.

Title: A Conceptual Approach to Understanding Treatment Heterogeneity in Human Capital Interventions

Authors and Affiliations: Greg J. Duncan* and Deborah Lowe Vandell, Education Department, University of California, Irvine.

*Corresponding author: Please direct correspondence to gduncan@uci.edu

Background / Context: *(Note: the format of this conceptual paper differs from a typical SREE empirical paper. Accordingly, we do not attempt to divide up into the SREE-suggested sections.)*

Policy research on children is heavily balkanized by discipline. Economists bring strong experimental and quasi-experimental methods to their policy research, and recognize in their conception of causation that policies may have heterogeneous treatment impacts. But economic theories make few concrete predictions regarding either the nature of that heterogeneity or the processes by which the black-box policy impacts they estimate come about. Sociologists bring a sophisticated conception of the many contexts (e.g., neighborhoods, schools) in which children develop, but rarely link such conceptions to the circumstances of individual children within a given context.

Developmental psychologists have strong conceptual models of how policy interventions and other environmental conditions may differentially affect children within and across developmental stages – birth to school entry, middle childhood, adolescence and early adulthood. And while they have developed some of the most rigorous and consequential child interventions (e.g., Perry Preschool, Abecedarian), some of which incorporate random-assignment evaluation designs, most of their empirical research relies on nonexperimental data and relatively weak causal empirical methods.

To generate hypotheses regarding the likely impacts of education policies across and within children's developmental stages, we draw from the developmental psychology literature and conceptualize the importance of the *congruence* ("fit") between the developmental needs of children and youth and the design and nature of the intervention policies for understanding the nature of program treatment heterogeneity. In this view, children and youth profit from interventions to varying degrees, for two fundamental reasons. First, policies may not fit the developmental stage of the children or youth they target. We call this *stage/policy fit*. Second, there is substantial variation in treatment impacts across children within a given stage. We call this *child/policy fit*. We discuss each of these in turn and then apply them in the context of early childhood intervention programs.

Stage/policy "fit." Children in different developmental stages vary in their responses to policies because of differences in the fit between policy-induced changes in children's immediate environments and the accomplishment of stage-salient developmental tasks (Bronfenbrenner & Morris, 2006). For example, the potential for high payoffs to education interventions mounted early in childhood is supported by evidence regarding the critical importance of early childhood for brain development (Knudsen et al., 2006) and formalized in economic models of human capital development (Cunha and Heckman, 2007).

Not all policies fit the needs of the children and youth they target, as seen in Eccles' seminal work. Eccles et al. (1993) argue that the primary/middle-school model of education structure is inferior to an integrated K-8 structure because middle schools are ill-matched to the emerging developmental demands of children as they transition to adolescence. Transitioning children are in special need of close relationships with adults outside of their homes, and yet the transition to middle school involves moving from a single teacher to multiple teachers; heightened concern about their status relative to peers is exacerbated by middle-school tracking; needs for more complex academic tasks are often met by more rote teaching styles; and needs for self-determination, participation in rule making and emotional support are met by increased middle-

school regimentation and rigid disciplinary policies. As a consequence of these ill-fitting features of middle school, it is argued, too many students disengage from their school-related work and focus on peers and other non-school priorities.

Child/policy fit. Issues of program "fit" can also arise among children *within* the same developmental stage and are a likely source of heterogeneous treatment effects (Imbens & Angrist, 1994). As we detail below, early childhood interventions such as Head Start and Early Head Start are geared toward providing learning experiences to children whose family environments are unlikely to provide enough of them. Thus, they "fit" better, and likely generate larger impacts, for children from economically disadvantaged than advantaged circumstances. A second interesting "fit" hypothesis is that high-quality child care has particularly positive impacts and low-quality care has particularly negative impacts on children with difficult temperaments (Pluess & Belsky, 2009). Middle- and high-school programs aimed at preventing the onset of or reducing smoking, drinking and drug use are typically geared toward normative rather than problematic development. Thus they likely "fit" better for students who have not yet experimented with these substances. In the case of deviant students, these programs may even generate unintended negative impacts (Dishion, McCord & Poulin, 1999). Sometimes "fit" issues arise from the nature of the intervention. High-school exit exams focus attention on the differential impacts on children with achievement skills near or far from the pass/no pass thresholds. A fundamental premise of our conceptual approach is that effective policies must fit with individual children's achievement of stage-specific developmental tasks, and the degree of fit is a powerful predictor of program treatment heterogeneity.

