Developmental Science and the Media

Early Brain Development

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Media coverage of early brain development not only has focused public attention on early childhood but also has contributed to misunderstanding of developmental neuroscience research. This article critically summarizes current research in developmental neuroscience that is pertinent to the central claims of media accounts of early brain development, including (a) scientific understanding of formative early experiences, (b) whether critical periods are typical for brain development, (c) brain development as a lifelong process, (d) biological hazards to early brain growth, and (e) strengths and limits of current technology in developmental brain research. Recommendations are offered for strengthening the constructive contributions of research scientists and their professional organizations to the accurate and timely coverage of scientific issues in the media.

An uneasy partnership exists between research scientists and the media. It derives from the informal ways that scientific knowledge enters the popular media and the different orientations and goals of the scientific and journalistic communities (Lindblom & Cohen, 1979; Melton, 1987; Weiss & Singer, 1988). In their search for newsworthy stories, journalists seek what is new, interesting, and unexpected. This approach contrasts with scientists' efforts to contribute to cumulative, enduring, generalizable knowledge that will stand the test of time and critical review. Journalists report information to the public that is practical and relevant, whereas scientists report new knowledge to their peers that may be incomplete, abstract, or esoteric. Their different approaches to knowledge contribute to the uneven communication between scientists and journalists that can result in media representations of scientific advances that are criticized by researchers as misinterpreted and overgeneralized (Goodfield, 1981; Lynn, 1978). But the ability of scientists and journalists to collaborate productively is important. Journalists learn about significant advances in knowledge from the scientific community, and scientists benefit from media attention to their work because it provides public and professional recognition; circumvents the lengthy lag times of scientific journals; and draws the attention of policymakers to their research area, which potentially enhances research applications and future grant funding (Dunwoody & Ryan, 1985).

This uneasy partnership is particularly troubled with respect to social science, especially research on human development, for several reasons (Dunwoody, 1986; McCall, 1987, 1988; Tavris, 1986). First, there is considerable public interest in human behavior and its practical implications. Although this interest contributes to extensive coverage, it can also result in overgeneralizations and inappropriate applications of research findings in media accounts. Second, in contrast to research in the physical sciences, social science research is perceived to be easily comprehended and applied. However, this means that the validity of research findings in the social sciences is judged by their consistency with intuitive theories and prior beliefs, and research can be reinterpreted in media accounts to make it more consistent with what journalists believe to be common knowledge about human behavior (Lindblom & Cohen, 1979). Third, research in the social sciences is often relevant to policy problems in education, human welfare, the justice system, family functioning, and many other areas. This means that social science reporting is commonly framed in terms of broader public debates, even though the research is seldom designed to directly address these debates (Caplan, 1976; Weiss & Bucuvalas, 1980). These difficulties are especially true of media coverage of developmental science because (a) almost everybody is interested in questions of human development and their applications to child rearing and education; (b) folk theories of human development (e.g., "spare the rod and spoil the child") are influential and constitute the prior belief systems of many people; and (c) there are significant policy implications of the scientific understanding of child development with respect to early child care, parent support, family law, and other issues (Melton, 1987; Weiss, 1987).

A fourth reason for the uneasy partnership between research scientists and the media concerns the influence of "campaign journalism" in social science coverage. In con-

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trast to the relatively piecemeal, focused reporting of science that is typically initiated by journalists (particularly science journalists), campaign journalism occurs when media accounts of social science are collectively provoked by a broad public information campaign to advance a particular perspective or action plan to the public. Just as political campaigns attract news coverage by creating newsworthy events and disseminating information supporting a viewpoint, the organizers of public information campaigns on topics such as educational practice, the effects of divorce on children, child care, or youth substance abuse likewise enlist research (and researchers) to attract journalists' attention to their issues and point of view. The reporting that results is not necessarily less accurate than traditional journalism. However, campaign journalism begins not with the findings of relevant research but rather with the goals of an advocacy effort that has been initiated by concerned interest groups, political officials, influential celebrities, and other nonscientists. Campaign journalism is not new (past debates about IQ illustrate its historical impact), but it has become more influential in recent years as the popular media has become more commercial, competitive, and consolidated, raising further concerns about the accurate dissemination and appropriate applications of social science research.

Recent public interest in early brain development exemplifies these concerns. "The Decade of the Brain" of the 1990s fostered widespread interest in neuroscience that, when combined with the public's long-standing concern with child development, permitted enduring questions of early childhood influences to be addressed with the technical sophistication and rigor of neuroscience. By the late 1990s, this resulted in a broad range of media reports on the effects of early experiences on young children in relation to critical periods of brain development and the enduring effects of early stimulation or deprivation. As a result, not only have developmental scientists witnessed unprecedented public attention to important questions of early childhood development, but they also have seen developmental research applied inappropriately, such as when critical-period formulations are used to conclude that Head Start begins too late to stimulate the developing brain or in reports that classical music instruction stimulates early intellectual growth. Although parents are encouraged by media coverage to do the right things for their young offspring (e.g., talking to and playing with their infants), it is often for the wrong reasons, thus contributing to unwarranted expectations concerning the long-term effects of early social stimulation on brain development. At the same time, other newsworthy conclusions from developmental neuroscience neglected by the media—such as the significant brain capacities that develop after age three, the biological requirements of healthy brain development, and the lifelong adaptability of the brain—have not reached public attention.

