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Childhood Environmental Unpredictability and Adolescent Mental Health and Behavioral Problems

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ABSTRACT

Childhood adversity takes a toll on lifelong health. However, investigations of unpredictability as a form of adversity are lacking. Environmental unpredictability across multiple developmental periods and ecological levels was examined using a multiethnic, longitudinal birth cohort (1998–2000) oversampled for unmarried parents. Data were from the Future of Families and Child Wellbeing Study ($N = 4898$ youth at birth; 52% male; 48% Black, 27% Hispanic, 21% White) to examine unpredictability at ages 1, 3, 5, and 9 with later adolescent outcomes. An unpredictability index was associated with age 15 outcomes ($N = 3595$) including depressive symptoms ($\beta = 0.11$), anxiety symptoms ($\beta = 0.08$), delinquency ($\beta = 0.13$), impulsivity ($\beta = 0.09$), heavier weight categories ($\beta = 0.09$), and internalizing ($\beta = 0.14$), externalizing ($\beta = 0.23$), and attention problems ($\beta = 0.16$). Findings support unpredictability as a unique form of adversity.

Childhood adversity takes a toll on the health and wellbeing of individuals across the lifespan (Shonkoff and Garner 2012). Despite these well-documented associations, there remain open questions regarding the core features of adverse experiences that negatively shape youth developmental outcomes. Developmental scholars have called for expanding current conceptualizations to include aspects of environmental unpredictability as a form of adversity (Doan and Evans 2020; McLaughlin et al. 2021; Smith and Pollak 2021). The common, core feature of environmental unpredictability is the lack of consistency or the presence of variation in the occurrence of environmental experiences. Reflecting a bioecological model (Bronfenbrenner and Evans 2000; Bronfenbrenner and Morris 2006), children may experience unpredictability in both their social and physical environments ranging from the proximal settings children are directly embedded in to more distal environmental influences that may disrupt or produce variation within youth's proximal contexts. Additionally, sources of variation may operate on different timescales ranging from day-to-day variation to broader ecological transitions. As such, we consider multiple forms of environmental unpredictability, chaos, instability, ecological transitions, and fluctuations in environmental experiences both in combination and individually that have been found to shape child development.

Environmental unpredictability may constitute a form of childhood adversity as unpredictability may undermine child development in multiple ways. Unpredictability in one's environment may result in feeling a loss of control (Fiese and Winter 2010) and decrease the ability of youth to make predictions about their environment or during social interactions (Doan and Evans 2020). On the other hand, predictability underlies the development of neurobiological systems that support effective self-regulation skills (Miller 1981). Relatedly, uncontrollability is a key feature of stressors that acutely activate the stress response system (Dickerson and Kemeny 2004).

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Evolutionary developmental models posit that unpredictability in the environment signals shorter life expectancy thus prompting allocation of resources to reflect faster life history strategies (Ellis et al. 2009). Children may also be impacted by environmental unpredictability indirectly by interfering with developmental processes that promote competence (Bronfenbrenner and Evans 2000). Unpredictability and chaos outside children's immediate contexts may spillover and be disruptive to their caregivers' ability to provide sensitive and responsive care that serves as both a promotive and protective factor in child development (Doan and Evans 2020; Smith and Pollak 2021).

Existing research demonstrates specific forms of environmental unpredictability are associated with poorer child health and well-being. Moreover, children may encounter multiple sources of environmental unpredictability in multiple ecological settings. Beginning with the setting most proximal to children, within the family system, parents may be sources of environmental unpredictability through their own chaotic behaviors and inconsistent parenting. For example, maternal inattention and impulsivity are associated with differences in parenting behaviors (Chen and Johnston 2007). Parental impulsivity has been associated with higher body mass index in youth (Sleddens et al. 2016). Predictable maternal signals have been associated with better cognitive functioning in young children (Davis et al. 2017) while inconsistent discipline has been related to a higher likelihood of the onset of conduct disorder (Loeber et al. 1995). Inconsistency in positive parenting, as measured by greater variation in day-to-day warm parenting behaviors, was correlated with childhood ADHD (Li and Lansford 2018). In addition to inconsistency in their own parenting, inconsistency across multiple caregivers may be disruptive to children's development and ability to anticipate caregivers' behaviors, whereas consistency across caregivers may be beneficial to their development. For example, supportive coparenting was associated with fewer child behavior problems (Choi and Becher 2019).

At the broader family level, family routines provide organization and structure to daily life that have been found to be beneficial to children's development. For example, consistency in the timing of daily events such as meals and sleep is an important aspect of daily routines (Jensen et al. 1983). Greater regularity in family routines was associated with lower child aggression (Rijlaarsdam et al. 2016) and internalizing problems (Ivanova and Israel 2006). However, a lack of bedtime routines in childhood was associated with greater adolescent body mass index (Lee et al. 2019). Beyond unpredictability in daily life, instability may be reflected in the structural changes and transitions experienced by the family. For example, individuals exiting and entering the family may be disruptive to the organization, stability, and functioning of the family. Both coresidential and dating transitions were related to increased maternal stress and harsh parenting (Beck et al. 2010). Multiple family transitions were associated with higher levels of internalizing and externalizing behaviors in children, with the transition out of two-parent families particularly detrimental for youth (Lee and McLanahan 2015). Maternal relationship dissolution has also been associated with greater increases in youth body mass index (Schmeer 2012).

