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The Causal Impact of Schooling on Children's Development: Lessons for Developmental Science

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Abstract

Entry into formal schooling is a signature developmental milestone for young children and their families and represents an important period of cognitive, social, and emotional development. Until recently, few researchers have attempted to isolate the unique impact of schooling on children's developmental and academic outcomes. The application of quasiexperimental methods has provided researchers with the tools to examine when and how schooling shapes children's development. In this article, we summarize three main insights from this work: (a) Schooling produces major, unique changes in children's growth across a wide range of psychological processes important for learning; (b) the effects of schooling are not universal across all domains; and (c) schooling impacts cognitive processes that are not explicitly taught. We also propose that a deeper look at classroom instruction and brain development can expand our understanding of how schooling influences academic success and positive life outcomes and provide a model for developmental science more broadly.

Keywords

schooling, development, causal inference, regression discontinuity, school cutoff

Children's transition to school has become a major focus of inquiry across a number of scientific fields. From a theoretical perspective, cognitive and developmental scientists have catalogued rapid changes in children's cognitive, emotional, and social skills during this period, encapsulated in the phrase *the five-to-seven shift* (Sameroff & Haith, 1996; White, 1965). On a more practical level, education researchers have documented significant variability in children's literacy, numeracy, and related skills that emerge well before the beginning of school and that predict academic achievement in later childhood and life success in adulthood (Moffitt et al., 2011; Morrison, Bachman, & Connor, 2005). These early academic differences, coupled with the broader changes uncovered, have raised questions about the sources of variability responsible for children's trajectories over this period.

One of the most significant changes occurring in advanced societies during this time is children's entry into formal schooling. Hence, it is reasonable to examine the role of early schooling in contributing to (a) the growth in children's cognitive skills as well as (b) the variability in important academic skills needed for school success. Until recently, most research on this topic was correlational in nature and not equipped to disentangle the unique effects of school experiences from genetic and other environmental influences (e.g., parenting) that impact children's growth. However, over the past several years, scientists across a variety of disciplines, including economics, psychology, and education, have been exploiting a natural experiment created by the near universal practice of school districts using a rather arbitrary cutoff based on a child's date

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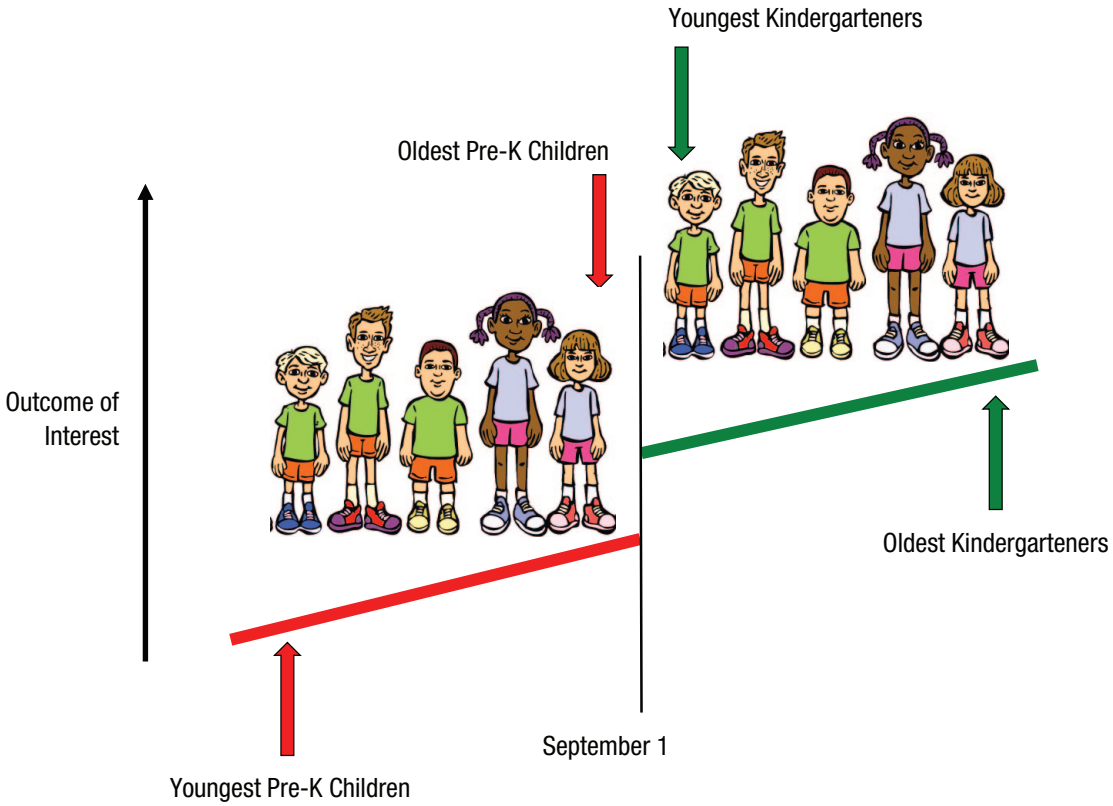

