

Integrating developmental neuroscience with community-engaged approaches to address mental health outcomes for housing-insecure youth: Implications for research, practice, and policy

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ARTICLE INFO

Keywords:

Early-life stress
Housing insecurity
Unpredictability
Community-engaged research
Policy

ABSTRACT

One in three children in the United States is exposed to insecure housing conditions, including unaffordable, inconsistent, and unsafe housing. These exposures have detrimental impacts on youth mental health. Delineating the neurobehavioral pathways linking exposure to housing insecurity with children's mental health has the potential to inform interventions and policy. However, in approaching this work, carefully considering the lived experiences of youth and families is essential to translating scientific discovery to improve health outcomes in an equitable and representative way. In the current paper, we provide an introduction to the range of stressful experiences that children may face when exposed to insecure housing conditions. Next, we highlight findings from the early-life stress literature regarding the potential neurobehavioral consequences of insecure housing, focusing on how unpredictability is associated with the neural circuitry supporting cognitive and emotional development. We then delineate how community-engaged research (CEnR) approaches have been leveraged to understand the effects of housing insecurity on mental health, and we propose future research directions that integrate developmental neuroscience research and CEnR approaches to maximize the impact of this work. We conclude by outlining practice and policy recommendations that aim to improve the mental health of children exposed to insecure housing.

1. Introduction

Across the globe, access to secure, affordable, and safe housing represents a critical social determinant of health and well-being for children and their families (Rolfe et al., 2020). It is estimated that 11 % of the national population—or approximately 37 million households—are currently experiencing housing insecurity (The State of the Nation's Housing 2020 | Joint Center for Housing Studies, 2023) and that nearly one in three children in the United States is living in a household burdened by housing costs (Dawson, 2020). For many children, insecure housing conditions such as overcrowding, frequent moves, and exposure to hazardous materials represent significant sources of early-life stress (Dunn, 2020). Empirical evidence suggests that youth exposed to housing insecurity face profoundly increased risks of developing physical and mental health challenges (E. Baker et al.,

2019; P. J. Fowler et al., 2014; Lepore et al., 1991). As such, examinations of the psychological and neurobiological correlates of exposure to early-life stress may shed light on potential neurobehavioral pathways linking exposure to housing insecurity with children's mental health. These findings can promote translation of developmental science to both inform intervention and service needs, and motivate structural change for youth exposed to housing insecurity. However, optimally translating scientific discovery to improve the health of youth exposed to housing insecurity requires that researchers carefully consider context throughout the research process. Feedback and engagement from community members with lived experience is critical to accessing and thoughtfully integrating such context. This integration will ultimately improve efforts to understand and target the role of complex structural issues in youth mental health.

In the current review, we begin by centering structural inequities,

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<https://doi.org/10.1016/j.dcn.2024.101399>

Received 30 December 2023; Received in revised form 16 March 2024; Accepted 30 May 2024

Available online 5 June 2024

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such as structural racism, as key factors that create and exacerbate racial and ethnic disparities in housing insecurity. We then provide a brief summary of the range of stressful experiences that children may face when exposed to issues with housing design, maintenance, and affordability. Next, we harness multiple lenses through which to document the consequences of housing insecurity for youth, and discuss how they can be addressed. First, we adopt a neurodevelopmental lens to review the potential effects of stressors related to insecure housing on the structural and functional development of corticolimbic regions, such as the prefrontal cortex (PFC), amygdala, and hippocampus. Given the unpredictable nature of housing insecurity, we specifically focus the current review on the hypothesized neural and cognitive processes by which children detect environmental unpredictability, as well as how unpredictable experiences may affect corticolimbic circuits that support cognitive and emotional development. Second, we adopt a community-based lens, in which we highlight how community-engaged research (CEnR) strategies have been used to understand the effects of housing insecurity on youth development. Third, we adopt an integrated, transdisciplinary lens to describe how CEnR approaches in developmental neuroscience research can improve outcomes for youth experiencing housing insecurity. Finally, we conclude the present review by adopting a practice-oriented and policy lens through which we highlight key implications for professional practice and policy change. Here, we make recommendations for policymakers, researchers, clinicians, designers and architects to both prevent and mitigate the harmful effects of insecure housing on youth mental health.

2. Why neuroscience?

Critically, we wish to highlight at the outset that housing insecurity is *not* a psychological or neurobiological issue. Rather, it is a sociohistorical issue caused and exacerbated by macro-level systemic factors such as social exclusion practices (Green and Hulme, 2005), racial and ethnic discrimination (Dickerson, 2020; see the Structural racism and housing inequity subsection), growing income inequality sustained by a hyperconcentration of income in the top 1 % of households (Hacker and Pierson, 2010), and inequitable opportunities for vocational, residential, and educational upward mobility (Pager and Shepherd, 2008). Just as racism, not race, contributes to racial and ethnic health disparities (Chadha et al., 2020), it is similarly the case that macro-level racist and classist practices and policies are the factors that may increase risk for mental health problems in youth and families facing housing insecurity.

What, then, should be the role of neuroscience research in discussions on housing insecurity? The causes, exacerbating factors, and ultimate solutions to housing insecurity are systemic, not individual. However, housing insecurity does exert significant effects on youth and family mental health, likely in part, through neurobiological systems that govern stress responding. Applying a neurodevelopmental lens to issues of housing insecurity has the potential to do two things. First, neurodevelopmental research can contribute to understanding of how insecure housing conditions impact psychological outcomes. These mechanistic findings can clarify specific service needs for youth and families facing housing insecurity, including what types of housing conditions are least and most optimal for child development. This may, in turn, inform directions that practitioners (e.g., architects and urban planners) and policymakers can take to support access to health-promoting environments. Second, neurodevelopmental research can contribute to ongoing conversations in a variety of fields (e.g., public health, social work, medicine) that aim to communicate research findings to motivate policymakers to implement comprehensive and effective legislation—and allocate federal funding—to eliminate housing insecurity in the United States. Critically, for research in developmental neuroscience to live up to this potential, it must comprehensively consider broader contextual factors. Until such context is considered and centered in our work, the contributions of neuroscience to practice and policy will be inherently limited. Engaging in the co-production of

knowledge with community members themselves allows for our research questions and outcomes to better align with the experiences and needs of youth and their families (Wallerstein, 2021). As such, a CEnR approach to neurobehavioral research on the developmental effects of housing insecurity has the potential to enhance health equity.

3. Structural racism and housing inequity

As noted above, disparities in mental health outcomes are inextricably linked to systems of inequity, such as structural racism. Structural racism is defined as the “macrolevel systems, social forces, institutions, ideologies, and processes that interact with one another to generate and reinforce inequities among racial and ethnic groups” (G. C. Gee and Ford, 2011; Powell, 2007). While research in the neurosciences has begun to consider how broader socioeconomic contexts, such as housing insecurity, affect brain structure and function (see Hackman and Farah, 2009 for a review), this work has largely ignored the central role that structural racism plays in creating and exacerbating racial and ethnic disparities in socioeconomic disadvantage (Webb et al., 2022). By not centering sociohistorical factors, such as structural racism, as being responsible for disparities in health outcomes, this unintentionally conflates racial and economic health disparities with biological differences. This conflation promotes harmful notions of race and class as biological constructs ((Cardenas-Iniguez and Gonzalez, 2023; Simmons et al., 2021). More so, the designation of characteristics and contexts, such as race and poverty, as risk factors for genetic, neural, and psychological difference, reifies skewed narratives that place the blame for these disparities in outcomes on individuals and families, instead of on larger systemic and structural forces (Carter et al., 2022; Wastell and White, 2017).

Racial disparities in housing and homeownership are the product of longstanding structural racism. The United States has a history of implementing racist policies and practices meant to limit Black people's access to homeownership and future wealth accumulation. Redlining was one such practice. The term “redlining” comes from the Home Owners' Loan Corporation (HOLC) categorization system in the 1930s. The HOLC characterized some neighborhoods as more “desirable” and some neighborhoods as “high risk,” which determined which residents would and would not be given access to mortgages. The “desirability” of a neighborhood was based almost entirely on race, since neighborhoods that were predominantly Black and immigrant were categorized as less desirable than predominantly white and non-immigrant neighborhoods, and were shaded red on maps (thus “redlining”) (Nardone et al., 2020). The color-coded maps were adopted by the private banking and mortgage industry, with many lenders deciding that no loan could be economically sound if the property was located in a neighborhood that was redlined (i.e., that was or could become populated by Black people) (Fishback et al., 2022). These practices, as well as other federal policies such as the Federal Housing Act of 1949 and the Federal Aid Highway Act of 1956, significantly limited Black homeownership, promoted racial segregation across neighborhoods, and contributed to a lack of federal investment in predominantly Black neighborhoods (Ware, 2021).

The effects of these racist government policies have persisted over the last half-century (Rothstein, 2017). A recent study showed that the wealth gap in racial inequality has hardly decreased since the 1950s (Derenoncourt et al., 2022). This study found that the ratio of the average white household home value to the average Black household home value has remained a consistent 2.5–1 since 1970. Currently, housing returns are 3.7 % lower for Black homeowners, and 2.0 % lower for Latinx homeowners than for white homeowners (Racial Differences in Economic Security: Housing, 2023). Indigenous families in the United States experience significant need for more federally-funded affordable housing on tribal lands, which has been chronically underfunded for decades, particularly in more rural and remote areas (Pindus et al., 2017). As a result of centuries of forced separation and genocide at the

hands of a colonial settler State (Pindus et al., 2017), approximately one-third (32 %) of Native households on tribal lands live in poverty, compared to 18 % of households nationwide. Tribal lands in the Plains, a largely rural region, have an especially high poverty rate of 41 % (Native American, 2022).

4. The psychological consequences of insecure housing

Though definitions vary, in the current review, we define housing insecurity as a lack of security in an individual residence due to a variety of factors including high housing costs relative to income, poor housing quality, unstable neighborhoods, and overcrowding. Though sometimes an antecedent to homelessness, housing-insecure conditions—which have been referred to as experiences of “hidden homelessness” (Bess et al., 2023)—encompass experiences in which individuals and families are not living in shelters or on the street, but instead are living in unaffordable, inconsistent, and unsafe residences. Despite the robust literature on the detrimental effects of housing conditions and homelessness on children’s physical health (for a review, see Gultekin et al., 2020), we focus our review on the relatively under-investigated effects of the range of experiences related to housing insecurity on children’s emotional, cognitive, and social development. We intentionally limit our review to the psychological impacts of stressors associated with exposure to housing insecurity, namely unaffordable, inconsistent, and unsafe housing conditions. We note that, due to the constraints of the present review, we have chosen not to delineate impacts of additional features that often co-occur or precede housing insecurity. For example, though low socioeconomic status often contributes to and/or co-occurs with housing insecurity, we largely focus our review on the effects of income as they relate to housing, given the unique impacts of housing-related unaffordability (Bess et al., 2023). Further, though the majority of our review focuses on housing insecurity in proximal dwellings (i.e., houses or apartment complexes), we acknowledge the inextricable link between housing and neighborhood conditions (Chambers et al., 2015) and therefore highlight several findings on the effects of neighborhood conditions on child mental health.

