


Special Issue Article

Childhood unpredictability research within the developmental psychopathology framework: Advances, implications, and future directions

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Abstract

Greater unpredictability in childhood from the level of the caregiver-child dyad to broader family, home, or environmental instability is consistently associated with disruptions in cognitive, socioemotional, behavioral, and biological development in humans. These findings are bolstered by experimental research in non-human animal models suggesting that early life unpredictability is an important environmental signal to the developing organism that shapes neurodevelopment and behavior. Research on childhood unpredictability has surged in the past several years, guided in part by theoretical grounding from the developmental psychopathology framework (shaped largely by Dr. Dante Cicchetti's innovative work). The current review focuses on future directions for unpredictability research, including probing intergenerational effects, the role of predictability in resilience, cultural and contextual considerations, and novel developmental outcomes that should be tested in relation to childhood unpredictability. We urge the integration of multidisciplinary perspectives and collaborations into future research on unpredictability. We also provide ideas for translating this research to real-world practice and policy and encourage high-quality research testing whether incorporating predictability into interventions and policy improves developmental outcomes, which would support further dissemination of these findings.

Keywords: childhood; developmental psychopathology; interventions; unpredictability

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Developing children require regular cognitive and social inputs, as well as basic necessities such as nutrition, shelter, and clothing, in order to thrive. Abrupt, involuntary, or unexpected disruptions to these inputs and resources signal environmental unpredictability and can pose significant risk to healthy development. Experimental non-human animal research and emerging correlational research in humans suggests signals of early life unpredictability can shape the developing brain with implications for cognition, emotion, and social behavior throughout the lifespan (Davis & Glynn, 2024). Importantly, these associations between unpredictability and offspring outcomes remain even after accounting for other environmental factors such as psychosocial adversity and poverty. These findings strongly suggest that childhood unpredictability shapes development above and beyond other environmental signals. While significant advances have been made in unpredictability research, there is great potential for growth in our understanding of this topic, which we will review in the current paper.

Developmental psychopathology as a framework for understanding childhood unpredictability

The field of developmental psychopathology, shaped in large part by the contributions of Dr. Dante Cicchetti, involves multilevel analysis of both typical and atypical patterns of development, which may contribute to psychopathology, psychosocial wellbeing, and physical health across the lifespan (Cicchetti, 1984, 2006; Doom, 2022). As discussed below, developmental psychopathology is an ideal framework for understanding the effects of childhood unpredictability at multiple levels on developmental trajectories. For the purposes of this review, “unpredictability” is broadly defined and inclusive of constructs like instability, inconsistency, and chaos or disorganization (see Ugarte & Hastings, 2023) for working definitions of these terms). Unpredictability at multiple levels (e.g., in the caregiver-child dyad, within the home, or in the community) likely contribute to psychopathology above and beyond other environmental signals such as parenting quality and environmental harshness (e.g., Davis & Glynn, 2024; Ellis et al., 2009). As a result, it is important to integrate childhood unpredictability into studies of risk and protective factors for mental health and related outcomes using the developmental psychopathology framework.

The aims of the current paper are to highlight exciting findings integrating unpredictability into research on developmental psychopathology and to propose future directions for this research area. The current paper will not be a comprehensive conceptual or methodological review as those exist elsewhere (Davis &

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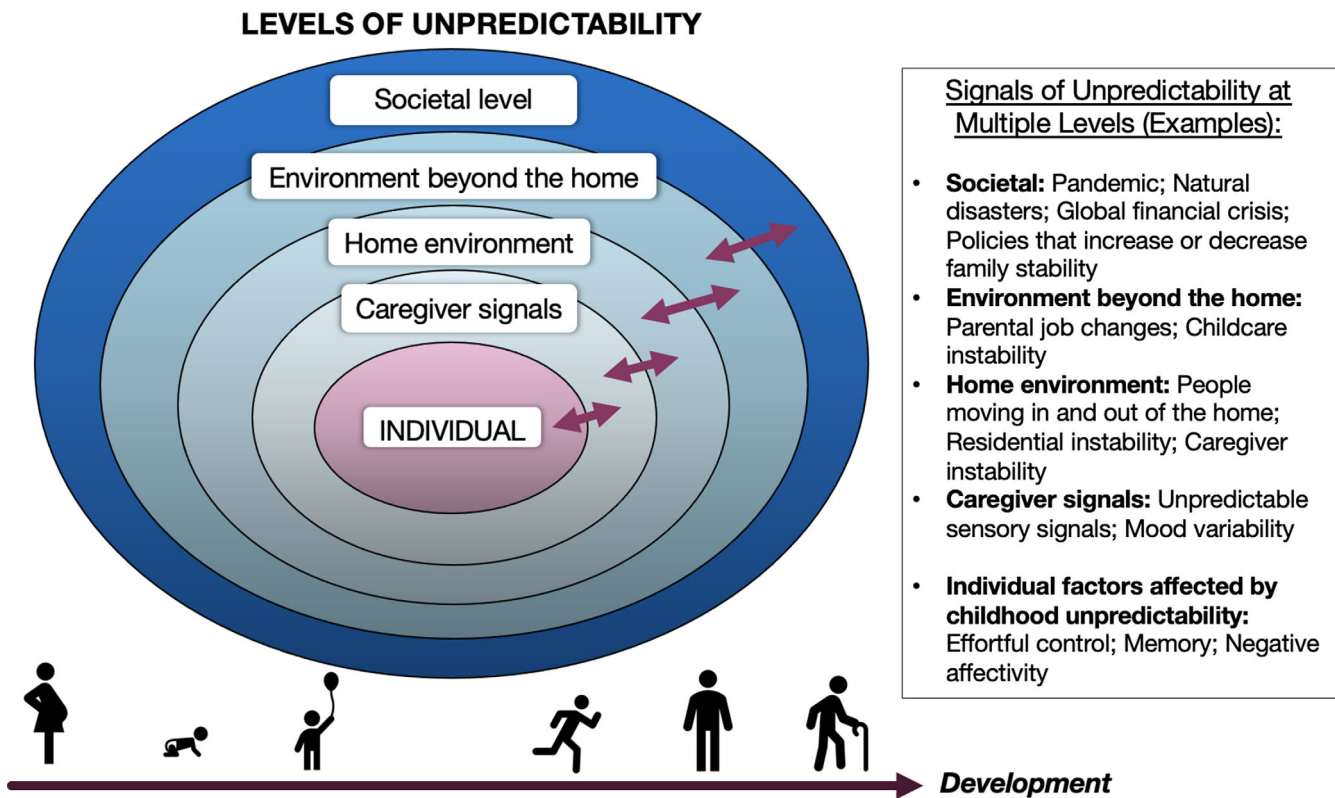


