Neuroscience and the Future of Early Childhood Policy: Moving from Why to What and How

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DOI 10.1016/j.neuron.2010.08.032

There is a need for greater synergy between advances in neuroscience and the formulation of innovative policies to improve life outcomes for children experiencing significant adversity. Translational developmental neuroscience can inform new theories of change to catalyze more effective interventions that lead to a more productive and healthier society.

Ten years ago, the Institute of Medicine and National Research Council published a report entitled *From Neurons to Neighborhoods: The Science of Early Childhood Development.* In the introductory chapter, the authoring committee stated:

> *This report addresses two complementary agendas. The first is focused on the future and asks: How can society use knowledge about early childhood development to maximize the development of the nation's human capital and ensure the ongoing vitality of its democratic institutions? The second is focused on the present and asks: How can the nation use knowledge to nurture, protect, and ensure the health and well-being of all young children as an important objective in its own right, regardless of whether measurable returns can be documented in the future? The first agenda speaks to society's economic, political, and social interests. The second speaks to its ethical and moral values. The committee is clear in our responsibility to speak to both.* (Shonkoff and Phillips, 2000)

After a decade of advances in neuroscience, molecular biology, and genomics, these two agendas remain compelling and urgent. For some, the priority is to leverage science to accelerate learning and skill acquisition, particularly in the earliest years. For others, the most important challenge is to employ new knowledge to mitigate the impacts of adverse early experiences to prevent developmental impairment. In both cases, the translation of neuroscience into principles that can inform sound policymaking offers considerable promise.

The last 10 years of the 20th century were designated by the National Institutes of Health as the "Decade of the Brain." Beyond the remarkable scientific progress achieved during that period, considerable efforts were made by government agencies, private foundations, and professional societies to increase public knowledge about brain development and disease. The opening decade of the 21st century leveraged this enhanced awareness through a growing infrastructure of early childhood policies and programs that reflects broad support for science-based investment in the development of young children.

A primary driving force for this commitment is compelling evidence that demonstrates the robust interactions among genes, early experiences, and environmental influences that shape the architecture and function of the developing brain (Fox et al., 2010). This fundamental concept is underscored by advances in molecular biology and epigenetics that have deepened our understanding of the underlying causal mechanisms that link early experiences to later behaviors, as well as to both physical and mental health (Meaney, 2010; Shonkoff et al., 2009; Taylor, 2010). As this knowledge base has matured, neuroscience has had less to say about the specific mechanisms that underlie positive influences on brain and child development in comparison to those gene by environment interactions that lead to undesirable outcomes (Hackman and Farah, 2009). As a result, the scientific contribution to policymaking has been strongest in making the case for intervening early in the lives of children who face significant adversity (Shonkoff, 2010). That said, and without minimizing the influence of contemporary neuroscience on early childhood policy, the value of that relationship is approaching a plateau that demands thoughtful examination.

In practical terms, the long-term utility of neuroscience for informing public investment in young children requires a fundamental reorientation from the current focus on answering the relatively easier "why" question to actively confronting the more challenging "what" and "how" inquiries. Although responses to the first question will undoubtedly become more sophisticated over time, the power of the current answer needs no further augmentation. A growing percentage of the population (and increasing numbers of policymakers across the political spectrum) now understand that young children do not simply follow fixed genetic trajectories, environments do matter, and significant early adversity can have lifelong consequences for learning, behavior, and health. The challenge for those who wish to build a continuing role for neuroscience in early childhood policy and practice must now shift to confront the more complex questions about "what" should be done to increase the impacts of current interventions and "how" can that be done most effectively, particularly for young children who experience toxic stress.

The Challenge of Translating the Biology of Stress for Policymakers

As the primary organ of stress and adaptation, the brain interprets and regulates behavioral, neuroendocrine, autonomic, and immunologic responses to adverse events, serves as a target of both psychosocial and physical threats, and changes both structurally and functionally as a result of significant adversity The fact that stress responsiveness evokes alterations in the architectural, physiological, and molecular status of multiple systems that feed back to central circuits that mediate cognition, executive function, and emotional regulation underscores the potential consequences of ignoring this serious threat to child well-being (McEwen, 2007). The extent to which some amount of stress is an unavoidable part of life that is viewed as character-building by many policymakers, however, presents a problem for those who support investments in preventive interventions for children experiencing significant disadvantage. In an effort to address this challenge directly, and recognizing the difficulty of communicating complex scientific information effectively to nonexperts, the National Scientific Council on the Developing Child proposed a simplified three-level taxonomy—positive, tolerable, and toxic—to describe the physiological expression of the stress-response system (not the nature of the stressor or the distinction between objectively measured versus perceived stress) that can affect brain development. Although further research is needed to elucidate the underlying causal mechanisms, the conceptual basis of this model is grounded in well-established biological principles, and its explanatory value for nonscientists appears to be strong (Shonkoff, 2010).