5. Unaffordable housing

5.1. Rates of exposure to unaffordable housing

Since 2012, the cost of rent in the United States has increased an average of 3.18 % per year, while average household income has not increased at a comparable rate (Bitton, 2023). In 2020, 31 % of children were classified as living in households burdened by housing costs—households in which more than 30 % of the family’s income was spent on housing (Dawson, 2021)—and in August 2023, mortgage rates surged to their highest in 21 years (Schmidt, 2023). These drastic increases in housing costs are a well-documented risk factor for psychosocial, socioeconomic, and physical health (Fowler et al., 2015; Stahre et al., 2015). Racial and wealth gaps in housing continue to uphold the deeply inequitable nature of the housing market. For example, in 2022, the homeownership rate for white households was 75 % compared to 45 % for Black households (Racial Differences in Economic Security: Housing, 2023). This inequity leaves low-income families and communities of color at heightened risk for exposure to insecure housing conditions (Dickerson, 2020).

5.2. Stress related to unaffordable housing

Systemic inequities, such as structural racism, place youth and families at increased risk for experiencing unaffordable housing conditions, and as a result, increased risk for exposure to certain stressors. A recent housing report from the Department of Housing and Urban Development (US Department of Housing and Urban Development (HUD), 2013) states that, “Paying one-half of a limited total income for

rent leaves very little income for essentials, such as food, medical care, transportation expenses, education, and childcare.” This degree of socioeconomic hardship, in which paying for housing comes at the expense of affording other basic necessities, is an impactful stressor for caregivers and their children and may be associated with a variety of mental health outcomes. For example, housing unaffordability is directly linked with lower child well-being (Clair, 2019; Harkness and Newman, 2005). Living in a more affordable housing market is correlated with higher parent mental health ratings for younger children (ages 6–11), and better mental health and behavior ratings for older children (ages 12–17; Leventhal and Newman, 2010). Housing affordability problems may also limit families’ housing options to neighborhoods that are zoned to lower-income and more highly segregated schools, which may suffer from significant disparities on a number of dimensions of school quality and pose risks to youth’s academic achievement and attainment (Holme, 2022). In addition, housing affordability problems (where housing costs are at or greater than 30 % of income) have been negatively associated with reading and math skills, as lower rent burdens may free up resources that families might spend on services or resources that improve such skills (Holme, 2022). One mechanism by which housing costs can impact child mental health and well-being is via parental stress. Warren and Font (2015) found that maternal stress mediated associations between housing unaffordability and risk for child abuse and neglect. Here, it was suggested that housing insecurity may play a unique role in maltreatment risk, above and beyond the association between poverty and maltreatment.

6. Inconsistent housing

6.1. Rates of exposure to inconsistent housing

Housing unaffordability is consistently linked with experiences of housing inconsistency (Lennon et al., 2016; Skobba and Goetz, 2013). Housing inconsistency, also referred to as residential mobility, is characterized by frequent moves due to factors such as changing household circumstances (e.g., changes in employment or family composition), housing quality failures, or evictions (DeLuca et al., 2019). Inconsistent housing may be a more common occurrence among low-income families, with 55 % of children in a sample of children from low-income families reporting having moved at least once in the past 3 years, exceeding the national average moving rate for families (Theodos, 2014). It is suggested that individuals and families with higher incomes may be more likely to use their economic privilege to secure a residence and location that best meets their social, occupational, and health-related needs, thus limiting their residential mobility (E. Baker et al., 2016). People and families with fewer resources may be more limited in their choice of housing early on, and may need to migrate to alternative locations more frequently to secure a residential environment that meets their needs (E. Baker et al., 2016). In addition to the quantity of moves, structural racism makes it more likely that racially marginalized individuals will experience negative moves (i.e., moving to a home that is similar or worse in terms of housing quality and safety) compared to positive moves (i.e., moving to a higher-quality housing unit or neighborhood) (Phinney, 2013).

Evictions—in which landlords communicate their intention to end a tenant’s lease—are one common reason for housing inconsistency. Evictions may occur for a variety of reasons, including the nonpayment of rent or rental unit health or code violations (C. Hartman and Robinson, 2003). Evictions can be unpredictable and sudden; in most states, landlords can file for evictions quickly (e.g., immediately after a late or partial rent payment) with little documentation and minimal fees (Leung et al., 2021). An average of over 3.6 million eviction cases are filed annually; between the years of 2000 and 2018, this amounted to 69.7 million evictions (Gromis et al., 2022). Households with children are more likely to experience evictions (Desmond et al., 2013; Ramphal et al., 2023), and structural racism contributes to Black and Latinx

families with children being overrepresented in eviction court dockets relative to other sociodemographic groups (Goplerud et al., 2021; Nelson et al., 2021).

Beyond the stress related to individual family evictions (Acharya et al., 2022), practices such as gentrification can affect both residential and community consistency. Gentrification occurs when an influx of people with a higher socioeconomic status move into historically low-income, often predominantly Black and Brown neighborhoods (Dragan et al., 2019). Nearly 20 % of neighborhoods with lower incomes and home values have experienced gentrification since 2000 (Gentrification in America Report, 2015), and gentrification has been linked to changes in neighborhood cultures, increases in both rents and the cost of daily living, and the displacement of long-term residents (Dragan et al., 2019). More so, due to structural racism, the consequences of gentrification on the residential mobility patterns of financially disadvantaged residents are unequally distributed by race. Families of low SES who are white and displaced by gentrification are more likely to move to more advantaged locations compared to Black families of low SES (Hwang and Ding, 2020).

6.2. Stress related to inconsistent housing

Previous studies have found that experiences of inconsistent housing, including multiple moves and evictions, represent unique stressors for youth and their families, and may be associated with a variety of developmental outcomes (Fowler et al., 2015). We note here that moving is often a normative part of a child's family experiences. However, frequent relocation (often from environments that do not meet basic needs for a family to housing of a similar or worse quality) has been linked with increased rates of depression and substance use in adolescents (Fowler et al., 2015), altered verbal and nonverbal skills in children (Fowler et al., 2015), and decreased child behavioral functioning across a broad range of measures (Mollborn et al., 2018). In terms of evictions, the current knowledge base on how evictions impact youth mental health is limited. One recent longitudinal study examining the impact of eviction on youth mental health from adolescence into young adulthood found that being evicted was associated with more depressive symptoms and worse self-rated well-being (Hoke and Boen, 2021).

There are several proposed pathways by which frequent moves and evictions may impact youth mental health. Psychosocial stress is a critical pathway by which eviction is associated with youth mental health; nearly one-fifth of the total effect of eviction on depression risk was explained by perceived social stress (Hoke and Boen, 2021). In addition, parental stress may represent another important pathway, with mothers who have experienced an eviction reporting higher rates of depression and parenting stress, and worse overall well-being for both the self and child (Desmond and Kimbro, 2015). The chaos of housing changes may also make it harder for caregivers to scaffold children's daily rhythms, as evidence by an association between multiple moves and difficulties implementing consistent nightly bedtime routines among toddlers (Bess et al., 2023). Frequent moves may also affect youth and family social development, such as by limiting opportunities to develop stable and meaningful relationships with peers in apartment buildings, neighborhoods, or schools (Pettit and McLanahan, 2003). Additional work has identified that these losses in relational social capital partially explain the association between residential mobility and declines in adolescent achievement (Leventhal and Newman, 2010; Pettit and McLanahan, 2003).

Going beyond individual moves and evictions, large-scale discriminatory housing practices have been linked with risk for mental health issues in Black youth. A recent study found that youth living in neighborhoods with lower social cohesion experienced greater internalizing symptoms and behaviors (Sadler et al., 2022). In particular, Black girls living in gentrifying neighborhoods reported lower perceived neighborhood cohesion, which in turn predicted elevated levels of

internalizing symptoms. As such, the unpredictable nature of inconsistent housing may represent a significant stressor for Black youth in particular, acting simultaneously on individuals, relationships, families, and entire communities.

7. Unsafe housing

7.1. Rates of exposure to unsafe housing

In addition to affordability and consistency, the safety of a child's immediate living environment is a central aspect of housing that has important implications for a child's development. Here, we define "unsafe" as the presence of conditions that may harm or disrupt a child's healthy mental and physical development, or the lack of conditions known to be adaptive and necessary for healthy development. Unsafe conditions in a residence, such as structural deficiencies, pests, mold, excessive heat/cold, overcrowding, or exposure to lead, can negatively affect a child's mental health (Cardenas-Iniguez et al., 2022; Cutts et al., 2011). According to the Joint Center for Housing Studies at Harvard University, "the lowest-income households ... accounted for the largest share of renters reporting overcrowded conditions and physical housing problems such as toilet breakdowns, exposed electrical wiring, heating equipment breakdowns lasting six hours or more and the presence of rats in the unit" (Lew, 2016). Furthermore, the report specifies that in 2013, 13 % of extremely low-income renters reported that the owner of their unit frequently did not start major repairs or maintenance on their residence quickly enough, compared to 6 % among higher-income renters. Overcrowding, often assessed using a ratio of persons per bedroom or room, has been shown to be more prevalent in Black and Latinx households (Pendall et al., 2012). Here, we differentiate between voluntary, multigenerational housing compared to forced overcrowding in family dwellings. More common in racial/ethnic minority households, multigenerational homes—in which extended family members live together and may participate in child rearing—have often been linked with positive outcomes for children in the home (United, 2021). Alternatively, forced overcrowding—often due to housing unaffordability and improper design of building complexes—may be a critical component of housing inequity.

7.2. Stress related to unsafe housing

Unsafe, unsanitary, and overcrowded housing conditions have been linked with worse emotional and cognitive outcomes for youth. Children exposed to indicators of unsafe housing, such as leaking roofs, rodents, peeling paint, and exposed wiring had more emotional and behavioral problems than those who lived in housing without these conditions (Coley et al., 2013). Overcrowding in particular can affect child outcomes by creating a home environment with constant overstimulation and a lack of privacy. Amongst youth, a lack of comfortable, quiet spaces is associated with difficulties studying for school, worries about living with unknown people, a lack of productive sleep, and increased conflict with siblings and caregivers (Lorentzen et al., 2023). Consistent with these findings, crowded housing conditions are negatively associated with math and reading achievement, and are positively associated with externalizing behaviors in children (Coley et al., 2013). In addition, overcrowding in homes has been associated with increases in caregiver stress and less responsive caregiving behaviors (Bradley and Caldwell, 1984). More recently, overcrowding in homes has also been linked with an increased risk of families contracting COVID-19 due to forced close proximities and limited spaces to quarantine (Kamis et al., 2021), which has been associated with increased stress and internalizing symptoms (Patel et al., 2020). Finally, beyond the immediate home environment, lower quality in neighborhood conditions—such as the lack of neighborhood amenities (e.g., a recreation center or playground) or poor physical characteristics (e.g., dilapidated neighborhood housing)—has been linked with childhood mental health, including an increased risk

for anxiety, depression, ADHD, and disruptive behaviors (Butler et al., 2012).

8. Summary

Overall, experiences of unaffordable, inconsistent, and unsafe housing have been linked with various emotional, cognitive, and social outcomes for youth and their families. Macro-level factors, such as policies and practices that promote structural racism, often create and exacerbate disparities in secure housing for racially and ethnically marginalized youth and their families. These disparities may cause acute and chronic strain on children's development. The literature to date has delineated pathways by which insecure housing conditions may impact youth development, including exposure to greater unpredictability and heightened caregiver stress, limited or inconsistent opportunities to engage in academic and social spaces, and reduced sleep and privacy. Still, the precise mechanisms by which insecure housing conditions may impact child mental health have remained largely unexplored.