An application to early childhood intervention programs

The child/policy fit framework can be illustrated with treatment effects heterogeneity in early childhood intervention programs. A central proposition of bioecological theory (Bronfenbrenner & Morris, 2006) and life course theory (Elder, 1996) is that experiences have differential impact depending on the individual's developmental status and personal and family characteristics. Both human and animal studies highlight the critical importance of early childhood for brain development (Sapolsky, 2004; Knudsen et al., 2006), while some economic models of human capital development (e.g., Cunha and Heckman, 2007) presume that preschool cognitive and social-emotional capacities are key ingredients for success during the school years. Social cultural development theories of learning and the conceptualization of a zone of proximal development (Vygotsky, 1978) focus on the quality of the match between the child's background and skill level and the level and quality of instruction, hypothesizing that learning occurs when quality instruction is slightly above the child's skill level.

In the context of early childhood intervention programs, these ideas lead to competing hypotheses about differential program effects in developmental research and theory. Two of these hypotheses are relevant to children's participation in high quality early education programs and specify who is expected to derive greater benefit from these high quality programs. The *compensatory* hypothesis (Rutter, 1987; Sameroff & Chandler, 1975) predicts that children who are at risk because of economic disadvantage, low skills, difficult temperaments, etc. derive greater benefit from skill-building high quality early education programs relative to children who are not at risk. This hypothesis provided the rationale for the initial and continued funding for programs such as Head Start and Early Head Start. Two alternative hypotheses, *accumulated advantages* and *skill begets skill* (Cunha and Heckman, 2007) posit that children with greater initial individual abilities (*skill begets skill*) or less-risky advantage-laden family environments (*accumulated advantages*) will derive greater benefits from high quality early education

programs than less advantaged peers because of their ability to build on existing skills or family advantage.

The *compensatory* hypothesis is depicted in Figure 1. Child care quality runs along the X axis while some valued child achievement or social-emotional outcome runs up the Y axis. The parallel lines for high- (solid) and low- (dashed) risk children reflect assumed modest and parallel boosts in child outcomes as child care quality improves. The compensatory hypothesis (shown with the non-linear dashed line) presumes that the fit of a well-designed high-quality program to the needs of high risk children produces positive benefits that may reduce or even be sufficient to eliminate the outcomes gap between higher and lower-risk children.

In contrast, the *accumulated advantages* hypothesis presumes that the higher skills of lower-risk children will increase the productivity of investments like child care quality and impart a steeper slope for low-risk relative to high-risk children. In terms of Figure 1, a steeper slope to the low-risk relative to high-risk line would produce a larger between-group gap in the high-quality condition.

A special case of *accumulated advantages* hypothesis is the *skill begets skill* hypothesis, in which attention is focused on the child's own baseline cognitive and noncognitive skills. To motivate this hypothesis, Cunha and Heckman (2008) develop a model of the production of human capabilities that includes the cumulative role of cognitive (S^C) and noncognitive (S^N) skills, as well as skill investments (I) made by families, preschool programs and schools in producing adult human capital h. To focus on preschool investments, we distinguish the periods birth to age 3 (period 1), and ages 4 to 6 (period 2).

At birth (period 0), children have endowments of cognitive potential and temperament (S^C_0, S^N_0) that reflect some combination of genetic and prenatal influences. It is assumed that school readiness human capital (h) is a product of an individual's eventual period 2 cognitive and noncognitive skills: h = $g(S^C_2, S^N_2)$. Cunha and Heckman (2008) presume that achievement-related skills in period t are a product of both cognitive/achievement and noncognitive skills in the prior period, plus current-period investments:

(1) $S^C_t = f^k_t(S^C_{t-1}, S^N_{t-1}, I^k_t)$.

Our concern is with how skills acquired during $t = 2$ are related to both the achievement and noncognitive skills (S^C_1, S^N_1,) that children bring to preschool, coupled with the interaction between those start-of- preschool skills and the preschool investments (I^k_2) themselves. Indeed, it is this interaction, in which the productivity of a child's preschool investment is presumed to be enhanced by higher skill levels coming into preschool, that isolates the "skill begets skill" effect.