Positive stress is characterized by moderate, short-lived increases in heart rate, blood pressure, and stress hormone levels. Precipitants include such challenges as dealing with frustration and separation anxiety. The essential nature of positive stress is that it is an important aspect of healthy development that is experienced in the context of stable and supportive adult relationships which facilitate adaptive responses that restore the stress-response system to baseline status.

Tolerable stress refers to a physiological state that could potentially disrupt brain architecture (e.g., through cortisol-induced damage of neural circuits or neuronal death) but is buffered by supportive relationships that facilitate adaptive coping. Precipitants include the death or serious illness of a loved one or a natural disaster. The defining characteristic of tolerable stress is that it occurs within a time-limited period during which protective relationships help to bring the body's stress-response systems back into homeostatic balance, thereby giving the brain time to recover from potentially damaging effects.

Toxic stress refers to intense, frequent, and/or prolonged activation of the body's stress-response and autonomic systems in the absence of the buffering protection of adult support. Major risk factors include chronic neglect, recurrent abuse, severe maternal depression, parental substance abuse, and family violence, with or without the additional burdens of poverty. The defining characteristic of toxic stress is that it disrupts brain architecture and neurochemistry, adversely affects other organs, and leads to stress-management systems that establish relatively lower thresholds for responsiveness that persist throughout life.

Stated simply, toxic stress during the early childhood period increases the risk of physical and mental illness, as well as cognitive impairment, well into the adult years. This admittedly simple taxonomy of stress responses helps differentiate normative life challenges that do not require programmatic intervention from significant adversities that threaten lifelong outcomes and therefore warrant a pre-emptive response. The potential long-term impacts of these physiological disruptions, however, are unknown to most policymakers. Other fundamental neuroscience concepts that are supported by extensive research in both model systems and humans that have equally important implications for policy development include (1) the hierarchical nature of simple-to-complex circuit formation (Hammock and Levitt, 2006); (2) the neurobiology that underlies the concept of complex skills building on a foundation of simpler skills; (3) the highly interactive nature of cognitive, emotional, and social development; and (4) the decreasing plasticity of brain circuitry over time. The effective communication of these concepts provides a compelling rationale for public investment in early childhood intervention to protect the developing brain from the anatomical, molecular, and physiological disruptions that can be associated with excessive or prolonged activation of the stress response.

The Need for a More Robust Science-to-Policy Agenda

The task of formulating a credible scientific framework to inform more effective approaches to reducing the consequences of early adversity begins with the need to move beyond the already answered "why" question and to confront a more complex set of challenges. For example, how can we leverage advances in neuroscience to inform the design of testable, new interventions and the measurement of their impacts? More specifically, how can we capitalize on a deeper understanding of how experiences are built into the body (for better or worse) and thereby influence learning, social behavior and executive function, and both physical and mental health? The following areas of investigation offer considerable promise.

The critical importance of digging deeper into the elucidation of causal mechanisms from the perspectives of molecular biology, genetics, developmental-behavioral research, and studies of intervention effects is clear. Are there sensitive or critical periods during which positive or adverse experiences have a particularly significant effect on a young child that have short- and long-term impacts on cognitive, language, or social-emotional competencies? Are there sensitive or critical periods for specific developmental domains during which it is most advantageous to intervene, and how are these effects sustained over time? How and why do outcomes differ depending on whether a child experiences acute or chronic adversity? How