9. The cognitive and neurobiological correlates of unpredictability related to insecure housing

Unpredictability is a critical element underpinning the stressors that youth experience related to housing insecurity. While much of the previous research relating affective input in the early familial environment to later behavioral development has focused on the quality (Aunola et al., 2013; Waters et al., 2017) or quantity (Dubowitz et al., 2002) of environmental input, a growing cross-species literature focuses on the predictability (or lack thereof) of input in the early environment (Glynn and Baram, 2019; Granger et al., 2021; S. Hartman et al., 2018; Ivy et al., 2008; Noroña-Zhou et al., 2020). Unpredictability in the early physical and social environment represents a critical aspect of early adversity that may shape a variety of developmental and mental health-related outcomes throughout the lifespan (Glynn et al., 2019; Ross et al., 2022). Though very few studies have specifically investigated the effects of housing insecurity on children's neurodevelopment and mental health, the existing literature suggests that the unpredictable experiences inherent to unaffordable, inconsistent, and unsafe housing conditions may place youth at risk for a variety of maladaptive developmental outcomes.

In order to inform mechanisms by which housing insecurity may relate to youth well-being, here we draw upon the extant empirical and theoretical literature on the cognitive and neural processes by which children track and interpret unpredictable events in their physical and social environments, and we posit how these processes may contribute to the effects of unpredictable occurrences in insecure housing situations. Though the exact mechanisms by which children perceive unpredictability in the early environment are not entirely clear, we focus our review on a growing body of work that identifies processes of statistical regularity extraction as being critical to the encoding and semantic generalization of unpredictability. We next highlight the neurobiological mechanisms underlying the effects of unpredictability on behavioral and mental health. Here, we posit how unpredictability inherent in housing-insecure conditions may be associated with differential structural and functional development of corticolimbic circuitry, a network of regions implicated in emotion regulation and fear learning processes.

10. Theories of how children process unpredictability in early environments

10.1. Statistical learning in unpredictable environments

We highlight that the exact mechanisms by which children perceive early unpredictability remain largely unexplored. However, an increasing number of theoretical pieces have hypothesized how children

identify, track, and interpret environmental stochasticity. As such, the current section aims to synthesize the main theories and models that have been put forth on this topic, as well as highlight the currently limited empirical work that lends support to these ideas. Children's perceptions and tracking of statistical regularities are central to learning about their environments, and especially the extent to which their environments are predictable or unpredictable. Young and colleagues (2020), who define environmental unpredictability as the level of spatial-temporal variation in environmental harshness, highlight the variation in statistical properties of an environment (e.g., mean, variance) as a critical component of unpredictability. The authors propose two proximate mechanisms for the perception and detection of environmental unpredictability. The first mechanism is referred to as an ancestral cue approach, which theorizes that natural selection across evolutionary history has programmed organisms to treat certain environmental cues as reliable and informative indicators of potential unpredictability. For example, a single experience of a residential transition (e.g., eviction) may be an ancestral cue that individuals use to draw inferences about the likelihood of environmental unpredictability, regulating development without requiring repeated experiences (Ellis et al., 2022). The second proposed mechanism posits that unpredictable environmental signals are detected using statistical learning. According to this approach, the developing organism engages in cognitive computations to consistently monitor the state of their environment. Models of the statistical structure of the environment are built with the data that the organism experiences, and these models impact the degree to which the organism can make accurate predictions about future events and occurrences.

Most commonly, the processes by which individuals perceive and track regularities in their environments have been studied in the context of infant and early childhood language development. Early research in this area found that infants were sensitive to the organized patterns of sounds and visual signs present throughout all languages (Saffran et al., 1996). More recent literature has applied a statistical learning framework to other domains of learning, such as the processing of affective stimuli in the early environment. Abstracting patterns from complex emotional cues, such as facial expressions, tone, and behavioral action tendencies requires learners to obtain information about distributions and co-occurrences of elements in the environment. More so, associative learning processes allow for young learners to identify and predict how the co-occurrence of specific sets of stimuli may represent specific internal states (i.e., feelings), such as the co-occurrence of frowns, direct eye contact, increased tone, and use of specific words in particular contexts as being indicative of an angry state. Relevant to the current review, statistical learning of affective information may link exposure to early-life stress with biases in emotional processes. For example, children exposed to physical maltreatment display a specific sensitivity to the presence of stereotypical anger configurations (Pollak and Kistler, 2002), and are less accurate than non-maltreated children at identifying configurations that represent non-angry emotions, such as emotions with a positive valence (Harms et al., 2019). Here, it has been suggested that caregivers who physically maltreat their children express more anger, thus influencing which emotions their children are more likely to encode and perceive in the future (LoBue and Ogren, 2022; Plate et al., 2019). More recent work showed that tracking statistical probabilities of faces influenced how children categorized emotions (Woodard et al., 2022). The authors presented different levels of intensity in facial behavior to children aged 6–10 years old and found that children's threshold for categorizing a facial configuration as "upset" shifted when exposed to unique facial cue-based statistical information. These findings indicate that the ability to detect patterns and regularities in the environment across domains (i.e., linguistic, affective) is present in early childhood. Statistical learning may represent a key process by which children track and encode the predictability of early environments.

10.2. Entropy of signals in the early environment

Regularities in affective, linguistic, behavioral, and other aspects of child-caregiver interactions can provide informative cues of environmental predictability for a child. Such regularities may signal associations between “needs + needs-are- or are-not-met” (Ugarte and Hastings, 2022), thus contributing to the extent to which the child can use environmental cues to estimate caregivers’ profiles of quality of care (Frankenhuis and de Weerth, 2013; Ugarte and Hastings, 2022). Contingency, often characteristic of predictability, refers to the likelihood of one event or action being followed by another (Smith and Pollak, 2021). Within a statistical learning framework, higher magnitudes of prediction errors, generated from the estimated contingency structures of the current environment, reflect increased levels of environmental unpredictability. For example, children might utilize repeated occurrences of temporary housing changes due to lead exposure as “raw data” to estimate and developmentally adjust to unpredictability across time (Ugarte and Hastings, 2022). Here, statistical learning is considered to play a central role in the detection of unpredictable signals in the environment.

The entropy rate is one approach to characterizing contingency in the early environment. Entropy rates define the degree to which one can deduce the next event or behavior from the most recent event or behavior, providing an index of predictability (Davis et al., 2019, 2022). The extant literature on unpredictability in early child-caregiver interactions has operationalized entropy in a number of different ways. For example, Davis and colleagues (2019, 2022) measured the unpredictability of sensory inputs (visual, tactile, and auditory) derived from observations of mothers interacting with their children in semi-structured play episodes. They calculated the entropy rate using a timeseries of each mother’s signals to create a matrix of transition probabilities, with each entry in the matrix capturing the proportion of time that the mother transitions from providing the signal identified by the row (e.g., visual) to providing the signal identified by the column (e.g., auditory). This approach to examining patterns of moment-to-moment parental signals could provide novel insight into how children encode unpredictable experiences and how these experiences relate to developmental outcomes.

10.3. Schema-based learning and the predictability of stimuli

Regularity extraction in the developing brain serves to guide information processing, allowing children to make predictions about subsequent stimuli they might encounter in their environments. The extent to which subsequent stimuli are congruent with prior knowledge might reinforce our predictions, increasing the strength of predicted information in memory and linking it to existing knowledge structures through memory integration. Stimuli that are incongruent with prior knowledge structures, in turn, might require that we either update our existing knowledge to allow for the integration of novel information, or that we store conflicting information as a separate memory (Van Kesteren et al., 2012). Schemas—representations in semantic memory that reflect similar past experiences—exert top-down control over the processing of information and serve as general reference templates to which new information can be compared (Sweegers et al., 2015). Schema-congruent and -incongruent learning processes provide frameworks by which new information can easily be integrated, allowing for strengthening or weakening of current semantic representations. In the context of early caregiving environments, repeated episodes of experiences with caregivers eventually semanticize into schematic working models, generating predictions about caregivers’ likely behavior and predictions about the affective world more broadly (Tottenham, 2020).

Current theoretical models suggest that unpredictability in the early environment can facilitate the development of a schema characterized by unpredictability. For example, repeated exposure to housing transitions may lead to the strengthening of a world view characterized by uncertainty, in which children learn to “expect the unexpected,” or to

understand their caregiver relationships—and by extension, their broader social worlds—as unpredictable (Ugarte and Hastings, 2022). In the context of schema-congruent and schema-incongruent learning, future experiences of unpredictability and inconsistency in interpersonal relationships (i.e., schema-congruent experiences) may further strengthen an existing unpredictability schema and be more likely to be remembered (Moscovitch et al., 2023). In contrast, subsequent interpersonal experiences characterized by predictability and consistency (i.e., schema-incongruent experiences), may be difficult to integrate within a strong existing unpredictability schema, and may be less likely to be remembered. Here, representations of the world characterized by unpredictability and uncertainty may serve as a mediator in the relationship between youths’ experiences of housing-insecure conditions and the development of later mental health problems. Findings from Ross and Hill (2002) suggest that childhood unpredictability is linked with the development of an unpredictability schema. Future empirical studies should continue to assess the validity of this model.

10.4. Neurobiology of statistical learning in early environments

Extracting regularities in the early environment to formulate predictions and shape memory involves the hippocampus and its connections with other neural regions. Here, we synthesize literature that has identified the development of the hippocampus as being critical to changes in how children perceive regularities in the early environment, and relatedly, how children might process unpredictable experiences. Given that a hallmark function of the hippocampus is the binding of disparate elements that make up an event, its role in the encoding and tracking of relations between individual stimuli is unsurprising (Covington et al., 2018). Hippocampal regions, for example, are recruited during visual statistical learning tasks and are specifically engaged when individuals track regularities that provide a predictive cue about what may occur next (Schapiro and Turk-Browne, 2015). Impaired statistical learning processes have been observed in a patient with bilateral damage to the hippocampus (Schapiro et al., 2014), further implicating the hippocampus in statistical learning.

Importantly, the hippocampus exhibits both functional and structural changes during childhood and adolescence; these changes are thought to support maturation of processes related to detecting regularities. Compared to more cortical regions, the hippocampus is characterized by a faster pace of structural maturation (Sowell et al., 2003). However, there is evidence for continued structural development in the hippocampus and its projections to cortical regions through adolescence (Calabro et al., 2020; DeMaster et al., 2014). Bilateral hippocampal volumes increase linearly with age, while hippocampal shape development is more heterogeneous and dynamic (Lynch et al., 2019). Developmental changes in the functional organization of the hippocampus include increases in hippocampal engagement during specific memory processes (Ghetti et al., 2010). This ongoing structural and functional development is reflected in age-related differences in regularity detection processes. Intact statistical learning processes are evident from as early as 8 months in humans (Saffran et al., 1996). Hippocampal regions are engaged when infants are exposed to statistical regularities (C. T. Ellis et al., 2021), and volume of the right hippocampus is predictive of auditory statistical learning performance in young children (Finn et al., 2019). Subtle differences in hippocampal structure across development—namely dissociable developmental patterns across anterior (head) and more posterior (body) regions—are coupled with gains in memory performance on statistical learning tasks (Schlichting et al., 2017), consistent with the idea that hippocampal maturation supports age-related changes in statistical learning.

