the functional needs of the organism. The uniquely important argument Edelman makes is that the units of selection at different levels of complexity are not single entities, such as molecules, cells, reflexes, or percepts, but dynamic, large-scale patterns of interactions among groups of neurons, which support diverse global mappings. Perception is not limited to isolated objects of sensory input, but is constituted by conscious actions that engage the entire senorimotor apparatus of the organism. Accordingly, Edelman takes the position that knowledge is not representational, but relational and pluralistic—a theory of knowledge that is grounded in the pragmatism of James and Dewey.

Attempts have been rare among developmental scientists to advance general theories of neuropsychological development that address from interdisciplinary standpoints how biological structures, mental processes, and social conduct are interrelated. A general theory should account for phenomena that occur at different levels of complexity and explain how they are combined to produce coherent and integrated behavior. Chapter 2 critically examines the prevailing hierarchical conception of brain function and

proposes an alternative, nonhierarchical conception to better reflect the interrelated physical and psychological aspects of emergent processes. We focus on the problem of hierarchy and indicate how the interdependence among physical, physiological, and psychological attributes of sentient organisms contributes to the emergence of consciousness.

To be certain the explanatory gap between neuronal processes and psychological functions remains considerable. We do not pretend to close this gap in understanding how physical and mental events are interrelated. Nevertheless, we believe that the elusive phenomenal dimension of conscious states can be better understood by examining how human sentient capacities and motor skills set the boundaries in which sensory input is converted into gestures and behaviors that possess meaning and significance. We contend that the threshold of consciousness is reached only when there is multimodal stimulation sufficient to sustain intersensory perception. Multimodal stimulation is essential because it furnishes organisms a way to make discriminations involving judgments about equivalence. By equivalence, we do not simply mean the " the same as." Equivalence also entails the sense that one thing may be substituted for another to reach the same judgment or attain the same outcome differently. Unisensory organisms cannot detect and process complex signals and thus do not have the ability to make such comparative judgments. Only organisms that possess a multisensory apparatus are fully capable of discriminating among and integrating multiple sensory inputs into scenes that involve a conscious experience.

Only within the last two decades has it been possible to observe prenatal development in real time. Ultrasound and vibroacoustic stimulation are providing a more detailed picture of how the prenatal brain grows and acquires sensory access, and how fetal behavior becomes differentiated. Chapter 3 examines how prenatal sensation and movement become organized into coherent neurobehavioral states by late term. Chapter 4 describes the multimodal processes through which infants attain sensorimotor integration after birth. These chapters reveal the underlying continuity in the processes through which complex functions become integrated from late term through the first year.

Drawing on evidence from animal stimulation studies, Chapter 5 scrutinizes the conventional theory that motor functionality is attained only after a rapid process of synaptic proliferation and elimination. Instead a more heterogeneous process comes into play involving the recombination of sensory inputs and the strategic deployment of attention

and memory that depends less on the absolute numbers of synapses than on their scope and pattern of interaction. Chapter 6 moves this line of inquiry forward to explain why some children derive larger cognitive benefits than other children who undergo similar experiences. The challenges that children with brain-based disorders face in learning from experience are traced to limitations of conscious awareness that appear in the earliest stages of sensory processing, which compromise attention and memory.

Chapter 7 describes how the acquisition of language and recognition of intentional behavior are rooted in motor development. We contend that language use involves the same principles of selection on variation as those entailed in the construction of motor repertoires and gestures. Prelinguistic children possess only a limited understanding of intentional behavior. Only when children use language with gesture to distinguish between desires and beliefs, and when they recognize that other people possess knowledge and beliefs different than their own, do they fully grasp intentional behavior. This chapter critically examines attempts to explain the neural processes underlying language and intentionality, and it advances an alternative theory based on the recursive nature of consciousness.

