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*Eunice Kennedy Shriver* National Institute of  
Child Health and Human Development  
**Scientific Vision Workshop  
on Behavior**

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## Workshop White Paper

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*Views expressed herein are the opinions of the authors and do not necessarily reflect those of the NICHD.*

NICHD Vision Workshop on Behavior  
Growing Up Healthy: Developmental Theory to Models to Interventions

This workshop addressed key issues in the domain of behavior that should be priorities for research over the next decade because of their potential for substantive impact on research and practice. The focus was on development, from conception through adulthood, which means that the dynamic nature of change during childhood has to be a cornerstone for any research program. It is conditioned on a view that optimizing developmental outcomes for children involves a range of research that begins with theory and the mapping of typical developmental trajectories in multiple domains of inquiry; then using this research to develop models of typical and atypical development that integrate mechanisms derived across domains involving the genes, brain, and environment; and finally testing these theories and models through studies ranging from observational to rigorous interventions (i.e., theories to models to the real world to interventions). To facilitate the identification of key areas likely to have the greatest impact, the workshop included eight short presentations on major issues that are ripe for investigation:

**1) Normative Developmental Trajectories**, with an emphasis on key periods in promoting healthy transitions, including the transition from adolescence to adulthood. Critical developmental windows are an important concept in understanding why and when typical and atypical behaviors develop in children and why and when both biological and environmental interventions are effective. There are multiple pathways to influence in the period from conception to adulthood and certain transitions may be periods of stronger malleability than others. In his presentation, James Heckman emphasized that a core set of capabilities explains a variety of diverse socioeconomic outcomes. Cognitive and personality capabilities, which also are products of genes and environments, affect many adult outcomes. Early health conditions also play important roles in explaining adult behaviors. The effects of early life conditions on adults are not solely genetic in origin, but also entail gene-environment interactions. Sensitive periods vary for cognitive (earlier) and noncognitive (later) capabilities. Gaps in capabilities open up early; they persist at later ages. A unified approach to human development that extends previous research in a common framework was encouraged as a basis for policy intervention in health, education, crime, and employment.

**2) Impact of environmental factors on behavioral development**, including:  
a) physiological environment, biology, and the intrauterine environment; b) the physical environment; (c) the familial and social environments, including schools, daycare, correctional facilities, and other institutions, peer groups, and cultural factors; and d) the policy environment. In his presentation, Jason Boardman emphasized the importance of documenting the simultaneous influence of social factors that are shared by members of certain environments in combination with factors that are unique to individuals as co-determinants of health related behaviors.

**3) Understanding behavior in social, economic, and cultural contexts.** Developmental trajectories may vary across the U.S. population of children, differing by race, ethnicity, cultural background, immigration status, and socioeconomic status or other social or cultural groups. The same behavior may have different origins and different consequences, depending on the context in which it occurs. Behaviors with similar biological origins may appear to manifest differently

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across contexts because of varying environmental influences. It is critically important to understand how contextual factors lead to health disparities and inequitable access to schooling and economic resources. In her presentation, Paula Braveman emphasized the social context of health-related behaviors and the need for an understanding of the social circumstances of people's lives that could be shaped by social policy.

**4) Comprehensive, integrated modeling of neurobiological, genetic, and environmental mechanisms underlying behavioral development.** Multiple, highly integrated interdisciplinary levels of scientific inquiry and analysis (genes, environment, brain, behavior) will reveal more valid constructs of typical and atypical behavioral development. Science has progressed to the point where this type of multi-systemic modeling is possible, with strong examples in children and adults with developmental disorders associated with specific risk factors (such as single gene and contiguous deletion syndromes). In her presentation, Elizabeth Dykens focused on children and adults with intellectual and developmental difficulties as exemplifiers of the scientific opportunities represented by multi-system models of gene, brain, behavior, and environment.

**5) Phenotypic descriptions of behaviors that cut across typical and atypical development** (i.e., endophenotypes). It is important to differentiate “primary” or “core” behaviors from “secondary” behaviors when considering both typical and atypical behaviors. In his presentation, Bryan King discussed primary behaviors that map to known brain circuits and can be observed in other animal species and across atypical populations in a recognizable form (e.g., response inhibition, habituation, etc.). These may represent translational or endophenotypes that share mechanisms and question the value of simply studying categorical disorders. Cross-disorder, cross-species comparisons will facilitate the identification of these domain crossing primary behaviors.

