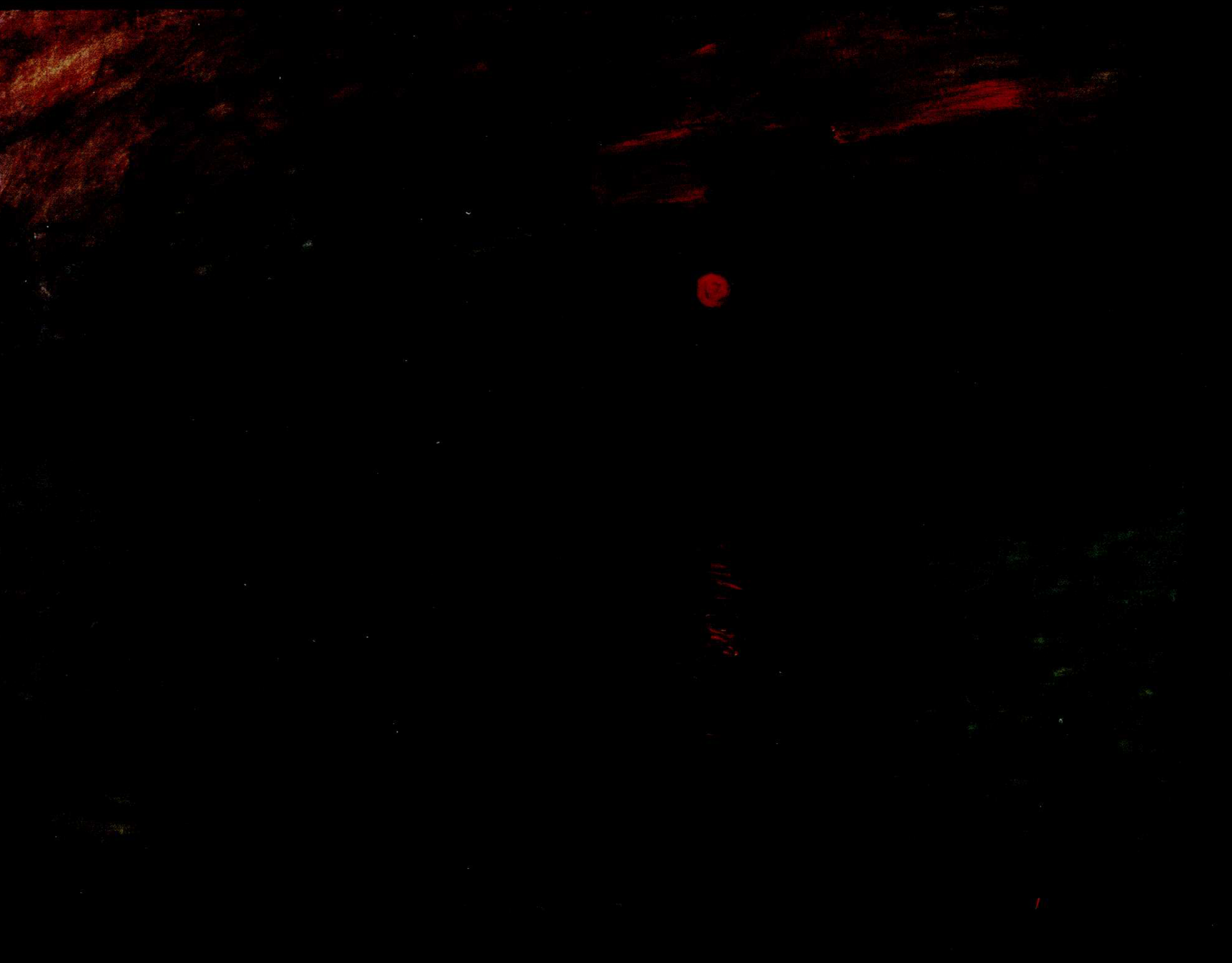
Lifespan Cognition

MECHANISMS OF CHANGE



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Preface

Interdisciplinary! The word is heard often in academic circles. It is a state of affairs appreciated by students, encouraged by funding agencies, beloved by university administrators, yet often treated with reserve and suspicion by scholars and scientists themselves. One reason for this negative reaction is the desire of researchers to pursue their goals in a focused and single-minded fashion. But what if two groups of researchers in the same discipline who are asking the same basic questions have so little contact and shared resources that they each create their own methodologies and establish their own knowledge systems, profiting little if at all from the efforts of the other group? This, we believe, is the situation for researchers in cognitive development and cognitive aging. Our purpose in editing this book is to contribute to a resolution of this divide through the model of interdisciplinary research, in which unique skills are blended to create a richer and more powerful set of ideas and methods to address a common problem.