Hippocampal-cortical interactions are implicated in regularity detection and event prediction. In particular, schema-based learning processes rely on connections between the ventromedial prefrontal cortex (vmPFC) and the hippocampus (Brod et al., 2017; Gilboa and Marlatte, 2017). The vmPFC is involved in monitoring the encoding and

construction of information to make sure that it conforms to expectations consistent with the schema. The vmPFC detects the congruency of incoming information and compares this incoming information with pre-existing information in the neocortex. This detection functions through a sort of resonance, as information matching prior knowledge triggers a synchronous oscillation within the vmPFC (Gilboa and Marlatte, 2017; Van Kesteren et al., 2012). Higher congruency between the incoming information and the pre-existing information corresponds to greater resonance and greater activity within the vmPFC, thus strengthening the schema (Van Kesteren et al., 2012). The hippocampus plays a key role in the encoding of novel information that may not match a pre-existing schema (Brod et al., 2017; Van Kesteren et al., 2012). Specifically, hippocampal-dependent mechanisms are engaged when there is sufficient conflict between the schema's expectations and either the experience of an event or stimulus to trigger a prediction error signal in the brain. Prediction errors driven by the hippocampus (in communication with other regions such as the lateral PFC and amygdala) may be sufficient to weaken or update an existing schema with new information (Moscovitch et al., 2023). As such, early experiences of unpredictability may lead to the development of internal working models of the external environment characterized by unpredictability via hippocampal-vmPFC connectivity, and subsequent experiences of unpredictability or inconsistency may strengthen such schemas via the same neural mechanisms (Tottenham, 2020).

10.5. Regularity extraction processes in youth exposed to housing-insecure conditions

Predictive information in the caregiving environment is valuable for encoding and processing information in early development (Benitez and Saffran, 2018; Ruba et al., 2022). Extracting regularities in early caregiver-child interactions promotes learning and memory development (Aslin, 2017), and the presence of predictable information reduces uncertainty and may strengthen a child's representation of their world as being characterized by a sense of perceived control or influence over their relationships and environment (Ugarte and Hastings, 2022). In contrast, a lack of predictable patterns in the caregiving environment may hinder the development of these competencies and perceptions of agency, and may contribute to the development of a worldview characterized by unpredictability. While much of the research on unpredictability in early childhood has focused on caregiver-child interactions, predictability in the early caregiving environment is often related to the presence of factors beyond the immediate familial context. Community, sociocultural, and broader structural factors—such as insecure housing conditions—may create or exacerbate experiences of proximal unpredictability for a child and family (Liu and Fisher, 2022). Unpredictability inherent in exposure to insecure housing conditions may affect child development by increasing the likelihood of experiencing more proximal unpredictable events and interactions (such as environmental unfamiliarity and caregiver stress), thus making it more difficult for children to extract reliable patterns of input relevant for adaptive development.

Structure and consistency in youths' housing situations may facilitate more effective socioemotional learning via regularity extraction processes compared to housing situations characterized by unpredictability and uncertainty. Familial stress caused by increases in rent prices might be associated with more variability in emotional cues from caregivers. For example, a caregiver may express extreme frustration in the presence of their child following one situation and indifference during a similar situation the next day, thus complicating a child's efforts to extract regularities in emotion-context occurrences across experiences. Inconsistency in available space in a building complex for a child to play due to numerous, unpredictable periods of maintenance might make it difficult for children to identify when opportunities for engaging in certain developmentally-adaptive behaviors (i.e., pretend play) are present. A sudden move from one residence to another

following an eviction might make it difficult for a child to develop consistent expectations regarding which of their neighbors might serve as supportive figures (e.g., friends, caretakers). In summary, we posit that regularity extraction processes, supported by hippocampal functioning and connectivity with cortical regions, may represent key mechanisms by which children perceive and respond to the aforementioned unpredictable situations caused by housing-insecure conditions.

10.6. Neurobiological stress response mechanisms underlying the impact of housing insecurity

Thus far, we have focused on the cognitive and neural mechanisms by which children may perceive, interpret, remember, and respond to unpredictability in their early environments. In addition, consistent with conceptualizations of unpredictability as a core dimension of early-life stress (Cohodes et al., 2020; B. J. Ellis et al., 2009, 2022), aberrant patterns of emotional and cognitive input in the early environment can affect development via neurobiological stress response systems. For the remainder of this section, we attend to cross-species evidence documenting the structural and functional effects on the brain of stress characterized by unpredictability, with a focus on corticolimbic circuitry. While previous work has examined how unpredictability in the proximal early environmental context (e.g., caregiver behaviors, family income) is associated with alterations in corticolimbic circuits, aforementioned higher-order social contexts (e.g., policy changes that shape community and neighborhood factors) are rarely considered. As such, though the majority of findings highlighted below consider the effects of proximal unpredictability on neurobehavioral development, we extend these findings to consider the more distal, structural causes of unpredictable and inconsistent housing conditions. Here, we emphasize the relationship between distal and proximal unpredictability, as structural factors may induce unpredictability in the immediate, family context (Liu and Fisher, 2022).

10.7. Early-life stress and corticolimbic circuitry

Corticolimbic pathways are particularly susceptible to the effects of early-life stress. This sensitivity is in part due to the rich innervation of this circuitry with glucocorticoid, or stress hormone, receptors (Kaiser et al., 2018; Teicher and Samson, 2016; Tottenham and Sheridan, 2010). The hypothalamic-pituitary-adrenal (HPA) axis, a major neuroendocrine system in the body, is responsible for regulating the production of glucocorticoids, which interact with the brain to elevate or reduce an organism's readiness to confront or flee from threat (S. M. Smith and Vale, 2006). Over time, chronic exposure to stressors, both physical and psychological, activates the HPA axis by increasing the production and release of glucocorticoids (Lupien et al., 2009; McEwen et al., 2012). Such chronically elevated levels of glucocorticoids can have long-lasting effects on the human brain, particularly in corticolimbic regions with large densities of glucocorticoid receptors, such as the hippocampus, amygdala, and vmPFC. Prolonged hyperactivity of the HPA axis and resultant increased levels of glucocorticoids in the brain have been linked to a variety of alterations in these neural regions, including abnormalities in levels of brain-derived neurotrophic factor (BDNF), a key molecule involved in plasticity changes related to learning and memory (Smith and Vale, 2006), as well as the death of pyramidal neurons in the hippocampus (Magarinos et al., 2011). In addition, through a process known as stress sensitization (Hammen et al., 2000), chronic exposure to early-life stress is theorized to dysregulate the functioning of neurobiological stress response systems, thus reducing an individual's capacity for adaptive coping in response to subsequent stressful events (Manyema et al., 2018). As such, experiences of stress early in life have been shown to exacerbate the mental health effects of subsequent stress experienced in adulthood (McLaughlin et al., 2010; Pearlin et al., 2005).

Converging evidence points to the long-lasting effects of stressors (e.g., physical abuse, neglect by or separation from a caregiver, or exposure

to parental psychopathology during childhood) on neural regions such as the amygdala, PFC, and hippocampus, as well as the connections between them. Stress exposure in childhood has been linked with volumetric reductions in prefrontal, amygdala, and other subcortical regions (e.g., Tyborowska et al., 2018). Greater early-life stress severity is associated with alterations in white matter morphometry in tracts implicated in emotion regulation and cognitive processing (e.g., Chahal et al., 2021). Cumulative stress exposure is associated with decreased resting-state functional connectivity between the amygdala and the pregenual anterior cingulate cortex, and heightened activity in the medial prefrontal cortex, bilateral hippocampus, and posterior cingulate cortex (e.g., Fan et al., 2014). Consistent with the role of corticolimbic circuitry in core affective processes, alterations in fear learning and emotion regulatory capacities have been observed following early-life stress (Herrington et al., 2013; Izquierdo et al., 2006; Tottenham et al., 2010). Additionally, stress-related alterations in corticolimbic circuitry have been implicated in the development of a variety of psychopathologies, including anxiety and post-traumatic stress disorder (PTSD; Herrington, 2017; Shin, 2006; Wolf and Herrington, 2016). Fewer investigations have examined the effects of early-life stress on neurodevelopment with respect to specific dimensions of early experiences (Ellis et al., 2022; McLaughlin et al., 2021). Stress characterized by unpredictability, in particular, may exert unique impacts on corticolimbic regions and their connections.

10.8. Insights on the effects of early unpredictability on neurodevelopmental outcomes from non-human animal models

In non-human mammals, including monkeys and rodents, patterns of maternal input relate to neural region and circuit development. In a longitudinal developmental study, juvenile monkeys who were exposed to more unpredictable maternal signals during infancy showed impaired working memory performance, suggesting that unpredictable patterns of sensory signals during early infancy may shape brain circuit maturation (Davis et al., 2022; McCormack et al., 2015). A more direct examination of neurobiological functioning in non-human primates found that unpredictable maternal care was associated with alterations in the expression of proteins in the vmPFC known to be necessary for long-term memory functioning (Fulton et al., 2021). Among rodent pups, chronic exposure to unpredictable maternal behavior is associated with aberrant maturation of both cortical and limbic regions, including greater c-Fos expression in the basolateral amygdala and alterations in prefrontal GABAergic and glutamatergic signaling, compared to animals raised in typical conditions (Baram et al., 2012; Ivy et al., 2008; Malter Cohen et al., 2013; Shepard et al., 2016). Unpredictable sensory signals in infancy in rodents have also been associated with attenuated long-term potentiation, a cellular hallmark of memory functioning, and with impoverished dendrites and synapses in the dorsal hippocampus (Brunson et al., 2005; Ivy et al., 2008; Short and Baram, 2019). In addition, rodents exposed to unpredictable maternal signals in infancy displayed aberrant functional connectivity of reward- and stress-related neural circuits, including corticolimbic regions such as the central amygdala (Bolton et al., 2018). These findings indicate that early-life stress involving fragmented and unpredictable maternal signals may alter neurocellular processes, which may impact maturation in corticolimbic circuits, including the amygdala, hippocampus, and medial PFC.

10.9. Insights on the effects of early unpredictability on neurodevelopmental outcomes from human models

More recent work has begun to examine the effects of exposure to unpredictable stress in humans. Several studies have examined biological correlates of exposure to experimentally manipulated unpredictable and uncertain stress (see Grupe and Nitschke, 2013 for a review). For example, humans show larger startle responses for cues that can precede either low- or high-intensity shocks than for cues that always precede

high-intensity shocks (Shankman et al., 2011), as well as for cues preceding shock on 20 % or 60 % of trials than for cues that predict shock with 100 % certainty (Hefner and Curtin, 2012). Exposure to unpredictably timed neutral tones also elicits more amygdala activity and anxious behavior than predictably timed tones (Herry et al., 2007), suggesting that patterns of stimuli presentation may impact neuro-behavioral outcomes, regardless of their severity. A limited body of work has examined the neural mechanisms by which unpredictable signals in the early environment are associated with developmental outcomes in humans. In one study, exposure to unpredictable maternal signals in infancy was associated with aberrant maturation of the uncinate fasciculus, the primary fiber bundle connecting the amygdala to the orbitofrontal cortex and a key component of the medial temporal lobe–PFC circuit (Granger et al., 2021). Specifically, children 9–11 years of age who were exposed to early unpredictability displayed greater uncinate fasciculus integrity, coupled with decreased hippocampal cingulum integrity, suggesting an imbalance in cortical development. Exposure to early unpredictability has also been linked with functioning in the salience network, which is anchored by regions such as the anterior cingulate cortex and more limbic-related ventral anterior insula (Seeley, 2019). A recent longitudinal study observed weaker salience network integrity and reduced variation in salience network connectivity (i.e., inflexibility) in adolescents who were exposed to higher unpredictability in prenatal maternal mood (Jirsaraie et al., 2023). Another study found that exposure to higher levels of unpredictability in childhood was linked with lower initial levels of functional connectivity within the salience network, and smaller decreases (i.e., more stability) in functional connectivity across time between the salience network and other networks, such as the default mode network and frontoparietal network, in adolescence (Chahal et al., 2022). These alterations in circuit and network function may lead to changes in typical cognitive (e.g., memory) and affective developmental processes following early unpredictability (Baram et al., 2012; Bolton et al., 2018; D. G. Gee and Cohodes, 2021; Liu and Fisher, 2022).