This article profiles the emergence of public interest in early brain development and critically summarizes developmental neuroscience research pertinent to the central claims of media accounts about early brain growth. Recommendations are offered for how social scientists and their professional organizations should seek to constructively engage the media in light of the significance of campaign journalism and its growing influence.

Early Brain Development and the Media

As it has been widely reported, the "new" research in the developmental neurosciences highlights several characteristics of early brain development that were believed to be previously unknown (see Kotulak, 1996; Shore, 1997; and the "I Am Your Child" campaign Web site at http://www.iamyourchild.org). First, early experiences are crucial in shaping the cultivation and pruning of neural synapses that underlie the functional capabilities of the developing brain. The genetic plan guiding brain development relies significantly on early experiences to stimulate the organization of neural interconnections. Second, key experiences must occur during sensitive or critical early periods of heightened sensitivity to stimulation because of the cumulative nature of brain development. If these "windows of opportunity" are missed and such periods close, enduring deficits in psychological functioning are likely. Third, among the most important of these early experiences is nurturant, sensitive care, which stimulates the developing brain because it is multimodal, contingently responsive, and calibrated to the young child's capabilities. Finally, technological advances promise significant future discoveries about the developing brain.

Media coverage of early brain development increased significantly in scope in the 1990s. A 1994 Carnegie Corporation report entitled *Starting Points: Meeting the Needs of Our Youngest Children* (Carnegie Task Force on Meet-

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ing the Needs of Young Children, 1994) and a Pulitzer Prize-winning series of articles on brain research by *Chicago Tribune* writer Ronald Kotulak (1996) were important early catalysts of public interest. Another significant influence was a national public engagement campaign that, in April 1997, riveted public attention to these issues in a prime-time special on ABC-TV; a White House conference on early childhood development; a weeklong series of daily reports on morning broadcasts of *Today* and *Good Morning America*; a special issue of *Newsweek* magazine; the release of a book, video, and CD-ROM designed for parents and practitioners; and other media events. This "I Am Your Child" public information campaign was the result of more than two years of planning by a group organized by Rob Reiner (actor, director, and cofounder of Castle Rock Entertainment) that included media celebrities, representatives of the White House, major foundation officials, child advocates and early childhood experts, and consultation with the Ad Council (Thompson, 1998). Supported by contributions from major corporations and private foundations, the campaign was also distinguished by its attention to state and community child advocacy groups and efforts to engage national, state, and local media. The national scope and broad media impact of the "I Am Your Child" campaign crystallized the central messages of early brain development for the public. It also provoked federal and state legislative initiatives concerning early childhood, contributed to the California Children and Families First Initiative (which earmarks more than $700 million annually in cigarette taxes for early childhood programs), spurred interest in brain development at the National Governors Association and the National Conference of State Legislators, and contributed to the creation of a National Research Council committee on early childhood development (National Research Council, Committee on Integrating the Science of Early Childhood Development, 2000).

These diverse media accounts have communicated to the public many important features of current scientific understanding of early brain growth. By emphasizing that early processes of brain development are qualitatively different from later stages, for example, they have drawn attention to the unique developmental opportunities and vulnerabilities of infancy and early childhood. By emphasizing that early experiences and exposure to environmental stimulation assume an important role in many aspects of brain growth, they have undermined the traditional (but inaccurate) notion that brain development is a genetically hard-wired process. By focusing on the importance of the quality of early care, these media accounts have provided guidance to parents about helpful caregiving practices that are, on the whole, worthwhile regardless of their effects on early brain growth (and are contrary to other unfortunate, but well-publicized, portrayals of the relative unimportance of parental care; see Harris, 1998). Perhaps most important, the media has drawn attention to the needs of young children and stimulated helpful policy initiatives that might not have otherwise occurred.

These are valuable contributions. However, these media accounts have also tended to exaggerate how much is actually known about the developing brain, overinterpreting current scientific knowledge and overpromising its applications while also unduly narrowing public understanding of the range of important influences on brain development. There are many examples, including (a) the decision by Georgia's Governor Zell Miller to send the parents of each newborn infant in the state a classical music CD and Florida's policy of playing classical music in state-run child-care centers, each based on very limited research findings concerning the "Mozart effect" on early intellectual growth (see "Bach-a-Bye Baby," 1999); (b) claims that early brain damage or stimulus deprivation can account for recent incidents of school violence, despite no evidence for this in many of the perpetrators; (c) reports that children reared in Romanian orphanages have abnormal brains, as revealed by positron emission tomography (PET), because of their deprivation; and (d) widely publicized reports that maltreated children have significantly damaged brains caused by their abuse or neglect, despite no published research systematically documenting that this is so (see Blakeslee, 1996). The concern is not simply that the scientific picture is far more complex than its representation in the media, or that journalists are inaccurate (sometimes simply generalizing from existing knowledge to issues that have not yet been studied or cannot be studied well). More important, however, is that valuable public interest in early childhood may evaporate as quickly as it has emerged if parents, practitioners, and policymakers conclude that they were misled about how they could contribute to optimizing early development, especially if simplified interpretations and applications of research on early brain development do not yield expected outcomes for enhanced intellectual and socioemotional growth.

