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Childhood disadvantage, neurocognitive development and neuropsychiatric disorders: Evidence of mechanisms

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Abstract

Purpose of review—Children living in socioeconomically disadvantaged households have excess risks of neurodevelopmental and neuropsychiatric problems. The purpose of this review is to synthesize evidence for mechanisms that may contribute to these excess risks.

Recent findings—The majority of the 60 studies included in our review focused on children's neurocognitive development and behavioural problems. About half conducted mediation analyses of factors in the family and neighbourhood environments, including access to resources (e.g. cognitive inputs within the home environment) and exposure to stressors (e.g. negative parenting practices), as well as neurobiological embedding of childhood disadvantage. In addition, many studies conducted moderation analyses of factors that were hypothesized to interact with (i.e. exacerbate or mitigate) the harmful effects of childhood disadvantage.

Summary—Many of the factors that contribute to the excess risk of neurodevelopmental and neuropsychiatric problems among children in disadvantaged households are potentially modifiable (e.g. cognitively stimulating materials, parental language input, cultural resources, parental stress and psychopathology, negative parenting, neighbourhood violence). If their causality is ultimately established, they could be targets for the prevention and reduction of disparities. The continued search for mechanisms should not detract from work to reduce and hopefully eliminate children's exposure to disadvantage.

Keywords

children; mechanism; mental health; neurodevelopment; socioeconomic disadvantage

INTRODUCTION

Children raised in socioeconomically disadvantaged households carry with them into adulthood a heightened vulnerability to multiple forms of psychopathology, including

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depression, bipolar disorder, psychosis and anxiety disorders, and a heightened risk of comorbidity between psychiatric disorders [1–8]. Given that adult psychiatric disorders tend to be preceded by psychiatric disorders in childhood [9,10], that psychopathology has a strong neurodevelopmental basis and is influenced by cognitive development during childhood [11–13], and that early life conditions [14–17] can adversely impact neurodevelopment, it is important to pursue an improved understanding of the *mechanisms* underlying the long-term vulnerability not only to psychopathology following childhood disadvantage, but to children's neurocognitive development as well. Our review sought out the most recent evidence for such mechanisms.

Mechanistic research has the potential to identify targets for interventions designed to reduce socioeconomic disparities. There are a range of likely mechanisms that underlie the consistent association between lower socioeconomic status (SES) and psychopathology [18■], particularly psychopathology during childhood [19,20]. In the context of material hardship, children are often exposed to food insecurity, lack of healthcare, and unstable or low-quality housing [21–23], which may reduce the availability of social and cognitive stimulation that scaffolds children's cognitive development [24,25]. In the context of low SES, there is also a heightened risk of exposure to adverse childhood experiences ranging from domestic violence and family conflict to parental separation, harsh parenting, and parental mental illness, with enduring impacts on nearly all aspects of health [26].

Effects of childhood disadvantage are likely to be pervasive across developmental systems, to be environmentally mediated [27■,28], and to manifest as both subtle variations in normative development – including language, executive function, academic performance and behavioural problems – in addition to frank psychopathology. Therefore, our review covers the most recent studies to evaluate candidate mechanisms underlying socioeconomic disparities in children's neurocognitive development and in neuropsychiatric disorders.

MATERIALS AND METHODS

We searched PubMed (NLM) and PsycNet (APA) on 18 November 2020, for English language studies published from 1 October 2019. We developed a broad set of keywords and controlled vocabulary terms that captured the domains of socioeconomic circumstances, infancy and childhood, and neurocognitive development and psychiatric disorder (Supplemental Table 1, http://links.lww.com/COOT/A7). We included studies that quantitatively assessed mechanisms underlying associations between childhood (approximately ages 12 or younger) disadvantage and neurocognitive development or mental health. We used a broad view of quantifying mechanisms that captured both traditional mediation analyses [29] as well as studies that examined synergistic, or interactive, effects of putative mechanism [30], the rationale being that a factor that enhances or reduces the effects on development of socioeconomic disadvantage is operating as a mechanism and could in theory be a target for reducing disparities.

After combining the PubMed and PsycNet results into a single Endnote library and eliminating duplicates, we screened the titles and abstracts of 1310 articles to identify studies that potentially met our inclusion criteria. We then reviewed the full text of 340

articles to determine the final set of studies (n = 69) for our review (see Supplemental Figure 1 for the flowchart of study selection process, http://links.lww.com/COOT/A7).

RESULTS

Our presentation of the 60 empirical studies included (Table 1) is organized around the broad categories of mechanisms that have been examined underlying the neurocognitive and neuropsychiatric effects of being exposed to disadvantage early in life.

Pathways of Risk

Studies that tested hypotheses about mechanisms focused on three broad categories, as depicted in Fig. 1: less family and community resources (e.g. cognitive stimulation and cultural resources), more family and community stressors (e.g. family conflict, harsh parenting and neighbourhood crime), and (3) neurobiological systems in stress responsivity and children's brain development [31■].

Family and community resources

Several studies found that less enrichment of the home environment and lack of positive parenting contributed to socioeconomic disparities in multiple domains of cognitive development (e.g. memory-guided attention, language, reading and math skills) [32–34, 35■,36■,37,38■■]. Results from these studies suggest that quality of the home physical environment, access to books, quantity and complexity of adult language input, parental educational support, parenting self-efficacy and parental involvement may be candidates for interventions to reduce disparities.

Similarly, resources within the family environment such as cognitive stimulation and parental language input were evident in mediating SES effects on domain-specific cognition (i.e. self-regulation and executive function) [34,39,40■]. Votruba-Drzal *et al.* [38■■] examined community resources in addition to family investment, and found that less cultural resources and cognitive stimulation both contributed to income disparities in children's executive function. Cognitive stimulation also played a mediating role in the association between socioeconomic disadvantage and children's behavioural problems [39,41■■].

Family and community stressors

Stressors within the family and community environments that are associated with child executive function and academic performance are disproportionately represented in disadvantaged families. These include child-caregiver conflict, maternal psychological stress, less parental warmth and sensitive support, corporal punishment, neighbourhood disadvantage and neighbourhood violent crime [38■■,42–44].