Figure 1. Multiple levels of childhood unpredictability investigated in relation to developmental outcomes.

Glynn, 2024; Glynn & Baram, 2019; Ugarte & Hastings, 2023; Young et al., 2020). Rather, we will highlight some of the areas of research on unpredictability we believe will be the most fruitful to pursue in the coming years.

Our review starts with an overview of how childhood unpredictability research intersects with developmental psychopathology concepts of multiple levels of analysis (including how unpredictability has been conceptualized at multiple levels), developmental considerations, and equifinality and multifinality. We then briefly review some of the most consistent findings on childhood unpredictability and developmental outcomes, particularly cognitive, behavioral, emotional, and social outcomes. We review recent findings on biological and behavioral correlates of childhood unpredictability, in addition to emerging research on the intergenerational transmission of unpredictability, that will be important to probe in future studies. We shift to focusing on how *predictability* could serve as a promotive factor for positive development or as a protective factor in the context of childhood adversity. We then focus on future directions in prevention and intervention research on unpredictability, including potential implications for caregivers and policymakers. Finally, we review how multidisciplinary perspectives and a cross-cultural lens can enhance this future research.

Multilevel perspectives on unpredictability

The developmental psychopathology perspective argues that examining a phenomenon across multiple levels of analysis is optimal for better understanding processes that lead to adaptive or maladaptive outcomes. One of the most compelling aspects of the study of childhood unpredictability is that unpredictability captured at multiple levels of analysis (Fig. 1) is associated with

various developmental outcomes. Experiences of unpredictability can be characterized by different time scales (e.g., moments, weeks, years) and settings (e.g., home, school, community) (Davis & Glynn, 2024; Munakata et al., 2023). Davis and Glynn (2024) provide an extensive review of specific experiences of unpredictability across various contexts and time scales, though we highlight some examples here of types of unpredictability that have been studied. For example, some studies capture global shifts or macrosystem-level shifts in stability (COVID-19 pandemic or national financial instability; Kalil, 2013; Liu & Fisher, 2022). At a more proximal level, unpredictability can include changes in the environment beyond the home, such as parental job changes or childcare instability. Within the home environment, factors such as residential instability (e.g., people moving in and out of the home, frequent moves or homelessness), and caregiver instability (e.g., changes in primary caregiver or caregiver becoming incarcerated), and household chaos have all been investigated as sources of unpredictability. Finally, specific caregiver behaviors, including moment-to-moment parent sensory signals and caregiver mood variability (Davis et al., 2017; Glynn & Baram, 2019), have been studied as signals of unpredictability in both humans and non-human animal models.

As discussed by Ugarte and Hastings (2023), little work has tested whether more distal signals of unpredictability such as housing or financial instability correlate with moment-to-moment experiences like caregiver unpredictability. Although we would expect these two to be correlated even at a small magnitude, it is also possible that caregivers experiencing instability may draw upon other resources such as social or financial support that may reduce unpredictability in caregiving. Further, even fewer studies account for macrosystem sources of unpredictability (e.g., pandemic, global financial crisis, natural disasters) that

influence families by shifting neighborhood or family financial or social factors, which can *then* influence moment-to-moment caregiver signals or mood. More studies need to include both distal and proximal measures of unpredictability over time to track children's experiences longitudinally.

An interesting finding within the existing literature is that associations with developmental outcomes have been reported with highly varying measurement strategies for assessing unpredictability. For example, some groups have measured unpredictability in a more objective manner by relying on reports of residential, employment, or social transitions within a family (Doom et al., 2016; Hartman et al., 2018). Non-human animal studies have experimentally manipulated unpredictable maternal behavior by limiting nest bedding materials (Davis et al., 2017; Glynn & Baram, 2019), a stressor that reliably induces unpredictable behaviors in the mother. Finally, other studies have relied on subjective reports of one's perceptions of childhood unpredictability, either concurrently during childhood (e.g., Xu et al., 2023) or retrospectively during adulthood with measures such as the Questionnaire of Unpredictability in Childhood (QUIC; Glynn et al., 2019). However, few studies have incorporated multiple methods of assessing unpredictability within the same study. It would be highly informative to know how correlated concurrent or retrospective perceptions of unpredictability are with more objective measures of family or job transitions. For individual measures of unpredictability (e.g., parental divorce, frequent moves), children's reports are corroborated by prospectively-collected maternal reports (83% for frequent moves and 99% for divorce; Glynn et al., 2019). In addition, adolescents exposed to more unpredictable maternal sensory signals and mood in infancy report higher childhood unpredictability (Glynn et al., 2019), though these correlations are small-to-moderate. As a result, there is evidence that these measures may be correlated, though it will be important to understand similarities and differences across measures for understanding potential mechanisms by which these various measures of unpredictability may exert effects on development.