Media attention recently returned to the topic of early brain development in discussions of John Bruer's (1999) book entitled *The Myth of the First Three Years of Life,* which questioned earlier reports of developmental neuroscience research and the developmental significance of early childhood. In focusing on Bruer's description of the importance of the early years as a "myth," news coverage called into question the significance of early brain development and the importance of early stimulation (see Charen, 1999), although Bruer's book, albeit its title, adopted a more balanced approach to these issues. As a consequence, media accounts then questioned whether parents need to be so concerned about stimulating healthy development and whether the initial years of life provide a significant foundation for later development.

Thus, media attention to early brain development and subsequently to Bruer's (1999) critique has provided very conflicting messages about the nature and importance of early brain development. For the public, this raises questions about the meaning and significance of developmental science; for policymakers, it creates dilemmas concerning the practical yield of federally funded research into early childhood; and for researchers, it poses problems concerning the accurate and meaningful dissemination of research findings through the media. For this reason, the research on early brain development raises important questions about the communication of developmental science to the public, especially in the context of campaign journalism.

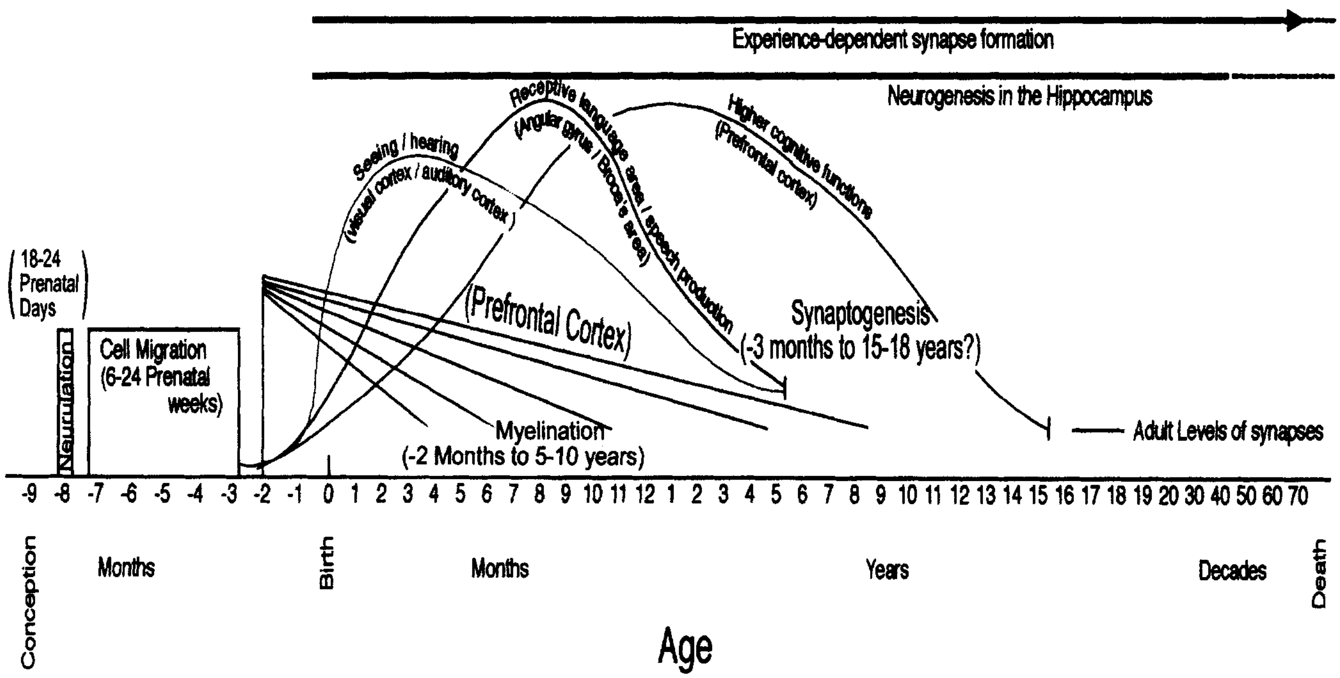
Perspectives From Developmental Neuroscience

Despite the excitement over the "new" brain development research, much of the knowledge reported in media accounts is based on studies that have been around for a long time. More fundamentally, there has been misunderstanding of several basic concepts in developmental neuroscience, to which we now turn. (See Figure 1 for a basic overview of the major events of brain development; see also Nelson and Bloom [1997] and McCall [1999].)