Evidence for pathways leading to mental health problems was inconsistent across studies, even though mental health problems, including attention deficit hyperactivity disorder (ADHD) and internalizing and externalizing problems, were almost uniformly more common among disadvantaged children. Parental psychiatric disorder was not a mediator of socioeconomic disparities in ADHD [45■■], but parental depression partially explained

socioeconomic disparities in internalizing problems [41■■]. Harsh discipline, less parental warmth and neighbourhood crime each contributed to disparities in children's behavioural problems [38■■,39,46■■,47■,48■■].

Several studies are notable for having examined sequences of pathways linking disadvantage to neurodevelopment and neuropsychiatric conditions (i.e. 'serial mediation'). Totsika *et al.* [48■■] found that family poverty was associated with increased parental psychological distress at 9 months, which then was associated with more adversarial parenting between 3 and 5 years, and in turn, more hyperactivity and conduct problems at 7 years. Zhang and Han [41■■] reported that parental depressive symptoms and cognitively stimulating materials existed along pathways underlying the association between socioeconomic disadvantage and internalizing problems. Relatedly, other studies integrated mediation and moderation mechanisms together. Ugarte *et al.* [46■■] examined how pathways to externalizing problems involved interacting sets of risk factors reflecting both economic disadvantage and parental mental health, leading to less emotional responsivity or more harsh parenting, and in turn, more externalizing problems. These studies illustrate the principle that multiple chains of events involving pathways of risk across domains link environmental exposures to later health across development stages [49–52].

Neurobiological embedding

The early environment, as early as the prenatal period [20,53–56,57■] and possibly preconception [58■], is crucial for neurocognitive development as well as brain health throughout the lifespan [7]. Therefore, processes that underlie the connection between environmental experiences and the developing brain should play a role in the neurobiological embedding of socioeconomic disparities [57■,59–65]. Immune activity is one such process: prenatally, maternal immune activity is influenced by stressors including low SES [59–61] and has been linked with offspring neurodevelopment as well as long-term risk for neuropsychiatric disorders [62–65]; during childhood, concentrations of inflammatory markers show consistent elevations in the context of low SES [57■]. There were two studies in our review on immune activation. Yu *et al.* [66] found that lower family SES was associated with lower concentrations of the pro-inflammatory cytokine interleukin-8 in mothers during pregnancy, and this was partly responsible for lower child self-regulation at age 4. Kokosi *et al.* [67■■] assayed inflammation during childhood and found that greater financial difficulties between 0 and 3 years of life were associated with concentrations of interleukin-6 at 9 years, and in turn, worse working memory at age 10.

Other studies directly examined brain development [68,69■]. Cantiani *et al.* [68] focused on neuronal oscillatory activity in infants; they found that higher parental occupation was associated with more positive central EEG gamma power at 6 months and in turn better child language development at 24 months. Raffington *et al.* [70] is one of many studies documenting neuroanatomical correlates of the social environment; they found that household income was associated with higher hippocampal volume in children between 6 and 9 years old. They also investigated whether this difference in hippocampal volume was a mediator of SES disparities in child memory; it was not. In contrast, Merz *et al.* [71] found in a cross-sectional study that cortical surface area (notably in the perisylvian region) was

involved in the association between parental education and lower reading skills in children at 7 years. This was also the case for subcortical volume, which was a mediator of disparities in ADHD [72■], and brain connectivity for disparities in externalizing and internalizing problems [72■,73].

Further evidence of neurobiological (and neurodevelopmental) embedding is provided by studies showing that socioeconomic disparities in developmental deficits at one point in time (e.g. lower language skills and executive functioning) constitute pathways to disparities in later developmental deficits (e.g. low academic performance) [34,40■,74–77,78■,79]. These studies reinforce the importance of early interventions to interrupt the chain of developmental cascades that result from adversity, promote school readiness and reduce achievement gaps [80,81].

Synergistic Effects of Risks

The studies reviewed thus far investigated intermediate processes through which socioeconomic disadvantage exerts its negative impact on child development. SES also works synergistically with other environmental (and in one study, genetic [82■]) factors [83–85]. As Fig. 2 illustrates, the synergistic processes examined can both exacerbate the negative effects of socioeconomic disadvantage as well as provide resilience in the face of hardship.

Risk factors that exacerbate socioeconomic disadvantage

Children raised in disadvantaged households face multiple adverse conditions. For example, among children born 1990–1999 in Denmark, the combinations of poverty, parental unemployment and low parental education had superadditive effects on ADHD risk [45■■]. Studies identified a wide range of factors that exacerbated risks of developmental problems in the context of disadvantage: exposure to violence [86], negative perceptions of disadvantage [87], limited opportunities for educational activities [88], corporal punishment [89■■], harsh parenting [90], television exposure [91■] and receipt of financial assistance or social services [92■,93]. Broadly, the pattern that emerged in these studies was that in the context of disadvantage, the presence of these risk factors was associated with a higher risk of mental health problems and developmental deficits, whereas this association was either not found or was considerably weaker in more advantaged households. We also uncovered evidence that some factors disproportionately benefit higher SES children, effectively amplifying disparities [94, 95■■,96■■,97].

Protective factors that mitigate socioeconomic disadvantage

In contrast, there is evidence for protective factors that particularly benefit lower SES children; these can be thought of factors that if intervened on could reduce disparities. For example, Kirby *et al.* [98■■] found that the protective effect of maternal warmth on children's internalizing and externalizing problems was more pronounced in families reporting financial strain. Maternal social support was associated with greater neonatal brain volume [99], and self-esteem was associated with greater cortical thickness [100], in lower SES children. Those studies are observational, but experimental studies also suggest that interventions could be designed to benefit socioeconomically disadvantaged children.

A randomized trial of a spatial training intervention led to the largest improvements in cognitive test scores among low SES children [101■]. The renowned Perry Preschool Program had the largest and longest-lasting benefits on cognitive test scores among the most disadvantaged children [102■].