Recent empirical and theoretical work has aimed to tease apart the contributions of different types of early environmental signals or stressors, including unpredictability, adverse childhood experiences (e.g., abuse, neglect, parental mental illness), and poverty, on developmental outcomes. Ellis et al. (2022) have proposed an integrated theoretical model that examines predictability in two different dimensions of adversity: threat and deprivation. Threat includes harm imposed by external agents (e.g., physical or emotional abuse), while deprivation encompasses a lack of environmental input to the child (e.g., physical or emotional neglect). The authors propose that threat and deprivation can be signaled by both proximal and distal cues (i.e., cues at multiple levels of analysis), which provide information about the predictability of these threatening or depriving experiences. In this model, threat and deprivation may occur on different time scales (e.g., seconds, days, years), which can provide signals to the individual about the predictability of these experiences and thus inform developmental outcomes. This model and the supporting empirical work emphasize the importance of measuring unpredictability alongside other types of environmental experiences or adversities. In addition to examining these dimensions of environmental experiences together in studies, it will be important to understand the interactions between unpredictability and other types of adversity. For example, one's perceptions of past stressors as being more predictable or controllable may reduce the potential

impact of that stressor on mental health (Cohodes et al., 2023). Interestingly, the effects of perceptions of predictability of stressors on mental health may be most potent for stressors experienced during middle childhood, adolescence, or adulthood (Cohodes et al., 2023). This study suggests that unpredictability should be considered as potentially interacting with severity of various forms of stress and that effects likely differ by developmental period. As a result, researchers should collect data on severity, type, and developmental timing of stressors, in addition to characteristics such as predictability of stressors, for a more nuanced understanding of individual differences. It is also possible that greater unpredictability serves as a pathway by which other forms of adversity impact development. For example, unpredictable maternal sensory signals and mood signals in infancy partially mediate the effects of lower socioeconomic status on child effortful control and negative affect, respectively (Davis & Glynn, 2024). Researchers should test whether different types of unpredictability may act as a mediator between adversity and child outcomes.

Developmental considerations

As with all potential risk and protective factors, the effect of unpredictability on an individual depends on one's stage of development. Existing research with both humans and non-human animals proposes infancy and adolescence as potential sensitive periods during which unpredictable signals are more likely to impact development, though more work is needed in this area (Davis & Glynn, 2024). In addition, the salience of predictability factors likely differs by developmental timing as well. For example, the predictability of maternal sensory signals is likely more salient to an infant than to a young adult. Detecting changes in parental job stability, neighborhood factors, and other environmental signals of predictability may be more salient to an older child or adolescent whose experiences are less mediated by the parent. This is not to say that infants or young children are not affected by distal unpredictability; however, it is more likely that these distal factors influence children through more proximal factors such as alterations in caregiver stress and behaviors (Belsky et al., 2012; Ellis et al., 2022; Ugarte & Hastings, 2023). Due to children and adolescents' increased cognitive capacity and interaction with the environment outside of their homes, these distal forms of unpredictability such as neighborhood or societal instability may be more likely to directly affect their perceptions.

Trajectories of development: equifinality and multifinality

A principle central to the developmental psychopathology perspective is the consideration of equifinality and multifinality in developmental trajectories. Equifinality occurs when individuals with different histories and experiences have similar developmental outcomes (e.g., individuals with and without a history of experiencing childhood emotional abuse both developing adult depression). Multifinality occurs when individuals with similar histories and experiences have different developmental outcomes (e.g., two individuals experienced childhood emotional abuse though only one develops adult depression). In relation to the study of unpredictability, researchers must consider how individuals with different histories of unpredictability can arrive at the same developmental outcome and also consider how those with similar histories of unpredictability can arrive at different developmental outcomes. As a result, considering biological, psychosocial, cultural, and other contextual factors that may

influence individual differences in response to unpredictability will be essential.

Childhood unpredictability and developmental outcomes

A rapidly expanding body of work has documented associations between childhood unpredictability and child outcomes across multiple domains, including cognition, behavior, emotion, and social development. A recently published review by Davis & Glynn (2024) describes these findings in detail, though we will highlight some of the primary findings here.

Cognitive functioning and behavior

Unpredictability in housing, finances, parental employment, and parental mental health is linked to alterations in cognitive-behavioral processes and outcomes, including effortful control, impulsivity, school outcomes, substance use, behavior problems, and neurodevelopment related to cognitive processes (Davis & Glynn, 2024; DeCandia *et al.*, 2022; Doom *et al.*, 2016; Fowler *et al.*, 2015; Schneider & Harknett, 2022; Sosu & Schmidt, 2022). Similarly, household chaos is linked to poorer self-regulation, greater externalizing problems, substance use, and other cognitive outcomes (Andrews *et al.*, 2021; Davis & Glynn, 2024; Deater-Deckard *et al.*, 2009; Delker *et al.*, 2020; Dumas *et al.*, 2005). As with these daily and more long-term measures of unpredictability, moment-to-moment unpredictability in parental sensory signals is associated with poorer cognitive functioning, including memory and effortful control (Davis *et al.*, 2017, 2022; Davis & Glynn, 2024; Holmberg *et al.*, 2022).

Social and emotional functioning

A growing body of work has documented associations of childhood unpredictability at multiple levels with emotional and social functioning. Unpredictability in domains such as housing, childcare, finances, parent employment, and parent mental health is linked to greater internalizing problems, poorer social adjustment, and poorer neurodevelopment related to social functioning (e.g., Bratsch-Hines *et al.*, 2015; DeCandia *et al.*, 2022; Pilarz & Hill, 2014; Schneider & Harknett, 2022). Greater household chaos is associated with more negative infant temperament (Bridgett *et al.*, 2013) and greater child and adolescent internalizing symptoms (Deater-Deckard *et al.*, 2019; Richie *et al.*, 2023; Wilhoit *et al.*, 2021). Similarly, fewer family routines are associated with poorer child emotion regulation (Barton *et al.*, 2019; Zajicek-Farber *et al.*, 2012). Additionally, greater variability in parental warmth is associated with higher adolescent internalizing symptoms (Lippold *et al.*, 2021), and unpredictable maternal mood predicts higher internalizing problems across development (Davis & Glynn, 2024). Greater unpredictability in maternal sensory signals is associated with greater parent-reported and self-reported child fearfulness and anxiety (Aran *et al.*, 2024). In non-human animal models, more unpredictable maternal sensory signals cause disruptions in neural circuits underlying emotion processing (Birnie & Baram, 2022; Bolton *et al.*, 2018).