The Early Experiences Essential to Brain Development Are Largely Unknown

Twenty years ago, Rakic and colleagues began to demonstrate in the monkey (e.g., Rakic, Bourgeois, Eckenhoff, Zecevic, & Goldman-Rakic, 1986) and Huttenlocher began to demonstrate in the human (e.g., Huttenlocher, 1979; Huttenlocher & Dabholkar, 1997) that the primate brain massively overproduces neural connections, or synapses, early in development. As a result, the brain of the full-term newborn has many more synapses than the adult brain. This period of synaptic overproduction (synaptogenesis) is normally followed by a period of synaptic retraction, or re-

Figure 1
The Developmental Course of Human Brain Development



Note. This graph illustrates the importance of prenatal events, such as the formation of the neural tube (neurulation) and cell migration; critical aspects of synapse formation and myelination beyond age three; and the formation of synapses based on experience, as well as neurogenesis in a key region of the hippocampus (the dentate gyrus), throughout much of life.

duction, that confers efficiency on brain functioning. The time course for synaptic "blooming and pruning" varies enormously by brain region in humans (see Figure 1). Huttenlocher estimated that the peak of synaptic overproduction in the visual cortex occurs at about the fourth postnatal month, followed by a gradual retraction until the middle to the end of the preschool period, by which time the density of synapses has reached adult levels. In areas of the brain that govern audition and language, a similar although somewhat later time course is observed. However, in the medial prefrontal cortex (the area of the brain where some forms of higher level cognition and self-regulation take place), the peak of overproduction occurs at around one year of age, and it is not until middle to late adolescence that the adult density of synapses is obtained.

What determines the timing and course of synaptic overproduction and subsequent retraction? Both genetic guidance and experiential exposure are believed to be influential. An interpretation proposed by Greenough and his colleagues suggests that the purpose of synaptic overproduction is to capture and incorporate experience into the developing synaptic architecture of the brain, and experimental studies with rodents have provided impressive supportive evidence (Black, Jones, Nelson, & Greenough, 1998; Greenough & Alcantara, 1993; Greenough & Black, 1992). Such processes are undoubtedly influential in human brain development also, but it is unclear how extensively and for which brain areas this occurs and at which periods of growth.

This uncertainty exists because the best estimates of age-related differences in synaptic density are derived from human autopsy specimens, with sometimes only a handful of samples at any particular age. More important, the estimates of synaptic density represent static figures and do not indicate whether the synapses that are counted owe their existence to a genetic program or to experience (e.g., a synapse "born" a week before death is not distinguished from one born 70 years before death). There is evidence that genetic processes as well as early experience may be important. Bourgeois, Reboff, and Rakic (1989) demonstrated that the number of synapses in the visual cortex of a rhesus monkey born three weeks prematurely was identical to that of a monkey born full-term. This finding suggests that, at least in the visual cortex of the monkey, experience may assume little role in accounting for the number of synapses at this stage of development (leaving open, of course, the possibility that experience does influence the visual system at a later stage).

In short, scientific descriptions of the overproduction and retraction of synapses based on early experience are derived from important research and theory based primarily on comparative data. They undoubtedly generalize to human brain development—especially in the development of sensory processes—which means that early experiences are important to the developing brain. However, existing human data provide little clear insight into the relative influences of genetic guidance and experiential exposure for most brain regions or into the types and timing of experiences that are most influential. It is probable that different experiential influences contribute to the development of different regions of the human brain, such as those governing basic sensory and motor abilities, language, emotion and emotion regulation, and thinking and reasoning, but it is unknown what most of these experiences are.

This issue is important because without a greater understanding of these processes in human brain development, it is difficult to identify the experiences that are of critical importance; precisely when these experiences must occur; and the ways, in turn, that the developing brain is buffered against certain experiential influences. This makes it difficult to provide parents with definitive guidance, based on neuroscientific research, concerning the influence of specific parental practices on the developing brain and, most important, the extent to which early or enhanced stimulation can have specific consequences for brain development.

Critical Periods Are Exceptional, Not Typical, in Brain Development

These considerations are relevant to the concept of critical periods in early brain development: whether certain brain regions require exposure to particular environmental influences at specific points in time (or "windows of opportunity"). Unless these time-specified exposures can be clearly identified, critical periods may be misleading for conceptualizing early brain growth. It is unfortunate that the relevance of critical periods to human brain development is frequently misunderstood in the media. In the developmental neurosciences, a critical period typically connotes a very narrow period during which a particular experience must occur. A classic example is the zebra finch, which must be exposed to the father's song at exactly the right time for song to develop (for discussion of sensitive and critical periods, see Bornstein, 1989; Knudsen, 1999).

In humans, there are relatively few critical periods for brain development. Developmental scientists know that exposure to normal speech in the first year confers on the infant the ability to discriminate speech sounds and eventually to correctly produce those sounds. In a similar manner, exposure to patterned visual information in the first few years of life is essential if some aspects of the visual system (e.g., binocular depth perception) are to develop normally. These phenomena, however, are best characterized as "sensitive" periods rather than critical periods, because the time period in which they function is broader and more flexible (Bornstein, 1989), and whether they can serve as "model systems" for other aspects of development is not clear. For example, conclusions from research in the developmental neurosciences must be considerably more limited concerning socioemotional and cognitive growth (Nelson, 1999a, 1999b; Thompson, 2000, in press). A very broad sensitive period may exist for the formation of initial human attachments, for example, although there is little relevant human research on the neurobiological functions of attachment relationships (see Gunnar, in press; Thompson, in press). In terms of cognitive development, very little is known (for a discussion of memory development, see Nelson, 2000). The fact that intervention programs, if they begin early and are sustained, can support cognitive growth for children living in difficult environments suggests that continued plasticity exists in cognitive development. However, as in the case of socioemotional development, this has not been examined in terms of neuroscience.