Fig. 1. Depiction of the school-cutoff (SC) method and regression-discontinuity design (RDD). In this example, children must be 5 years of age on or before September 1 to be eligible to enroll in school. By comparing outcomes between the two groups of children—who are virtually the same age but differ only in the schooling experiences they receive—researchers can draw valid inferences regarding the unique effect of schooling on children's outcomes. In the SC method, slopes are flat because the outcomes for children in each group are averaged together because sampling of children occurred in a narrow time window. In the RDD, the positive slopes within each grade indicate that the outcome improves with age. The jump at the cutoff reveals that kindergarten schooling is associated with better outcomes compared with same-age pre-K children, over and above the effect of chronological age.

of birth to determine eligibility for school enrollment (kindergarten or first grade). Using well-established quasiexperimental techniques and leveraging the natural experiment offered by the cutoff date, scientists have succeeded in isolating the unique contribution of schooling experiences to children's development across the transition to school. Employing these techniques, three insights on the effect of schooling on children's growth have emerged: (a) Schooling produces major, unique changes in children's growth across a wide range of psychological processes important for learning; (b) the effects of schooling are not universal across all aspects of literacy and mathematics and may depend on instructional and noninstructional influences; and (c) schooling impacts domain-general cognitive processes that are not explicitly taught but are important for academic skill development, as shown by evidence in both brain and behavioral studies.

Causal-Inference Techniques for Examining Schooling Effects

The school-cutoff (SC) method and the regression-discontinuity design (RDD) are two common types of natural experiments that have been frequently used to examine the causal effect of schooling on child outcomes. Figure 1 illustrates the methodology. In a typical implementation of the SC method, children with birth dates that cluster around the cutoff (typically, a 2- or 3-month window before and after the cutoff) are examined. Using a before–after design in which children are assessed in the beginning and the end of the school year, it is possible to examine differences in growth between older prekindergarten children and younger kindergarten children. Because these children are essentially the same age but differ only in their school experience, it is possible to attribute observed growth to experience in school. Our

research group has used this technique to demonstrate effects of schooling on academic, behavioral, and cognitive outcomes in early childhood (Burrage et al., 2008; Christian, Morrison, Frazier, & Massetti, 2000; Morrison, Smith, & Dow-Ehrensberger, 1995; Skibbe, Connor, Morrison, & Jewkes, 2011; Varnhagen, Morrison, & Everall, 1994).

RDD has also attracted attention from developmental psychologists and education researchers. Similar to the SC method, assignment to treatment (i.e., schooling) is determined by an individual's position on a date-of-birth scale relative to a cutoff point. Unlike the SC method, constraining the sample is not necessary. Accordingly, RDD allows the researcher to flexibly model the relation between the outcome and the age-based continuous scale. Our research group has used RDD to demonstrate that different grade-level schooling experiences exert differential effects on various dimensions of early literacy (Kim & Morrison, 2018) as well as electrophysiological measures of executive functions (Grammer et al., 2019). Other researchers have also used the technique to examine a range of child academic and behavioral outcomes (Gormley, Gayer, Phillips, & Dawson, 2005; Weiland & Yoshikawa, 2013; Wong, Cook, Barnett, & Jung, 2008). Table 1 provides a broad (but not exhaustive) summary of the empirical literature in which SC and RDD were employed to examine schooling effects on children's early literacy and mathematics skills and selected domain-general cognitive skills. Table 2 presents detailed information for the studies presented in Table 1.