Because communication between the groups is so rare, the division between researchers in development and aging takes on the proportions of that between such pairs as physicists and chemists, linguists and philosophers, or economists and geographers. In these latter cases, however, the differences are obvious—academic convention has placed these scholars in different departments, often in different buildings, calling for an effort of will for interaction to take place. The term *interdisciplinary* is recognition of this effort, and the fruits of those collaborations are admired and respected. Normally, researchers in cognitive development and cognitive aging live together, yet without some special incentive there has been little reason to walk down the corridor. We believe that collaborations between these groups of researchers are not only desirable but also *necessary* for the evolution of a comprehensive model of cognitive lifespan development.

Our proposal is to create a bridge between these two areas of specialization to gain a perspective on issues and processes that transcend their differences. Our interest is in the problem of change. How do the cognitive skills that constitute our mental lives evolve across the lifespan? The components of cognition mature through childhood, building in sophistication and complexity, to construct the machinery of the adult mind. Eventually these same processes begin to wane, dimming in their clarity and becoming compromised in their precision. A set of important and scientifically exciting questions may be asked about the nature of these processes and mechanisms that drive cognitive change across the lifespan.

We offer this volume as part of the growing enterprise concerned with integrating the insights of researchers who endeavor to understand cognitive change at the two ends of the life course. We invited pairs of authors to write complementary chapters on a set of central topics in cognitive psychology—attention, memory, language, problem solving, and so on—with one member of each pair working in child development and one working in cognitive aging, and then asked Shu-Chen Li and Paul B. Baltes to describe the main issues from the lifespan perspective. The paired authors were asked to present the main issues on either the developmental or aging side of their allotted topics, to respond to some of the comments raised by the researcher on the other side of the lifespan, and to reflect on the implications for lifespan psychology and the search for mechanisms of cognitive change. Not surprisingly, the nature of these interactions varied substantially, with some pairs of authors embracing converging views and others arguing for the need for more independent explanations at the two life stages. Our intention was not to propose a solution but to create a dialogue in which researchers concerned with cognitive change can share insights and amalgamate resources. Our greatest hope is that these opening exchanges will fuel a conversation that takes on its own energy. Our greatest reward will be an increase in the number of walks down these previously untraveled corridors.

We have been supported by many individuals and institutions in this project, and we are grateful to all of them for their roles in bringing the work to completion. Our research, and the time to work on this manuscript, has been funded by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) to each of us, and by a grant from the Canadian Institutes of Health Research (CIHR) to us jointly. We are indebted to the Rotman Research Institute and to its director, Donald Stuss, for providing the context in which the collaboration took place and for supporting our work on it. Jane Logan took on the responsibilities as editorial assistant and brought the chapters into their final forms. Catharine Carlin at Oxford University Press provided the support and resources for the book to be published. Most important, we thank our colleagues and students with whom we have worked and who have shaped our ideas on these issues. In the end, however, it is our families who have allowed us the time and space to immerse ourselves in these ideas and follow them wherever they led. To them we are deeply grateful.

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LIFESPAN COGNITION

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On Structure and Process in Lifespan Cognitive Development

Fergus I. M. Craik
Ellen Bialystok

John Macnamara ended his book *Names for Things* with the following observation:

> I know of no evidence that the minds of children and adults differ structurally. In this book we have seen considerable evidence that even to learn names for things, a modest part of what the very young child learns even in language, they must be structurally equivalent. That, together with the strategic wisdom of taking two mysteries as one (the null hypothesis) commends the conclusion that they are equivalent. (1982, p. 236)

There is nothing apparently radical in Macnamara's conclusion about the structural similarity of the minds of children and adults, but the insight contradicts a considerable portion of the research examining cognitive change across the lifespan. The practical assumption in this research appears to be that the minds of children and adults are different entities. For the most part, researchers in cognitive development investigate the emergence of cognitive abilities from birth until about 10 or 12 years old, and researchers in cognitive aging confine their inquiries to adults beyond the age of about 60 years. In both cases, although more so in cognitive aging, comparisons are also made with the performance of high-functioning young adults, usually university undergraduates, from whom deviations in performance are measured. Attempts to integrate these bodies of research into a single function that traces cognitive changes from the rapid increases in childhood, through the more subtle variations in adulthood, to the slower but inevitable deterioration in many of these processes with aging, are extremely rare. And yet, if the minds of children and adults were "structurally equivalent," then one would expect continuity in the genesis and decline of cognitive function across the lifespan.

Some official acknowledgement of the mandate to study cognitive change across the entire lifespan is found in the textbooks that circumscribe the fields for novice students. For example, in an introductory textbook on developmental psychology, Shaffer, Wood, and Willoughby (2002) define development as the "systematic continuities and changes in an individual that occur between conception . . . and death" (p.2). Within this broad view, some texts situate child development as a subset of developmental psychology within a more specific age band. For example, Berk (2000) defines developmental psychology as including "all changes we experience throughout the lifespan" but child development as addressing "those factors that influence the dramatic changes in young people during the first two decades of life" (p. 4). Other textbooks take a more bifurcated view of the processes of development and aging. Birren and Schroots (1996) note that "the psychology of aging is grounded in a two-stages-of-life perspective; the two stages, development and aging, are usually thought of as two successive processes of change in time, with the transition point or apex at maturity" (p.9). It is this latter view that defines most of the research conducted on the development and decline of cognitive functions across the lifespan.