Other hypotheses have focused on differential effects of *poor quality* programs on child developmental outcomes. This c*umulative risk* hypothesis (Sameroff & Chandler, 1975) predicts that poor quality programs are particularly detrimental for children who at already at risk because of economic disadvantage, low birth weight, difficult temperament, or other reason. This is illustrated in Figure 2 by the dashed line producing the worst outcome in the low-quality care condition. Alternatively, the *protective hypothesis* (Garmezy, 1985; Rutter, 1987) predicts that poor quality programs in early childhood are less detrimental for children whose own personal qualities or whose family resources serve to protect or offset the negative impacts of poor quality programs. This is shown by the dotted line in Figure 2.

An intriguing fifth hypothesis, *differential susceptibility,* incorporates differential effects of both high quality and low quality environments in its formulation (Belsky, 1997; 2005; Belsky, Bakermanns-Kanenburg, & van Ijzendoorn, 2007). This hypothesis, first documented in animal

studies (Suomi, 1993) and recently proposed for human children by Belsky and colleagues, posits that some individuals are more susceptible to adverse effects of negative environments *and* to beneficial effects of supportive environments (Figure 3). This view is juxtaposed to the concept of vulnerability that focuses only on negative effects of adverse environments or positive effects of enriched environments. Belsky has observed that temperamentally difficult children are more negatively affected by poor quality environments AND more positively affected by high quality environments.

Testing these hypotheses

It is relatively straightforward to test these often competing hypotheses. This is best done with experimental data such as those available for the Infant Health and Development Program, Early Head Start, the National Head Start Impact Study (NHSIS), and the randomized Preschool Curriculum Evaluation Research Study. And since the tests involve interactions between treatment assignment and baseline child and family characteristics, they are less vulnerable to the identification problems that plague nonexperiment studies.

For example, the *compensatory hypothesis* that, owing to their greater environmental vulnerability, high-risk children benefit the most from high quality programs, can be tested once "high risk" is defined (e.g., as low (as opposed to higher) child baseline cognitive performance; low SES (compared to middle and higher SES); many (as compared to few) family risk factors; younger as compared with older age; males as compared with females; and ethnic minority children (particularly African-Americans and Hispanics) as compared with whites.) Using child's low cognitive ability as an example and "X" to indicate other baseline controls, the model is one in which the treatment dummy T is interacted with an indicator (LowIQ) of a child's baseline cognitive ability:

(2)   Later Skills = $b_0 + b_1\,T + b_2\,LowIQ + b_3\,T \times LowIQ + j\,(X) + u$

The *compensatory hypothesis* posits a positive sign for coefficient b_3, indicating larger program impacts for children with fewer cognitive skills. In direct contrast, the *skill begets skill* hypothesis predicts that children from advantaged groups have the higher skills that enable them to profit most from high-quality child care – in other words, a positive interaction between baseline child IQ and assignment to the treatment condition.

The *differential susceptibility* hypothesis has two parts – that, for children with difficult temperaments, (a) high-quality child care magnifies positive impacts, and (b) low-quality care magnifies negative impacts. In this case, we need three levels of quality rather than the two typically provided in the treatment vs. control contrasts in our experiments. Suppose we divide the treatment group into those with above and below-quality care, i.e., high-quality treatment (HQT) and low-quality treatment groups. Suppose further that it could be established that the control group (Control) in the NHSIS experienced lower quality care than even the below-median-quality Head Start centers. Then the differential susceptibility hypothesis could be tested with the model:

(3)   Later Skills = $b_0 + b_1\,HQT + b_2\,Control + b_3\,Difficult\ Temperament + b_4\,HQT \times$
        Difficult Temperament $+ b_5\,Control \times Difficult\ Temperament + j\,(Controls) + u$

with the expectation that b_4 is positive and b_5 is negative.

Appendices

Appendix A. References

Belsky, J. (1997). Variation in susceptibility to environmental influence: An evolutionary argument. *Psychological Inquiry, 8*(3), 182-186.

Belsky, J. (2005). Family influences on psychological development. *Psychiatry*, *4*(7), 41-44.

Belsky, J., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). For better and for worse: Differential susceptibility to environmental influences. *Current Directions in Psychological Science, 16*(6), 300-304.

Bronfenbrenner, U. & Morris, P. A. (2006). The bioecological model of human development. In R. M. Lerner (Ed.), *Theoretical models of human development*. Volume 1 of *Handbook of Child Psychology* (6th ed.). Hoboken, NJ: Wiley.