Three Insights on the Effects of Schooling on Children's Development

Over the past three decades, numerous studies have been conducted to examine children's growth from preschool to early elementary school. The pattern of findings permits us to offer three insights about schooling as well as specific recommendations for future research.

Early schooling produces major, unique changes in children's growth across a wide range of psychological processes important for learning

As shown in Table 1, the majority of studies implementing SC and RDD have focused on foundational academic skills important in the early grades, such as literacy and numeracy. But other investigations have examined domain-general cognitive processes, including executive functions and verbal memory skills, as well as self-regulation (behavioral and emotional). Across domains, clear evidence of strong schooling effects has been revealed. Perhaps the most extensively investigated domain is reading, in which the effects of schooling emerge across many dimensions of reading skill, from basic letter recognition and writing, through early phonological processing, to more advanced comprehension skills. Importantly, a recent RDD investigation demonstrated that early schooling effects on literacy differ in magnitude depending on grade level and particular type of literacy skill. Specifically, decoding ability was uniquely predicted by pre-K, kindergarten, and first-grade schooling, whereas passage comprehension was predicted by kindergarten and first-grade schooling; no significant grade-level schooling effects were found on expressive vocabulary and sound awareness (Kim & Morrison, 2018). These results reveal that instructional strategies should be tailored to children's developmental capacities as well as different trajectories of literacy-skill growth during the early grades. Future research will help explain how changes in schooling experiences interact with children's biological and social development across the elementary years to predict academic achievement.

Schooling effects are not universally demonstrated across all psychological processes and may depend on instructional and noninstructional influences

Table 1 reveals that a number of important cognitive skills are not shaped uniquely or consistently by schooling. Within reading, these include subsyllabic segmentation and vocabulary. For math, children's performance on conservation of number grew substantially from kindergarten to first grade; there was no evidence of a unique effect of schooling over that period. Finally, no schooling effects have been demonstrated for knowledge of syntactic constituents.

Initially, we assumed that the amount of instruction children received in different grades (e.g., more reading instruction in first grade than in kindergarten) was the primary mechanism underlying the schooling effect. Yet our early studies showed that the total amount of instruction alone did not explain the findings. Rather, we found that the impact of amount of instruction depended on children's language and reading skills (Connor, Morrison, & Katch, 2004); that is, there were Child × Instruction interaction effects on children's literacy achievement. Accumulating research shows these Child × Instruction interactions to be ubiquitous and causally implicated in growth of both literacy skills (Connor et al., 2013) and mathematics skills (Connor et al., 2018; Morgan, Farkas, & Maczuga, 2015). In a

Table 1. School- and Age-Related Effects From Research Using the School-Cutoff Method and Regression-Discontinuity Design During the School Transition Period

Domain and outcome	No. of studies	Grade-level schooling effect			Age-related effect
		Pre-K	Kindergarten	First grade	
Literacy					
Alphabet/letter recognition	2	10, ○	6, ○	⊘○	6, 10
Decoding	6	7, 8, 10, 11, 13, ○	8, 13, ○, ○, ○, ○	5, 13, ○, ○, ○, ○	5, 8, 10, 13
Expressive vocabulary	2	⊘⊘	○⊘	○⊘	10, 13
Knowledge of syntactic constituents	1	○	⊘	⊘	1
Passage comprehension	1	⊘	13	13	13
Phonemic segmentation	2	○○	○⊘	4, 6	4, 6
Print awareness	1	9	○	○	
Reading recognition	1	○	6	6	6
Receptive vocabulary	3	9, 11, ○	⊘○○	⊘○○	6
Sound awareness	1	⊘	⊘	⊘	13
Spelling	1	7	○	○	
Story production: structural complexity	1	○	2	2	2
Story recall: causal relations	1	○	2	⊘	⊘
Story recall: overall amount of recall	1	○	⊘	⊘	2
Subsyllabic segmentation	2	○○	○⊘	⊘⊘	4, 6
Syllabic segmentation	1	○	⊘	⊘	⊘
Numeracy					
Conservation of number	1	○	⊘	⊘	3
Math	5	7, 9, 11, ○, ○	⊘○○○○	5, 6, ○, ○, ○	5, 6
Mental arithmetic	1	○	3	3	⊘
Domain-general cognitive skills					
Executive functions	1	○	○	12	12
Executive function: cognitive flexibility	1	11	○	○	
Executive function: inhibitory control	4	8, 11, ○, ○	⊘○○○	13, 15, ○, ○	8, ⊘
Executive function: working memory	2	8, 11	8, ○	○○	8
Fluid intelligence	1	○	○	14	14
Sentence memory	1	○	⊘	1	
Short-term verbal memory	1	○	○	4	⊘
Strategic memory	1	○	○	4	⊘
Other					
Behavioral regulation	1	⊘	○	○	10
Emotion regulation	1	11	○	○	
General information	1	○	⊘	6	6