In addition to unpredictability in social functioning within the family, children may also experience unpredictability and disorder in their physical home environments. Living in crowded, cluttered, chaotic, and noisy homes may be disruptive to child development (Evans 2021). For example, background noise, including sounds from traffic, electronics, and human speech, is disruptive to child development (Erickson and Newman 2017). Background television noise has been found to reduce the quality and quantity of parent–child interactions during play (Kirkorian et al. 2009) and background television exposure was associated with lower executive function in children (Linebarger et al. 2014). With regard to physical space, household crowding, reflecting greater density of individuals in the home, was associated with lower academic achievement (Solari and Mare 2012). Overall household chaos has also been associated with adolescent impulsivity and delinquency (Joo and Lee 2020). Beyond the day-to-day chaos in a home, children may experience disruptions in their physical home environment through residential moves or displacement. Residential instability and the number of moves were associated with more behavioral problems in school-aged children (Jelleyman and Spencer 2008). Housing instability may include periods of homelessness, living in shelters, and multifamily (e.g., doubled-up) living arrangements resulting in disruptions and changes in the physical locations in which children live. Eviction during middle childhood has been associated with deficits in cognitive development (Schwartz et al. 2022). For some youth, residential instability results in not only changing home environments but also changes in additional microsystems, including their school, peer, and neighborhood contexts.

Beyond the home setting, children may experience unpredictability in other forms of caregiving, such as in daycare or other childcare settings. Instability in caregiving arrangements may be disruptive to children receiving consistency in care and expectations across caregivers. For example, childcare instability, having multiple non-parental caregivers, and needing back-up caregiving arrangements have been found to relate to more internalizing and externalizing problems in children (Pilarz and Hill 2014). Furthermore, disruptions in the mesosystem and exosystem may increase unpredictability for children. Instability in parental work may be associated with disruptions in parenting and increased stress. For example, unstable employment and workplace inflexibility were associated with reduced paternal involvement and increased parenting stress (Castillo et al. 2013; Nomaguchi and Johnson 2016). Maternal employment stability in early childhood, reflecting continuous employment and less job churning, was associated with fewer externalizing behaviors (Pilkauskas et al. 2018). Whereas work schedule inflexibility, unpredictable work schedules, non-standard work hours, and work-related stress were associated with increased behavioral problems (Castillo et al. 2020; Pilarz 2021; Schneider and Harknett 2022). Unpredictability and variation in these settings may spill over into and disrupt children's immediate contexts, their routines, and the care they receive.

There is ongoing debate by developmental scholars centered on how best to capture adversity (McLaughlin et al. 2021; Smith and Pollak 2021). Prominent approaches include investigations of singular forms of adversity, cumulative indices such as the number of adverse childhood experiences that occur prior to adulthood (Felitti et al. 1998), and dimensional models indexing

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variation in a shared common feature (e.g., threat, deprivation; McLaughlin et al. 2014). Critics of studies of singular forms of adversity note that these approaches overlook issues with regard to co-occurring adversities. Limitations of cumulative approaches that sum dichotomous (yes or no) adverse exposures ignore important features of adversity such as duration and severity. These approaches also leave little room for understanding the underlying shared features that may be targets of intervention and prevention when considering more narrow forms of adversity. For example, adverse childhood experiences (ACEs) reflect the sum of 10 varying experiences including neglect (emotional and physical), abuse (emotional, physical, and sexual), and family dysfunction (parental mental illness, parental substance use, parental incarceration, parental divorce, interparental violence) (Felitti et al. 1998).

Common to these divergent views are recent calls for expanding current conceptualizations to include aspects of environmental unpredictability as a form of adversity (Doan and Evans 2020; McLaughlin et al. 2021; Smith and Pollak 2021). Thus, the present study sought to examine the role of environmental unpredictability during childhood by creating a dimensional index of environmental unpredictability that takes into account variation in exposure and spans from infancy to preadolescence. Our primary aim was to assess how this dimensional unpredictability index shaped later adolescent mental health and behavioral problems. To examine the unique role of unpredictability, we examine the role of unpredictability net of ACE scores as an alternative current and prominent model for capturing adversity.

Developmental science theories highlight the role of individuals as active agents shaping their own development and exerting effects on their environmental contexts (Bell 1968). Children's own behaviors may in turn contribute to increasing subsequent environmental unpredictability. Children's disruptive behavior may evoke additional family chaos and be disruptive to family routines. Additionally, children's genetic propensity for more impulsive behaviors may shape and modify their environmental contexts. For example, previous research demonstrates that children's ADHD genetic risk was associated with household chaos (Agnew-Blais et al. 2022) consistent with evocative gene–environment effects (Knafo and Jaffee 2013). To date, investigations of whether children's behaviors contribute to unpredictability in their contextual environment are lacking.