We posit that alterations in both corticolimbic circuitry and networks with strong connections to corticolimbic regions (e.g., the salience network; Peters et al., 2016) following exposure to early-life unpredictability may have implications for a variety of developmental outcomes, including outcomes related to mental health. Exposure to variation in maternal employment and residence in early childhood has been associated with externalizing behaviors, including risky sexual behaviors and substance use during adolescence (Usacheva et al., 2022). In samples from both the U.S. and Finland—cohorts marked by significantly different sociodemographic characteristics and cultural contexts, evidence suggested that unpredictability in maternal behaviors may influence the development of executive functions (Davis et al., 2019). Exposure to caregivers' mood instability is associated with lagging cognitive and language development in children (Howland et al., 2021), and scores on a retrospective measure of childhood unpredictability are associated with increased depressive, anxious, and anhedonic symptoms in adolescents and adults (Glynn et al., 2019). In addition to exposure to actual unpredictability in childhood, perceptions of unpredictability have also been linked with cognitive and mental health outcomes. Perceptions of unpredictability have been shown to mediate associations between objective unpredictability, as defined by changes in maternal employment, residence, and cohabitation during childhood, and externalizing behaviors (Martinez et al., 2022). Together, these findings suggest that diverse manifestations of early-life unpredictability have myriad impacts on development and mental health across early childhood, adolescence, and young adulthood.

10.10. The protective role of predictive stress

Both animal and human studies suggest that exposure to unpredictable stress has consequences for the development of corticolimbic circuitry and related affective and behavioral outcomes. However,

predictability in the nature of stress may serve to buffer the effects of stress exposure on neurodevelopmental outcomes and mental health. Recent evidence in humans shows that retrospectively-reported perceived predictability of stressful events across the lifespan moderates the impact of stress on trauma-related symptomatology in adulthood, such that individuals who reported a higher degree of stressor predictability displayed a weaker association between cumulative number of stressful events and current symptomatology (Cohodes et al., 2023). Though the neurobiological mechanisms by which predictable stress may buffer against risk are currently unknown, it is likely that corticolimbic circuits play a role. In particular, the ability to predict aspects of a stressful experience—such as being able to predict the onset, severity, duration, and emotional impact of a stressor—may engage corticolimbic circuits to promote adaptive coping and reduce stress reactivity during subsequent stressors. Here, reduced discordance between one's prior expectations and the actual or perceived experience of an event or stimulus may promote adaptive neurobiological functions.

10.11. Corticolimbic circuits as mechanisms linking exposure to housing insecurity and mental health outcomes

Insecure housing conditions present children and families with a variety of unpredictable stressors, including uncertainty regarding increases in rent/mortgage prices, exposure to multiple moves and evictions, overcrowding, unexpected changes in access to safe locations to play and socialize, and sudden changes in neighbors, peers, and friends. These occurrences may impact youth's sense of predictability, certainty, and controllability over their environment, and may have a direct impact on corticolimbic development and functioning, as well as socioemotional outcomes. In rodent models, exposure to chronic unpredictable stress, which included variations in exposure to overcrowded housing and changes to nesting locations, led to decreased levels of glutamate receptors and BDNF in amygdala regions (Shi et al., 2015). In addition, long-term overcrowded housing is predictive of increased cortisol levels in rodent hair (Uarquin et al., 2016), as well as alterations in neurotransmitter levels in hippocampal and amygdala regions in rodents (Sabry et al., 2020). Inadequate housing conditions for rodents, defined by crowded/isolated housing and limited space, are associated with worse behavioral (i.e., sucrose preference and social interaction time) and physiological (i.e., weight and estrous cycle) outcomes (Antoniuk et al., 2019; S. Baker and Bielajew, 2007). Interestingly, housing conditions contribute to worse behavioral and physiological outcomes than exposure to non-housing-related chronic mild stress in rodents, with more adequate housing conditions buffering against the negative impacts of chronic mild stress (S. Baker and Bielajew, 2007). Exposure to positive housing conditions through environmental enrichment has been shown to ameliorate stress-induced pathology through changes in glucocorticoid receptor signaling within the central nucleus of the amygdala (Orock et al., 2020). Translational rodent studies can offer unique insight into potential neural mechanisms that link overcrowding and resource-limited conditions to behavioral outcomes. However, it is important to note the vast differences between investigations of overcrowding and resource insecurity in rodents and the complexities of living conditions and social and cultural contexts in humans (Hyde et al., 2020; Kirmayer et al., 2010). As such, rodent studies and cross-species research can play an important role in informing mechanistic research on structural inequities but—in isolation—will fail to capture the role that complex causal factors, such as structural racism, play in outcomes related to housing insecurity.

Understanding of the neural correlates of unpredictable and inadequate housing conditions in humans is limited. One recent longitudinal study found that household instability (defined as residential moves, changes in household composition, and caregiver transitions) during the first five years of childhood was associated with greater white matter structural network efficiency in adolescence, which in turn predicted greater depressive symptoms in young adulthood (Hardi et al., 2023).

These findings provide evidence that housing conditions may impact neurobiological development. We further posit that children exposed to long-term inconsistency and overcrowding in housing may be particularly vulnerable to alterations in hippocampal and amygdala regions, and may therefore be at risk for altered development of core affective capacities (i.e., emotion regulation, fear learning and extinction) and resultant mental health symptoms. Furthermore, we extrapolate that more predictable housing conditions, such as stability in rent/mortgage prices and limited unexpected residential changes, may buffer the impact of other experiences of early-life stress, such as financial hardship, on corticolimbic structure and function.

Importantly, theoretical and empirical research suggest that structural inequities (e.g., disparities in neighborhood socioeconomic disadvantage, structural racism) can impact individual brain and behavior functioning (Gard et al., 2021; Harnett and Ressler, 2021; Taylor et al., 2020; Webb et al., 2021). In the current context, unpredictability in higher-order social factors is thought to directly contribute to elevated unpredictability in the proximal, familial context (Liu and Fisher, 2022). There are a variety of macro-level factors inherent to insecure housing conditions, such as increasingly unaffordable increases in rent prices (Bitton, 2023), displacement of residents through gentrification (Gentrification in America Report, 2015), and the ongoing ramifications of practices such as zoning and residentially segregated communities that disproportionately affect Black families (Dickerson, 2020). These factors may not only cause and/or exacerbate severe material hardship and financial strain for families, but may also increase exposure to other, more proximal unpredictable stressors. A recent review (Bess et al., 2023) identified several pathways by which housing insecurity impacts health outcomes among children ages birth to 12 years, including maternal depression and psychological distress, material hardships, and parental nightly bedtime routines with children. As such, we posit that a variety of factors related to housing insecurity, both distal and proximal in nature, interfere with the predictability of children's experiences, in turn placing youth at greater risk for a variety of negative mental health outcomes through alterations in corticolimbic development.

10.12. Summary

Here, we have brought together two distinct bodies of literature in developmental neuroscience—how children process unpredictable experiences and how unpredictable experiences “get under the skin”—to posit how experiences of unpredictability inherent in housing-insecure conditions are associated with youth mental health. We highlight how the processes by which children extract regularities in their environment (i.e., statistical learning) inform the development of predictive models and allow for the creation of more abstract, generalized, and semantic knowledge. For children exposed to inconsistency and uncertainty in early affective and behavioral stimuli, these predictive models, or schemas, may be characterized by an unpredictable worldview, and/or be schemas with poor integrity due to difficulties in abstracting reliable information from the world (Tottenham, 2020). In addition, cross-species evidence indicates that corticolimbic circuits and connected networks (e.g., the salience network), which underlie the functioning of core affective processes and are consistently linked to affective psychopathology, are susceptible to the effects of early-life stress and unpredictability. Alterations in corticolimbic circuits may thus serve as a central mechanism linking early-life unpredictability stemming from housing insecurity to mental health outcomes across the lifespan.

The burgeoning literature examining the cognitive and neural mechanisms by which children perceive and respond to early unpredictability may allow for more precise understanding of how housing insecurity can impact youth mental health outcomes. These findings can inform the specific service needs and structural interventions for youth and families facing housing insecurity. However, much of the existing neuroimaging work in this area has relied upon predominantly white

samples. A long history of both explicit and unrecognized racism in the neurosciences has led to the limited engagement of Black and Brown individuals as participants in this work (for a review, see [Ricard et al., 2023](#)). Given the aforementioned role of structural racism in creating and maintaining housing disparities, combatting exclusionary practices in recruitment protocols, methods, and analyses in neuroscience research is critical to improving the generalizability and equity of science. Importantly, these efforts to improve participation of Black and Brown individuals in neuroscience research should aim to center the impact of structural racism, and not race itself, on brain development and mental health. We highlight below how integrating neuroscience with more community-engaged approaches can combat some of the barriers to more inclusive and representative science.

11. Community-engaged research approaches to understanding the impact of housing insecurity on youth mental health

Neurodevelopmental processes occur not within the privacy of a child's brain, but rather through the interactions of the child with the social and physical environment surrounding them. Neurodevelopmental research, then, is in large part a study of person-environment interactions over time. With its power to document the relative risks and benefits of social and physical exposures to human development, neurodevelopmental science can furnish and disseminate claims in support of public health or environmental justice work ([Rauh and Margolis, 2016](#)). Findings from this research, both basic and applied, may direct funding to address community-identified issues; mobilize policy engines towards liberatory solutions; and empower families and neighborhoods to implement practices that support individual and collective health. However, most neurodevelopmental research findings do not have the opportunity to directly inform environmental justice movements. Researchers in medicine and social science are often aware of the "17-year lag": that it takes an average of nearly two decades between the publication of basic science research findings and the implementation of these findings ([Morris et al., 2011](#)). The slow journey of data "from the bench to the bedside" reflects cultural, practical, and even epistemic processes within developmental research fields.

Designing ecologically valid research that directly benefits communities is no small task. It requires methodological and theoretical adjustments to standard neurodevelopmental research protocols. A creative solution, co-developed by researchers and communities over the course of decades, is community-engaged research (CEnR). This umbrella term describes many different practices, such as action research, community-based research, and community-based participatory research (CBPR). What these orientations have in common is a commitment to using science for just purposes, grounded in specific local communities. CEnR projects do this by reducing (or even reversing) the power differential between researchers and community members and centering community needs in all steps of the research process ([Collins et al., 2018](#); [S. A. Smith et al., 2015](#); [Viswanathan et al., 2004](#)). Common methods include researcher-community partnerships with equitable power-sharing, co-creation of research questions and methods, community advisory boards, and mutual learning. When CEnR is successful, it often results in answers to community-identified questions, increased community capacity, respectful long-term relationships, and a resilience-based interpretive lens. There is, of course, a continuum of community engagement in research. Some teams consult with stakeholder groups while planning protocols and then design dissemination products that are community-facing, while still maintaining ownership of research goals and pacing. In other teams, researchers commit to addressing the questions identified by communities in the manners communities prefer, and their primary role is to give administrative, institutional, financial, or methodological support to these community-led projects ([Gorski and Mehta, 2016](#); [Key et al., 2019](#)).

If housing-insecure families are among the hardest groups to engage

in neurodevelopmental research, they are also among the most important stakeholders. CEnR can support the validity of neurodevelopmental research with families facing housing insecurity and instability. Families facing housing insecurity often have justifiable mistrust of institutions ([Chinchilla and Gabrielian, 2020](#); [Jagasia et al., 2023](#)), and research with marginalized communities is likely to disproportionately recruit people with more material resources and more trust in institutions. CEnR protocols take place with community co-ownership and by community co-design, addressing psychological and practical barriers to generate more representative samples ([Hodges et al., 2024](#)). Even seemingly simple processes in neurodevelopment cannot be interpreted without a wealth of ecological data, with genes nested within hormone levels, hormones nested inside daycare schedules, daycares nested within neighborhoods, and so on ([Gunnar et al., 2010](#)). Similarly, all developmental science is concerned with cascades, where occurrences at one level of analysis flow into other levels ([Masten, 2014](#)).