Note: Information on age-related effect is included only if the article explicitly reported or strongly inferred the presence or absence of such an effect. In the four effect columns, numbers refer to the studies identified in Table 2. Symbols indicate that the grade-level schooling effect was not examined (○) or was examined but not found to be significant (⊘). One symbol or number is given for each study that investigated the outcome described in that row.

series of randomized controlled trials, using Assessment to Instruction (A2i) technology, we found that when instruction was specifically individualized (or personalized or differentiated) to account for these Child × Instruction interactions, children's literacy and mathematics achievement were greater than those of their peers in control classrooms. Moreover, the effects on literacy accumulated from first through third grade to yield increasingly large effects (d = 0.76) on children's achievement by the end of third grade (Connor et al., 2013).

Focusing classroom observations on individual students within classrooms (rather than on more global characteristics of the classroom), coupled with a multidimensional conceptualization of instruction, has been crucial to understanding schooling effects (Connor et al., 2009). Dimensions include the structural organization of the classroom (i.e., class size, teacher qualification) and the global quality of the classroom learning environment (i.e., teacher warmth and responsiveness, classroom organization). These foundational dimensions are necessary but not sufficient to ensure student

Table 2. Studies That Investigated School- and Age-Related Effects Using the School-Cutoff (SC) Method and Regression-Discontinuity Design (RDD) During the School Transition Period

Study and outcome	Method	Sample size	Grade-level schooling effect			Age-related effect
			Pre-K	K	First grade	
1. Ferreira and Morrison (1994)	SC	48				
Sentence memory			○	⊘	✓	
Knowledge of syntactic constituents			○	⊘	⊘	✓
2. Varnhagen, Morrison, and Everall (1994)	SC	79				
Story recall: overall amount of recall			○	⊘	⊘	✓
Story recall: causal relations			○	✓	⊘	⊘
Story production: structural complexity			○	✓	✓	✓
3. Bisanz, Morrison, and Dunn (1995)	SC	56				
Mental arithmetic			○	✓	✓	⊘
Conservation of number			○	⊘	⊘	✓
4. Morrison, Smith, and Dow-Ehrensberger (1995)	SC	20				
Short-term verbal memory			○	○	✓	⊘
Strategic memory			○	○	✓	⊘
Phonemic segmentation			○	○	✓	✓
Syllabic segmentation			○	⊘	⊘	⊘
Subsyllabic segmentation			○	○	⊘	✓
5. Morrison, Griffith, and Alberts (1997)	SC	539				
Decoding			○	○	✓	✓
Math			○	○	✓	✓
6. Christian, Morrison, Frazier, and Massetti (2000)	SC	89				
Alphabet/letter recognition			○	✓	⊘	✓
Phonemic segmentation			○	⊘	✓	✓
General information			○	⊘	✓	✓
Math			○	⊘	✓	✓
Reading recognition			○	✓	✓	✓
Syllabic segmentation			○	⊘	⊘	⊘
Subsyllabic segmentation			○	⊘	⊘	✓
Receptive vocabulary			○	⊘	⊘	✓
7. Gormley, Gayer, Phillips, and Dawson (2005)	RDD	1,567				
Spelling			✓	○	○	
Decoding			✓	○	○	
Math			✓	○	○	
8. Burrage et al. (2008)	SC	45				
Decoding			✓	✓	○	✓
Executive function: inhibitory control			✓BE	⊘	○	✓BE
Executive function: working memory			✓BE	✓BE	○	✓BE
9. Wong, Cook, Barnett, and Jung (2008)	RDD	720—2,072[a]				
Receptive vocabulary			✓	○	○	
Print awareness			✓	○	○	
Math			✓	○	○	
10. Skibbe, Connor, Morrison, and Jewkes (2011)	SC	76				
Alphabet/letter recognition			✓	○	○	✓
Decoding			✓	○	○	✓
Expressive vocabulary			⊘	○	○	✓
Behavioral regulation			⊘	○	○	✓BE