In spite of this division of labor, the fields of developmental psychology and cognitive aging share a concern for formulating content descriptions of cognitive change over time, rely on similar theories to explain the nature of these changes and the reasons for their evolution, and employ comparable methodologies to detect such changes and situate them in descriptions of performance of the stable state. These commonalities are formidable and set both fields apart from the main enterprise of cognitive psychology that is concerned with description and theory of performance in the stable state. Our purpose in this book is to explore the possibility of integrating these fields to produce a more unified description of change that can constitute the basis of a lifespan approach to cognition.

An integrated account of lifespan cognitive change would benefit both developmental psychology in its endeavor to explain the emergence of cognitive skill and cognitive aging in its study of the decline of cognitive function with age. The common reference point for both of these fields has been the psychology of young adults, perhaps the most widely studied group in all of psychology, and understanding what precedes and follows that utopian state of cognitive efficiency would undoubtedly inform those models as well. The necessity to extract principles and methods that operate across the lifespan would inevitably refine our understanding of basic cognitive processes at all stages of life.

Consider some potential benefits more specifically. A lifespan account would provide a dynamic view of cognition and create a richer context for descriptions of the stable state usually studied in cognitive psychology. One example is the contribution to cognitive theorizing that would follow from considering the role of variability, a factor that is fundamental to descriptions of cognitive performance. Variability in performance has been assigned a crucial role in explaining the nature of cognitive change both for children (Siegler, Chapter 20, this volume) and older adults (Lindenberger & von Oertzen, Chapter 21, this volume). But there is also variability in adult performance even when the focus is not on mechanisms of change, and in those cases the variability is often treated as noise in the data. Understanding the function of variability when cognitive performance is more obviously in transition would contribute importantly to understanding the role of variability when transition is not the main interest. In general, cognitive models that are based on the explanation of how change takes place are also better able to explain variability—the question of why a participant performs better on day 2 than on day 1 has some parallels with the question of why a child performs better at 6 years than at 5 years, or why an adult performs better at 20 years than at 60 years.

Another example of the potential to provide richness to models of adult cognitive performance is the research that shows the centrality of the rise (Golinkoff & Hirsh-Pasek, Chapter 14, this volume) and fall (Kemper, Chapter 15, this volume) of language abilities on cognitive performance. Unlike earlier structuralist models of language that isolated linguistic processing from other cognitive skills, current theorizing places language abilities in an integrated network of cognitive processes. In spite of this, adult cognitive psychology pays little attention to the linguistic abilities of participants and how those abilities potentially interact with the cognitive processes under investigation. However, the dramatic changes in language competencies across the lifespan and the impact of those changes on performance indicate that more attention should be paid to the role of language proficiency in cognitive functioning, even during young adulthood when those abilities are relatively stable.

A lifespan approach to cognitive change would facilitate the enterprise of relating specific aspects of cognitive processing to changes in brain functions. There is a growing interest in both cognitive development and cognitive aging in understanding the complex relations between cognitive functions and brain structures. In both fields, tremendous progress has been made in both situating specific cognitive functions to brain structures and, more importantly, in understanding changes in those functions in terms of organic changes taking place in the brain at different points in the lifespan. These analyses have been enabled by new research revealing details of the growth (Taylor, Chapter 2, this volume) and contraction (Buckner, Head, & Lustig, Chapter 3, this volume) of brain structure and function over time. Ultimately, the changes documented for the emergence of cognitive function and the changes noted with the decline of cognitive function need to be specified in the same brain as follows a specific trajectory across the lifespan. For example, research has shown that the growth of executive functions in childhood (Diamond, Chapter 6, this volume) and their decline with aging (Daniels, Toth, & Jacoby, Chapter 7, this volume) are clearly related to structural changes in the frontal lobes in childhood and older adults, respectively. Changes at both ends of the lifespan emerge in concert with physical changes in the same brain. Finding commonality in the process of change would assist the task of relating those changes to structural changes that are taking place in the brain at different points in time.

Finally, discovering commonalities between development and aging can point to fundamental processes in cognitive change. The concept of change is among the most difficult targets of scientific inquiry; by definition, change is that which does not stand still. Mathematicians needed to invent calculus as an entirely new way of conceptualizing relations in order to capture the descriptions of change that were not conveyed in standard algebraic formulas. Similarly, researchers concerned with both development and aging struggle to create models that are sufficiently complex to incorporate the nonlinear dimensions that characterize the changes in cognitive processing that occur at different points in the lifespan. More shared resources and more cross-fertilization from work in the field focused on the opposite end of the lifespan would undoubtedly facilitate all these researchers in this difficult but crucial enterprise.