It is unfortunate that deprivation studies provide some of the most important evidence for critical or sensitive periods, but they must be carefully interpreted. Evidence concerning critical periods in visual or auditory processing is based on comparative studies involving considerable experimental control and on human studies in which confounding variables can be monitored or controlled. Evidence related to sensitive periods in human socioemotional or cognitive functioning is not as clear. Widely cited reports in the media of children from Romanian (or Russian or Chinese) orphanages, or of children suffering physical maltreatment, imply that enduring deficits in brain functioning are derived from their earlier experiences of deprivation or harm during critical periods of early brain development. It is very important, however, that scientific conclusions be based on systematic studies in which the effects of specific, documented deprivation can be studied independently of other hazards to brain development that may occur in the same samples (e.g., prenatal maternal alcohol or drug abuse, poor prenatal or postnatal nutrition or inadequate health care, or serious parental mental illness) or selective adoption practices in the case of orphanage studies. Such research should use carefully interpreted neuroscience research methods and study these children in relation to appropriate control groups. In addition, it is important to account for the varieties of developmental outcomes apparent in such children, not just the deficits documented in those who are most seriously traumatized (see, e.g., O'Connor, Bredenkamp, Rutter, & the English and Romanian Adoptees [ERA] Study Team, 1999). At present, the anecdotal, incomplete, and often unpublished evidence currently reported in the media (and by some scientists) does not meet these requirements and provides a very limited basis on which to derive conclusions concerning the effects of early deprivation on developing brain capabilities related to socioemotional or cognitive functioning.

If critical periods are exceptional rather than typical in early brain development, then it may be more important to be concerned with the overall quality of early experience than with the timing of specific influences. Furthermore, the breadth of the sensitive periods that have been documented for early neurobiological growth indicates that although sensitive periods may have a relatively abrupt onset (typically at birth or shortly thereafter), their duration is prolonged, and their offset is gradual. This provides many opportunities for exposure to the (usually ubiquitous) experiences required for healthy brain development and increases optimism for successful remediation when early disadvantage occurs.

Brain Development Is Lifelong

The emphasis of media accounts on brain development in the first three years of life focuses on a period of considerable importance, but not the only important period. Indeed, it can be argued that the prenatal months are an even more significant period of brain development during which neurulation (i.e., formation of the neural tube from which eventually evolves the central nervous system) occurs, followed by the generation, proliferation, migration, and, finally, differentiation of neurons. Moreover, both myelination (the fatty insulation of neurons) and synaptogenesis begin during the last trimester of fetal life, and these events are essential to the development of the functional architecture of the brain (see Figure 1 and Thompson, 2000). During the prenatal months, the developing brain is highly vulnerable to intrinsic hazards (e.g., errors in cell migration) that can account for significant developmental problems (e.g., dyslexia and possibly schizophrenia) and to external insults resulting from viral infection, drug or alcohol exposure, malnutrition, or other teratogens. Thus, there are significant practical and public health implications of attention to prenatal brain development.

Furthermore, the emphasis on critical brain development from birth to age three also risks ignoring important achievements of later years, as well as the enduring plasticity of the mature brain. The brain regions most relevant to higher cognition, including reasoning and problem solving, self-regulation, personality, and strategic functioning have a maturational course extending into adolescence, consistent with the research evidence (and everyday observation) of how significantly children develop during this period in their thinking, social functioning, self-control, and other capacities. The refinement, integration, and growing efficiency of brain functioning occur during childhood and adolescence (see Figure 1). This means that some of the most significant advances in neocortical growth occur well after the first three years of life.

Furthermore, even the mature adult brain retains considerable functional plasticity, a point long emphasized by Greenough and colleagues (e.g., Greenough & Black, 1992), whose studies of experience-related brain development showed that the same developmental processes are observed in mature as well as juvenile rats. In a similar vein, several research groups have demonstrated cortical reorganization based on adult experience (e.g., Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Ramachandran, 1995). And one of the most exciting research discoveries of the past few years has been the demonstration that neurogenesis (i.e., formation of new neurons) continues throughout much of the life span in the dentate region of the hippocampus (Eriksson et al., 1998; Gould, 1999; for a review, see Tanapat, Hastings, & Gould, in press) and possibly regions of the parietal and prefrontal cortex (Gould, Reeves, Graziano, & Gross, 1999). This finding suggests that brain growth may occur during adulthood in ways not yet understood.