(continued)

Table 2. (Continued)

Study and outcome	Method	Sample size	Grade-level schooling effect			Age-related effect
			Pre-K	K	First grade	
11. Weiland and Yoshikawa (2013)	RDD	2,018				
Decoding			✓	○	○	
Receptive vocabulary			✓	○	○	
Math			✓	○	○	
Executive function: cognitive flexibility			✓BE	○	○	
Executive function: inhibitory control			✓BE	○	○	
Executive function: working memory			✓BE	○	○	
Emotion regulation			✓	○	○	
12. Brod, Bunge, and Shing (2017)	SC	60				
Executive functions			○	○	✓BE	✓
Executive function: inhibitory control			○	○	✓BR	⊘
13. Kim and Morrison (2018)	RDD	334				
Decoding			✓	✓	✓	✓
Passage comprehension			⊘	✓	✓	✓
Sound awareness			⊘	⊘	⊘	✓
Expressive vocabulary			⊘	⊘	⊘	✓
14. Zhang et al. (2019)	SC	91				
Fluid intelligence			○	○	✓	✓
15. Grammer et al. (2019)	RDD	617				
Executive function: inhibitory control			○	○	✓BR	⊘

Note: Information on age-related effect is included only if the results explicitly reported or strongly inferred the presence or absence of such an effect. Symbols in the four effect columns indicate that a grade-level schooling effect was present (✓), that the effect was found using a behavioral measure (✓BE; applicable only for executive-functioning outcomes), that the effect was found using a brain measure (✓BR; applicable only for executive-functioning outcomes), that this grade-level schooling effect was not examined (○), or that this grade-level schooling effect was examined but not found to be significant (⊘). K = kindergarten. [a]Sample size for this study varied by U.S. state.

achievement. At the level of instruction, the dimensions include content (literacy, mathematics), specific aspects of that content (e.g., literacy-code- and meaning-focused instruction), and setting (whole class, small group), as well as who is focusing the child's attention on the learning activity (teacher and child, child alone, peers). These dimensions operate simultaneously to define instruction for each child in the classroom. We have repeatedly found that learning opportunities vary significantly for students who share the same classroom.

Activities outside these dimensions are considered noninstruction, which can be productive (explaining classroom rules, transitioning between centers) or unproductive (students waiting in line). Accumulating research shows that unproductive noninstruction has a negative effect on children's learning (Day, Connor, & McClelland, 2015). We have also found that considering the foundational aspects of the classroom (i.e., quality of the classroom learning environment) together with amounts and types of instruction that each student receives predicts more of the variability in students' outcomes than either construct alone (Connor et al., 2014). Taken together, these findings highlight the importance of discrete mechanisms in classrooms that affect the magnitude of schooling effects on children's learning.

Finally, the inconsistent effects of schooling on vocabulary merit additional attention. For example, it is common for curricular guidelines to highlight the importance of vocabulary instruction in the early elementary grades. Yet, in recent years, evidence has accumulated that vocabulary instruction during early schooling is sparse and unsystematic and focuses on single, brief word explanations (Nelson, Dole, Hosp, & Hosp, 2015; Wright & Neuman, 2014). Of the five SC or RDD studies conducted to date that have examined schooling effects on vocabulary, three showed no effects. Interestingly, both studies that revealed a positive schooling effect examined receptive vocabulary, not expressive vocabulary, and the state pre-K programs examined in both studies either had higher quality program standards (Wong et al., 2008) or implemented

a literacy and language curriculum that emphasized vocabulary instruction to a greater degree than is typical in the early grades (Weiland & Yoshikawa, 2013). These contrasting results may hold an important key to the underlying causes of the schooling effects observed to date and indicate that greater attention is needed in understanding classroom and school characteristics that interact with children's development. Observational assessments as well as measures of implementation could be used in future studies to examine how the broader instructional context predicts growth in literacy and math skills.