Measuring these complex systems requires community guidance at every step, as the framing and quantity of questions may influence participation rates or data quality ([Panter-Brick et al., 2020](#)). For example, community members may be aware of neighborhood-level adverse events and guide researchers to query about a family's connections to these events. Families living in shelters are well aware of many of the processes relevant to child development in these contexts. In one case, families in a supportive housing facility shared with researchers that their children were struggling to sleep through the noise and chaos of the environment, a variable that may have escaped the researchers' awareness if they had not had existing, power-sharing, and trusting relationships with stakeholders in the shelter ([Labella et al., 2017](#)). One study used CEnR methods to engage in co-learning with adults who had lived experience of homelessness as well as diabetes ([Campbell et al., 2021](#)). In addition to valuing and enjoying the study experience, co-researchers (the study participants) gained skills to advocate for their dietary needs in shelters and learned to translate their insights to policymakers. In another study, community organizations that served adults in permanent supportive housing helped to identify and implement health-promoting programs that were likely to be the most useful for their clients ([Schick et al., 2020](#)). Another project leveraged tools from public health and urban planning to document the role of public transportation in the lives of people experiencing homelessness following the decentralization of a city's emergency shelter system ([Canham et al., 2022](#)). In the context of youth mental health, one multi-site, longitudinal CBPR study examined the factors that drive residential instability in Somali refugee youth, identifying the impact of housing disruption on young people's mental health ([Gillespie et al., 2020](#)). These CEnR strategies represent especially ethical and effective approaches for researchers working with marginalized communities.

11.1. Summary

Here, we introduce CEnR as a powerful approach that has been used to understand the experiences of people facing housing insecurity. We argue that future research on the neurobehavioral implications of insecure housing conditions for youth would benefit from incorporating CEnR approaches. Importantly, not all neurodevelopmental research is compatible with CEnR methods to the same degree ([Gorski and Mehta, 2016](#)). For example, a researcher who values deference to community-endorsed methods may still find that blood draws are the only way to assess the biomarkers of interest and struggle to move forward with a planned study alongside stakeholders who do not endorse this method. However, for teams who plan to study multisystem, cascading processes in development like those implicated in housing insecurity, thoughtful community engagement is likely to be critical for ethical and effective research. Viewing CEnR as a continuum should prove useful to neurodevelopmental researchers, challenging teams to maximize community engagement and capacity-building as much as possible in each study ([Key et al., 2019](#)). Researchers whose grants and

institutions allow little flexibility in study questions and methods may build a community advisory board to guide their choice of recruitment and dissemination methods (for an example of the utilization of community advisory boards in developmental neuroscience research, see [La Scala et al., 2023](#)). Others may add study aims that support community-identified questions and policy priorities, identifying appropriate collaborators when these goals fall outside of their expertise ([Panter-Brick et al., 2020](#)). In other words, CEnR is not “all or nothing,” but is a lens through which to critically evaluate past, present, and future neurodevelopmental studies.

12. Recommendations – future directions on how developmental neuroscience and CEnR can inform one another

Thus far, we have examined how research in developmental neuroscience has informed the ways that unpredictable experiences inherent in housing-insecure conditions are associated with neural and cognitive processes in youth. We have also highlighted literature that has used CEnR approaches to understand the experiences of families and youth who have been exposed to housing insecurity. While both lines of work have the potential to yield insight into the impacts of housing-insecure conditions on youth development, these approaches have rarely intersected. In the following section, we propose several future directions for potentially fruitful lines of inquiry that integrate developmental neuroscience and CEnR approaches to understand and intervene on experiences of housing insecurity for youth and their families.

Future direction #1: What can we learn from youth and caregiver voices regarding the mechanisms by which children process and make meaning of unpredictability?

Insights from developmental science highlight how children, from infancy, are able to identify, interpret, and respond to cues in the early environment. More so, research in developmental neuroscience has elucidated the neural regions and circuits that support how children extract input from visual, auditory, and other sensory modalities. Recent research has begun to expand into the affective and social domains, and to consider how patterns of information in the early environment are processed across development. Still, the exact mechanisms by which children process and respond to unpredictability are unknown. For example, are all cues in the early environment given equal weight with regard to how and when they are attended to by youth? In their 2022 review, Ugarte and colleagues ([2022](#)) highlight that the processing of unpredictable experiences in the early caregiving environment might vary within and between individuals depending on stimuli valence (i.e., positive or negative), input (i.e., visual, affective, tactile), and levels (i.e., caregiver unpredictability, more distal unpredictability). Continued research in developmental cognitive neuroscience may allow increased specificity as to the neural and cognitive mechanisms that are involved in the processing and meaning-making of unpredictability across a variety of settings and stimuli.

In addition, CEnR approaches may be particularly well positioned to expand on these mechanistic questions. Incorporating youth and family perspectives into youth mental health research can capture more valid understanding of what is most relevant to youth experiences ([Jacquez et al., 2013](#)). In the context of unpredictable housing conditions, the use of more qualitative and mixed-methods approaches may be useful for capturing the complexity of these experiences and how they are processed. More human-centered techniques employed in CEnR may be especially useful for engaging community members. Photovoice is a visual participatory research strategy that instructs participants to photograph items to help them document, reflect upon, or communicate strengths and concerns to researchers ([Wang and Burris, 1997](#)). “Windshield and walking surveys” are a low-cost way to gather ground-level perspectives on lived experiences of community members ([Kiper and Geist, 2020](#)). In this method, participants drive or walk around a designated area making observations, often taking photographs as they move. These approaches may allow youth and families to

document and share what aspects of unaffordable, inconsistent, and/or unsafe housing have the most impact on their lives. For example, children and caregivers in a neighborhood with high rates of housing insecurity may use this method to capture aspects of their housing complex that are in need of repair or replacement. These methods may pave the way for more tailored research in developmental cognitive neuroscience that aims to identify the varied mechanisms by which children attend to specific elements of their environments.

Future direction #2: How do youth envision psychological safety in their homes? How might youth want their homes to be designed/maintained to promote psychological safety?

Perceptions of safety in the home environment play a role in healthy youth development. Safety cues in one’s environment may be used to inhibit fear responses, and may derive from repeated indication of the absence of a predicted aversive outcome (e.g., physical or emotional distress) following an encounter with a perceived threat ([Meyer et al., 2019](#)). Safety cues encompass a variety of interactions with the environment, including interactions with social support figures, the presence of a personal object, or being in a familiar context. Regardless of the exact nature of the stimulus, encounters with safety cues tend to be predictable, and are capable of dampening the fear responses that normally arise when a threat is perceived. This occurs through a process known as conditioned inhibition ([Christianson et al., 2012](#); [Meyer et al., 2019](#)). Existing knowledge about the neural correlates of safety signal learning via conditioned inhibition has identified the hippocampus and its interactions with cortical regions as playing key roles, and theoretical work suggests that the efficacy of safety signal learning in reducing stress responsivity may vary across the lifespan due to developmental changes in these connections ([Odrionzola and Gee, 2021](#)).

A more in-depth understanding of the role of safety cues during experiences of unpredictability in childhood and adolescence may be enhanced by CEnR approaches. The incorporation of youth engagement, youth participation, and youth-driven ideas throughout the research process can yield novel insight into what safety signals in the home environment might look like for youth facing housing-insecure conditions. For example, are there specific visual cues that children are drawn to in the built environment that instill feelings of safety and comfort? Might children who are exposed to unpredictable housing conditions derive felt safety from some aspect of a residence that remains predictable when moving from home to home (e.g., a window that provides access to sunlight, a couch to rest on)? Photovoice and other participatory photograph methods have been successfully used before with adults experiencing housing insecurity or homelessness ([Fortin et al., 2015](#); [Walsh et al., 2010](#)). In these studies, participants are honored as fellow investigators and conduct data collection themselves: Provided with cameras, they are given introductory training in photography and encouraged to document meaningful snapshots in their daily lives, often around a certain theme. For example, youth living in a shelter complex may be asked to capture five photographs over the course of the day that signify *safety*.

Given that caregiver stress serves as one mechanism that links housing-insecure conditions to child mental health issues ([Desmond and Kimbro, 2015](#)), partnering with caregivers to understand what in their own environment instills safety and reduces stress might impact how stress is transmitted from caregiver to youth. Furthermore, caregivers themselves may serve as safety signals for their children. The presence of predictable caregiving cues that signal safety during childhood may shape corticolimbic development and support caregivers’ role in guiding emotional learning and regulation later in development (D. G. [Gee and Cohodes, 2021](#)). CEnR approaches can be employed to hear directly from caregivers regarding the structural factors that might facilitate or inhibit engaging in predictable and supportive ways with their children. Overall, having youth and families drive questions regarding what aspects of a home environment promote psychological safety will allow for a more contextualized understanding of the role of safety signals in behavioral outcomes.

Future direction #3: How might youth in different contexts and at different developmental stages exhibit distinct behavioral outcomes following exposure to insecure housing conditions?

Insights from developmental neuroscience highlight that there is significant heterogeneity in neurobiological and behavioral responses following exposure to early-life stress (Cohodes et al., 2021). The developmental timing at which a stressor occurs may be one factor that accounts for variability in corticolimbic functioning and related emotional development. Stress exposure that occurs during sensitive periods of development may have particularly strong influences on longer-term neural structure and function (Tottenham and Sheridan, 2010). Particularly in the context of caregiving, the predictability of a stressor may be more strongly linked with corticolimbic development during infancy and early childhood, in comparison to later childhood and adolescence (Cohodes et al., 2021; D. G. Gee and Cohodes, 2021). Additionally, different domains of and contexts for unpredictable experiences may be associated with unique outcomes across development. Future research should investigate whether there are periods of cognitive and emotional neurodevelopment marked by heightened sensitivity to different domains of unpredictability (e.g., unpredictability in caregiver sensory signals during infancy, unpredictability in affect and responsiveness during early childhood) (Ugarte and Hastings, 2022).

CEnR approaches are optimally suited to elucidate how distinct dimensions of early unpredictable experiences, such as the age of exposure or context, might shape development. Opportunities to hear from families about what specific housing insecurity-related stressors are most impactful on their lives and the development of their children at various ages may offer particularly powerful insights. Importantly, the temporal aspects of CEnR represent both a challenge and a strength of this approach to understanding the role of developmental timing and context in early experiences. The development of equitable and reciprocal relationships with community partners takes time. However, once developed, researchers and institutions can develop longstanding partnerships with families and youth. These longstanding partnerships aid investigations of more longitudinal questions, such as how responses to unpredictability might change across development, as well as how changes in levels and domains of unpredictability are associated with mental health symptom trajectories.

Future direction #4: What are the familial, neighborhood, and systemic factors that community members view as being protective against the negative effects of unpredictable housing conditions?