What do current research results tell us about the similarities and differences between cognitive growth and decline? This question is answered in large part by the following chapters, but we precede these detailed descriptions with a brief examination of some basic issues in these inquiries. Judgments about the relative similarity or uniqueness of development and aging depend on the perspective one takes to describe performance and the grain of the analysis that is used to examine change at these two points in the lifespan. The broadest perspective is to consider the relation between the mind and the world at these different ontogenetic stages. In this view, one can explore the relative influence of exogenous factors given by the environment and endogenous factors given by the biological structure of the mind on development. A more precise description based on a more fine-grained analysis comes from the perspective that examines the structure of the mind itself, identifying its component abilities and exploring the changing relationships among those abilities. This view, while focused exclusively on the structure of the mind, nonetheless considers a wide and diffuse range of cognitive functions. Finally, the most detailed perspective places only a select set of cognitive processes under scrutiny—for example, the executive functions—and examines their lifespan evolution under the most detailed lens. From all these perspectives, systematic and coherent cognitive changes can be described across the lifespan. In all cases, however, the trajectory uncovered to represent that lifespan development is somewhat different and the mechanisms underlying those dynamics are most certainly different. Therefore, the pattern of development and decline of cognitive abilities depends on the observation perspective one takes and the size of the lens through which one peers. We shall illustrate these differences by describing the evidence from three perspectives that progressively narrow the lens and sharpen the focus: context and performance, differentiation-dedifferentiation, and representation and control. In each case, we consider whether there is evidence for developmental growth and decline; and if so, whether the rise and fall are symmetrical and whether the patterns of change can be traced to the same underlying mechanisms.

THE ROLE OF CONTEXT

A number of developmental theorists have stressed the crucially supportive roles played by physical, psychological, and social contexts on various aspects of the child's intellectual performance. Piaget (1959), for example, described the processes of intellectual maturation as involving a gradual detachment from the "here and now," enabling the older child to deal with abstractions, and with past and future events. In the present

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volume, Ornstein, Haden, and Elischberger (Chapter 10) describe how the young child's conversation is "scaffolded" by the mother's promptings, a type of contextual support that becomes less necessary as verbal abilities develop. Similarly, Vygotsky (1978) argued that social structures serve to support thinking by moving children beyond the level they could achieve by functioning alone, a view significantly expanded and explicated by Rogoff (1990). In an influential work, Bruner (1983) argued that Chomsky's innate language acquisition device (LAD) could not on its own lead a child into linguistic competence without the cooperation of the language acquisition support system (LASS). The LASS was the experiential and interactive context in which the child encountered language and assumed at least shared responsibility with the biological biases for the child's mastery of language. In all these cases, children's cognitive development is inextricably tied to the environment in which those abilities are learned and expressed.

There is good evidence to suggest that this developmental trend reverses in the course of aging such that older adults show progressively greater reliance on environmental and schematic support (Craik, 1983, 1986). Examples of the importance of environmental support include anecdotal reports of older people becoming confused and somewhat cognitively impaired (usually temporarily) after moving from their familiar home surroundings into assisted housing or a nursing home. In the laboratory, the memory performance of older adults typically shows differential benefits of context reinstatement and of recognition over recall (see Craik, 1983, 2002; Craik & Jennings, 1992, for details). Older adults are also supported in their behavior by relying on the context provided by past learning and ingrained habits. Thus, for example, older adults benefit more than do their younger counterparts from an increase in the meaningful relatedness of word pairs in a paired-associate learning paradigm (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005).

Another way of characterizing the role of context in lifespan developmental is to consider the support provided through a sort of "mental context"—that is, the conceptual schemas that have been built up through habit and experience in specific environmental contexts. Successful performance reflects an optimal balance between environmentally driven (bottom-up) and schematically driven (top-down) processes and, crucially, by interactions *between* these sets of processes. In both childhood and older adulthood this balance may become distorted, however, with individuals relying more heavily on the habitual schemas constructed through experience. That is, there can be an overreliance on habit. The classic A-not-B error in which an infant continues to search for a toy in an obsolete location in spite of seeing it hidden in a new place has traditionally been interpreted as evidence for a failure of object permanence (Piaget, 1954). Diamond (2002; Chapter 6, this volume), however, argues that the child is overrelying on a habitual response that successfully located the toy on previous occasions, and the new information from the environment is insufficient to overrule the previous scheme. Cognitive behaviors of older adults are similarly dominated by habit; this point has been well documented by studies from Larry Jacoby's lab (see Daniels, Toth, & Jacoby, Chapter 7, this volume).