Emerging areas of interest in the study of unpredictability

Exploration

Although the most consistent associations between unpredictability are with cognitive-behavioral and socioemotional outcomes, there are a growing number of studies examining other unique outcomes, which we highlight here. For example, a recent

paper reported that children who viewed their environments as unpredictable (reported via the QUIC) explored less in games involving risk and were more likely to respond in habitual ways than to choose an unknown option with potentially greater rewards (Xu *et al.*, 2023). As childhood and adolescence are important periods for exploration and learning, individuals who perceive their environments to be more unpredictable could be missing opportunities for learning. However, choosing more well-known options may also keep them safe from potential loss or danger in the environment. Although these findings may seem to diverge from the literature linking unpredictability to more impulsive or risky behaviors, these decisions around exploration may reflect a lack of strategic planning consistent with lower future orientation and lower inhibitory control for children who have experienced greater unpredictability (Xu *et al.*, 2023). Future work is needed to tease apart perceptions and objective experiences of unpredictability, and to understand how children who experience greater unpredictability may behave in various settings involving exploration or risk.

Physiology and brain development

Another exciting and growing area of research focuses on associations of childhood unpredictability with physiological processes and brain development. Though this area of research is relatively sparse in humans, we will highlight four papers from this growing area with outcomes that include vagal reactivity (Li *et al.*, 2023), cortisol regulation (Doom *et al.*, 2018), development of the uncinata fasciculus (Granger *et al.*, 2021), and salience network integrity (Jirsaraie *et al.*, 2023). Li *et al.* (2023) tested whether unpredictability and adolescent temperament interacted to predict vagal (parasympathetic) reactivity in response to a family conflict discussion task. This study found that adolescents with low dove temperament (low inhibition, high boldness and exploration) showed blunted vagal reactivity under high levels of family instability compared to adolescents with high dove (high inhibition, low exploration) temperaments. These findings suggest that adolescents with tendencies towards boldness and exploration may lead to difficulties in mobilizing energy and resources to cope with stressors in contexts of high family instability. Future research is needed to understand why temperamental differences may lead to these individual differences in vagal reactivity in response to family instability.

Research testing associations of multiple types of stressors (e.g., family conflict, negative life events, family chaos) with child stress reactivity and regulation found independent associations of unpredictability (assessed as family chaos) with diurnal cortisol regulation (Doom *et al.*, 2018). Greater family chaos reported during the preschool period was associated with a more flattened diurnal cortisol slope across the day in middle childhood. Specifically, greater chaos was associated with similar morning levels of cortisol but a lower decrease across the day, resulting in higher evening cortisol levels compared to children with lower exposure to chaos during preschool. A blunted diurnal cortisol pattern has been associated with poorer mental and physical health (Adam *et al.*, 2017), suggesting that altered diurnal cortisol regulation could mediate associations between unpredictability and poorer health. Future research is needed to understand the potential long-term consequences of greater childhood exposure to unpredictability for the developing stress system and later mental and physical health.

Granger *et al.* (2021) reported that greater exposure to maternal sensory signals during infancy are associated with greater uncinata

fasciculus generalized fractional anisotropy at 9–11 years of age. The uncinate fasciculus connects the amygdala to the orbitofrontal cortex, and thus is an important component of corticolimbic circuitry. Alterations in the uncinate fasciculus partially mediated the association between greater unpredictability in infancy and poorer episodic memory, suggesting that alterations in the uncinate fasciculus could mediate unpredictability-cognition associations. In addition to brain structure, Jirsaraie et al. (2023) examined the relation between maternal mood variability and adolescent brain function, as measured via salience network connectivity while viewing emotional faces. They found that fetal exposure to more unpredictable maternal mood during pregnancy was associated with a weakened and more inflexible salience network during adolescence. The salience network plays an important role in switching between mental states and exerting cognitive control, and disruptions to this network can have detrimental effects on mental health. Thus, these papers highlight potential neural mechanisms by which early life exposure to unpredictability could result in differences in cognition and emotion, which could have implications for later psychopathology and health.

These emerging areas of research on childhood unpredictability in humans, including changes in exploratory behavior, physiological regulation, and brain structure and function following greater unpredictability, will produce to new insights into the mechanisms by which unpredictability could lead to mental and physical health problems. Studies investigating multiple potential psychological and physiological mediators *in the same study* will be important as there are likely multiple pathways by which unpredictability influences outcomes. These studies will ideally be longitudinal, measuring unpredictability at multiple levels and timepoints first, then testing several theoretically informed mediators, and finally examining associations with mental and physical health outcomes later in development.

Physical health

Until recently, much of the research on childhood unpredictability has focused on cognitive, emotional, social, and behavioral outcomes, with their implications for mental health specifically. Given the connections between mental and physical health, and the theoretical strengths of using the developmental psychopathology framework to study the integration of mental and physical health (Doom, 2022), a logical extension of the work on childhood unpredictability is to examine its implications for physical health. Emerging research suggests that adults' perceptions of greater unpredictability in the first 10 years of childhood are associated with poorer self-reported health-related quality of life and greater functional disability (Maner et al., 2023). The association between unpredictability and health remain even after controlling for adversities with known health effects including adverse childhood experiences and childhood poverty (Maner et al., 2023). Although these findings are suggestive, more work needs to be done to capture unpredictability prospectively in childhood and include objective measures of physical health status later in development.