While the majority of this review has focused on how early experiences of unpredictability related to housing insecurity might have negative effects on mental health, there are also many factors that might protect against the harmful consequences of these experiences. A growing literature highlights the variety of factors—such as caregiver support—that promote resilience in the face of adversity (Masten et al., 2021). Caregivers and other supportive figures may play a central role in regulating neurobiological stress responses following exposure to early-life stress (D. G. Gee and Cohodes, 2023). For example, parental presence has been shown to buffer children's responses to stress by dampening cortisol reactivity (Hostinar et al., 2015) and amygdala responding (D. G. Gee et al., 2014). Among children who experienced institutional care before adoption, approximately 40 % displayed reduced amygdala reactivity to parental cues, which was associated with greater child-reported feelings of security with their parent and steeper anxiety reductions across time (Callaghan et al., 2019), highlighting the potential for supportive caregivers to buffer the effects of early adversity.

Given the focus of CEnR on identifying and amplifying strength-based approaches, CEnR may allow for the understanding and application of additional protective factors for youth exposed to housing insecurity. Here, CEnR prioritizes a focus on adaptive processes and well-being over a deficit-based focus. For example, qualitative interviews with youth may allow for a more precise examination of what elements of the caregiver-child relationship serve to protect against the impacts of

housing-related stress. A neurodevelopmental research team examining the effect of landlord absenteeism on toddlers' cognitive development may not intuitively be aware of the social impact it can have to portray poor neighborhoods as riddled with greed and corruption. With the help of communities, teams may work to frame findings in ways that support local rent justice movements, while also emphasizing protective factors like creativity, organization, and connectedness that support development even amid adverse or unpredictable circumstances. The study of young children's sleep habits in an emergency shelter emphasized how parents *enjoyed* bedtime as an opportunity for connection and co-regulation, even though these peaceful moments were made more difficult by the structural insult of housing loss (Labella et al., 2017). Community-based research with families experiencing insecure housing can describe parenting behaviors that caregivers can use to boost a child's well-being, while also informing policy discussions about early-childhood intervention for unhoused children (Herbers et al., 2011). Researchers should aim to understand what caregivers, despite being exposed to the oppressive structural causes of housing insecurity, do right for themselves and their children, as opposed to trying to identify what is "wrong" with them.

In addition to identifying protective factors at the levels of youth and their families, which implicitly places the onus of resilience on individuals, it is imperative that mechanistic research and interventions target systems-level protective factors. In this vein, CEnR approaches can also be used to gauge the perceived effectiveness of systemic changes. For example, both quantitative and qualitative methods have been used to examine people's perspectives on the effectiveness and impact of state and federal policies, such as nondiscrimination laws for LGBTQ+ individuals (Drabble et al., 2021; Riggle et al., 2010). In the context of housing insecurity, a quasi-experimental study investigated the effectiveness of rent assistance services, finding that individuals who received rent assistance showed significantly greater improvements over time in housing stability and quality of life compared to individuals who received other types of housing support (Pankratz et al., 2017). In addition, though neurodevelopmental research has historically focused on individual factors, more recent work on brain and behavioral development has considered neighborhood-level disadvantage (e.g., Gard et al., 2021; Harnett and Ressler, 2021; Ip et al., 2022), structural factors such as racial disparities in exposure to adversity (Dumornay et al., 2023), and how variations in state-level policies might modulate links between income and neural and mental health outcomes (Weissman et al., 2023). CEnR approaches can continue to build upon this work to ask more nuanced, context-based questions that center children's and families' perspectives on systems-level factors and interventions.

In addition to partner input, a core principle of CEnR is partner dissemination (Chen et al., 2010). The Belmont principle of justice posits that the risks and benefits of research participation must be evenly distributed across a population, such that one group does not bear the burden of participation without benefiting from the knowledge they produce (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1978). This is a worthy principle, made even more powerful when it incorporates the framing that researchers are ethically obligated to extend the benefits of research to groups that have not yet been invited to enjoy these advantages (Hodges et al., 2024). In other words, researchers are not only required to avoid exploitation of participant communities, but they also have a responsibility to use their positions to advance justice by extending the benefits of knowledge production to new communities. Once key protective and strength-based factors are identified, equitable and collaborative partnerships with community members may provide more avenues for prevention and intervention dissemination to youth and their families (Downs et al., 2009; Mance et al., 2020).

13. Recommendations – implications for practice and policy

The current review proposes a novel conceptual model (presented in Fig. 1) to depict how various neurobiological, psychological, and structural factors are implicated in the relationship between housing-insecure conditions and youth mental health. We have highlighted how cross-disciplinary collaboration between researchers in basic science and community-engaged scholarship may propel efforts to understand and address the psychological consequences of housing insecurity. Findings in both neuroscience and community-based scholarship underscore the critical need for policy changes that address the effects of stress faced by youth and families exposed to housing insecurity, and that eliminate experiences of housing insecurity altogether. In the following section, we outline recommendations for practice and policy that individuals and organizations across sectors—clinical care, academia, community and professional organizations, and government—can implement and use to guide future development, reform, and dissemination of practices and policies aimed to reduce, and eventually eliminate, disparities in exposure to housing insecurity. Specifically, we focus on practice and policy implications as they pertain to (1) the prevention of insecure housing-related stress through policies that enact structural change and abolish systemic racism, (2) accessible and effective mental healthcare, and (3) changes in the training, frameworks, and actions that guide professionals in residential architecture and design.

14. Addressing and ending systemic racism

Research on the impacts of housing insecurity on child mental health and neurodevelopment highlights that there remains a pressing need for policymakers to invest in housing needs, particularly for Black and Brown families. We urge policymakers to take an abolitionist approach to addressing housing insecurity, and call for an end to systemic racism. Until political leaders are willing to adopt anti-racist responses to remedy the disparities caused by racist federal, state, and local housing policies that favor higher-income homeowners, housing disparities for racially marginalized youth and their families will always exist (Dickerson, 2020). Forms of reparations, such as down payment assistance

programs for Black and Brown families who were pushed out of neighborhoods that were revitalized by urban renewal programs or gentrification, should be offered (McGlinchy, 2018). In order to truly address housing insecurity for youth and their families, other longstanding racist practices and policies must be recognized and addressed. Practices such as the mass incarceration of Black individuals undoubtedly contribute to issues of housing insecurity. For example, current federal regulations require housing authorities to ban public housing or vouchers for at least 3 years for applicants who have been, or who have a household member who has been, evicted from federally assisted housing for a drug-related crime in the past 3 years (Blankenship et al., 2023). In addition, higher rates of policing in neighborhoods with higher levels of housing unaffordability and instability contribute to an increased likelihood of interactions between Black and Brown youth and police (P. J. Carr et al., 2007), which has been linked with worse mental health outcomes (DeVylder et al., 2022; Jackson et al., 2021). Comprehensive federal policies that address the historically rooted and continually manifesting structures of oppression that Black and Brown people face are critical for ending housing-related inequity.

15. Local, state, and federal policies to prevent insecure housing-related stress

We urge the federal government to enact sweeping legislation to protect the rights of tenants and homeowners. Current policy decisions around zoning prevent families from obtaining affordable housing (Ortiz and Johannes, 2018). Zoning predominantly favors single-family homes, which tend to be owner-occupied and less affordable than multi-family homes. In recent years, the states of Washington, Montana, California, Oregon, and Maine have passed legislation to allow additional types of housing on land that had been previously zoned for single-family homes (The State of the Nation's Housing 2020 | Joint Center for Housing Studies, 2023). Existing studies have demonstrated the positive effects of zoning reforms. Rothwell (2012) found that eliminating exclusionary zoning in metropolitan areas would reduce school test-score gaps by 4–7 percent. More recent studies have demonstrated how zoning changes and other land-use reforms are serving to increase the supply of housing, control prices, and increase

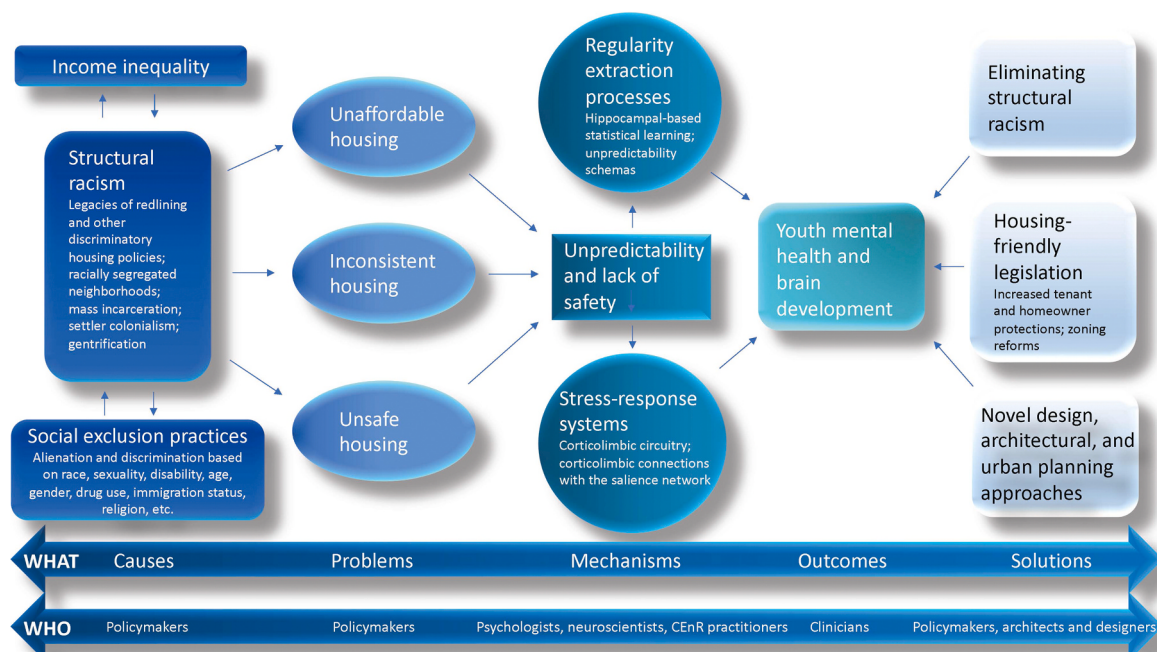


Fig. 1. Conceptual model of the structural, neurobiological, and psychological factors that contribute to the relationship between housing-insecure conditions and youth mental health and brain development.

local tax bases (Freemark, 2023).

In addition to zoning reforms, rent price restrictions, public housing developments, homeownership assistance, and community land trusts can be highly effective in addressing unaffordable housing (Schell, 2022). Rent stabilization policies—which strictly limit increases in rent—decrease tenant mobility, increase housing stability for rent-stabilized residents, and are associated with a moderate reduction of rent burden (Pastor et al., 2018). However, the beneficiaries of moderate rent control policies are often concentrated among wealthier, whiter households (Sims, 2011). It is necessary to develop rent stabilization policies that specifically target low-income families and residents of color. Homeownership assistance policies, and in particular lending and down payment assistance programs, have been shown to effectively increase rates of homeownership, while decreasing rates of foreclosure (Schell, 2022).

Our review also highlights how evictions may represent a particularly harmful and unpredictable experience for youth and their families. Increased federal protections are needed to ensure that all tenants can access representation during eviction proceedings. Several cities have enacted universal access to counsel, which guarantees free legal counsel for low-income tenants facing eviction and is associated with reductions in evictions filings and lower displacement (Ellen et al., 2021). More so, strong eviction moratoriums during the COVID-19 pandemic were associated with a significant reduction in mental distress (Leifheit et al., 2021). Enacting housing policies that prevent and address eviction must be a priority.