If human brain development is life course (varying in the nature and scope of developmental changes), then the problems of the media focus on the period from birth to age three become apparent. Influences during the early years of life are important, but parents, practitioners, and policymakers are mistaken if they conclude that establishing a foundation of optimal brain stimulation early in life will alone ensure satisfactory development in the years to come. This is due to the significant growth processes that occur after age three and the important influences shaping brain development in childhood and adolescence. They are also misled if they do not understand how much brain growth during the prenatal period provides a foundation for what follows after birth; thus, many important constituents of brain functioning are established before birth rather than afterward. Finally, the focus on early childhood suggests that later achievements in brain growth are primarily the outcome of early formative influences, but the new discoveries of continuing brain plasticity suggest that unique influences on neurobiological development occur after early childhood. Some of the most exciting research discoveries of the next decade will add clarity to this emerging portrayal of continuing brain plasticity.

Biological Hazards Are Significant Threats to Early Brain Development

The media's focus on the first three years of life offers a basis for emphasizing the importance of the quality of early care on brain growth. Although there are few relevant human neuroscience data, caregivers are encouraged to talk and sing to, play with, and sensitively nurture young children because of how these contingent multisensory experiences provide stimulation to the developing brain. It is impossible to argue against the value of sensitive, responsive care for young children because of the evidence from behavioral studies of its importance in promoting secure attachment, self-confident exploration, self-awareness, and a sense of well-being.

However, other features of early care may also be very significant for brain growth. Nutritional adequacy is a crucial prenatal and postnatal influence on brain development because of the growing brain's reliance on folic acid, iron, vitamins, and other nutrients (Morgan & Gibson, 1991). Malnutrition is a biological hazard to which the developing brain is especially vulnerable. Other hazards include fetal exposure to maternal viruses like HIV and rubella, illicit drugs such as cocaine and heroin, maternal alcohol ingestion, exposure to environmental toxins (e.g., DDT, lead, mercury, and PCB), and other teratogens (Sonderegger, 1992). The vulnerability of the developing brain to many of these hazards continues throughout the early years after birth.

Although considerable work remains to clarify the specific hazards posed by these biological teratogens, including the nature of dose–response contingencies and the timing of exposure, current evidence is not insignificant. There may, in fact, be a stronger scientific basis for arguing that early brain development is assisted by protections from biological hazards (e.g., adequate maternal health care and nutrition, satisfactory postnatal nutrition, avoidance of exposure to environmental toxins and dangerous drugs, protection against viruses, and avoidance of undue chronic maternal prenatal stress) than by the regularity with which caregivers talk to or play with their babies. This means that efforts to enhance brain development should focus at least as much on public health efforts, especially for pregnant women and young children from at-risk populations, as on public information campaigns encouraging greater parental social stimulation of infants and toddlers—although both are important.

The Study of Human Brain Development Is Still in Its Infancy

Finally, media accounts of early brain development research commonly overestimate the strengths of the new technologies used to study the brain and underestimate their interpretive cautions, but these technologies have significant limitations. Although electrophysiological tools (electroencephalograms and event-related potentials) have been used for two decades to study brain development and brain–behavior relations, these tools currently possess relatively limited ability to inform us about where in the brain functional activity is taking place.

The "new" technologies of magnetic resonance imaging (MRI) and PET are currently attracting the most attention (see Nelson & Bloom, 1997). Structural MRI has existed for many years and currently provides incredibly detailed and rich information about the anatomy of the brain, but it does not provide any information about brain function. Rather, that is the domain of "functional" MRI (fMRI). fMRI has revolutionized researchers' ability to examine both the function and the structure of the brain, but thus far, it has seen limited use by developmental investigators. More important, it is currently not feasible to use fMRI to study children younger than approximately six years of age, primarily because of the requirement that the participant sit very still for relatively long periods of time (e.g., 30 minutes; for a review, see Casey, Thomas, & McCandliss, in press).

The use of PET with children is highly restricted because it involves injection of a radioactive isotope. Thus, the Food and Drug Administration limits the use of PET to clinical populations of children who have medical cause for the procedure. Moreover, there are only a handful of institutions in the United States where PET has been used at all with children. Thus, there have been no studies of typical development using PET, and of the clinical studies that have been published, all have involved children with neurological problems or those suspected of such (e.g., epilepsy). Moreover, the spatial resolution of PET is now inferior to what can be accomplished by fMRI (which is noninvasive), and like fMRI, PET also has relatively poor temporal resolution (on the order of seconds to minutes).

Although these new technologies provide astonishingly greater insight into the developing brain than what existed only a decade ago, and they are improving rapidly, limitations in their use with children continue to constrain scientific insight in this field. These limitations will be overcome with further technological development, but at present, it is important to be realistic about which tools can be used to address which questions and for children at what ages. At present, in other words, research on early brain development remains technologically limited compared with research on brain processes in animals or older individuals.