Intersectionality

Several studies in our review investigated racial/ethnic, sex/gender and age/developmental stage differences in the associations between early childhood disadvantage and children's subsequent risk of neurodevelopmental deficits and neuropsychiatric disorders [75,100,103–105,106■,107]. These studies highlight the importance of intersectionality theory in understanding disparities given that multiple social identities implicate the mechanisms described above, and often these mechanisms are reinforced in the context of multiple, marginalized identities and likely need to be addressed by interventions that aim to serve individuals exposed to disadvantage along multiple axes [108].

DISCUSSION

Our review sought to identify evidence for factors that could explain the increased risk of neurodevelopmental and neuropsychiatric problems associated with childhood disadvantage. This evidence is important both for advancing the science of disparities as well as for identifying intervention targets for reducing disparities and optimizing the timing of such interventions [109]. The majority of the studies included in our review addressed deficits in children's neurocognitive development rather than diagnosed psychiatric disorders, but given evidence for neurodevelopmental precursors to many forms of psychopathology, these studies have broad ramifications for psychiatric risk.

Our interpretation of the evidence that emerged from our review is that children raised in disadvantaged households face a constellation of risks, which can lead to nearly all types of developmental problems and ultimately most forms of mental disorders. There was no single pathway that emerged as prominent, nor any single pathway that could be rejected. Rather, the studies included in our review are collectively more indicative of effects that are pervasive and general than impacting specific pathways and endpoints. One implication is that in addition to raising the material living conditions of children, interventions that target intervening mechanisms would be expected to have wide-ranging benefits. Many of the factors identified are modifiable. Interventions targeting family investment (e.g. cognitively stimulating materials, parental language input) and reduction of toxic stressors (e.g. family conflict, parental depression, negative parenting) are examples. That said, most of the studies in our review examined single rather than multiple pathways simultaneously; therefore, we do not yet have sufficient evidence to determine the relative importance of distinct pathways. Those studies in our review that examined unique contributions of multiple pathways and how each pathway may operate differently under different circumstances present an important step in this direction [38■■,41■■,43].

There are several methodologic factors to note regarding the studies in our review. First, the measurement of disadvantage varied considerably across studies, and most studies used a single measure or a single composite measure of disadvantage. This approach simplifies the

complexity of children's environments and may obscure heterogenous etiologic processes. Sophisticated approaches to synthesize information on numerous aspects of a child's socioeconomic environment are needed to advance our understanding of how experiences shape development [96■■]. Second, the composition of the samples included in each study differs. As a result, 'more' or 'less' disadvantaged has different meanings across studies; some of the studies included diverse, general population samples whereas others included samples within narrow socioeconomic ranges. Third, longstanding tradition in developmental psychopathology calls for greater clarity in determining not only the presence or absence of risk factors (i.e. those that *increase* risk), but also the presence or absence of protective factors (i.e. those that *decrease* risk), especially in the context of disadvantage [110]. However, in many studies of factors that can exacerbate or reduce disparities, risk and protective factors might have been analysed interchangeably (e.g. considering lack of a protective factor to be a risk factor). Finally, although we selectively highlighted evidence of factors that interacted with socioeconomic disadvantage in ways that either exacerbated or reduced disparities, many other interactions tested in those studies were either nonsignificant [111] or went in opposing directions, reinforcing the illusive nature of interactions that most studies are underpowered to detect.

CONCLUSION

Research on the mechanisms underlying the neurodevelopmental and neuropsychiatric consequences of childhood disadvantage has the potential to transform policy and intervention efforts to reduce disparities over time and across generations. Much more work is needed, however, to establish the causality of hypothesized mechanisms and their applicability to diverse populations. Research on interventions to reduce childhood disadvantage should be pursued just as forcefully as research on interventions targeting pathways.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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KEY POINTS

- Increasingly more research seeks to understand mediating and moderating mechanisms linking socioeconomic disadvantage to neurocognitive and neuropsychiatric problems.
- Most of recent research has focused on language development, executive function, academic performance and behavioural problems, whereas less mechanistic research has examined neuropsychiatric disorders.
- Both family investment (particularly cognitive stimulation and parental language input) and stress (e.g. parental depression and negative parenting) processes contributed to socioeconomic disparities in neurocognitive and behavioural problems.
- More research is warranted on cultural and community factors, neurobiological embedding of childhood disadvantage and protective factors that help reduce socioeconomic disparities as well as the complex interplay of multilevel factors.