Chapter 8 addresses the crucial problem of whether attempts to modify the human behavioral phenotype through alterations in individual development and strategies of learning have value in terms of enhancing human powers or threaten to compromise or weaken them. This requires an assessment of the possibilities and limits to genetic and experientially induced changes in the phenotype. Preschool programs, such as Head Start, recognize that learning is affected by diverse biological and experiential factors. That is why attempts to implement educational strategies to attain uniform outcomes run the risk of ignoring significant differences among children in how their brains develop and how they use them to learn. Parents and children need to be better informed about brain development and how neural processes affect learning. This book concludes by proposing interdisciplinary, multisector strategies to increase the use of knowledge of individual neurodevelopmental processes to improve educational outcomes.

ACKNOWLEDGMENTS

The first author would like to express his appreciation to Gerald Edelman, Einar Gall, and several fellows at the Neurosciences Institute in San Diego for their encouragement and stimulating discussions as a visiting fellow since 1999. Special thanks also go to Gilbert Gottlieb, who supported this project from its inception. We also thank Bill Weber for his early support in getting us signed with Lawrence Erlbaum Associates, and for Lori Handelman's patience as our editor.

Contents

1

Historical and Contemporary Perspectives in Developmental Neuroscience

Scientific advances in understanding how the brain develops and functions in relation to behavior were made possible by four related transformations that provided new ways to conceptualize the relationships among brain and mind and knowledge and perception. The first involved a transition from a spiritual to a scientific conception of mind. René Descartes' doctrine that the brain and mind are different entities supported a dualistic distinction between the physical and mental that discouraged scientists from trying to understand how neural and psychological processes are related. Only when brain scientists ignored religious doctrine and viewed the mind as physically embodied in the brain did they make progress in identifying the neural determinants of perception and memory.

The second transformation involved a philosophical change in how knowledge is understood in relation to experience, perception, and learning. The American pragmatists William James and John Dewey enabled philosophers to conceive of knowledge about the world in relational rather than representational terms. This has freed philosophers from equating meaning or physical identity with truth by showing that all knowledge is experientially variable and contextual. This epistemological reconstruction of learning and knowledge is slowly changing scientists' theories of how neural processes affect the relationship between perception and behavior.

The third transformation involved a shift from a Newtonian to Maxwellian conception of physical phenomena. A universe governed by the pendular swing between the forces of attraction and repulsion was replaced by a dynamic conception involving less predictable self-organizing interactions between energy and matter. Through his collaboration with infant experimentalist Myrtle McGraw, Dewey outlined how the brain and consciousness could be understood in naturalistic terms, whereby Newtonian physics is replaced with a Maxwellian conception of mind as matter in motion. This shifted the emphasis from a genetically deterministic conception of human development to one stressing the contingencies of growth and experiential variability.

Finally, the fourth transformation showed how a Darwinian conception of natural selection could be used to explain how brain development occurs through selection on variations that involve the behavior of whole populations of neurons. Darwin contributed fundamentally to our knowledge of how the principles of natural selection explain human evolution, but knowledge of how they apply to neurobiological development remained unclear and controversial. Embryologists attempted to discover the genetic principles that accounted for continuity of life forms across species, but little was known about the underlying mechanisms. Neuropsychologist Hebb (1949) acknowledged the role of selection in the formation of cell assemblies through use-dependent reinforcement of synaptic activity. Not until the late 20th century, however, was neuroscientist Edelman (1987) able to show how selection works at multiple levels of biological complexity by enabling the brain to select behavioral and perceptual strategies to respond to the contingencies of experience. The complete implications of these four breakthroughs in understanding the relation between brain growth and behavioral development have yet to be fully appreciated by developmental psychologists.

This chapter is intended to introduce readers to the developmental phenomena discussed in this book, and to provide them with the conceptual tools to better understand the different roles of genes and experience in the evolution and development of the brain, cognition, and behavior. There is little consensus about how genetic and experiential factors interact in the brain through developmental sequences that mold and reshape the human behavioral phenotype. The relationship between growth and development is construed in the broadest theoretical terms to enable a firmer grasp of the underlying complexities involved in these interactions.