One study with clinical measures of immune outcomes found that unpredictability assessed as family structural changes does not predict asthma-relevant clinical or immune outcomes (Lam et al., 2022). At least one recent study examining indirect pathways between unpredictability from 0 to 5 years of age to body mass index (BMI) at 15 years, a predictor of adult metabolic syndrome and cardiovascular disease. This study found that unpredictability was associated with greater BMI through pathways of greater

impulsivity at age 5 and overeating at age 9 (Doom et al., 2023). Interestingly, unpredictability from 0 to 5 years was not related to emotion dysregulation at age 5 in the same model, suggesting that pathways from unpredictability to later health outcomes could be more likely to operate through alterations in cognitive versus affective processes. This finding of a stronger association of unpredictability from 0 to 5 years with impulsivity versus emotion dysregulation at age 5 was replicated in the same study with a different cohort (Doom et al., 2023). Future studies of childhood unpredictability and physical health should (1) measure multiple forms of unpredictability (e.g., self-reported perceptions of unpredictability, objective assessments of household unpredictability, observed maternal sensory signals), (2) use both subjective and objective measures of physical health status, (3) use prospective longitudinal data to reduce reporting bias, and (4) probe potential biological and behavioral mechanisms from unpredictability to physical health.

Intergenerational transmission of unpredictability

An additional important question that needs to be explored in depth is whether unpredictability experienced during pregnancy by the mother can be transmitted biologically and behaviorally to their fetus. That is – do unpredictable environmental signals experienced during pregnancy by the mother lead to altered maternal biological signals (e.g., increased stress hormones and inflammation) and behaviors (e.g., substance use, diet) which could be transmitted to the fetus? The literature on maternal prenatal mood variability provides initial support for this hypothesis. Fetal exposure to unpredictable maternal mood is associated with altered neural functioning (Jirsaraie et al., 2023), neurodevelopment, temperament, and mental health (Glynn et al., 2018; Howland et al., 2021). No studies to our knowledge have examined whether mothers' experiences of environmental unpredictability during pregnancy (e.g., financial or housing instability) are uniquely associated with fetal development and postnatal outcomes. Questions around the intergenerational transmission of adverse experiences, including unpredictability, are important for developing and testing interventions to improve both maternal and offspring outcomes.

A related question around the intergenerational transmission of unpredictability is whether parents' experiences of childhood unpredictability shape their own parenting behaviors, which can then shape offspring development. Evidence from two cohorts suggests that unpredictability experienced during early childhood (indexed by parent job, residential, and cohabitation changes) is associated with a more negative parenting orientation for men, but not for women, in adulthood (Szepeswol et al., 2015). As a result, one's own experiences of childhood unpredictability may be passed down to the next generation through parenting orientation and behavior unless these parenting cognitions and behaviors are intervened upon. An interesting future direction within this area is understanding coparenting relationships with caregivers who have had different experiences of childhood unpredictability.

Another possible avenue for future research involves whether parents' own experiences of childhood unpredictability match their current parenting context. For example, if a parent experienced a great deal of unpredictability in parental sensory signals and instability in their home and neighborhood as a child, how might their parenting be influenced by the stability of their environment when they become parents? There is evidence that greater household unpredictability (defined by residential and paternal transitions) in the first 5 years of parenting is associated

with greater maternal depressive symptoms and less sensitive parenting (Belsky et al., 2012), suggesting that current levels of unpredictability in the parenting context are important. However, it is unclear how parents' own childhood experiences of unpredictability may interact with current context. This may be particularly relevant for immigrant parents who experienced a great deal of uncertainty and instability during that transition period but are now able to provide greater stability for their own children. These intergenerational questions can be addressed with new measures such as the QUIC that assess retrospective reports of childhood unpredictability, or longitudinal studies that span multiple generations.

Risk and protective factors in the face of unpredictability

As mentioned above in regard to equifinality and multifinality in developmental trajectories, biological, psychosocial, contextual factors can exacerbate or buffer the effects of unpredictability on developmental outcomes (Adams & Dubay, 2016). For example, individual- and parent-level characteristics can increase susceptibility to environmental unpredictability for outcomes such as vagal stress reactivity (Li et al., 2019), sensory processing sensitivity and temperament (Li et al., 2022), and maternal depression (Zhang et al., 2022). Understanding contextual factors that may lead to individual differences in risk or resilience in the face of unpredictability will inform intervention.

Overall, unpredictability seems to be most prevalent and also impactful for those who hold marginalized identities or experience systemic disadvantages (Adams & Dubay, 2016; Maner et al., 2023). While challenges like immigration, homelessness, incarceration, and involvement in the child welfare system are inherently unpredictable experiences, they also often contribute to unpredictability in other aspects of life. For example, children in foster care may experience high levels of residential and school mobility due to multiple placements. Further, the effects of unpredictability are often most pronounced for racial/ethnic minority and low-income individuals (Doom et al., 2016; Maner et al., 2023), perhaps because these populations are already experiencing higher levels of stress in other domains (e.g., discrimination, lack of resources) compared to majority racial/ethnic or higher-income groups.

Recent studies have also begun to identify factors that contribute to resilience amid unpredictable circumstances. For example, adolescents with low *dove* temperament displayed better adaptation to parenting unpredictability than those with high *dove* temperament (Li et al., 2023). Additionally, parental investment buffers the effects of environmental unpredictability (i.e., unpredictable life events, family conflict) on children's life history development (Yang et al., 2023). Future research should continue identifying and examining protective factors beyond temperament and parenting that buffer the effects of unpredictability on development. An important future consideration for risk and protective factors in the context of unpredictability is clarifying whether these factors are specifically interacting with unpredictability as opposed to other dimensions of adversity, such as harshness, threat, or deprivation. Yang et al. (2023), for example, found that parental investment moderated the effects of both environmental unpredictability and harshness on children's aggression and delinquency, treating unpredictability and harshness as two distinct constructs. This specificity will allow us to sharpen our theoretical models and intervention efforts.