**6) Understanding dimensionality in typical and atypical development.** Many atypicalities in children (ADHD, learning disabilities, obesity) exist on a continuum that blends imperceptibly with typical development, yet researchers and practitioners persist in dealing with them categorically. In his presentation, Robin Morris discussed the importance of being explicit about the classifications that underlie all efforts to communicate about people and behavior. Conceptualizing child behaviors in a dimensional (as opposed to categorical) fashion will provide a more accurate representation of real world behavioral constructs and may fundamentally change research paradigms, facilitating the integration of different levels of inquiry (genes, brains, environment, behavior).

**7) Self regulation of behavior and executive functions,** such as planfulness, conscientiousness, delayed gratification, persistence, long time horizon, and its impact on healthy development through adulthood. How can skills and abilities in this domain be enhanced through schooling and other personalized and environmental interventions? Adele Diamond provided a model for the development of executive functions and emphasized the importance of interventions addressing these overarching cognitive and social skills because they influence many domains of adaptation.

**8) Promoting healthy development.** Issues in developing, implementing, and scaling interventions, including interventions developed in laboratories, clinical settings, or observational

studies. Lindsay Chase-Lansdale highlighted the importance of interventions in the first five years, but also the importance of a focus on later transitions to promote sustainability of these efforts. The family has a critical role, as do the neighborhood contexts in which children develop. Study designs should include biology, behavior, AND the environment. A critical question is what can be done to foster healthy development given children's exposures to multiple environmental risks. Interventions focused on individual change are not enough and individual-level and context-level interventions need to be combined.

From these themes and the resultant workgroups, the workshop focused on proposals that addressed (1) the compelling scientific research opportunities within the scientific area of behavior consistent with the NICHD mission; (2) what research tools, methods, or approaches should be developed to realize these scientific and public health opportunities?; and (3) what innovative training and other workforce development activities should be pursued?

### **Compelling Scientific Opportunities and Research Questions**

**1) *Linking multiple levels of inquiry.*** An opportunity that emerged from all of the working groups was the possibility of linking different levels of explanation in more comprehensive models of behavior. It is clear that genetic, neural, and environmental factors are involved at least as main effects in all behavioral domains. However, to date, interactions among these domains have largely been addressed with reductionist, two-level, (putatively) directional analyses: gene-behavior, brain-behavior, gene-brain, environment-behavior. For example, in studies of children with disabilities, genetic, neural, and behavioral outcomes can be modeled, but there is little research that addresses the manifestations of these different systemic levels across the environmental contexts in which these children develop. Broad, multi-level systemic modeling will provide more valid models of how human behaviors develop and are maintained in the context of reciprocal influences between the brain and environment that influence genetic expression and behavior.

To address this opportunity, research questions need to re-evaluate traditional concepts. Efforts to model behavior at multiple levels are excessively influenced by traditional classifications that focus on people as fulfilling (or not fulfilling) diagnostic criteria as opposed to the dimensions on which individual differences may occur. Many scientists feel compelled to approach investigations of clinical disorders in terms of categories laid out in classifications like the DSM4/5 (Diagnostic and Statistical Manual of Mental Disorders, fourth or fifth edition) or ICD-10 (International Statistical Classification of Diseases and Related Health Problems 10th Revision) that have weak empirical bases and are designed to support insurance reimbursement for practitioners. People don't exist in categories, although classifications are useful for communication among clinical practitioners. What may be more important for research are dimensional conceptualizations because atypicalities tend to occur on both ends of a continuum. Some common childhood disorders involving behavior (e.g., dyslexia, ADHD, obesity) clearly exist on a continuum, whereas others (e.g., Williams syndrome) have qualitative features that support a diagnostic category. However, even these latter disorders share characteristics that blend typical and atypical. The concept of endophenotypes is hardly new, but still highly applicable to this scientific opportunity because of the possibility of identifying genetic

expression on specific behavior (e.g., disinhibition) that cuts across behavioral domains and promotes similar behavioral expressions through the brain, depending on social context. Studies of the validity of categories, including cross-disorder comparisons, would facilitate this modeling. In addition, research focusing on endophenotypes and overarching phenotypic and genotypic markers that are shared and not shared across disorders and species would facilitate this modeling. Research on how to translate these multi-systemic models into everyday practice would also be encouraged.

**2. *Environmental Influences on Behavior.*** Although the importance of understanding environmental influences on behavior is hardly new, the scientific opportunities involve the need to move beyond the family to schools, neighborhoods, and structural factors. In addition, there is a need to redefine traditional concepts like socioeconomic status (SES), disadvantage, disability, stress, adversity, and social network/support. These constructs have become iconic and need to be unpacked.