This chapter focuses on several questions that are pertinent to framing a general theory of neuropsychological development: 1) How do the forces

of nature affect human sentience and our self-perceptions? 2) How does selection act on variability to produce stable but adaptive neuronal structures? 3) How does the brain provide knowledge of the world and support memory and judgments based on value? 4) Is knowledge about the world representational or relational? Historically, philosophers were preoccupied with the epistemological dilemma posed by the last question long before brain science elevated the importance of these other issues for understanding the human mind. Only in the last few decades have fundamental advances occurred in brain science, providing knowledge about perception, attention, and memory and their relationship to behavioral development. Special techniques are described later in this chapter, by which researchers identify the neural and electrophysiological mechanisms involved and the models they employ to simulate the conditions involved when learning occurs.

KNOWLEDGE, PERCEPTION, AND MOTOR CONTROL: REPRESENTATIONAL OR RELATIONAL?

Neuroscientists and developmental psychologists are challenged to understand the relationship between perception and knowledge without collapsing the distinction between them. Individuals differ fundamentally in how and what they perceive and the modes of inference and reasoning they use to extract meaning and gain understanding. Moreover, perception happens quickly, with little awareness of the innumerable sensory inputs that make it a coherent experience. Being aware of something is not the same thing as knowing what it is or knowing how to reproduce it. Knowledge is not simple recognition, but understanding the conditions that change the behavior of things or alter the course of familiar events. The history of the philosophical debate about knowledge gained traction when discussion about mind was grounded in human experience and merged with the scientific study of the brain.

Dualism and Its Repercussions

Philosophers since antiquity have struggled to understand the perceptual, behavioral, and experiential processes that humans use to acquire knowledge of their world that is reliable and valid. The Greek philosopher Plato proposed an analogy of a cave to argue that human perception was indirect and limited to the light and shadows reflected off the walls. Truth was instead embodied in preexisting concepts that represented the form of an idea in its perfection. For many centuries, religion also has furnished

an answer to the ultimate question of validity by positing the origin of truth in a deity. But as science advanced, philosophers struggled to reconcile their philosophical theories about the relationship among mind, consciousness, and the human soul and the emerging knowledge about the brain that sometimes strained credulity.

René Descartes' attempt to advance a conception of knowledge that was consistent with theological views of the mind and soul in the 17th century illustrates how this prevented a clear understanding of the role of the brain in the production of knowledge. For nearly 1,500 years preceding Descartes' work, the prevailing view was that the seat of knowledge resided in the ventricular spaces or the empty sinus cavities of the brain (Gross, 1998). This was consistent with church doctrine that the mind and soul were not material substances, and thus could not be corrupted by being located apart from the gray and white matter. Descartes supported this dualism by cleverly proposing that human sensory images are processed through *hollow* optic nerves connecting the eyes to the pineal gland, where the information from each eye is fused into a single upright image. Descartes believed that some ideas, such as unity or God, are innate because their conceptualization requires experientially transcendent rational thought, whereas other, more worldly ideas are shaped by experience (Wade, 1995).

Immanuel Kant completely sidestepped the brain science and soul-based theology of his day by holding that mind consisted of transcendent, *a priori* categories that are not directly accessible to the senses, such as space, time, causality, and motion. This categorical knowledge furnished the ultimate standards of truth and validity. The British empiricists took another tack by according a larger role to human experience. John Locke rejected Cartesian nativism and Kantian transcendentalism, contending instead that human perception and knowledge come from experience. Locke was strongly influenced by Thomas Willis, a 17th-century British neuroanatomist who repudiated ventricular theory in favor of a cerebral, cortically based system of memory and cognition (Finger, 2000; Martensen, 2004). Locke believed that the mind is a blank slate on which ideas are passively inscribed and actively combined through reflection to form complex thoughts. Locke originated the theory that ideas could be associated with one another to enable learning—a theory that led to the formation of the school of "association psychologists" in the 19th century. The behaviorist John Watson revived Locke's conception of mind in the early 20th century by holding that infant brains and behavior are malleable and shaped significantly by environmental influences.