Inherent in evolutionary models of development, including life history theory (Ellis et al., 2022; Kaplan & Gangestad, 2015), is the assumption that individuals make adaptations to environments with the goal of increasing survival and fitness in that environment. Beyond risk and protective factors, Ellis et al. (2022) propose an adaptation-based approach to resilience (Ellis et al., 2017). In contrast to the traditional strengths-based approach to resilience, which focuses on assets and resources that compensate for the negative effects of stress, the adaptation-based approach focuses on the ways in which stress *enhances* certain abilities to match the environment and ultimately increase evolutionary success. For example, higher caregiving instability is associated with reduced inhibitory control and working memory capacity, but enhanced cognitive flexibility in children (Fields et al., 2021). Future work should continue to explore how individuals adapt to stress and what types of unique strengths can be leveraged to enhance resilience, specifically within unpredictable environments.

Predictability as a promotive or protective factor

While much of the literature has conceptualized unpredictability as a stressor and documented its negative consequences, we should also study how low levels of unpredictability (i.e., greater predictability) may promote more adaptive outcomes both within and outside the context of adversity (Davis & Glynn, 2024). When conceptualized as being protective in the context of adversity specifically, predictability would be a *protective factor*. If predictability is associated with better outcomes for all individuals regardless of adversity history, it would be conceptualized as a *promotive factor*. Previous research has highlighted the benefits of creating structure through routines and rituals for young children and families (Fiese et al., 2002), particularly for those experiencing adversity or instability in other aspects of their lives. Child- and family-level routines, for example, have been shown to protect against the negative effects of daily hassles (Bridley & Jordan, 2012), domestic violence exposure (David et al., 2015), and the COVID-19 pandemic (Glynn et al., 2021) on children's wellbeing. Children may also rely on predictability in out-of-home contexts, especially when their home environment is not as stable. Child care and school environments, for example, often serve as safe havens for children experiencing adversity (Leonard & Gudiño, 2016; Sciaraffa et al., 2018). Future studies should continue to examine whether and which aspects of predictability in these environments (e.g., classroom routines and structure, planned transitions, reliability of peers and adults) promote greater resilience in children. Furthermore, less research has examined whether predictability in the form of parent sensory signals can buffer the negative effects of adversities or challenges. Future studies should test whether the predictability of caregiver cues towards children, such as their sensory signals during dyadic interactions and parental mood patterns, can serve as a protective factor for children experiencing adversity.

There is emerging interest in the predictability of childhood *stressors* themselves. An abundance of human and non-human animal studies demonstrate that exposure to unpredictable stress is associated with poorer outcomes than predictable stress (Foa et al., 1992; Miller, 1981; Seligman et al., 1971; Weiss, 1970). However, there is a smaller body of research that focuses on how predictable stress may contribute to resilience. A recent study by Cohodes et al. (2023) reported that higher perceived predictability of a stressor was shown to buffer the impact of that stressor on

later trauma-related symptomology. This research emphasizes the protective function of *perceived* predictability, regardless of whether the events in question were objectively predictable or not (Smith & Pollak, 2021). Importantly, predictability is not to be conflated with controllability, which refers to the ability to exert control over a stressor, though these two constructs are related and often interact to mediate resilience (Cohodes et al., 2023).

As we discuss the effects of greater unpredictability, we must also explore the potential downsides of *too much predictability* in caregivers' behaviors towards children. This issue has been documented with children who have behavioral issues such as aggression. For example, coercion theory examines how parental responses to their children's aversive behaviors result in escalating child negative behaviors over time (Patterson, 2002). Both caregivers and children mutually shape each other's behaviors through operant and classical conditioning (Lunkenheimer et al., 2016). Research has found a positive relation between caregivers' behavioral rigidity (i.e., highly predictable parenting behaviors) and children's misbehavior, indicating that higher levels of rigidity are associated with elevated levels of perceived childhood misbehaviors (Riley, 2014). Caregivers repeatedly respond a specific way to their children's misbehavior, and children become conditioned to respond a specific way to their parents' behavior as well. Becoming "stuck" in a particular behavioral repertoire and being unable to switch behaviors can be problematic (Hollenstein et al., 2004). These highly predictable and rigid parent responses may reduce opportunities for their child to build their own ability to regulate their behavior and adapt to changing environmental demands. As a result, highly predictable parenting that does not shift in response to child and environmental demands can be problematic for child development. Understanding how too much predictability at various levels (e.g., parent sensory signals, rigid daily routines) may impact child development will be important to consider in future research.

Implications for caregivers

Caregivers shape the environments in which children grow, and thus, caregivers can shape their children's experiences and perceptions of predictability across development. As previously mentioned, which environmental signals are most salient to children likely differs by developmental stage. During the earliest years of life, caregivers play an important role in coregulation and providing signals to the developing brain (Gee & Cohodes, 2021). Therefore, caregivers of infants and young children may choose to focus on improving their micro-level behaviors, such as how to provide more predictable sensory signals during caregiver-child interactions. However, adjusting these rapid, potentially unconscious behaviors will likely be difficult without support. It may be more practical to guide caregivers to predictably respond to infants' or toddlers' bids for attention. As children grow older and rely less on physical cues, caregivers can promote predictability across longer time scales, such as implementing family routines, ensuring a well-organized home environment, or being a reliable support figure. Caregiving or authority figures outside of the home, such as child care providers and teachers, also play a role in promoting predictability. Research shows, for example, that continuity of care in infant-toddler classrooms (i.e., where a child stays with the same caregiver across multiple years) is associated with better child behavioral outcomes (Horm et al., 2018). Other aspects of predictability include schedules and routines, planned transitions between activities, and well-organized classroom

environments. Finally, caregivers can promote continuity across contexts. A strong home-school partnership, for example, can include shared beliefs, expectations, and practices that promote consistency across settings, which can support child development.