Implications for Developmental Science and the Media

Current research from developmental neuroscience provides a critical, cautionary perspective on many media accounts of early brain development. Critical periods are exceptional rather than pervasive in human brain growth. Windows of opportunity for early stimulation better characterize basic sensory and motor capacities than higher mental and personality processes, and even so, most such windows close very slowly with development. The relative influence of genetic guidance and experiential exposure in shaping the young brain is complex, and it is unclear what specific experiences are important, and when they must occur, for healthy brain development. The first three years of life are significant, but other periods are also important, and the brain retains its capacity to grow throughout life. This means that the developmental significance of the first three years is certainly not a "myth," even though it has often been overstated. Protection from biological hazards (particularly during the prenatal period) is as important as sensitive, nurturant care in how parents encourage healthy brain development. Further conclusions are that the brain is a complex organ, it does not develop in a homogeneous fashion over time, and different influences are preeminent for different areas of brain growth.

In some respects, these conclusions do not seem as interesting, provocative, and thus newsworthy as most media accounts. But consider the following conclusions. Brain development can be facilitated not only during the first three years but also at other developmental stages. This is important news for adoptive and foster parents, child-care providers, and parents and teachers of children of all ages. Building babies' brains begins at conception, not at birth. This is important news for mothers and their physicians and for public health agencies, especially those concerned with underserved and at-risk populations. Caregivers are influential not only relationally but also in the physical care, nutrition, and protections they provide to foster young brains and minds. This is important news for parents, grandparents, and child-care providers. Eliminating early disadvantages is important, but the plasticity of brain development means that early deprivation and harm can be treated in later years, especially with carefully designed interventions. This is important news for therapists, educators, and others concerned with aiding troubled children. Adult brains are developing. This is important news for all of us.

There are other newsworthy implications of a more careful, acute reading of the developmental neuroscience research that have not yet reached public attention. Enhanced public information about the importance of prenatal care, early nutrition, immunizations, and elimination of environmental toxins may accomplish as much to promote early brain development as public information campaigns focusing on the significance of talking and singing to young infants. It is very important for parents to schedule early vision and hearing tests for young children because of the importance of early sensory experience for neurobiological organization. And contrary to the impression created by some media accounts, researchers are at the vanguard—not the end—of exciting new discoveries about brain development. Continued vigorous support of this work is needed from funding agencies for which, for some, funding priorities have already shifted to other areas of research.

These new conclusions from developmental neuroscience are important not only because they are more consistent with the research evidence but also because they build constructively on public interest in addressing issues of early childhood development with the technical sophistication of neuroscience and offer recommendations that are interesting, practical, and relevant to public policy. They are newsworthy. However, this raises the question of why other conclusions, but not these conclusions, predominated in the media coverage of early brain development. To be sure, the uncertainty in knowledge created by new scientific discoveries almost inevitably contributes to misunderstanding, misrepresentation, and omission in news coverage, which is particularly problematic in the social sciences because of the practical implications of this knowledge (Blum, 1999; Dunwoody, 1999). However, media attention to early brain development also exemplifies the challenges presented by campaign journalism, in which the message and the intended audience of the campaign can influence how scientific findings are integrated into a public information effort. Campaign journalism is very likely to be part of the future landscape of media coverage of the developmental sciences (Thompson, 1998). Consequently, it is important for social scientists and their professional organizations to be constructively engaged in the dissemination of scientific findings to the public and to be capable of responding constructively to media accounts of research that are misleading or incomplete.

One of the most important ways of doing so is through a more active, ongoing interaction between journalism and research communities, which are typically in contact only after a news story has emerged. In the current era of increasing media competition, currency, and campaign journalism, however, scientists and their professional societies must become more aware of emerging topics of public interest and be prepared to respond promptly (sometimes proactively) with a clear description of the science that is timely and useful to journalists. This can occur as news bureaus associated with scientific organizations become capable of quickly convening one-day meetings (or conference calls) of prominent researchers with science journalists on emerging news themes identified by journalists. It can also occur as "science celebrities" (i.e., the small cohort of researchers regularly consulted by the news media; see Weiss & Singer, 1988) work more with their professional colleagues to provide timely and accurate information to the media, often as they work with specific science journalists. Indeed, journalists value the unsolicited contacts they receive from recognized experts as one way of updating their own knowledge of current trends on their coverage beat (Weiss & Singer, 1988). Developmental scientists should also carefully examine the example of professional journals in other fields that profile significant research findings that have practical or policy implications in editorials that are reliably (and rapidly) reported by the media or that solicit timely review articles on important public concerns. These and other efforts to develop new avenues of continuing dialogue between journalism and research communities are important and worthwhile in light of the findings that government administrators, foundation officials, and the public learn about science primarily through the media but that news stories are derived primarily from the initiative of journalists, not from the public information efforts of researchers (Caplan, 1976; Weiss & Singer, 1988).

There are additional ways of improving this dialogue (McCall, 1987, 1988). Professional organizations like the American Psychological Association (APA), the American Psychological Society (APS), and the American Association for the Advancement of Science can convene symposia at professional conferences that are designed to convey a balanced account of current research conclusions in a concise, clear manner. These meetings are typically well attended by journalists and are significant sources of science news reporting (Dunwoody, 1997). Professional organizations can also regularly prepare briefing papers for journalists that provide integrated, clear, news-ready statements of the status of current research on topics of public concern. On a broader level, the APA Public Policy Office and new journals like *Psychological Science in the Public Interest* provide ongoing avenues for accurately disseminating behavioral science to the public. Professional organizations are especially well suited to these tasks because they have the resources and the media contacts to quickly gather needed information in response to rapidly breaking media events or in response to "news pegs" (e.g., a school-yard shooting) for which journalists are seeking timely, accurate, and current scientific information (Weiss & Singer, 1988; Zigler & Hall, 2000).