1 | Present Study

Environmental unpredictability may constitute an additional form or dimension of childhood adversity. As such, we sought to examine environmental unpredictability across childhood and test it in association with adolescent outcomes using a large, prospective, multiethnic population-based birth cohort study. As forms of environmental unpredictability often co-occur (Doan and Evans 2020), the aim of the derivation of the environmental unpredictability dimensional index was to account for forms of unpredictability that spanned diverse forms, developmental settings, ecological levels, and time scales. As prominent models of childhood adversity such as ACEs often examine the effects of adversity prior to adulthood, we sought to examine environmental unpredictability throughout a larger span of childhood ranging from infancy to preadolescence. The goal of the present study was to conduct a confirmatory hypothesis test of the role of environmental unpredictability throughout childhood as a unique predictor of adolescent outcomes. We hypothesized that greater environmental unpredictability across childhood (as measured by the dimensional index) would be associated with poorer adolescent outcomes net of childhood ACEs as a covariate. We also include follow-up analyses examining the impact of unique forms of unpredictability. These analyses were exploratory; however, we hypothesized that more proximal forms of unpredictability, relative to more distal forms, may be more likely to be statistically significant predictors of youth outcomes. Consistent with the bioecological model (Bronfenbrenner and Morris 2006), we consider individual forms of unpredictability in youth's microsystems that they are directly exposed to be more proximal influences (e.g., parental impulsivity, lack of stable family routines, physical household chaos, family chaos, family instability) compared to unpredictability at broader ecological levels. Less proximal ecological levels in this study included unpredictability in youth's mesosystem reflecting interconnections among contexts (e.g., inconsistency in coparenting, childcare instability) as well as unpredictability in the exosystem in which caregivers but not youth are directly embedded (e.g., parental employment instability). Lastly, more proximal forms of unpredictability such as residential instability may also be in part influenced by the broader systems including the mesosystem (e.g., changes in neighborhoods resulting from residential moves) and the macrosystem (e.g., residential instability which is in part influenced by state and local eviction laws as well as broader macroeconomic conditions). However, because forms of adversity often co-occur and share variance with one another, the hypotheses regarding the unique roles of individual forms of unpredictability were exploratory. We also include exploratory analyses examining the impact of developmental timing of unpredictability; however, we do not make specific hypotheses given divergence in findings from timing analyses to date that support a variety of different timing models in existing research from the broader developmental science field such as support for early sensitive period models, recent exposure models, and cumulative models (Dunn et al. 2018, 2020, 2023). Although the focus of the current study is environmental unpredictability, we also report the unique and independent effects of childhood ACEs to contribute to the growing body of longitudinal evidence on childhood ACEs. Lastly, to test the extent to which earlier child behavior problems contribute to subsequent changes in environmental unpredictability, we examine the bidirectional associations among earlier child disruptive behavior and unpredictability across time. As children are active agents in their environment contributing to the family context, we expect bidirectional associations among childhood behavior and environmental unpredictability.

2 | Method

2.1 | Participants

The Future of Families and Child Wellbeing Study (FFCWS) is based on a stratified, multistage sample of 4898 children (52% male, 48% female) born in 20 large U.S. cities (populations over 200,000) between 1998 and 2000, where births to unmarried

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mothers were oversampled by a ratio of 3 to 1. This sampling strategy focused on unmarried parents resulted in a large number of minority and low-income families. Mothers were interviewed shortly after birth (M age = 25.28 years, SD = 6.04) and fathers were interviewed at the hospital or by phone. Follow-up interviews were conducted when children were approximately ages 1 (1999–2001), 3 (2001–2003), 5 (2003–2006), 9 (2007–2010), and 15 (2014–2017) years old. The present analyses used data from all available assessments. More information on sampling and U.S. cities included in the study can be found in Reichman et al. (2001) and at the FFCWS website (https://ffcws.princeton.edu/).

Of mothers, 48% were Black, 27% were Hispanic, 21% were White, and 4% reported other racial and ethnic backgrounds. At the time of the child's birth, 35% of mothers had less than a high school education, 30% had a high school diploma or equivalent, 24% had attended some college, and 10% had a college degree. At baseline, 38% of families were at or below the federal poverty line and an additional 26% were in the near poor (101%–200% federal poverty line). The median family income was $22,500 (USD). See Table 1 for complete demographics.