Policy implications

Research on the negative effects of unpredictability on child development emphasizes the need for programs and policies that promote greater predictability in children's lives through housing, food, family structure, employment, income, school, and childcare stability (Sandstrom & Huerta, 2013). Rigorous future research is needed on the effectiveness of such programs and policies (i.e., whether these efforts actually increase stability in the intended areas and promote more positive child development). For example, while childcare subsidies are intended to increase stability of care arrangements, the evidence for such impact is scarce and mixed at best, with some studies reporting that subsidized care is more stable than unsubsidized care (Forry et al., 2013) and others suggesting no relation between subsidy receipt and stability of care (Krafft et al., 2017). There is also mixed evidence on whether childcare subsidies are associated with more positive child outcomes (Forry et al., 2013). Further investigation is needed on childcare subsidy effectiveness (e.g., why they may be effective for some families and not others), and similar evaluation and impact studies should be conducted on other types of policies and programs intended to promote stability. Future research should also look at whether macro-level policy contexts are related to micro-level experiences of predictability (e.g., predictability of caregiver cues, child- or family-level routines, individuals' perception of predictability). One qualitative study, for example, found that maintenance of family routines and rituals differed across different types of housing programs (Mayberry et al., 2014), indicating that higher-level programs may affect families' more proximal experiences of predictability.

Additionally, policymakers must pay more attention to the stability and not just the level of family resources. For example, many programs and policies are based on family income levels that are measured at one timepoint or averaged across multiple timepoints, but these efforts do not address any fluctuations in income that may have occurred. Previous research suggests that income instability and material hardship unpredictability are associated with poorer behavioral and mental health outcomes in children, independently of income and material hardship levels (Liu et al., 2022; Zhang et al., 2023). Other safety net programs like Medicaid and the Supplemental Nutrition Assistance Program often have gaps in eligibility and coverage, leaving families without services for periods of time. These shifts in coverage can be detrimental for children, as moving between food security and insecurity is associated with poorer academic and cognitive functioning as well as greater externalizing behaviors (Gallegos et al., 2021). One potential implication of these findings is that policymakers should prioritize efforts that provide regular, consistent support to families rather than sporadic, one-time supports that provide only temporary relief. It is also important for policymakers to ensure the stability of services offered through various programs and policies, as breaks in these services can be detrimental to child development. For example, disruptions to subsidy receipt lead to unstable child care arrangements (Ha et al., 2012), which are associated with poorer child behavioral, social, and academic outcomes (Bratsch-Hines et al., 2015; Pilarz & Hill, 2014). Policymakers must develop innovative strategies to avoid

tying service eligibility to characteristics that may be unstable (e.g., parental employment, income, or residential status) so that children and families do not lose access to services when life circumstances change (Adams & Dubay, 2016).

Future directions

Integrating multidisciplinary perspectives to advance the field

Neurobiology and physiology

Multidisciplinary perspectives are essential for advancing the science of unpredictability. For example, research on psychosocial stress and development has benefited immensely from integrating neurobiological perspectives to understand how psychosocial experiences “get under the skin” to influence mental and physical health (Doom & Gunnar, 2013). As mentioned above, studies integrating neurobiology and physiology into the science of childhood unpredictability are growing in number, and these studies will allow us to probe mechanisms by which unpredictability may impact developmental outcomes. Theoretical and empirical work within stress physiology, developmental psychopathology, and evolutionary psychology has integrated unpredictability as an environmental signal that can activate stress-mediating systems independent of measures of environmental harshness (e.g., poverty). Understanding chronic environmental unpredictability as an additional source of stress that can activate the stress system repeatedly will inform our understanding of how this salient environmental signal impacts mental and physical health.

We would be remiss not to mention previous research on mechanisms by which unpredictability influences development, though much more comprehensive reviews of these mechanisms exist in other papers (e.g., Birnie & Baram, 2022; Davis & Glynn, 2024; Gee & Cohodes, 2021; Glynn & Baram, 2019). Much work has been done, particularly in non-human animal models, on the neurobiological mechanisms by which unpredictability influences cognition, behavior, emotion, and social functioning. This experimental non-human animal research suggests that unpredictable patterns of maternal care lead to aberrant synaptic connectivity and disrupted development of cognitive and emotional brain circuitry (Glynn & Baram, 2019). One newly-identified pathway involves a projection from the basolateral amygdala to the nucleus accumbens that may be particularly influenced by early unpredictability and lead to alterations in reward behavior (Birnie *et al.*, 2023). These unpredictable maternal care patterns and subsequent neurobiological disruptions in brain regions underlying stress responses and emotional functions produce problems with memory and greater anhedonia-like behaviors (Birnie & Baram, 2022; Glynn & Baram, 2019). As a result, these neurobiological, cognitive, and behavioral mechanisms documented in non-human animal models are potential mechanisms by which childhood unpredictability influences mental and physical health in humans.

This careful experimental work on the neurobiological mechanisms by which unpredictability influences mental health is often impossible in humans due to ethical considerations. However, recent longitudinal observational work in humans attempts to probe possible neurobiological mechanisms. One recent review (Gee & Cohodes, 2021) asks the question: Does unpredictable parental care during early sensitive periods accelerate maturation of corticolimbic circuitry, which then shortens the period of plasticity and sensitivity to caregiver signals?

According to this hypothesis, unpredictable care could lead to greater stress system activation which accelerates maturation and leads to fewer opportunities for learning from caregivers in the future. Behaviors that the child learned to adapt to these unpredictable signals may be helpful for that caregiving context but can lead to difficulties when using these coping behaviors in new contexts later in development. There is a great need for cross-species and interdisciplinary research to continue to investigate how these mechanisms unfold across development, from immediate alterations in neurocircuitry following unpredictable environmental cues to subsequent caregiver-child interactions within context.

Statistics

As discussed in Ugarte and Hastings (2023), advanced statistical techniques are needed to examine unpredictability at multiple levels across many timepoints longitudinally. Collaborations with statisticians will allow for a more precise measurement of ranges of unpredictability where we might expect deleterious developmental outcomes, as well as ranges at which *too much predictability* could also lead to more negative outcomes. Working with statisticians on large datasets with repeated measures of unpredictability at multiple levels will allow these important questions about developmental trajectories to be tested.