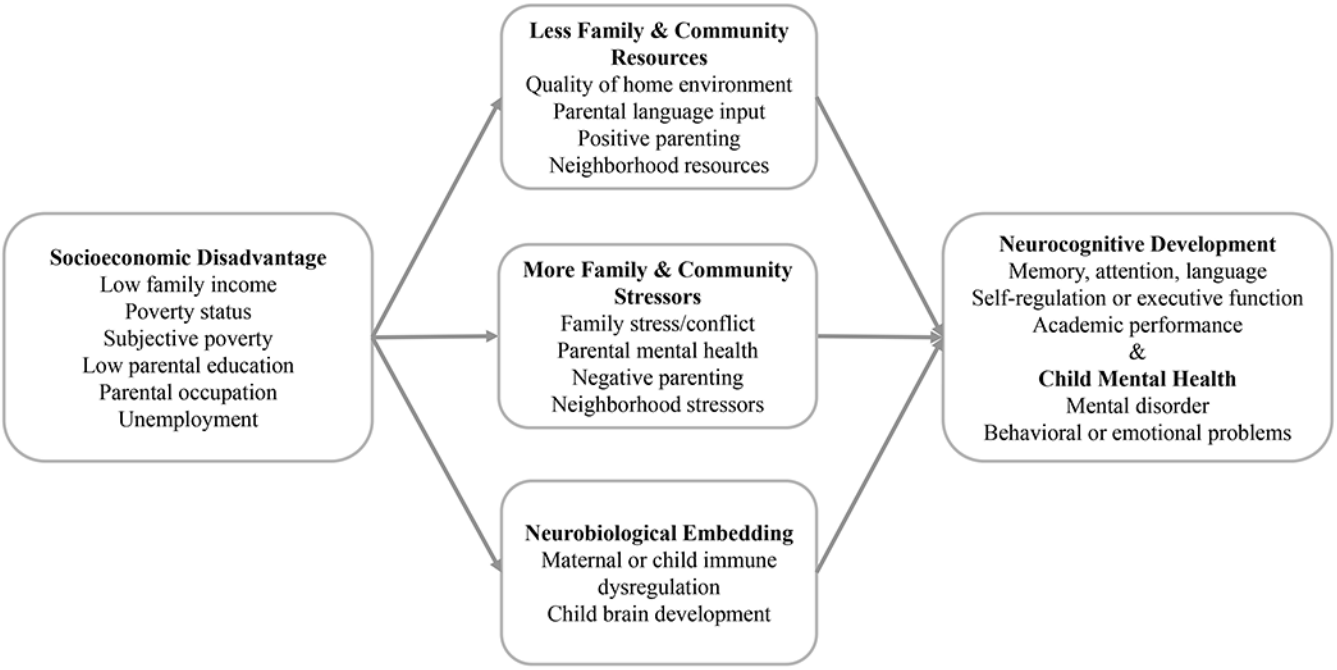

FIGURE 1.

Conceptual model depicting three primary mediating pathways examined in recent studies on mechanisms underlying excess risks of neurocognitive and neurodevelopmental problems among children raised in socioeconomically disadvantaged households. The major pathways included family and community resources (focusing on cognitive stimulation and parental language input) and stressors (mostly on negative parenting), and process contributing to the neurobiological embedding of socioeconomic disadvantage (focusing on inflammation and brain development).

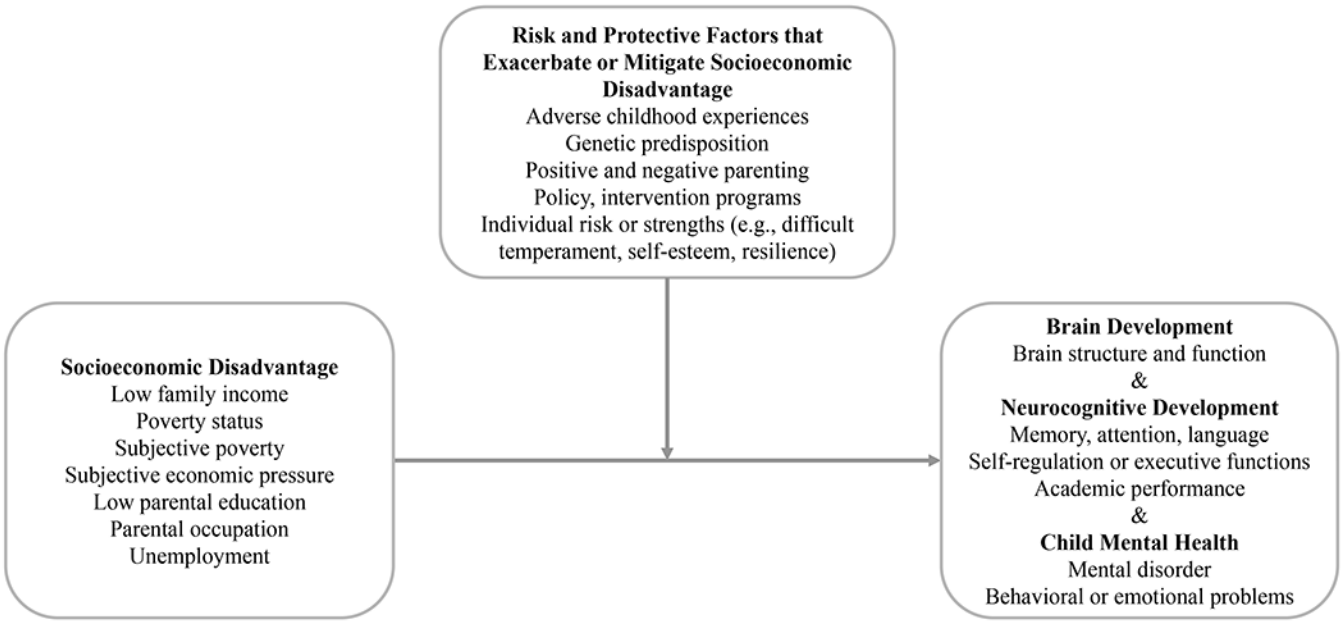

FIGURE 2.

Conceptual model depicting hypothesized moderating mechanisms that were examined in recent studies. These studies focused on risk factors that amplified the effects of socioeconomic disadvantage on child development and protective factors that differentially benefited children's development across SES levels.

Table 1.