The decreasing reliance on schematic and environmental support in the developing child and the increasing reliance in the aging adult reflect the growth and decline, respectively, of the biological systems that underpin and enable a variety of cognitive abilities. The consequence of this change in dependency is different for the two groups, however. For children, the decreasing reliance on such supports allows them to respond flexibly and adaptively to specific situations; that is, their behavior is governed by an intelligent appreciation of the current situation in light of relevant past experiences. For older adults, the increasing reliance on contextual support has both positive and negative implications. It is positively adaptive in that performance decrements that would otherwise occur are prevented or at least ameliorated. However, a negative consequence of this reliance on past learning and habitual responding is that the person's thoughts and actions become more stereotyped and predictable; adaptive as long as the environmental and social contexts remain stable and unchanging, but poorly adapted and inflexible in new surroundings.

It is generally agreed that the adaptive, self-initiated forms of control found in young adulthood are mediated by the frontal lobes, which are among the last parts of the brain to develop fully and among the first to deteriorate in the course of aging (Gogtay et al., 2004; Raz et al., 1997). Pathology of the frontal lobes is therefore associated with a loss of flexibility and an undue dependence on the current context. Patients who have suffered frontal damage can show "utilization behaviors" in which their actions are unduly controlled and driven by external stimulation. For example, such patients will continue to eat when plates of food are continually presented, or will automatically start to sew when materials are placed in their laps (Lhermitte, Pillon, & Serdaru, 1986). In such extreme cases, the external environment has gone from providing support to being overly controlling. The reliance on environmental support may be particularly salient when aging is accompanied by pathology. An early Alzheimer patient, for example, may not be able to describe the steps involved in writing a bank check but can carry out the various procedures capably and fluently (and with full knowledge of the implications!) when placed in the appropriate context.

Baltes and his colleagues have recently stressed the idea of *co-constructivism*—the notion that while most researchers have emphasized the role of the brain in determining mental processes and behaviors, it is equally true that the developing brain is itself shaped and molded by specific circumstances, experiences, successes, and failures (Baltes & Smith, 2004). We strongly endorse this transactional view of relations between brain function and the physical and social worlds, but would simply add that the nature of these brain–world interactions changes through the lifespan from a dominance of world-to-brain transactions in childhood to an eventual dominance of brain-to-world transactions in old age.

DIFFERENTIATION–DEDIFFERENTIATION

A second perspective on lifespan changes in cognition is to examine organizational differences in the mind at different stages of life. Specificity of representation is an aspect of lifespan development that appears to increase throughout childhood and then decrease in the course of aging. The evidence comes largely from behavioral studies of developmental changes in language, concept formation, and memory, but these traditional sources have been augmented recently by findings from cognitive neuroscience (Cabeza, 2002; Casey, Thomas, Davidson, Kunz, & Franzen, 2002). In the area of language development, children first acquire and name concepts at the basic object level (Brown, 1958; Clark, 1993); further development serves both to differentiate that basic level into specific exemplars and to fuse the object in question with similar objects to form more abstract concepts at a higher level (Karmiloff-Smith, 1992). Thus the initial learning of "dog" is both differentiated into spaniel, terrier, collie, and so on, and linked with cat, horse, and pig to form the concepts of mammals and animals. Studies of children's memory reveal a developmental trend in that recall of both specific detail and overall gist increase substantially as children age (Brainerd & Reyna, 1990).

Another example of the differentiation of children's knowledge representations into more detailed and increasingly organized categories is in the knowledge base revealed in their problem-solving ability, such as performance on Piaget and Inhelder's (1958) balance beam problem. In the task, children observe while different weights are placed at the ends of a balance scale in which the balancing arm has been fixed in place. The problem is to decide which (if either) end of the arm will go down when the stabilizing block is removed. In detailed research with children learning to solve this problem, Siegler (1978) has shown that children begin with simple rules based on one feature, such as the number of weights on each side, and increasingly add more rules that include more information and more detail about the nature of the weights. These rules incorporate increasingly detailed representations of the stimuli, providing a richer base upon which to solve the problem.

These developmental trends are mirrored in studies of aging, where it has been found that recall of gist is relatively unaffected between the ages of 20 and 70, but the recall of specific detail is markedly impaired in groups of older adults (Dixon, Hultsch, Simon, & von Eye, 1984). It is also well established that recollection of the source of acquired information (seen on TV? read in a newspaper? told by a friend?) is more affected by aging than is recall of the information itself (McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). Similarly, several studies have shown that recall of context is particularly impaired in older adults (Spencer & Raz, 1995). Older people also have great difficulty in retrieving names (Cohen & Burke, 1993; James, 2004). Putting these various memory problems together, Craik (2002) suggested that the common feature might be a greater age-related difficulty in accessing very specific representations (e.g., names and contexts in which events occurred) than in accessing information that is represented at a higher, more general level.