Surveys were completed by mothers, fathers, primary caregivers (PCGs), and youth. The majority of PCGs were the child's biological mother at each time point (age 3: 98.9%; age 5: 97.8%; age 9: 92.4%; age 15: 87.8%). Other PCGs included children's biological fathers (age 3: 0.5%; age 5: 0.9%; age 9: 4.0%; age 15: 7.2%), grandparents (age 3: 0.4%; age 5: 0.9%; age 9: 2.4%; age 15: 2.5%), and other adult caregivers (e.g., relative, non-relative, foster care; age 3: 0.2%; age 5: 0.4%; age 9: 1.2%; age 15: 2.5%).

Analyses are presented in reference to two analytic samples. The full birth cohort (N = 4898) is used to derive the metrics of unpredictability, examine demographic differences in

TABLE 1 | Demographic characteristics for the full FFCWS birth cohort sample and the subset of families participating at the Year 15 assessment.

		FFCWS full birth cohort sample			FFWCS age 15 participating sample		
Variable	**Assessment**	***N***	***M* (SD)**	**Range**	***N***	***M* (SD)**	**Range**
Family income (ln)	Birth	4897	9.83 (1.42)	0.00–11.80	3595	9.86 (1.40)	0.00–11.80
Maternal age	Birth	4894	25.28 (6.04)	15.00–43.00	3593	25.15 (6.03)	15.00–43.00
Child age	Year 1	4356	1.25 (0.29)	0.75–2.50	3377	1.25 (0.29)	0.75–2.50
	Year 3	4231	2.98 (0.22)	2.50–4.17	3338	2.97 (0.20)	2.50–4.17
	Year 5	4139	5.16 (0.24)	4.75–6.00	2111	5.31 (0.24)	4.08–6.33
	Year 9	3515	9.39 (0.38)	8.67–11.00	3169	9.29 (0.40)	8.67–11.92
	Year 15	3442	15.63 (0.71)	14.42–18.83	3442	15.63 (0.71)	14.42–18.83
Variable	**Assessment**	***N***	**%**		***N***	**%**	
Marital status	Birth	4897			3595		
Unmarried		3710	75.8%		2725	75.8%	
Married		1187	24.2%		870	24.2%	
Child sex	Birth	4897			3595		
Male		2556	52.2%		1862	51.8%	
Female		2341	47.8%		1733	48.2%	
Race and ethnicity	Birth	4886			3588		
White		1030	21.1%		783	21.8%	
Black		2326	47.6%		1799	50.1%	
Hispanic		1336	27.3%		881	24.6%	
Other		194	4.0%		125	3.5%	
Maternal education	Birth	4892			3590		
Less than H.S.		1699	34.7%		1145	31.9%	
H.S. or equivalent		1480	30.3%		1147	31.9%	
Some college		1189	24.3%		902	25.1%	
College degree		524	10.7%		396	11.0%	

Note: The demographic characteristics are reported for both the full original birth cohort sample as well as the families participating in the age 15 assessment.
Abbreviation: H.S., high school.

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unpredictability, and test bidirectional associations among early childhood disruptive behavior and unpredictability. A subset of the full sample reflecting the families participating at the age 15 assessment was used to test associations among unpredictability and adolescent outcomes ($N = 3595$). These sample sizes reflect the maximum sample sizes for both the full and adolescent subsamples (with sample sizes varying across specific analyses due to differences in reporters and patterns of data availability). Demographic characteristics are presented for both the full FFCWS sample and the families participating at age 15 in Table 1. At the age 15 assessment, 3595 families participated in the survey ($n = 3422$ both PCG and adolescent, $n = 158$ PCG only, $n = 15$ adolescent only). Families who participated at the age 15 assessment did not differ by child sex nor parental marital status at baseline compared to families who did not participate at age 15; however, families who did not participate at age 15 had lower baseline income ($p = 0.03$) and were more likely to be Hispanic or report other racial and ethnic backgrounds (compared to White and Black families; $p < 0.001$). We include these as covariates in analyses.

2.2 | Measures

2.2.1 | Environmental Unpredictability

To create a dimensional index of environmental unpredictability, the FFCWS surveys at ages 1, 3, 5, and 9 (all childhood assessments) were examined for constructs of environmental unpredictability, instability, and chaos. Because our goal was to capture a broad dimension of environmental unpredictability, we included constructs that range across ecological levels and time scales (e.g., daily routines, major transitions). Throughout, all items and constructs were scaled such that higher scores reflect greater unpredictability. We used proportion of the maximum scaling (POMS; Little 2013) to convert all environmental unpredictability constructs (described below) onto a 0 to 1 scale where 0 reflects the minimum score (often the absence of unpredictability within the construct) and 1 reflects the maximum score. The same longitudinal minimum and maximum scores were set across all assessments for the same or similar items. Items scored on a Yes/No scale were scored as No = 0 and Yes = 1. Because the relevant environmental influences and contexts may shift across development, we calculated the mean of all available environmental constructs at each assessment time point. To create a dimensional index of environmental unpredictability that spanned across childhood, the sum of environmental unpredictability at ages 1, 3, 5, and 9 was computed.