Recent studies that examined mechanisms for neurodevelopmental and neuropsychiatric consequences of childhood disadvantage.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
Abraham et al. [82■]	Prospective study of 1,292 children in the Family Life Project in North Carolina and Pennsylvania, USA	Cumulative socioeconomic risk from 6 months to 3 years	COMT genotype (Met alleles vs Val Val alleles)	Attention Deficit Hyperactivity Disorder (ADHD), 1st to 5th grade	With higher cumulative SES risk, children with MET alleles had higher ADHD symptom severity in early and/or middle childhood compared to children with only Val-Val alleles.
Assari et al. [104]	Cross-sectional study of 9,380 9-10-year-olds from the Adolescent Brain Cognitive Development Study	Subjective family SES (financial difficulty in the last 12 months), parental educational attainment	Race (Black, White); Ethnicity (Latino or not)	Amygdala volume	Less financial difficulty was associated with amygdala volume in Whites (but not Blacks) and in non-Latinos (but not Latinos). Parental education did not interact with race/ethnicity to predict amygdala volume.
Assari et al. [104]	Cross-sectional study of 4,188 9-10-year-olds from the Adolescent Brain Cognitive Development Study in the U.S.	Subjective family SES (financial difficulty in the last 12 months)	Race (Non-Hispanic Black, Non-Hispanic White)	Attention (stop-signal task) and attention problems (CBCL)	Less financial difficulty was protective for NHW children, but there was no association between SES and task-based attention for NHB children.
Assari et al. [103]	Cross-sectional study of 9,390 9-10-year-olds in the US Adolescent Brain Cognitive Development Study	Subjective family SES (financial difficulty in the last 12 months)	Race (Black, White), ethnicity (Latino or not)	Hippocampus volume	Less financial difficulty was associated with greater hippocampus volume, but these effects were greater for White children (compared to Black children).
Baker et al. [39]	Prospective study of 640 African American children in the Head Start Family and Child Experiences Survey across the US	Socioeconomic disadvantage (poverty, low maternal education, and single parent status) at about 3 years	Parenting practices (warmth, control/rule enforcement, harsh discipline, cognitive stimulation) at about 3 years	Executive function (attention and impulse control) and behavior problems at about 4 years	Socioeconomic disadvantage was associated with less cognitive stimulation, less parental control, and more harsh discipline, all of which in turn predicted more child behavior problems. Cognitive stimulation also mediated the effect of socioeconomic disadvantage on child executive function.
Biazoli et al. [73]	Cross-sectional study of 655 children (6-14 years) in the High Risk Cohort Study for Psychiatric Disorders in Childhood in Brazil	SES (income, access to goods and services, and parent education)	Spontaneous brain activity measured by fractional Amplitude of Low Frequency Fluctuations (fALFF)	IQ, internalizing and externalizing behavioral and emotional problems	fALFF in the right superior temporal gyrus marginally mediated the association between SES and internalizing problems but was not associated with IQ or externalizing problems.
Bower et al. [101■]	Intervention study of 187 preschoolers (3-year-olds) in two northeastern U.S. states	Primary caregiver's educational level	Spatial training	Spatial ability, mathematics ability	A spatial training intervention was particularly beneficial for improving spatial and math abilities among low SES children.
Cantiani et al. [68]	Prospective study of 84 infants in Italy	SES (Hollingshead parental occupation) at 6 months	Brain network (Left central EEG gamma power) at 6 months	Expressive vocabulary and mean length of utterance at 24 months	Higher SES was associated with increased positive central gamma power which in turn predicted improved vocabulary scores in children.
Company-Cordoba et al. [86]	Cross-sectional of 185 children and adolescents (6-17 years with a mean of 11.82 years) from 3 low-SES schools in Guatemala	SES (parental years of education, family income-per-capita)	Exposure to violence	Depression and anxiety symptoms	Low parental education combined with high exposure to violence was associated with elevated depressive symptoms in children. SES did not moderate effect of exposure to violence on anxiety.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
Daneri et al. [40■]	Prospective study of 1,292 children in the Family Life Project, North Carolina and Pennsylvania, US	Composite measure of socioeconomic risk at 6 months	Maternal language input between 15-36 months; Child receptive vocabulary at 36 months	Executive function at 48 months	Higher socioeconomic risk predicted less quantity or quality of maternal language input at 24 and 36 months, which subsequently led to lower executive functions. Children's receptive vocabulary partially mediated association between SES risk and executive functions.
Dicataldo et al. [97]	Cross-sectional study of a school-based sample of 111 preschool children (mean age of 61.9 months) in Padua, Italy	Composite SES (parental education and household income)	Bilingual exposure (length of exposure, daily exposure)	Cognitive development (vocabulary, reasoning, theory-of-mind)	Greater bilingual exposure was associated with higher theory of mind for children from higher SES families. Bilingual exposure was associated with better cognitive skills regardless of family SES.
Duran et al. [42]	Prospective study of 343 children in the Southeast USA	Maternal education; Receipt of public assistance at 5 years	Family stress (financial strain, general stress, and child-caregiver conflict) at 5 and 7 years	Self-regulation (executive functions, delay of gratification) at 5 and 7 years	Maternal high school dropout and receipt of public assistance were associated with more family stress (financial strains, general stress, child-caregiver conflict), and in turn, lower child executive functions.
Ebert et al. [32]	Prospective study of 224 preschool children in Germany	Family socioeconomic status at age 3	Book exposure and quality of verbal interaction at age 3; Language skills at age 4	Language skills at ages 4; Theory of mind at age 5 years	Lower family SES was associated with less book exposure and lower quality of verbal interaction but only book exposure partly mediated the SES association with child language skills. Language skills fully mediated the association between family SES and theory of mind.
Ellefson et al. [75]	A cross-sectional study of 835 9-16-year-old (avg. age Hong Kong sample: 12.21, avg. age UK sample: 11.92) children and their parents in Hong Kong and UK	SES (parental education, occupation, family affluence)	Executive function (inhibition, working memory, cognitive flexibility, and planning); General cognitive ability	Numeracy skills	Executive function mediated the association between SES and numeracy among UK males (but not among females from either site or HK males). SES was associated with executive function and numeracy through general cognitive ability in UK children only.
Gialamas et al. [88]	Prospective study of 4,253 children in the Longitudinal Study of Australian Children birth cohort	Time spent in educational activities at ages 2-3	SES (weekly household income) at ages 2-3 years	Receptive vocabulary and conduct, hyperactivity problems at ages 4-5	Less time spent in educational activities and low income combined would be associated with elevated risk of lower receptive vocabulary and higher conduct problems and hyperactivity.
Gonzalez et al. [96■■]	Cross-sectional study of 8,158 9-10-year-old children in the Adolescent Brain Cognitive Development Study	Income-to-needs ratio	Composite measure of "bio-psycho-social ecologies" of child development	Cortical surface area, cognitive performance (reading and vocabulary), executive function	Results of a latent variable analysis of 22 indicators of a child's environment yielded three dimensions of a child's "bio-psycho-social ecology" that were beneficial for brain and cognitive development; however, low SES children only benefitted from the highest degree of overall enrichment.
Heberle et al. [87]	Cross-sectional study of 94 4-9 years old children in a community sample in Boston, USA	Socioeconomic disadvantage (including poverty, social exclusion, education, employment)	Perceived material and financial disadvantage and negative stereotyping	Behavioral and emotional functioning (Anxiety, Depression, Attention Problems)	Child's perceived disadvantage was associated with more attention problems and anxious-depressive symptoms, and child's negative stereotyping was associated with more attention problems, only in low SES families.
Hendriks et al. [28]	Cross-sectional study of 7-year-old 12,056 twin pairs in the Netherlands Twins Register and 9,	SES (parental education)	Heritability	Behavioral problems	The heritability (proportion of familial variance due to genes) of children's behavioral problems was higher in higher SES families.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
	822 twin pairs from UK Twins Early Development Study				
Henry et al. [106■]	Prospective study of 9,100 kindergarten students in the US Early Childhood Longitudinal Study (Kindergarten to Grade 8)	Race	Household income; Parental educational attainment	Academic achievement in math, reading, and science	White-Black achievement gaps became smaller as household income increased, whereas achievement gaps became larger as level of parental educational attainment increased.
Hines et al. [78]	Prospective study of 800 twin pairs in the Early Childhood Longitudinal Study-Birth Cohort (ECLS-B).	Birth weight	SES (maternal education at time of birth, household income at 9 months)	Math and reading scores, externalizing behavior at age 4	For parents with lower education, there was a stronger positive association between birth weight and their children's reading scores. With lower family income, birth weight was more strongly associated with decreased externalizing behavior.
Huang et al. [94]	Cross-sectional study of 486 Chinese students from Grade 4 to 8 (avg. age: 12; age range: 9-16 years)	Average family monthly income	Resilience	Emotion regulation	Positive association between family income and adolescents' emotion regulation was only present for adolescents who had higher resilience.
Keilow et al. [45■■]	Prospective study of 632,725 children in the Danish medical registry born between 1990–1999	Social disadvantage (income poverty, unemployment, low education) two years before child's birth	Parental mental health (substance use and psychiatric diagnosis) as mediator; Parental history of ADHD as moderator	ADHD diagnosis or treatment by age 18	Any combination of the two or more disadvantages resulted in larger risk of ADHD. Parents' mental health did not mediate effect of SES disadvantage on child ADHD. SES disparity in child ADHD was larger in families with no parental history of ADHD.