To accomplish these goals, studies are needed of: (1) resilience factors at the community as well as individual level; (2) gene-environment interplay; (3) environmental factors at sensitive periods of development; (4) environmental effects on stress and coping; and (5) the role of environment in health disparities by race and SES. In addition, measurement studies of iconic constructs like SES, stress, social networks, and adversity are needed. These efforts can be accomplished in parallel with the first scientific opportunity, especially through studies that are sufficiently multidimensional and multi-level and through research to develop valid, reliable, and feasible measures of contextual factors. Some of these goals could be addressed by efforts to build consensus and set standards for measurement and analysis, integration of existing data sources, and significantly enhanced training for interdisciplinary collaboration across multiple fields.

**3. *Critical Periods of Development and Transition.*** As people develop, multiple pathways are important. Some of these pathways can be expressed in terms of age (prenatal to adult). However, important nonlinear periods of transition may also vary across individuals and may be particularly “sensitive” to perturbation. Development is also characterized by cascades that may introduce barriers to development. Regardless, development occurs across multiple individual and societal contexts. Development is malleable and context may change over time. Interventions must therefore be targeted at multiple levels to address individual variation and multiple contexts. As such, there are multiple levels of phenotypic expression (e.g., epigenetics, brain architecture, individual behavior, family, and peer systems).

Research questions and studies should focus on transitional periods as they occur in different contexts. As part of these studies, careful attention to normative and variable processes that moderate or mediate movement through these transitions is important because of the possibility of identifying malleable processes that might respond to intervention. Research on transitions would be facilitated by short or accelerated longitudinal studies that focus on community samples that are diverse and inclusive to permit assessment of the full range of variability and thus, greater generalizability. Processes may involve the dosage and intensity of an intervention, timing and specificity (individual vs. tailored), and number of components (comprehensiveness). Modeling of causal pathways that underlie transition and the level at which systems change or

impede change are especially encouraged. The most promising areas over the next 10 years are: (1) Integrating understanding of behavioral and biological factors and their interplay in development (examples: changing parent behavior can change developmental phenotypes, including biological functioning and epigenetic expression; changing maternal environment during pregnancy can change lifelong health patterns); (2) experimental design that includes biological by environmental moderators; and (3) interventions that target families with children in the first five years of life and critical transition periods after five years that might represent opportunities to bolster the effects of early intervention.

**4. Promoting Healthy Development: Intervention.** If we look back 10 years from this workshop, a remarkable accomplishment would be the capacity to trace the development of interventions from basic normative developmental research through multi-level analysis and subsequent development of evidence-based interventions. There are many domains of healthy development, including physical health, mental, and emotional well-being, relationships and social connectedness, academic learning and education, economic independence, civic engagement, and parenting. Over the next 10 years, interventions need to be conceptualized more broadly, especially in at-risk populations, and considered from conception to adulthood, with different phases of intervention at important transition periods. A particularly promising area for intervention involves the “executive function” domain, representing cognitive and behavioral constructs that influence multiple domains of adaptive functions and where intervention outcomes appear especially important. In addition, research on higher-level educational interventions focusing on better ways to teach reading comprehension, written expression, and mathematics are clearly linked to executive functions. Interventions that focus on self regulation and adaptation are also very promising and also linked to executive functions. Much of this intervention research has been conceptualized in a static, individual-centered approach without taking into account the larger environmental contexts in which the child is receiving intervention. In addition, the need for early intervention persists, but needs a longer-term focus. Early intervention studies must consider more fully the transition from early childhood to school. At the same time, more expertise in adolescent interventions is needed as children move into adolescence from childhood and then from adolescence into adulthood. Interventions that target the most biologically and environmentally at-risk segments of society include: immigrants and dual language children; low-income children; children with physical and cognitive challenges, including disabilities; and children who grow up in adverse environments (e.g., abuse and neglect).

New approaches over the next 10 years would begin with (a) community interventions across multiple domains within a family, and the social and economic context, and would recognize the need for sustained adaptive responses to intervention over time; and (b) for children who are at risk due to genetic or biological influences (e.g., prematurity) of moderate or greater effect, intervening (e.g., from pharmacology to gene therapy) at the level of *specific diseases* or targeting downstream pathogenic mechanisms affecting specific domains of behavior (e.g., inhibition), should be pursued with careful consideration of environmental factors that may be affecting phenotype or maintaining adaptive and maladaptive behaviors. Translational (scaling) research is critical. Many interventions are effective on a small, experimental scale, but can't be effectively scaled because of the specificity of the sample, the high skill set required for the

intervention, and the need to plan for scaling at the outset of the development of the intervention. Information about “what works” and best practices needs to be compiled and organized in ways that promote scaling, which requires an understanding of mechanisms. Over the next 10 years, best practices and interventions should be inventoried and evaluated, which would permit identification of interventions that may be effective across multiple contexts and samples. Local communities and stakeholders need to be incorporated into the design and implementation of interventions, especially if they are tailored for racial and ethnic subgroups, poor communities, and immigrants.