2.2.1.1 | Parental Impulsivity. Parental impulsivity was assessed using abbreviated versions of the dysfunctional impulsivity scale (Dickman 1990). At Year 1, paternal impulsivity was assessed via self-report using six items from the Dickman impulsivity scale. At Year 3, maternal impulsivity was assessed via self-report using the same 6 items. At Year 5, two of the items from the previous scale (e.g., I often get into trouble because I don't think before I act; I often say and do things without considering the consequences) were self-reported and partner-reported for both mothers and fathers, resulting in eight items reflecting parental impulsivity. At all assessments, items were reported on a 4-point Likert scale ranging from strongly agree to strongly disagree. Within each year, items were then averaged and then converted to a 0–1 scale to create an index of parental impulsivity.

2.2.1.2 | Family Routines. Lack of and inconsistency in family routines were scored using items reflecting the absence and frequency of bedtime routines in the family. At Year 3 and Year 5, PCGs reported whether the child had a regular bedtime, had a bedtime routine, and had a regular place to sleep (Yes/No scale; three items) and the frequency of each of these in the past week Monday through Friday (0–5 nights; three items). At Year 9 (three items), PCGs reported whether children had a regular bedtime (Yes/No) and the frequency of going to bed at that time in the past week (0–5 nights). PCGs also completed one item from the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al. 1995) regarding whether children in the family had a regular bedtime on a 5-point Likert scale ranging from definitely untrue to definitely true. The bedtime item from the CHAOS scale was included in this family routines scale and not included in the overall family chaos measure to reduce construct redundancy. At each assessment, Yes/No items were scored 0 and 1, and frequency or scale items were scored using POMS scoring from 0 to 1, with higher scores reflecting a lack of stable bedtime routines (items were reversed scored).

2.2.1.3 | Physical Household Chaos. An index was created to capture physical environmental chaos in the home reflecting noise, clutter, and crowding. At ages 3, 5, and 9, four items from the Home Observation of the Environment (HOME; Caldwell and Bradley 1984) were rated on a Yes/No scale by the interviewer that visited the child's home. Items reflected whether the home was crowded, cluttered, or overly noisy inside or outside the home. At age 9, the scale of the clutter item was reported on a 4-point Likert scale ranging from almost none to yes almost everywhere (rather than the previous Yes/No scale). Additionally, at ages 3, 5, and 9, PCGs reported how many hours the TV was on (even when no one was watching) during a typical day, and this was converted to a 0–1 scale by dividing by the maximum of 24 h per day. Yes/No items were scored 0 and 1, and hours or scale items were scored using POMS scoring ranging from 0 to 1, with higher scores reflecting more physical household chaos.

2.2.1.4 | Family Chaos. At age 9, PCGs completed a 4-item abbreviated version of the CHAOS scale (Matheny et al. 1995) reflecting the degree of family chaos in the home (e.g., it's a real zoo in your home, the atmosphere in your home is calm [reversed scored]). PCGs rated items on a 5-point Likert scale ranging from definitely untrue to definitely true. Items were averaged and converted to a 0–1 POMS score.

2.2.1.5 | Inconsistency in Coparenting. At ages 1, 3, and 5 both mothers and fathers rated the following question about the other parent on a 3-point Likert scale ranging from always true to rarely true: "He/she respects the schedules and rules you make for your child". At age 9, only mothers completed this item about the child's father. At each assessment, items were converted to a 0–1 scale and averaged across parents for an index of inconsistency in schedules and rules across coparents. Maternal and paternal reports of their partners were significantly correlated within time (Year 1 $r = 0.14$; Year 3 $r = 0.19$; Year 5 $r = 0.27$; all $ps < 0.001$).

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2.2.1.6 | Childcare Instability. At ages 1 and 3, mothers reported on the number of current childcare arrangements and the number of childcare arrangement changes since the previous assessment. Mothers also reported on the number of times special arrangements were needed because regular care fell through and the number of times they missed work or school because of the lack of regular care. Items were converted to a 0–1 scale using POMS with a maximum of 5+ times and then were averaged to create an index of childcare instability. Mothers who reported that children were not cared for by anyone other than the child's parents or were in childcare for fewer than 10 h per week were not asked the childcare arrangement questions and were thus scored as zero.

2.2.1.7 | Family Instability. Family instability was coded as the number of transitions of partners living in the home at ages 1, 3, 5, and 9. To code the number of exits and entrances, mothers' cohabitation and/or marital status with the biological father and/or a subsequent partner were compared to the previous data collection point (for age 1 baseline data at the time of birth was used) to determine whether the family underwent a transition and the number of transitions that occurred (e.g., a mother who reported being single at Year 1 and married at Year 3 was scored as one transition reflecting the entrance of a new partner whereas a mother married to the child's biological father at Year 1 and married to a new partner at age 3 was scored as two transitions reflecting the exit of the biological father and the entrance of a new partner). Additionally, at ages 5 and 9, mothers were also asked how many relationships they had in which their partner lived with them for at least 1 month since the last interview; this was used to calculate additional interim entrances and exits. This is consistent with existing research on family transitions in the FFCWS study (Cooper et al. 2011). Longitudinal POMS scoring was used with the maximum number of transitions between waves being scored as 4+.