Cunha, F., & Heckman, J. J. (2008). Formulating, identifying, and estimating the technology of cognitive and noncognitive skill formation. *Journal of Human Resources*, *43*, 738–782.

Cuhna, F. and Heckman, J. (2007). "The Technology of Skill Formation," *American Economic Review*, 97(2):31-47.

Dishion, T. J., Mc Cord, J., & Poulin, F. (1999). When interventions harm: Peer groups and problem behavior. *American Psychologist*, *54(9)*, 755-764.

Eccles, J. S., Midgley, C., Wigfield, A., Buchanan, C. M., Reuman, D., Flanagan, C., & Iver, D. M. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist, 48*(2), 90-101.

Elder, G. H. (1996). Human lives in changing societies: Life course and developmental insights. In R. B. Cairns, G. H. Elder, Jr., & E. J. Costello (Eds.), *Developmental Science*. New York: Cambridge University Press.

Garmezy, N. (1985). Stress-resistant children: The search for protective factors. In J. E. Stevenson (Ed.), *Recent research in developmental psychopathology (Journal of Child Psychology and Psychiatry Book Suppl. No. 4)*. Oxford: Pergamon.

Imbens, G. W. & Angrist, J. D. (1994). Identification and estimation of local average treatment effects. *Econometrica*, 62(2), 467-475.

Knudsen E., Heckman, J., Cameron, J., & Shonkoff, J. (2006). Economic, neurobiological, and behavioral perspectives on building America's future workforce. *PNAS*, *103*, 10155 - 10162.

Pluess, M., & Belsky, J. (2009). Differential susceptibility to rearing experience: The case of childcare. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 50*, 396-404.

Rutter, M. (1987). Psychosocial resilience and protective factors. *American Journal of Orthopsychiatry, 57*, 316-331.

Sameroff, A. J. & Chandler, M. J. (1975). Reproductive risk and the continuum of caretaker casualty. In F. D. Horowitz (Ed.), *Review of Child Development Research (Vol. 4)*. Chicago:

University of Chicago Press.

Sapolsky, R. (2004). Mothering style and methylation. *Nature Neuroscience, 7*, 791-792.

Vygotsky, L.S. (1978). *Mind and society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
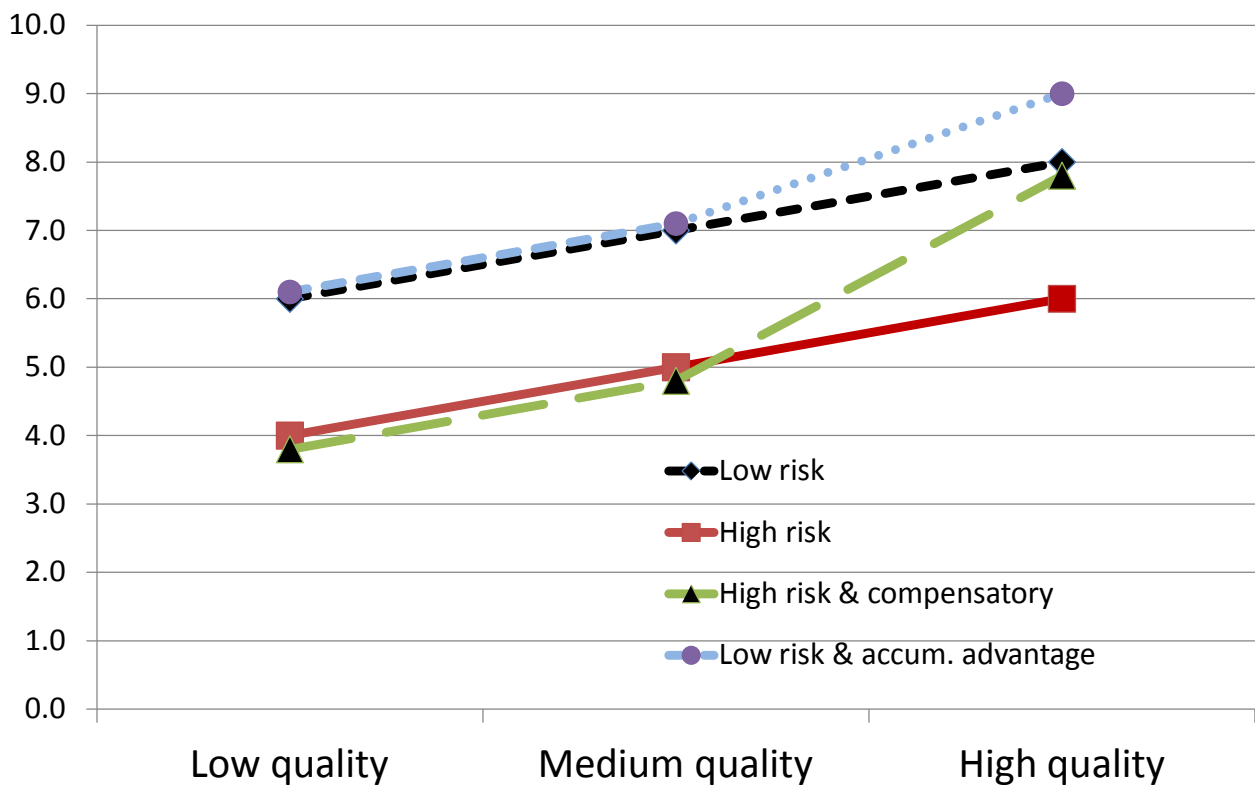
Figure 1: Compensatory hypothesis for high risk kids