Pragmatism and Relational Knowledge

Nearly two more centuries of the scientific study of the brain ensued before philosophers and psychologists saw a way around dualism to confidently theorize about the relationship between the brain and behavior and perception and knowledge. The American pragmatists James and Dewey played pivotal roles in this epistemological and scientific reconstruction. James and Dewey sought to ground mind and perception in a dynamic view of consciousness that supported a *relational* rather than representational theory of knowledge. James (1981) first likened consciousness to a stream or process that involved volition and a changing focus of attention—a conception that strongly influenced his fellow pragmatist, Dewey. James also argued that events which occur at the fringe or periphery of consciousness influence perception just as pervasively as those occupying the center of vision. Finally, he believed that underlying feelings contribute to perceptual and behavioral differences in conscious emotional states. This is a dynamic and relational theory of knowledge, whereby the concepts we use reflect the different degrees of access we have to our internal states and the amount of control of the surrounding environment.

Dewey (1981) surmounted the methodological dilemmas of mind-body dualism and reductionism that caused many philosophers and psychologists to vacillate between the mental and physical—between equating all psychological processes with cognition and reducing consciousness experience to physiological processes. Dewey also stubbornly resisted the modern trends toward materialism and reductionism in science and logical formalism and epistemological realism in philosophy, which threatened to erase the naturalistic origins of mind. He adopted a psychobiological conception of mind proposed by the "American school" of neurologists led by Clarence L. Herrick, who viewed consciousness as an instrument for motor, cognitive, and emotional integration (Windle, 1979). Dewey took the Darwinian position that the brain evolved in animals to mount more effective functional responses to environmental pressures.

The evolutionary advantage of consciousness is that it enables the organism to discover new values by rendering explicit and in commensurate terms the physical and mental attitudes and desires that influenced past behavior and that will affect the outcome of future events (Dalton, 2002a). As discussed later, Dewey was a naturalist who believed that the brain and mind develop by experiencing, responding to, and mobilizing

the forces of nature. The force of gravity, energy, motion, space, and time are not simply constants of nature that constrain and limit human behavior, but are tools with which humans master locomotion, increase their powers of perception, and, ultimately, overcome their terrestrial and sensorimotor limitations.

Dewey (1981) contended, like James, that consciousness is not a thing, but a process involving uncertainty and the transformation of indeterminate events into ones subject to human control. Beliefs and intentions are not about things that possess intrinsic worth or represent knowledge or truth, but refer to actions performed on things that change their sequence or relationship to one another and that affect their meaning, applicability, and efficacy. The capacity to shift attention between foreground and background is essential to balanced perception and judgment. This feature of consciousness makes mind contextual and dependent on the meaning and significance attributed to a situation in its entirety. Judgment grounded in sensorimotor functions is employed to detect and differentiate among qualitative and quantitative features of situations involving force, movement, duration, contrast, and balance, among other elements that affect sentient and energetic states and behavioral capabilities. Consciousness and judgment work in tandem with attitudes and emotions to enable the determination of whether changes in feelings, beliefs, behavior, intentions, or meanings make a difference that have value in situations that satisfy a need or desire.

Building on James' provocative distinction between the focal point and fringe of consciousness, Dewey described how our perceptions and assessments of situations change as we distance ourselves physically, emotionally, and conceptually (i.e., adopting someone else's perspective, looking at a situation from a different vantage point). These dimensions of perception furnish depth, breadth, volume, and other quantitative and qualitative features of experience that are vital to our judgment. The processes through which perception and action are coupled and decoupled depend, in part, on experiences in early development, whereby reflexive, sensory, and vestibular systems are engaged differently in response to nearby and remote events. Distance or proximity influences the weight or value we place on our perceptions, their urgency, and the time needed to reflect on memory of related events. This process of deliberation is essential to rational judgment, conceptualization planning and generalization.

As the context changes, so do our perceptions and the judgments that we make about the *relationship* between the foreground and background features of conscious experience. Dewey believed that this revolving