Paul Baltes and his colleagues (Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980; Baltes, Lindenberger, & Staudinger, 1998) have suggested that the developmental processes underlying differentiation in children are mirrored in older adulthood by processes of "dedifferentiation" (see also Rabbitt & Anderson, Chapter 23, this volume). One type of evidence is that different cognitive abilities intercorrelate to a much higher degree in children and in older adults than in younger adults (Li et al., 2004), suggesting that good cognitive performance in childhood and old age is more attributable to some general ability (g, for example, or fluid intelligence) than to specific abilities or experiential factors. The fractionation of that common ability in young adulthood—that is, the differentiation of cognition—reflects the impact of exogenous factors on the growth of knowledge. Baltes and Lindenberger (1997) have also shown that sensory-motor losses (e.g., in audition, vision, and grip strength) correlate highly with age-related losses in various aspects of cognitive performance. As one possible explanation of this dramatically unexpected finding, they suggested that some common cause underlies the correlated drop in such a wide range of physical and intellectual abilities, with the result that abilities are less differentiated in older than in younger adults. The nature of this common cause, however, is still a matter of active debate.

The notion that abilities are "functionally closer" in the aging brain and are therefore more vulnerable to mutual interference was suggested speculatively by Marcel Kinsbourne some 25 years ago (Kinsbourne, 1980). Recent evidence from brain imaging studies has supported the idea that the neural representations of cognitive function become more specific and delimited as children develop, but then they dedifferentiate and are less focally represented in older adulthood. For example, Casey and her colleagues have shown that performance of a simple stimulus-response compatibility task is mediated by brain regions that are more diffuse in children aged 7–11 years than in young adults (Casey et al., 2002). In older adults this trend is reversed; cognitive processes such as inhibition (Colcombe, Kramer, Erickson, & Scalf, in press) and memory retrieval (Park & Gutchess, 2004) are largely represented unilaterally in young adults, but bilaterally in older adults. This pattern of an age-related decrease in the specificity of cortical representation has also been attributed to a compensatory adjustment of brain function—the recruitment of additional resources from the corresponding area in the opposite hemisphere (Cabeza, 2002; Grady et al., 1995). Similarly, a recent study by Park and colleagues (Park et al., 2004) provides interesting evidence that areas of the ventral visual cortex are specialized to process specific patterns (e.g., faces, houses, chairs) in young adults, but show significantly less neural specialization for these stimulus categories in older adults. In our view, the growing consensus is that mental representations become more specified and focally represented as children develop, and that the processes of dedifferentiation result in a reversal of this trend in the course of aging. These focal representations are more specialized than the general abilities from which they develop and the undifferentiated representations to which they eventually return.

The observed processes of dedifferentiation may be neither compensatory nor adaptive but rather reflect a less efficient central nervous system, in the same way as less stable and less speedy walking and running in older adults is not truly adaptive in any sense, but simply reflects less efficient musculature and motor control. The present evidence on this point is mixed, with some studies finding that greater degrees of bilateral representation in older adults are associated with better performance and are therefore compensatory (e.g., Cabeza, 2002) but with other studies finding the opposite relationship (e.g., Colcombe et al., in press). One logical difficulty with the compensatory view is that bilaterality decreases from childhood to maturity, and this trend toward unilateral representation is related to higher levels of cognitive performance. If *bilaterality* relates to better performance in the elderly (the compensatory view), then somewhere in the lifespan the relation between bilaterality and cognitive performance reverses—not impossible, but unlikely in our view.

REPRESENTATION AND CONTROL

Most theorists agree that cognitive performance draws on two rather different systems, one being a relatively stable repository of stored knowledge and experience, the other being a more flexible set of processes that deal with new problems and with the acquisition of new information. This distinction has been captured under such headings as *fluid versus crystallized intelligence* (Horn, 1994; Rabbitt & Anderson, Chapter 23, this volume) or *mechanics versus pragmatics of intelligence* (Li & Baltes, Chapter 24, this volume). The distinction between the knowledge base and the control processes that operate on it provide a clear case of asymmetry in the lifespan trajectory. Both the knowledge base and the control processes continue to develop substantially during childhood, adolescence, and young adulthood; at older ages, however, knowledge holds up (provided the information is accessed and used from time to time), but control processes decline in efficiency.

The development of knowledge representations and control processes in children is well documented and not controversial. Specifications for the development of knowledge in young children have been studied from a variety of perspectives, including the impact of expertise, or specialized knowledge (Chi, 1978), and the cognitive reorganization and effect on problem solving that take place as knowledge accrues (Carey, 1985). This line of research is critically examined also by Nelson (Chapter 12, this volume). A major outcome of development is the straightforward acquisition and representation of knowledge in many different domains and the increasing *organization* of these representations into coherent schematic structures having different levels of specificity and abstraction (Karmiloff-Smith, 1992). Similarly, the executive control functions develop throughout childhood, beginning at about 5 years of age (Diamond, 2002; Diamond, Chapter 6, this volume; Zelazo, Muller, Frye, & Marcovitch, 2003). Mastery of these processes is linked to the maturation of the frontal lobes, the last region of the brain to become myelinated.