2.2.1.8 | Residential Instability. Residential instability reflected experiences of homelessness, doubling up (e.g., multiple family cohabitation), eviction, and frequency of moves. Both mothers and fathers completed the following items. At ages 1, 3, 5, and 9, the number of moves was reported. Number of moves was converted to a 0–1 POMS with 5+ moves used as the longitudinal maximum. Families were coded as Yes/No for homelessness using reports of current living situation for response categories of 'homeless/on the streets' or 'living in temporary housing' as well as endorsing the item of 'stayed somewhere other than meant for housing e.g., homeless' in the past 12 months. Families were also coded as Yes/No for doubling up based on response categories for current living situation (e.g., living with family or friends and contributing part of the rent or not paying rent) as well as endorsing the item of 'moved in with other people because of financial problems' in the past 12 months. Lastly, items were coded Yes/No for experiencing an eviction due to nonpayment of rent in the past 12 months. Yes/No items were scored 0 and 1. Items were averaged and mother and father reports were averaged to create an index of residential instability. Maternal and paternal residential instability were significantly correlated at all time points (Year 1 $r = 0.41$; Year 3 $r = 0.34$; Year 5 $r = 0.22$; Year 9 $r = 0.09$; Year 9 $p = 0.002$, all other ps < 0.001).

2.2.1.9 | Parental Employment Instability. Parental employment instability was calculated using a series of items reported by both mothers and fathers. At ages 1, 3, 5, and 9, unemployment was coded on a Yes/No scale for parents who answered both 'no' to did you do any regular work for pay (in the past week) and 'yes' to are you currently looking for a regular job; all other combinations were coded as not currently unemployed. Length of time looking for a job was reported on a 5-point Likert scale ranging from less than 1 week to more than 12 months. Scores were set to the midpoint of the category, converted to months, and the POMS maximum category was calculated as 12+ months. Parents also reported on a Yes/No scale whether they worked variable work hours (e.g., work different times each week). Work schedule stress was calculated as the average of three items (e.g., my shift and work schedule cause extra stress for me and my child) rated on a 4-point Likert scale ranging from always to never. Additionally, at Years 3, 5, and 9, parents reported the number of jobs held in the past year and these were converted to a 0–1 POMS scale using 8+ as the longitudinal maximum score. Yes/No items were scored 0 and 1 and scale or time variables were calculated on a 0–1 POMS scale; items were averaged, and mother and father reports were averaged to create an index of parental employment instability. Maternal and paternal employment instability were significantly correlated at all time points (Year 1 $r = 0.12$; Year 3 $r = 0.10$; Year 5 $r = 0.10$; Year 9 $r = 0.09$; all ps < 0.001).

2.2.2 | Adverse Childhood Experiences

The number of ACEs across childhood was computed reflecting the presence or absence of each ACE at any point across all available childhood time points (e.g., ages 1, 3, 5, and 9). The FFCWS surveys were used to derive scores reflecting the 10 ACEs including physical abuse, emotional abuse, sexual abuse, physical neglect, emotional neglect, maternal interparental violence, parental mental illness, parental substance use, parental incarceration, and parental divorce (Centers for Disease Control and Prevention 2021; Dube et al. 2003; Felitti et al. 1998). Although all 10 categories are represented in the data, we scored a combined ACE for physical and emotional neglect due to the nature of the CPS response scaling for neglect in FFCWS. ACEs were summed to create a score ranging from 0 to 9. See the supplemental materials for detailed information on how each ACE was coded.

2.2.3 | Adolescent Outcomes–Adolescent-Report

2.2.3.1 | Depressive Symptoms. At age 15, adolescent depressive symptoms were assessed via youth self-report on a 5-item abbreviated version of the Center for Epidemiological Studies Depression Scale (CES-D; Radloff 1977). Youth responded on a 4-point Likert scale ranging from strongly disagree to strongly agree during the past 4 weeks (e.g., I feel sad). The mean was calculated with higher scores reflecting higher depressive symptoms. There was adequate internal reliability in the abbreviated CES-D in the present study ($\alpha = 0.76$).

2.2.3.2 | Anxiety Symptoms. At age 15, adolescent anxiety symptoms were assessed via youth self-report on a 6-item

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abbreviated version of the Brief Symptom Inventory 18 (BSI 18; Derogatis and Savitz 2000). Youth responded on a 4-point Likert scale ranging from strongly disagree to strongly agree during the past 4 weeks (e.g., I feel nervous or shaky inside). The mean was calculated with higher scores reflecting higher anxiety symptoms. There was adequate internal reliability in the abbreviated BSI anxiety scale in the present study ($\alpha = 0.76$).