Sociology and public health

Sociologists use data at the society-level to examine changes in nationwide financial stability and other trends within the macro-system, which may have direct or indirect effects on environmental predictability experienced by the child. Similarly, researchers in public health also use macrosystem-level data to better understand factors that shape health. Most research on childhood unpredictability has focused on whether unpredictability at the home-level or in dyadic interactions is associated with child outcomes. However, it will be essential to collaborate with sociologists and public health researchers using societal-level data to understand what indicators of unpredictability in the macrosystem (e.g., changes in immigration policy; economic or political transitions) might impact child outcomes.

In addition to examining nation- or region-level indicators of unpredictability, neighborhood-level unpredictability will be important to consider as this environment is more proximal to the child. However, few studies have examined whether neighborhood instability is associated with child outcomes, though some recent investigations have used indicators such as neighborhood residential stability as an index of unpredictability associated with child behavior problems (e.g., Li *et al.*, 2022). Greater neighborhood unpredictability or instability could alter social factors in the neighborhood, such as perceptions of social cohesion, which can then lead to downstream effects on families and children. For example, having neighbors moving in and out of the neighborhood frequently might prevent social cohesion among neighbors, leading to fewer high-quality relationships that could serve as protective factors for children. Thus, it will be essential for longitudinal studies to understand neighborhood-, regional-, or nation-level data to better understand how unpredictability beyond the home may contribute to child outcomes.

Anthropology and evolutionary biology

Collaborations with anthropologists and evolutionary biologists will be important to better understand how unpredictability in factors such as threat and deprivation have changed across history

and by region. These investigations are important for understanding species-typical versus atypical levels of unpredictability. Alternatively, recent investigations suggest that there has been high variability in levels of threat and deprivation over time, suggesting that human evolution likely favored high levels of plasticity to adapt to environmental unpredictability (Frankenhuis & Amir, 2022). These collaborations will inform our understanding of the range of unpredictability that may lead to altered developmental outcomes and our understanding of neuroplasticity in response to unpredictable cues. They will also help us to understand how unpredictable environments are detected and acted on by humans (e.g., Young et al., 2020).

Cross-cultural and contextual considerations

A major weakness in the history of developmental psychology broadly is the assumption that developmental processes unfold similarly across cultures. While this assumption has been challenged by a growing body of research demonstrating the importance of culture and context in shaping development (Abu Salih et al., 2023; Buhler-Wassmann & Hibel, 2021; Keller, 2018), it is important to continually test these cultural and contextual factors in research on early experiences. Many of the samples utilized in research on unpredictability have focused on White samples using measurement tools developed from a White perspective (Buhler-Wassmann & Hibel, 2021). There is growing evidence that unpredictability is a salient environmental signal across many contexts (e.g., rural and urban, high- and low-resourced, across multiple continents including Africa, Asia, Europe, and North and South America, Davis & Glynn, 2024; and across species, Davis et al., 2017, 2022). However, given cultural differences in parenting behaviors and values and variations in contexts that may give rise to unique forms of unpredictability (e.g., greater unpredictability in caregiver sensory signals vs. greater national or regional financial instability influencing employment), it is likely that associations between childhood unpredictability and developmental outcomes likely vary by these important factors. For example, in cultures where predictability and routine in parenting may be less emphasized or valued, are there smaller associations between unpredictability and child outcomes compared to cultures where predictability and routine are highly valued? Relatedly, associations between childhood unpredictability and developmental outcomes likely differ by either the type of unpredictability and the outcome (e.g., cognitive, affective, social) assessed, and the strength of these associations likely also vary by cultural or contextual factors. Future research should test associations between unpredictability and developmental outcomes in samples that are geographically, ethnically, and socioeconomically diverse using culturally appropriate and validated measures. Similarly, future studies should systematically capture cultural or contextual factors (e.g., childcare policies; cultural values around predictability; economic stability) that could lead to differential associations between unpredictability and developmental outcomes.

Our research on unpredictability

Research by our team has contributed to the field of developmental psychopathology by informing our understanding of how family-level unpredictability, including family chaos, residential moves, job transitions, and other family changes, are associated with psychosocial, behavioral, and biological functioning across the lifespan (e.g., Doom et al., 2016, 2018, 2023). These studies

establish connections between unpredictability in the first few years of life with multiple developmental outcomes that have known implications for lifelong mental and physical health. Together, this work suggests a potential sensitive period for unpredictability in the first 5 years of life predicting cascades of poorer health-related outcomes later in development. As a result, future research in developmental psychopathology should continue to examine sensitive periods during which unpredictability may be particularly important for development, including understanding what types of unpredictability (e.g., parental sensory signals, family chaos or transitions) may be most salient and/or amenable to intervention at different developmental timepoints. Our team's future research plans include: (1) collaborating with other groups examining unpredictability at the level of caregiver sensory signals to integrate multiple levels of unpredictability into our research, (2) examining unpredictability in relation to markers of physical health from childhood through adulthood, and (3) testing the role of predictability as a protective factor for multiple developmental outcomes in contexts of high adversity.

Conclusions

Research on the lasting associations of childhood unpredictability with multiple developmental outcomes across the lifespan has exploded in the past decade, unlocking new insights into unpredictability as a powerful signal of the early environment that shapes developmental trajectories. It is certainly an exciting time to be studying unpredictability, its associations with different outcomes, potential risk and protective factors that moderate the effects of unpredictability, and the mechanisms by which unpredictability may ultimately shape mental and physical health. Additional considerations for future research include studying intergenerational pathways, the role of predictability in resilience, and cross-cultural or contextual differences in the effect of childhood unpredictability. Investigating these questions will benefit from integrating multidisciplinary perspectives and collaborations. Furthermore, as this research has important implications for real-world practice and policy decisions, greater efforts must be made to connect with practitioners and policymakers who can translate this science into action, while rigorously testing the impacts of programs and policies that reduce childhood unpredictability. We hope this review provides fruitful new avenues of research on how childhood unpredictability may uniquely shape development.

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