Khundrakpam et al. [100]	Cross-sectional study of 704 participants in the Pediatric Imaging, Neurocognition and Genetics (PING) study (avg. age: 12 years; age range: 3-21)	Parental occupation, family income, parental education	Self-esteem; Age	Brain structure (cortical thickness, surface area, and cortical volume	Higher elf-esteem related to higher cortical thickness and volume only in the low parental occupation group. Higher SES (esp. occupation and education) was related to greater cortical thickness, surface area, and cortical volume only in certain age groups (e.g., 7-16 years).
Kim et al. [90]	Prospective study of 102 infants, mothers, and fathers in Midwestern US	Unmanageable temperament at ages 2–3	Parents' power-assertive control (forceful discipline) at ages 4.5 and 5.5; SES (parental age, education, and family income) at 7 months as moderator	Disruptive behavior (sum of oppositional defiant disorder, conduct disorder, and overt aggression) at ages 6.5-8	Among low SES families (but not high SES families), child unmanageable temperament predicted more disruptive behaviors partly through mothers' and fathers' power-assertive control.
Kirby et al. [98■■]	Prospective study of 636 children in the Born in Bradford cohort, UK	Objective (up to date with their bills or not) and subjective (financial worry) financial difficulty during pregnancy	Maternal warmth at 24 months old	Mental health difficulties (conduct problems, hyperactivity/ inattention, emotional and peer problems) at ages 4-5	Maternal warmth was more strongly protective against children's mental health problems among families with objective financial difficulty. Subjective financial difficulty was not associated with child mental health problems.
Kokosi et al. [67■■]	Prospective study of 4,525 children in the Avon Longitudinal Study of Parents and Children, UK	Parents' perceptions of financial difficulties between birth and 3 years	Concentrations of interleukin 6 (IL-6) and C-reactive protein at 9 years	Working memory at 10 years	Children in households with greater financial difficulties had higher concentrations of the pro-inflammatory cytokine IL-6, and in turn, worse working memory.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
Kuhhirt et al. [91■]	Prospective study of 2,678 Scottish children in the Growing Up in Scotland Study	Parental education	Hours of television exposure between ages 2-4 years	Cognitive competence at 3 years and behavioral and emotional problems at 5 years	Television exposure was associated with more emotional and behavioral problems of children with lower educated parents but was associated with fewer emotional symptoms for children with higher educated parents and not associated with any cognitive outcomes.
Lecheile et al. [74]	Prospective study of 236 children enrolled at birth in the US Southwest	SES (parental education and family income) at 30 months	Effortful control between 30-54 months	Language ability at 54 months	Lower SES was associated with decreased child effortful control at 42 months, which in turn predicted lower language ability a year later, controlling for prior levels of effortful control and language ability.
Lee et al. [89■■]	Prospective study of 4,149 U.S. children in the Fragile Families and Child Wellbeing Study and supplemental In-Home Longitudinal Study	Income-to-poverty ratio	Maternal spanking between the ages 1 and 9	Externalizing behavior problems at ages 3, 5, 9	Maternal spanking had a more persistent association with children's behavioral problems over time among lower SES families.
Liu et al. [33]	Cross-sectional study of 2-3-year-old migrant and non-migrant children in Shanghai, China	Family SES (parental education and household income)	Parental involvement (e.g., daily care, learning activities) and parenting self-efficacy (e.g., play, nurturance, teaching, discipline)	Cognitive competence	Parenting self-efficacy and parental involvement (separately and sequentially) mediated associations of parental education with higher child cognition. Parenting self-efficacy also mediated associations of family income with child cognition.
Machlin et al. [72■]	Cross-sectional study of 874 children in the Pediatric Imaging Neurocognition and Genetics Study	Family SES (income, education, occupation)	Cortical thickness, surface area and subcortical volume	ADHD group (based on diagnosis or severe attention problems)	Lower SES was associated with smaller subcortical volume in the left and right cerebellum which in turn was associated with lower risk of ADHD.
Maguire et al. [112]	Cross sectional study of a community sample 90 low-income and high-income 10-11-year-old children in the US	Low income (defined as eligibility for free or reduced cost lunch)	Resting state EEG (alpha power, theta power)	Children's vocabulary and working memory	Lower resting state alpha power was associated with vocabulary scores (not working memory) only among low income children
Merz et al. [71]	Cross-sectional study of a community sample of 94 children 5 to 9 years of age in NY, USA	Parental education and income-to-needs ratio	Home linguistic input and language-related brain structure	Brain structure and reading skills	Parental education, but not income-to-needs ratio, was associated with greater parental language input, and in turn, larger left perisylvian cortical surface area. Cortical surface area further mediated the positive association between parental education and child reading skills.
Molloy et al. [111]	Prospective study of 3,790 children from birth cohort of the Longitudinal Study of Australian Children	Family socioeconomic position	Receipt of five social, health, and educational services from ages 0-5 years	Reading skills at ages 8-9	Higher service utilization was associated with improved reading scores, similarly for socioeconomically disadvantaged and non-disadvantaged children.
Mudrák et al. [37]	Cross-sectional study of 5,537 Czech fourth graders (10 years-old) in the Progress in International Reading Literacy study	Latent parental SES (highest education and occupation)	Parental resources (expectations, educational support, reading resources); Reading confidence and engagement	Reading literacy	Lower SES children had fewer parental resources and lower reading confidence, and in turn, lower reading literacy.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
Narea et al. [95■■]	Prospective study of 1,544 Chilean children (12-24 months old) in the Chilean Longitudinal Study of Early Childhood	Type of care (center-based vs. full-time home care) entered at 24 months	SES (family income, maternal education)	Cognitive outcomes at 36-48 months old	Children in lower income households had lower gains in cognitive test scores from receiving center-based care than children in higher income households. Center-based care was beneficial for child cognitive outcomes regardless of maternal education.
Nicolaou et al. [113]	Prospective study of 1,210 children in the Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development birth cohort study in Bangladesh, India, Nepal, Peru, South Africa and Tanzania	Socioeconomic conditions (mean water and sanitation, wealth and assets, maternal education, and household income) averaged over the first 24 months	Head circumference assessed monthly from first 2 weeks to 24 months	Cognitive function and gross motor development at 6, 15, and 24 months; language ability at 15 and 24 months	Socioeconomic conditions were positively correlated with cognitive function, gross motor, and language development but none of these associations were mediated by head circumference.
O'Connor et al. [93]	Prospective study of 42,619 Australian children in first grade	Maternal education	Additional developmental and health needs in the first year of school (at about 5 years)	Reading and numeracy in third grade (at about 9 years)	Children requiring additional developmental and health needs in school had reduced reading and numeracy scores, and this effect was stronger for socioeconomically disadvantaged children.
Padilla et al. [79]	Prospective study of 3,480 sibling pairs in the Child and Young Adult Supplement of the National Longitudinal Survey of Youth 1979	Infant temperament (about 12 months)	SES (maternal education and income-to-needs ratio) averaged over first five years of life; Parenting behaviors (averaged between 0-2 years old)	Internalizing and externalizing problems at 4-6 years (avg. age: 60.57 months)	Negative reactivity predicted more externalizing problems among children of mothers with low education. Negative reactivity predicted greater internalizing problems regardless of SES levels. Spanking predicted higher externalizing behaviors for children of mothers with high education.
Raffington et al. [70]	Prospective study of 142 children in Berlin, Germany	Household income	Hippocampal volume at 6-7 and 8-9 years	Memory ability at 6-7 years and 8-9 years	Lower income was associated with lower child memory and hippocampal volume, but hippocampal volume did not mediate SES disparities in child memory.
Ramphal et al. [69■]	Prospective study of 112 children born <30 weeks gestation in St. Louis, USA	Socioeconomic disadvantage at birth (public versus private health insurance)	Brain connectivity at birth	Internalizing and externalizing symptoms at 2 years	Lower SES children had more externalizing symptoms and lower behavioral inhibition, in part because of SES differences in neonatal brain connectivity.
Rosen et al. [114]	Prospective study of a community sample of 101 children in Seattle, USA	Income-to-needs ratio at 5 years	Quality of the home physical environment; Attention	Attention at 5 years; Academic achievement at 7 years	Lower income-to-needs ratio was associated with lower quality of the home physical environment (e.g., cleanness, safety), and in turn, worse memory-guided attention. Memory-guided attention contributed to income disparities in children's academic performance.
Rosen et al. [34]	Prospective study of a community sample of 101 children (60-75 months old) in Seattle, USA	Parental education and income-to-needs ratio at 5 years	Cognitive stimulation; Language exposure (mean length of utterance and number of different words); Executive functions at 5 years	Executive functions (working memory, inhibition, and cognitive flexibility) at 5 years; Academic achievement at 7 years	Higher income and parental education were concurrently associated with more cognitive stimulation and in turn higher executive functions. Parental education was additionally associated with inhibition through larger mean length of utterance. Lower family income-to-needs ratio was associated with worse working memory which in turn predicted lower academic achievement.