2.2.3.3 | Impulsivity. At age 15, adolescent impulsivity was assessed via youth self-report on a 6-item abbreviated version of the dysfunctional impulsivity scale (Dickman 1990). Youth responded on a 4-point Likert scale ranging from strongly disagree to strongly agree (e.g., I often get into trouble because I don't think before I act). The mean was calculated with higher scores reflecting higher levels of impulsivity. There was adequate internal reliability in the abbreviated impulsivity scale in the present study ($\alpha = 0.79$).

2.2.3.4 | Delinquency. At age 15, adolescent delinquency was assessed via youth self-report on 13 delinquent behaviors on a 4-point Likert scale ranging from never to five or more times in the past 12 months (e.g., deliberately damage property that didn't belong to you). Items were adapted from the National Longitudinal Study of Adolescent Health (Add Health). Items included behaviors of damaging property, theft, physical fighting, and selling drugs. The mean was calculated with higher scores reflecting higher levels of delinquency. There was adequate internal reliability in the delinquency scale in the present study ($\alpha = 0.74$).

2.2.3.5 | Body Mass Index Categories. At age 15, body mass index (BMI) was calculated in accordance with CDC guidelines (Kuczmarski et al. 2000) using adolescent self-reports of height and weight. BMI scores were then coded into CDC recommended BMI-for-age categories (e.g., underweight, healthy weight, overweight, obese). In the present sample, 2.6% of youth were classified as underweight ($n = 80$), 59.2% of youth were classified as at a healthy weight ($n = 1878$), 18.8% of youth were classified as overweight ($n = 593$), and 19.3% of youth were classified as obese ($n = 587$). The BMI categories were used as an ordinal variable in analyses (0 = healthy weight, 1 = overweight, 2 = obese) with the underweight youth omitted from BMI-specific analysis.

2.2.4 | Adolescent Outcomes–Caregiver-Report

2.2.4.1 | Youth Behavior Problems. At age 15, PCGs completed an abbreviated set of items from the Child Behavior Checklist (CBCL; Achenbach and Al Rescorla 2001). PCGs completed eight items of the internalizing problems scale (e.g., child worries), 20 items of the externalizing scale (e.g., child gets in many fights), and three items of the attention problems scale (e.g., child can't sit still; is restless or hyperactive) PCGs rated each behavior on a 3-point Likert scale ranging from not true to often true. The mean of items within each subscale was computed with higher scores reflecting more child behavior problems. There was adequate internal reliability in the abbreviated subscales in the present study (internalizing $\alpha = 0.79$, externalizing $\alpha = 0.89$, attention $\alpha = 0.82$).

2.2.5 | Early Disruptive Child Behavior–Caregiver-Report

2.2.5.1 | Childhood Externalizing Problems. At ages 3, 5, and 9, PCGs completed the externalizing problem subscale of the age-appropriate Child Behavior Checklist (Achenbach 1992; Achenbach and Rescorla 2000; Achenbach and Al Rescorla 2001). At age 3, there were 22 items from the destructive and aggressive behaviors scales. At age 5, there were 28 items from the delinquent and aggressive behavior scales. At age 9, there were 35 items from the rule-breaking and aggressive behavior scales. PCGs rated each behavior on a 3-point Likert scale ranging from not true to often true. The means of items at each age were computed, with higher scores reflecting more childhood externalizing problems. There was good internal reliability in the present study (age 3 externalizing $\alpha = 0.88$, age 5 externalizing $\alpha = 0.85$, age 9 externalizing $\alpha = 0.91$).

2.3 | Data Analysis Plan

First, we report descriptive statistics including means, standard deviations, and correlations in the full FFCWS sample. For descriptive purposes, we also report differences in environmental unpredictability and total ACE score by parental marital status at birth reflecting the sampling strategy as well as by child sex and race and ethnicity. We also report the means and standard deviations for study variables within the subset of families participating at age 15. To test our main hypotheses, we examined the impact of environmental unpredictability across childhood using an unpredictability dimensional index across childhood (ages 1–9) as a predictor of each age 15 adolescent outcome using the adolescent subsample. Because we were interested in examining the unique impact of environmental unpredictability, we also include total ACE score (ages 1–9) as a covariate. Regression analyses were conducted in Mplus (Muthén and Muthén 1998–2017) and missing data was estimated using full information maximum likelihood estimation. Ordinal regression was conducted for the ordered BMI categories (excluding the underweight youth category) and linear regressions were conducted for all other continuous outcome variables. All analyses include family income and parental marital status at birth, child sex, race and ethnicity, and child chronological age at Year 15 as covariates. We also include city fixed effects in analyses to account for clustering by birth city. We report regression analyses including an index within each specific form of environmental unpredictability (e.g., parental impulsivity, family routines, physical household chaos, family chaos, coparenting inconsistency, childcare instability, family instability, residential instability, and parental employment instability) as unique predictors of adolescent outcomes in the adolescent subsample. We then report findings examining the developmental timing of unpredictability by examining the unique contributions of unpredictability at each assessment (ages 1, 3, 5, and 9) in the adolescent subsample. Further, we report findings stratified by child sex in the adolescent subsample. Lastly, to test the extent to which early child behavior contributes to environmental unpredictability, we examine the bidirectional, transactional associations between child externalizing problems and unpredictability (at ages 3, 5, and 9) using a random-intercept cross-lagged panel model (Hamaker et al. 2015). The focus of these analyses is on

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earlier child externalizing problems to test the role of disruptive child behavior in contributing to subsequent changes in environmental unpredictability and use the full FFCWS analytic sample.