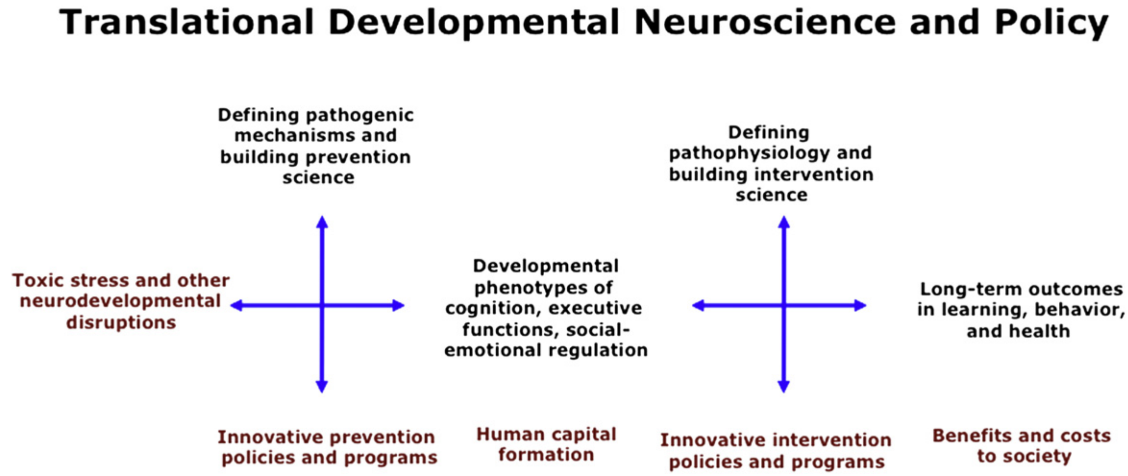

Figure 1. The *"Next-Generation"* Neuroscience-Public Policy Interface
In black, basic and clinical brain research produces an advancing body of knowledge that explains causes, mechanisms, and functional states of adverse brain and child development outcomes. In red, the public policy community develops new strategies for utilizing mechanistic insights and defining both acute and long-term outcomes from neuroscience to stimulate innovative thinking and more effective approaches to prevention and intervention.

can early childhood interventions move beyond a single risk factor-single phenotype approach (e.g., only learning) to address multisystemic issues? Productive investigation in these areas could catalyze enhanced theories of change to guide both the formulation of innovative intervention strategies and the identification of short- and medium-term measures of their impacts.

There also is an urgent need for continuing research on the biology of both adversity and resilience. What accounts for the observation that some children do better than others, despite similar risk profiles? Are there developing neural systems that are relatively more resilient than others, and why? How can we apply growing evidence about the role of gene-environment interactions and the intriguing issue of differential sensitivity to context as an explanation for disparities in developmental outcomes (Boyce and Ellis, 2005)? The extent to which new thinking about differences in resilience and vulnerability can inform the design, implementation, and targeting of more effective policies and services underscores the potential benefits of bringing these fields of study closer together.

Early childhood policy and practice also have much to gain from further advances in the science of learning. How can we reduce emotional and behavioral barriers that undermine the acquisition of early literacy skills? Can we formulate new therapeutic approaches to address brain-based impairments in self-regulation caused by significant adversity rather than focusing exclusively on enhanced instruction? To what extent can greater understanding of executive functioning from both a behavioral and biological perspective inform innovations in both assessment and intervention in the preschool years?

The contribution of neuroscience to innovation in social policy could be formidable (Figure 1). Basic and clinical research over the past two decades have created a highly promising yet underdeveloped interface between these two worlds that would benefit considerably from a more permeable boundary. The extent to which contemporary understanding of gene-environment interaction has superseded the now outdated nature-versus-nurture debate has produced a newly emergent field of translational developmental neuroscience which provides a solid foundation of principles that offers an important opportunity for integrative problem-solving (National Advisory Mental Health Council Report, 2008). The scientific case for investment in vulnerable, young children is clear—brains require more physiological energy to compensate later in life when neural circuits are not formed appropriately in the beginning, and society is likely to pay higher costs in remedial education, clinical treatment, public assistance, and incarceration when opportunities for preventive intervention are ignored. Neuroscience can play an important role in catalyzing the creative, new thinking needed to shape a new era of policies that will produce greater social and economic returns on those future investments.

REFERENCES

Boyce, W.T., and Ellis, B.J. (2005). Dev. Psychopathol. *17*, 271–301.

Fox, S.E., Levitt, P., and Nelson, C.A., 3rd. (2010). Child Dev. *81*, 28–40.

Hackman, D.A., and Farah, M.J. (2009). Trends Cogn. Sci. *13*, 65–73.

Hammock, E.A., and Levitt, P. (2006). Hum. Dev. *49*, 294–309.

McEwen, B.S. (2007). Physiol. Rev. *87*, 873–904.

Meaney, M.J. (2010). Child Dev. *81*, 41–79.

National Advisory Mental Health Council Report. (2008). Transformative Neurodevelopmental Research in Mental Illness (http://www.nimh.nih.gov/about/advisory-boards-and-groups/namhc/neurodevelopment_workgroup_report.pdf) .

Shonkoff, J.P. (2010). Child Dev. *81*, 357–367.

Shonkoff, J.P., and Phillips, D.A., eds. (2000). From Neurons to Neighborhoods: The Science of Early Childhood Development (Washington, DC: National Academy Press).

Shonkoff, J.P., Boyce, W.T., and McEwen, B.S. (2009). JAMA *301*, 2252–2259.

Taylor, P. (2010). Proc. Natl. Acad. Sci. USA *107*, 8507–8512.