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
Shavlik et al. [76]	Prospective study of a community sample of 205 2-3-year-old children in Austin, USA	Maternal education	Early word learning skills	Receptive and expressive vocabulary	Maternal education was associated with better word learning skills, and in turn, more growth in child receptive and expressive vocabulary.
Spann et al. [99]	Prospective study of 37 American infants in a study of perinatal exposures on infant brain development	Parental socioeconomic status (parental education and occupation)	Social support (partner status) assessed during prenatal period	Neonatal brain structure	There appeared to be a synergistic effect between social support and low parental SES on neonatal brain structure in some regions.
Sullivan et al. [107]	Cross-sectional study of 180 children (mean age of 11.46 years) in a cohort of families with a history of parental depression	Cumulative SES risk (family income, public assistance, education, single parent, and teen parent)	Gender	Internalizing and externalizing problems	Girls from households with high cumulative SES risk had more self-reported internalizing problems and parent-reported externalizing problems, but these associations were not found in boys.
Swanson et al. [35■]	Prospective study of 96 children in the Infant Brain Imaging Study with and without familial risk for autism at 4 US sites	Maternal education	Home language environment at 9 and 15 months	Language skills at 24 months	Maternal education was associated with more adult words and conversational turn counts, and in turn, better language skills in children with and without autism.
Torvik et al. [27■]	Prospective study of 34,958 families in the pregnancy cohort study Norwegian Mother, Father and Child Cohort Study	Parental education	Genetic liability	Symptoms of ADHD, depression, and academic problems at age 8 years	Associations between parents' educational attainment and child symptoms of ADHD and academic problems were independent of shared genetic liability.
Totsika et al. [48]	Prospective study of 555 children with intellectual disabilities in the Millennium Cohort Study, UK	Poverty at 9 months	Parental psychological distress at 9 months; Adversarial parenting (frequent discipline, conflict in relationship, harsh parenting) and positive parent-child relationship at 3 or 5 years	Child behavioral problems at 7 and 11 years	Poverty was associated with increased parental psychological distress, and then increased adversarial parenting, which in turn, increased children's hyperactivity and conduct problems. Positive parent-child relationship was not a unique mediator of early adversity in the mutually adjusted model.
Ugarte et al. [46■■]	Prospective study of 8,860 children in the Chilean Longitudinal Study of Early Childhood	Clustering of risk (maternal education, poverty, teen mother, single mother, neuroticism, prenatal and postnatal depression)	Parenting (emotional support and harsh parenting)	Externalizing problems at 3 and 5 years	Low SES was associated with harsh parenting and lower emotional responsivity, and in turn, more externalizing problems. Less emotional responsivity partly mediated the combined effect of maternal depression and poverty, whereas harsh parenting fully explained the combined effect of father absence and poverty, on children's externalizing problems.
Vernon et al. [36■]	Prospective study of 1,292 children in the Family Life Project in rural US communities	Parental education	Maternal language quantity and complexity (6-36 months)	Latent construct of child language skills at pre-k and kindergarten	Maternal language quantity and complexity partially explained parental education related disparities in children's language skills.
von Stumm-2020 et al. [77]	Prospective study of 661 children in the Twins Early Development Study in England and Wales	Family SES at 18 months	Verbal and non-verbal cognitive ability at age 4.5 years	School performance at ages 7- 16 years	Higher SES led to higher verbal ability and non-verbal ability, which in turn led to better school performance at age 7 (though not changes between 7 and 16).
Votruba-Drzal et al. [38■■]	Prospective study of 17,600 children in the national Early Childhood Longitudinal Study-Kindergarten Cohort, USA	Household income between kindergarten to Grade 3	Community (cultural resources, service availability, neighborhood advantage; crime, air	Cognitive/ academic skills (reading and math), executive functioning, and	Lower household income was associated with children's cognitive skills, executive function, and externalizing problems via multiple indirect pathways and mostly through serial mediations:

Reference	Study Design and Sample	Exposure	Hypothesized Mechanism	Outcome	Major Findings
			pollution, neighborhood disadvantage) and family (parental warmth, cognitive stimulation, and corporal punishment) factors	externalizing problems at Grade 3	Income was associated with fewer neighborhood resources or more neighborhood stressors which were then associated with less cognitive stimulation or more corporal punishment, and ultimately more negative cognitive and behavioral development.
Vrantsidis et al. [43]	Prospective study of 151 children in the Midwestern Infant Development Study, Illinois and Nebraska, USA	Parental education and income-to-needs ratio (averaged across pregnancy, 6 months and 36 months)	Maternal psychological distress and cognitive stimulation at 36 months	Executive function at 36 months	Low parental education, but not income-to-needs ratio, was associated with more psychological distress, and in turn, lower executive functions in children. Cognitive stimulation was not a significant mediator.
Xie et al. [102■]	Prospective study of 123 children aged 3-4 in the Perry Preschool Program in Ypsilanti, MI	Socioeconomic disadvantage	Participation in the High/ Scope Perry Preschool Program at ages 3-4	Academic motivation (ages 6-7, 8-9) and cognition (ages 3-5, 7-9, 10-14)	The Perry Preschool Program had a stronger and longer-lasting effect on academic motivation and cognition for children who were the most socioeconomically disadvantaged.
Xu et al. [92■]	Prospective study of 267 children (mean age of 7 years old) in the National Survey of Child and Adolescent Well-being	Poverty and subjective economic pressure at each of 3 waves	Receiving financial assistance at each of 3 waves through (1) Temporary Assistance for Needy Families (TANF) or (2) Foster Care payments	Internalizing and externalizing problems at each of 3 waves	For children receiving financial assistance through TANF, poverty was more strongly associated with their externalizing problems but subjective economic pressure was less strongly associated with their internalizing problems.
Yu et al. [66]	Prospective study of 1,628 children in the US Collaborative Perinatal Project	Family SES (income, education, occupation)	Maternal inflammation during pregnancy	Self-regulation at 4 years	Concentration of maternal interleukin-8 during pregnancy partially mediated SES disparities in child self-regulation.
Yu et al. [44]	Prospective study of a community sample of 359 African American and Latino children in the Southwest US	Severe poverty from age 2.5 to age 7 years	Parenting sensitive support and intrusiveness at 2.5 years	Self-regulation (executive function) at age 3.5, 6, and 7 years	Lower maternal sensitive support (not intrusiveness) partially mediated the association between severe poverty and slower growth in self-regulation in Latino but not African American families.
Zhang et al. [41■■]	Prospective study of 9,250 children in the Early Childhood Longitudinal Study, Kindergarten Cohort, USA	Patterns of deprivation (on poverty depth, poverty spell, income volatility from Kindergarten to Grade 3)	Parental depressive symptoms, cognitive stimulation, parental school involvement, and punitive parenting styles at Grade 5	Internalizing behaviors at Grade 8	Parental depressive symptoms and cognitively stimulating materials (separately and sequentially) mediated the associations between deprivation classes and adolescent internalizing problems.
Zheng et al. [47■]	Prospective study of 710 kindergarten children in the Fast Track project in 4 U.S. sites	SES (Hollingshead: occupation and education) at Kindergarten	Parental warmth lability (within-person fluctuations from Kindergarten to Grade 5)	Externalizing & internalizing problems at Grade 7	Lower SES was associated with more fluctuations in parental warmth over time which in turn predicted more internalizing problems in girls (though not boys).

Note: Not all of the 60 studies were highlighted in the main text of the review.