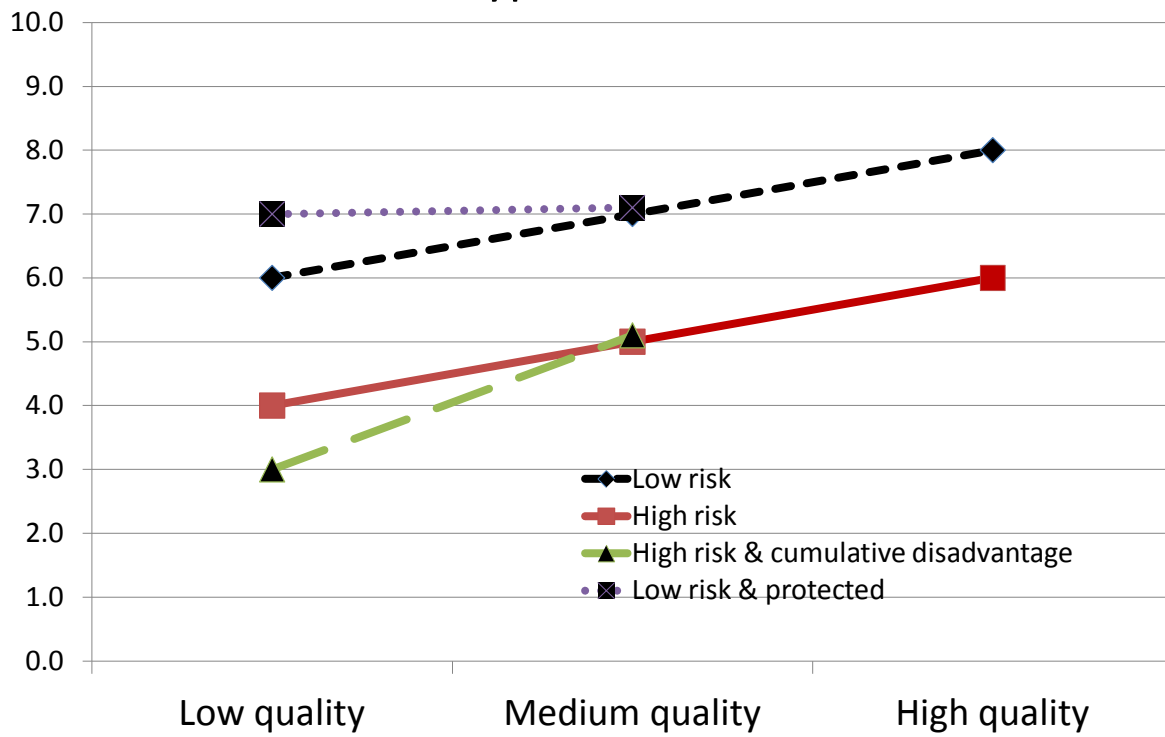Figure 2: Cumulative disadvantage and protective hypotheses

Figure 3: Differential susceptibility hypothesis for high risk kids