## **Research Tools, Methods, and Approaches**

1. *Develop reliable, valid, and feasible measures of key concepts.* Some concepts, such as SES, adversity, or disability incorporate a number of dimensions, rely on the categorization of continuous measures, or are difficult or expensive to obtain. Effort to develop state-of-the-art measures of critical behavioral, social, and environmental constructs could be done through collaborative teams incorporating investigators from different disciplines. These might include measures of the social and environmental context, genetic and epigenetic assays, brain structure and function, or behavioral phenotypes across a range of dimensions. In some cases, terms for the same underlying concepts differ across fields. Some cross-walk, translation, and reconciliation among disciplines would greatly facilitate research across these boundaries.

2. *Develop and implement statistical modeling approaches that can capture multi-level, interactive levels.* Our call for research that links multiple levels of inquiry requires data across all those levels and methods to analyze them. Research on critical transition periods in development likewise needs appropriate data and methods. Some effort will have to be put into development of robust methods appropriate for these much more complicated conceptual and causal models. The dissemination of these methods broadly in the form of well-documented software and procedures will also be essential.

3. *Improve the availability of and access to existing data through an NICHD-supported data archive.* Although NIH has requirements for data sharing, there are insufficient archives for storing and promoting access to these data. In particular, data on many existing interventions are not publicly available to the general scientific community. An archive of data from NICHD-sponsored studies, including interventions and evaluations of them, support for users, consistent formatting and technical material, available to the scientific community at large, is a very cost-effective way to increase the quantity and quality of research that will also promote scaling. This archive could include data sets with measures of social, environmental, and community characteristics.

4. *Support analysis, evaluation, and synthesis of available data.* Meta-analysis of studies on similar topics, reanalysis of existing data on interventions, and follow-up of study participants later in life all hold the potential to address some of the questions we pose above.

## **Barriers to Behavioral Research**

1. *Lack of fluency in concepts, methods, or approaches in other disciplines raises costs of interdisciplinary collaborations, multi-level research, and considerations of subgroups, contexts, critical periods, and developmental trajectories.* Fluency across fields could be improved through short courses, summer workshops, or interdisciplinary research networks. Training across disciplines could be supported through post-doctoral training in another discipline, programs (e.g., T32) that explicitly focus on trans-disciplinary approaches, K awards with coursework and mentorship in other related disciplines, dual Ph.D. programs or MD-PhD programs, and training grants for mid-career and senior scientists who seek skills in another discipline. Interdisciplinary work could be fostered through encouragement of co-PIs across disciplines, K awards for team scientists, multi-country collaborations, multi-disciplinary journals, and interdisciplinary training workshops on specific data sets or approaches.

2. *Regulatory restrictions (HIPAA, or Health Insurance Portability and Accountability Act; FERPA, or Family Educational Rights and Privacy Act; and IRBs, or institutional review boards) impede observational behavioral science, interventions, and evaluations, many of which carry very low risks to study participants.* Although IRBs are implemented at the local level, the interpretation of federal regulations varies considerably. Behavioral research often presents minimal risk to the participant, especially if confidentiality is protected through de-identified data. IRBs often treat behavioral research, especially when children are involved, as high-risk and without consideration of the administrative exemptions that noninvasive and minimal risk studies involve. This problem has been intensified because of misinterpretation of HIPAA and FERPA that often restricts researcher access to data which is intended to be in the public domain.

## **Relevance to NICHD Mission**

The four scientific opportunities identified in this white paper would have significant impact on public health and promote the NICHD mission. The integration of multiple levels of analysis builds upon existing research and would address mechanisms that provide more comprehensive explanations of behavior at biological and environmental levels. In tandem, more comprehensive explanations would lead to a better understanding of the complex transitions from conception to adulthood that characterizes and promotes healthy development. From these two sources, interventions could be developed that address the multiple levels at which change must occur—not just individual change, but also in larger social contexts. Better measures, statistical models, interdisciplinary training, and a reduction in barriers are needed for behavioral research to address these scientific opportunities over the next 10 years.

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