The correlated and progressive development of these two processes in children is not mirrored in aging. The representation of knowledge is relatively unaffected by the processes of normal aging, and is even considered by some theorists to undergo continuing positive development, resulting in the perceived wisdom of older people (e.g., Baltes, Staudinger, Maercker, & Smith, 1995). At the very least, the representation of knowledge (semantic memory) is spared relative to such other cognitive processes as episodic memory, working memory, and executive processes (e.g., Burke, Chapter 13, this volume; Light 1992). What does appear to change is the *accessibility* to stored knowledge, with older adults experiencing progressively greater difficulty in the retrieval of information they demonstrably *know*, as illustrated by its retrieval at a later date or in response to cues and prompts. Retrieval of proper names seems particularly vulnerable to age-related loss (Cohen & Burke, 1993; James, 2004; but see also Maylor, 1997), although it is possible that names are examples of highly specific information, including the original source of remembered information and the contextual details of a remembered episode (Craik, 2002). In summary, the difficulties with knowledge utilization in children appear to be largely due to the incomplete *acquisition* of relevant knowledge, its representation, and its organization. The problems for the elderly, in contrast, appear more to do with inefficient *accessibility* to knowledge that is still "there" in some sense. It would be interesting to see whether there is a genuine lifespan parabola—a continuous rise and then fall—in the contextual specificity of knowledge utilization. Such an outcome would mean that children first learn new information or a new skill in a specific context and can use it only in that context, they gradually extend its generality and scope to new contexts, and this increasing generality unwinds in old age, so that the ability to exercise skills and access knowledge becomes restricted to specific contexts once again.

The age-related decline in executive process functioning is well documented. Older adults are less able to deploy inhibitory processes effectively, with the result that processing is more vulnerable to interference and may be less precisely focused and directed (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). Extending this idea, Jacoby and his colleagues have argued that older people are also less able to *accentuate* specific types of processing to enhance them when required; the resulting deficit is one of overall cognitive control, not merely of inhibition (Daniels, Toth, & Jacoby, Chapter 7, this volume). The notion of executive control of cognitive processing is often discussed and illustrated under the heading of *working memory*. The original formulation of this concept (Baddeley & Hitch, 1974) emphasized its temporary storage aspects, but later versions have linked working memory to attention and executive processes (e.g. Cowan, 1999; Engle & Kane, 2004). Indeed, Baddeley himself has commented that he might well have labeled the concept *working attention* (Baddeley, 1993). In this context, many studies have shown age-related decrements in working memory (see Craik & Jennings, 1992, for review) and these may be interpreted as showing impairments in control.

PATTERNS OF DEVELOPMENT AND DECLINE

Does cognitive aging simply reflect cognitive development in reverse? Evidence from the three perspectives cited in the present chapter, and those developed at greater length in succeeding chapters, make it clear that the issue is much more complex. There are certainly striking instances of inverted U-shaped patterns across the lifespan, the most obvious being the increasing speed of cognitive processing as children develop (e.g., Kail, 1991) and the general slowing associated with aging (e.g., Cerella, 1985; Salthouse, 1996). Another salient example of the mirror-image pattern is executive control, whose development is chronicled by Diamond (Chapter 6, this volume). The age-related decline in inhibitory control is also well documented (Hasher & Zacks, 1979, 1988) as is its rise and fall across the lifespan (Dempster, 1992).

An important point to consider regarding lifespan trajectories of cognitive skills is the level of detail incorporated into various descriptions. It seems unlikely, for example, that attentional control is a single entity. Just as theorists have distinguished between automatic and controlled aspects of information processing, so too they will further subdivide the broad category of controlled processing into task- and context-specific components that show different lifespan trajectories. A more complete description of cognitive changes across the lifespan, therefore, will need to incorporate more detail and more complexity into the account and explain those details in ways that acknowledge both the similarity and the diversity of cognitive performance at different times of life.

Some examples of the need to impose finer distinctions on broad processes are found in studies of visual search. Trick and Enns (1998), for example, found that the ability to detect conjunction targets (defined by two features) increased through childhood and decreased again in the course of aging, but the ability to perform a single feature search improved early in life and then remained stable throughout adulthood. Similarly, in a large-scale study examining search processes across the lifespan, Hommel, Li, and Li (2004) reported that simple feature searches took three times as long as a simple reaction-time (RT) task for children, but that this difference was no greater in older adults than it was in younger adults. In contrast, the increases in RT associated with increasing the number of distractors and with target-absent compared with target-present trials were roughly equivalent for children and young adults but substantially longer for older adults. The authors conclude that, in spite of clear similarities between the performance of children and older adults, there are differences specific to aspects of information processing. For example, children's difficulties appear to be related to the mere presence of distracting items, whereas older adults exhibit both a general decline in speed and a more cautious decision-making style, shown in their particularly long RTs in target-absent trials. The growth of attentional control processes in children may be linked primarily to a mechanics-related growth of myelination, whereas age-related declines in the same functions may be related both to a decline in mechanics (neural degeneration) and to pragmatic experiential factors such as an increased tendency to conservatism and caution in decision-making situations.