A major challenge in addressing housing insecurity is that government-owned public housing in the United States is underfunded. There are approximately 1.1 million public housing units in the United States, serving over 2 million people (Homes Guarantee | We Will End the Housing Crisis, 2019). Existing public housing units require over \$70 billion for physical improvements to account for dilapidation and poor conditions, and 66 % of public housing residents are people of color (Homes Guarantee | We Will End the Housing Crisis, 2019). Congress's failure to adequately fund ongoing maintenance and repairs in public housing represents a major driver of racialized housing inequality, and denies youth of color the right to a safe and healthy living environment. Certain organizations are focusing on increasing funding for public housing; the Choice Neighborhoods Initiative allocates grants each year to public housing developments (Fischer et al., 2021). However, there have been no funds provided to build additional public housing since the mid-1990s (Fischer et al., 2021). Given the robust positive impacts of affordable housing on overall well-being, policymakers should prioritize public funds for new public housing construction, as well as reinvest in public housing where it currently exists.

In addition, energy-efficient housing and climate-resilient housing facilitate the availability and affordability of housing. One report demonstrated that a 25 % reduction in energy costs reduced the combined rent and energy costs by approximately 8 % in an average housing unit (Office of Research & Development, 2011). In 2023, the U.S. Department of Housing and Urban Development (HUD) announced that \$18 million in grant funding was being allocated to support energy efficiency and climate resilience in multi-family assisted housing properties (HUD, 2023). This funding was granted by the Green and Resilient Retrofit Program (GRRP), which was established by President Biden's Inflation Reduction Act (HUD, 2023). While these initiatives represent an important step in the right direction, continued action is necessary to ensure continued and optimized utilization of federal funds for such efforts.

16. Individual and family interventions and mental healthcare

Addressing and ending structural inequity perpetuated by the State is the only effective and lasting approach to ending housing insecurity. Still, the development and dissemination of quality mental health services for children and families facing housing insecurity is a necessity. A

growing body of research using methods in developmental neuroscience and CEnR underscores how experiences of housing insecurity can exert significant impact on child and family mental health and brain development. Social workers, counselors, clinical psychologists, psychiatrists, pediatricians, and other healthcare workers play essential roles in the prevention and alleviation of housing-related stress. Clinicians are uniquely positioned to identify patients who are currently or may be at risk for experiencing housing-related concerns, such as eviction and overcrowding, and are well-positioned to make referrals to public and community-based solutions (Ramphal et al., 2023). There are various screening measures related to housing that clinicians can access (Carlozzi et al., 2023), and healthcare institutions should provide and require training with these measures. In addition, clinicians should be aware of government and community-based services that are currently available for families facing housing insecurity, such as promoting and, when possible, facilitating enrollment in Medicaid, Temporary Assistance for Needy Families (TANF), Special Nutrition Assistance for Nutrition (SNAP), and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (Council on Community Pediatrics et al., 2013). When working with children and families exposed to housing insecurity in individual care, clinicians should acknowledge and address the barriers that may hinder participation in continued mental healthcare, such as weekly psychotherapy sessions. For example, clinicians should make a communication plan that takes into consideration patient access to telephone and mail services, assist with transportation through vouchers for public transit or other means of transportation, offer more flexible office visit scheduling including the option for teletherapy sessions, and make treatment as affordable as possible, such as through taking insurance and offering a sliding scale.

Treatments offered to children and families facing housing insecurity should be culturally sensitive and trauma-informed. Healthcare institutions should provide ample opportunities for training in structural competency and cultural humility. Clinicians should be educated on how health conditions and behaviors are the downstream consequences of such upstream determinants as laws, policies, and regulations. For example, it is important that clinicians learn about the historical implications of redlining practices on disparities in housing opportunities for Black communities today. Research identifies that historical redlining practices influence the contemporary mental health and well-being of Black individuals through factors such as disinvestment in neighborhood infrastructure and strains on social and environmental conditions (Pearson et al., 2023). Clinicians should further be familiarized with principles from interventions designed to help Black youth and their families recognize, process, and heal from historical and current racial trauma, such as Emotional Emancipation Circles (Grills et al., 2016) and Engaging, Managing, and Bonding through Race (EMBRace; Anderson and Stevenson, 2016). In addition, effective treatments for mental health sequelae of childhood stress and trauma exist and need to be more widely disseminated. Redlined areas are associated with lower per 1000 population counts of psychologists, counselors, and therapists compared with non-redlined areas, further contributing to present-day disparities in diagnosis and treatment of health conditions for Black individuals (Erikson et al., 2022). Approaches such as task-sharing, in which community members are trained by mental health professionals to provide specific services to other members of their community (Hoeft et al., 2018), can be adopted in order to increase accessibility to effective interventions. In addition to existing treatment options, continued research in developmental neuroscience and CEnR may aid in optimizing interventions for youth that experience mental health challenges as a result of housing insecurity. We argue that an integration of the two approaches will likely yield the greatest impact for child brain and behavioral health.

17. Architecture and design

Professionals in the fields of architecture and design are in unique

positions to address issues of housing insecurity for youth and their families. Architects and designers are equipped with significant knowledge about planning and building regulations (Goodwin, 2021), and recommendations for future directions in their training and practice may provide increased avenues for this knowledge to impact housing-insecure families. Carr (2021) states that dwelling is the most contested space of wellness, a consistent argument that revolves around the equity and morality within our city structure. A report from the Center on the Developing Child at Harvard University (Shonkoff, 2017) states that a child's relationship to the built environment will influence lifelong learning, behavioral, and health factors as they age. The report outlines that factors such as open and natural spaces promote healthy emotional development in infants and children. The development of professional training within higher education and design's governing institutions (e.g., the American Institute for Architects) that focuses on the importance of these promotive aspects of the built environment is critical for promoting large-scale change and for challenging students, academics, and the larger design industry to center equity in residential, cultural, and community-oriented design.

In a recent volume of Architectural Design entitled "Housing as Intervention: Architecture towards Social Equity" (Kubey, 2018), architects with expertise in housing design propose how housing projects, and the design processes behind them, can serve as interventions towards greater social equity. They propose that novel design and construction strategies should leverage land more effectively to promote physical, social, and emotional well-being for residents. These practices include promoting the co-location of housing with key supportive programs like daycare, healthcare clinics, and food access, as well as the inclusion of health-promoting amenities in designs for apartment complexes, such as a welcoming pedestrian circulation loop aligned with building entries to encourage residents to be physically active and initiate social connections. In addition, mirroring CEnR approaches, Kubey encourages architects to work closely with individuals in communities as housing is being designed, renovated, and constructed. This co-creation of the built environment represents an approach to residential design that aims to center cultural and community-oriented values.

However, in practice, approaches such as CEnR have been scarcely utilized in the fields of architecture and design, with only a limited number of licensed practitioners taking into account the effective nature of community-engaged design. Firms like WXY are at the forefront of community engagement (for a list of their projects and initiatives, see <https://www.wxystudio.com/projects>). Their work branches into shifting time-limited planning and built environment initiatives into long-lasting change for disadvantaged populations. These projects use CEnR practices to develop effective workshops that identify actionable initiatives and objectives for building and neighborhood design. For example, in their East Harlem Neighborhood Plan, WXY, in partnership with Hester Collaborative, was commissioned to identify the complex and emerging needs of the public. Through public engagement workshops, they were able to outline twelve categories of focus, which included housing preservation and affordable housing. The plan helped develop concrete recommendations that aimed to preserve cultural diversity and support long-existing residents of East Harlem in their goal to remain in the evolving neighborhood. In addition, we highlight WXY's Peninsula Affordable Housing Complex initiative, developed in collaboration with Body-Lawson Associates. Currently in phase two of construction, this multi-use campus in Hunts Points, Bronx, was designed to support economic development for marginalized communities. The design focused on three pillars: creativity, entrepreneurship, and wellness. Phase one, which is now completed, implemented 183 affordable housing units alongside a cultural center, performance theater, daycare, and industrial space that will serve minority- and women-owned businesses and local food entrepreneurs. Phase two will include the construction of two more affordable housing buildings holding 359 units, a vehicle parking garage, and a large community facility space.

The housing units will be designated primarily for individuals and families at or below 60 percent of the area median income.

In the South Bronx, architect Andrea Steele worked in partnership with the New York Restoration Project (NYRP) and Urban Air Foundation to design the Casita, or "little house" in Spanish, as a social centerpiece for community well-being (for a description of this project, see <https://architizer.com/projects/casita/>). Andrea and her firm reimaged the traditional casita as a modular pavilion for community gardens of varying sizes, locations, and functionalities. By co-developing the design with the community, the architects expanded their vision of the casita as a performance stage, a classroom, a gathering spot, and a shaded front porch for the neighborhood. The scalable Casita includes a roof for shade, weather protection, and water collection; walls for climate control, vertical gardening, and storage; and an elevated platform for games, dining, individual and collective study, food preparation, and community gatherings. We emphasize that continued partnership with youth and their families can elucidate creative and important ways in which building designs can be optimized to support mental health and brain development. In addition, partnerships between researchers and design professionals can allow for investigations into the short- and long-term impacts of such architectural efforts on child and family well-being.

18. Conclusion

Housing-insecure conditions represent significant sources of stress and adversity in the lives of youth and families. We have identified some of the major stressors associated with unaffordable, inconsistent, and unsafe housing, and how these experiences may be associated with children's psychological functioning. We have also highlighted how unpredictability—a core facet of housing insecurity—is associated with neurobiological development and mental health. We have specifically outlined the neurocognitive mechanisms through which children process unpredictable experiences, as well as the corticolimbic connections that may link exposure to unpredictability with mental health. Building upon this review, we have described how CEnR approaches can be leveraged to understand the effects of housing insecurity on mental health in youth, and we have proposed future research directions that integrate developmental neuroscience research and CEnR approaches to maximize the impact of work in this domain. Finally, we have outlined several recommendations for policymakers, clinical practitioners, and professionals involved in the design, construction, and maintenance of housing. These recommendations highlight how effectively addressing housing insecurity and its effects on youth mental health requires the recognition and elimination of macro-level policies that exacerbate inequities in housing, particularly for Black and Brown families. We urge policymakers to commit to enacting policies that guarantee safe, accessible, sustainable, and permanently affordable housing for everyone. Such change will have profound impact on the mental health and brain development of youth in the United States.

CRedit authorship contribution statement

H.R. Hodges: Conceptualization, Writing – review & editing, Writing – original draft. **Erik Anderson:** Conceptualization, Writing – review & editing, Writing – original draft. **Mirelle Q Phillips:** Conceptualization, Writing – review & editing, Writing – original draft. **Emily M Cohodes:** Conceptualization, Funding acquisition, Writing – review & editing, Writing – original draft. **Anna Beloborodova:** Conceptualization, Writing – review & editing, Writing – original draft. **Dylan G Gee:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing, Writing – original draft. **Bunmi Fagbenro:** Conceptualization, Writing – review & editing, Writing – original draft. **Jordan C Foster:** Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Conceptualization.

Declaration of Competing Interest

None.

Data Availability

No data were used for the research described in the article.

Acknowledgements

This work was supported by National Science Foundation CAREER Award (BCS-2145372), Jacobs Foundation Early Career Research Fellowship, and The Society for Clinical Child and Adolescent Psychology (Division 53 of the American Psychological Association) Richard "Dick" Abidin Early Career Award and Grant to D.G.G.; National Science Foundation Graduate Research Fellowship Program Award (NSF DGE1752134), The Society for Clinical Child and Adolescent Psychology (Division 53 of the American Psychological Association) Donald Routh Dissertation Grant, the American Psychological Foundation Elizabeth Munsterberg Koppitz Child Psychology Graduate Fellowship, a Dissertation Funding Award from the Society for Research in Child Development, and a Dissertation Research Award from the American Psychological Association to E.M.C.; and a National Science Foundation Graduate Research Fellowship Program Award to J.C.F.

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