Professional organizations such as APA and APS and the research scientists they represent can also collaborate productively with other organizations that contribute to media coverage of issues concerning children and families. Foundation staff have become skilled at identifying and studying emerging public concerns and effectively disseminating research conclusions (Muenchow, 1996). The Carnegie Corporation, the Harris Foundation, and the Charles A. Dana Foundation were each significant contributors to the "I Am Your Child" campaign, for example, and remain committed to child and family concerns. The Annie E. Casey Foundation has also emerged as a significant national resource for coverage of children's concerns, having established the Casey Journalism Center for Children and Families at the College of Journalism at the University of Maryland, which sponsors an annual conference for journalists and publishes a quarterly magazine, *The Children's Beat,* that is a resource for journalists concerned with children and families (see http://www.casey.umd.edu).

Other organizational resources include professional groups, typically associated with universities, that specialize in communicating developmental science to the public. These include the Office of Child Development at the University of Pittsburgh (http://www.pitt.edu/~ocdweb), which provides review articles and other resources, and the public education and media unit at the Bush Center in Child Development and Social Policy at Yale University (sponsored by the Pittway Foundation; http://www.yale.edu/bushcenter). These units are especially important because they typically involve scientists and professional writers in collaborative work and thus offer a valuable resource for scientists who wish to contribute to accurate, timely media reporting of critical research issues. They are also a valuable resource for journalists who, under increasing financial pressure, benefit from the legwork provided by these professionals (Muenchow, 1996).

Researchers are thus not alone in their effort to become more constructively engaged in the dissemination of scientific findings to the public. But scientists themselves also have important responsibilities for the accurate, clear, and timely dissemination of their research (Melton, 1987; Weiss & Singer, 1988), especially in light of the limited capabilities of the public information offices of local universities (Dunwoody & Ryan, 1983). Social scientists must be willing to understand the needs and priorities of journalists, learn how to speak clearly and cogently to those outside the academic community, and become committed to sharing their research knowledge as their contribution to public understanding (Tavris, 1986). This effort requires learning how to integrate new information with the prior knowledge and implicit beliefs of the public (e.g., "brain development in early childhood is significant and so is brain growth at later ages"), create appropriate outcome expectations (e.g., "parental talking, singing, and nurturant care start young children down positive developmental pathways that are influenced by a lifetime of experiences"), emphasize responsible practical applications (e.g., "good prenatal care, attention to nutrition, and early childhood vision and hearing screening are important contributions that parents can make to early brain development"), and clarify the scientific basis for recommendations to parents and policymakers (e.g., "a secure attachment is associated with psychosocial competence even if its effects on brain growth are unclear"). These skills require learning how to speak and write for public as well as professional audiences, which is not typically taught or encouraged by research-oriented graduate programs (Dunwoody & Ryan, 1985).

One of the additional challenges faced by research scientists who communicate with the media derives from another feature of their professional socialization. Although scientists are conventionally characterized as equivocal, qualifying, and uncertain in their conclusions, competition in research funding and editorial review can also cause scientists to significantly overstate the importance of their research or the significance of a single study. Indeed, the misrepresented findings and exaggerated applications commonly criticized in media accounts of science sometimes result from scientists' overstatements of the significance of their work, which may occur because it can contribute to professional prominence and potential external funding (McCall, 1988; see also "Science, Technology, and the Press," 1980). Moreover, when public attention is focused on an important topic (e.g., the needs of young children), albeit for potentially misleading reasons (e.g., critical periods of brain development), it is tempting for research scientists to remain silent or uncritical to avoid diminishing much-needed public interest in their field. This tendency can be true even for the science celebrities who are often consulted by journalists. It is thus very important for researchers to be capable of distinguishing how to meaningfully communicate their work to different audiences (e.g., professional reviewers vs. the media) and in a manner that constructively builds on the accuracies in public understanding while correcting mistaken beliefs.

Conclusion

Dunwoody (1999) recently proposed that scientists and journalists are in the midst of developing a "shared culture" in which the interests of each professional community are contributing to greater mutual respect and understanding. For social scientists who have increasingly had to defend public funding for research, media attention that is accurate and timely helps to increase public interest in their work and to enhance its perceived importance. For journalists who are also stressed by decreased funding, the development of cooperative, constructive relationships with scientists enables them to work better and more efficiently.

In the end, a constructive dialogue between scientists and journalists serves the interests of each professional community, especially in an era of campaign journalism when the initiative for public interest may derive neither from journalists nor scientists but from a carefully designed public information effort by concerned advocates. There is nothing wrong with these efforts to advance public interest on a topic, but as a consequence, scientists and their professional organizations must be especially thoughtful about how science reaches the public and about their own responsibilities for its accurate and timely dissemination. Scientists provide the information that journalists need. They are thus essential to informing a thoughtful public.

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