Similar results that called for more detailed explanations of lifespan change in visual search were reported by Williams, Ponese, Schachar, Logan, and Tannock (1999). They found that RT on a two-choice task fell from young children to young adults and then rose in older adults, but the time taken to stop a response after stimulus presentation remained relatively stable throughout the lifespan. Similarly, the study by Hommel et al. (2004) found that visual search rates were comparatively slow during both childhood and old age, but that this apparent symmetry masked the effects of a variety of factors that behaved *asymmetrically* across different age groups. These studies show that even the apparently homogeneous process of visual search comprises a number of different components that show different behavioral effects depending on such features as the depth and complexity of the processing operations demanded by the task in question. Thus, attentional control processes may resemble other similarly broad constructs such as working memory in being umbrella terms for families of processing operations whose exact form and characteristics vary substantially depending on the nature of the task, the materials, and the participant.

These examples from studies of visual search point to the need for more detailed descriptions to form the basis for a lifespan framework. One point to emphasize is the level of analysis applied to the behavior; behaviors that look similar at a surface level of analysis may be carried out by very different mechanisms. As an example, McIntosh and colleagues (McIntosh et al., 1999) had younger and older adults carry out a short-term visual memory task while in the positron emission tomography (PET) scanner. The results showed that both age groups performed the task equally well and that they activated many of the same brain regions, but the patterns of connections among activated regions differed markedly between the age groups. The authors concluded that the new network seen in adults might have evolved to compensate for the reduced interactions between areas most active in younger adults. Another example is the reduction in speed of processing found in children and older adults relative to young adults. Slow rates of processing could stem from a number of causes, including the degree of myelination, synaptic density and aborization, the burden of vascular lesions, and the number of areas required to perform the task in question (Raz, 2000). Equivalent slowing in children and older adults is likely attributable to different mixes of these factors, with the first two dominating performance in children and the second two coming progressively into play in the course of aging. Finally, Bialystok and colleagues (Bialystok et al., 2005) found that monolingual and bilingual young adults performed the Simon task with relatively equivalent speed, but that the two groups recruited different frontal regions, with the bilinguals relying more on areas associated with language processing. These examples point to the need to include other levels of analysis in conjunction with behavioral observation to detect aspects of performance that may diverge even when observable behavior remains constant.

The related notions of plasticity, adaptation, and compensation are central to understanding lifespan changes in cognitive processing. Brain plasticity underlies learning and it is clearly an aspect of development that does *not* first rise and then fall across the lifespan. Children are extremely efficient learners of new information but this general ability declines through adulthood and old age (Hultsch & Dixon, 1990). Nonetheless, learning is eminently possible at all ages, and much current research in aging is directed at exploring the limitations of this plasticity and investigating ways to optimize learning at different stages of life (Kramer, Larish, Weber, & Bardell, 1999; Schaie & Willis, 1986). We alluded earlier to neuroimaging studies that have shown bilateral activations in older adults during episodic memory retrieval—cognitive operations that are predominantly localized in the right hemisphere in younger adults (e.g., Cabeza, 2002). Such findings are often interpreted as signaling compensatory brain mechanisms, but in our view a simpler account is that the bilaterality reflects a reversion to a less complex manner of functioning, given such age-related changes as demyelination, cell loss, and loss of connectivity. More generally, although human optimism urges us to believe that all change is for the better, a more cautious view suggests that many of the neurological changes associated with aging may not be biologically intended or evolutionarily selected, but rather reflect optimal ways for the neural machinery to function given the reduced state of its component parts.

On a related point, it may be important to distinguish between biological compensation and social compensation in aging. While biological compensation may reflect less efficient or less well-coordinated neural components, social compensation may reflect more truly compensatory age-related changes in preferences, goals, and motives (Isaacowitz, Charles, & Carstensen, 2000; Staudinger & Pasupathi, 2000). Age-related changes in cognition at both ends of the developmental spectrum should be construed within a framework delineating a set of goals and values. There may also be compensatory activities that are reasonably classifiable as cognitive, such as wearing glasses and hearing aids to compensate for declining sensory efficiency and leaving Post-it notes on the fridge or computer to compensate for memory failures. The richness and complexity of this topic is well covered in a collection of chapters on age-related compensation edited by Dixon and Bäckman (1995).

In conclusion, questions of what develops and what declines across the lifespan form the subject matter of the present book. Perhaps our main point in setting the scene for the subsequent chapters is that these questions must be answered in the context of specific levels of analysis and description. What seems like a smoothly continuous rise and fall of performance at one level may break down into a variety of different underlying cognitive and neurological mechanisms at other levels. In our view no one level is more correct or has greater reality than any other; rather, any final theory of lifespan development will have to show how variables at one level map onto variables at adjacent levels. Our hope is that the present attempt to initiate a dialogue between researchers in the cognitive development and cognitive aging fields will illuminate the mechanisms of development and decline and illustrate the complex ways in which development and aging are related.

References

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