Schooling effects have been demonstrated for domain-general cognitive processes that are not explicitly taught, and some effects have been found at the neurobiological level

Research has increasingly focused on the potential influence of schooling effects on the developing brain, particularly the cognitive processes that support learning and academic achievement. The development of executive functions, which include the ability to pay attention, inhibit inappropriate behaviors, and follow multistep directions, has been of particular interest to researchers focused on children's development. Complementary research from developmental cognitive neuroscience using event-related potentials (ERPs) and functional MRI (fMRI) revealed that early childhood experiences (e.g., growing up in poverty) predict differences in brain development in regions that support executive functions, such as the prefrontal cortex.

We have recently employed RDD to examine the causal impact of classroom experience on electrophysiological and behavioral markers of executive functions. We have found differences in the magnitude of two ERP components—the error-related negativity and error positivity, which each reflect different aspects of attention and response monitoring (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring, Goss, Coles, Meyer, & Donchin, 1993; Overbeek, Nieuwenhuis, & Ridderinkhof, 2005)—as a function of different classroom experiences (Grammer et al., 2019). Interestingly, differences in children's accuracy and reaction time—key behavioral markers of performance—were not observed as a function of schooling. Our results suggest that schooling might impact neural function before it is possible to observe changes in behavior. These results largely mirror separate findings using the SC method and fMRI, in which a greater increase in activation of right posterior parietal cortex—a brain region associated with sustained attention—was observed in children who completed first grade than in children who had completed kindergarten (Brod, Bunge, & Shing, 2017). Taken together, these findings provide evidence for the importance of incorporating neuroscience methods to examine the causal impact of schooling. Further, the practical implications of these findings may prove equally profound: Finding schooling effects on the brain before they appear in behavior could pave the way for earlier detection and diagnosis of learning problems well before they manifest overtly.

Sensitivity of general cognitive skills to early schooling also raises the intriguing possibility of indirect effects of schooling stemming from mediational influences of academic skills on general cognition. Indeed, Stanovich (1986) argued that reading activity in later childhood enriches vocabulary growth and comprehension skills; recent research supported this conjecture (Connor et al., 2016). There is additional evidence that noninstructional activities in the classroom may impact children's working memory and attention control through better classroom organization and management by the teacher (Cameron, Connor, & Morrison, 2005; Cameron, Connor, Morrison, & Jewkes, 2008). Clearly more research is warranted on possible bidirectional relations between domain-specific academic skills and more domain-general cognitive and emotional processes in shaping children's growth over the school transition.

Conclusion

Advances in quasiexperimental approaches such as the SC method and the RDD, as well as increasing attention to examining changes in both children's brains and behavior during the school transition period, have begun to yield a body of evidence indicating that schooling exerts meaningful influences on a range of children's academic, behavioral, and cognitive functioning. Findings from investigations of schooling effects highlight the complex, multilevel, interactive nature of the forces shaping human developmental trajectories, providing a blueprint for developmental studies more generally. Schooling effects are not uniform even during the early schooling years—in fact, these effects depend on important contextual factors, such as classroom and instructional characteristics, that can attenuate or magnify the positive impact of schooling. With the growing trend toward interdisciplinary research that melds multiple levels of analysis—brain, behavior, and context—future investigations will continue to yield valuable information regarding how schooling benefits children in different contexts and areas of functioning, with the potential to inform both policy and practice.

Recommended Reading

Cahan, S., & Cohen, N. (1989). Age versus schooling effects on intelligence development. *Child Development*, *60*, 1239–1249. One of the first empirical articles to utilize the school-cutoff technique to disentangle age and schooling effects on child outcomes.

Lipsey, M. W., Weiland, C., Yoshikawa, H., Wilson, S. J., & Hofer, K. G. (2015). The prekindergarten age-cutoff regression-discontinuity design: Methodological issues and implications for application. *Educational Evaluation and Policy Analysis*, *37*, 296–313. doi:10.3102/01623737028002153. Describes common threats to internal validity in prekindergarten age-cutoff regression-discontinuity designs and offers potential solutions.

Miller, P., Henry, D., & Votruba-Drzal, E. (2016). Strengthening causal inference in developmental research. *Child Development Perspectives*, *10*, 275–280. Provides a summary of commonly used causal-inference methods in developmental science and a discussion of how to strengthen internal validity.

Action Editor

Randall W. Engle served as action editor for this article.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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