3 | Results

3.1 | Descriptive Statistics

Descriptive statistics for the environmental unpredictability dimensional index ($M = 0.58$, SD = 0.29), ACEs ($M = 3.85$, SD = 1.42), individual forms of unpredictability by year, and adolescent outcomes are presented in Table 2 (descriptive statistics reported for each analytic sample). Table S1 includes descriptive statistics (means, standard deviations, *n*s) for individual components that contribute to each form of environmental unpredictability by year. Correlations between adversity (unpredictability index, individual forms of unpredictability, ACEs) and adolescent outcomes are depicted in Table S2. Additional correlations among outcomes are depicted in Table S3, and among individual forms of environmental unpredictability are reported in Table S4. Environmental unpredictability was positively correlated with childhood ACEs ($r = 0.56$, $p < 0.001$). ACEs and unpredictability were significantly correlated with all adolescent outcomes. With few exceptions, individual forms of unpredictability were significantly correlated with one another (see Table S4).

We conducted a between-subjects analysis of variance (ANOVA) to examine whether there were differences in the environmental unpredictability dimensional index and childhood ACEs by parental marital status at birth, reflecting the FFCWS sampling strategy and race and ethnicity, and child sex in the full FFCWS analytic sample. There were significant differences in unpredictability ($F(1,4817) = 575.82$, $p < 0.001$) and ACEs ($F(1,4895) = 92.35$, $p < 0.05$) by parental marital status at birth such that children born to unmarried parents experienced more unpredictability ($M = 0.64$, SD = 0.29) and ACEs ($M = 3.96$, SD = 1.42) throughout childhood compared to those born to married parents ($M = 0.41$, SD = 0.23; $M = 3.51$, SD = 1.37, respectively). There were significant racial and ethnic differences in both environmental unpredictability ($F(3,4804) = 81.15$, $p < 0.001$) and ACEs ($F(3,4882) = 10.95$, $p < 0.001$). Significant Bonferroni pairwise posthoc comparisons are reported. Black children ($M = 0.65$, SD = 0.29) experienced higher levels of unpredictability compared to White children ($M = 0.53$, SD = 0.30), Hispanic children ($M = 0.52$, SD = 0.28), and children from other racial and ethnic backgrounds ($M = 0.51$, SD = 0.30). Black children ($M = 3.94$, SD = 1.40) also experienced higher childhood ACEs compared to Hispanic children ($M = 3.76$, SD = 1.46). Children from other racial and ethnic backgrounds ($M = 3.43$, SD = 1.30) experienced fewer ACEs than White ($M = 3.85$, SD = 1.41), Black, and Hispanic children. There were no child sex differences in the unpredictability dimensional index ($F(1,4817) = 0.62$, $p = 0.43$; boys $M = 0.59$, SD = 0.30; girls $M = 0.58$, SD = 0.29) nor ACEs ($F(1,4895) = 0.04$, $p = 0.84$; boys: $M = 3.85$, SD = 1.41; girls $M = 3.86$, SD = 1.41). Youth's chronological age during the adolescent assessment was significantly correlated with the unpredictability index ($r = -0.05$, $p < 0.002$) but not ACEs ($r = -0.03$, $p = 0.15$).

Comparisons by parental marital status, race and ethnicity, and child sex among individual forms of unpredictability are reported in Table S5. Children born to unmarried parents experienced higher unpredictability in all individual forms except family chaos. There were significant differences by race and ethnicity for all forms of unpredictability, with Black children experiencing higher levels of unpredictability among family routines, physical household chaos, coparenting inconsistency, childcare instability, family instability, residential instability, and parental employment instability. White children experienced higher levels of family chaos, coparenting inconsistency, and childcare instability. Boys experienced more childcare instability compared to girls. We also report the prevalence of individual ACEs by marital status at birth, race and ethnicity, and child sex in Table S6.

3.2 | Regression Results

3.2.1 | Environmental Unpredictability Dimensional Index and ACEs

Regression analyses were conducted for each adolescent outcome, including the environmental unpredictability dimensional index and childhood ACEs for the adolescent subsample (e.g., using data from families with the dimensional index and adolescent outcome data). Covariates included city, family income, and parental marital status at birth, child sex, race and ethnicity, and child chronological age at Year 15. Results are presented in Table 3. Higher levels of environmental unpredictability were associated with all adolescent outcomes, including higher rates of adolescent-reported depressive symptoms ($\beta = 0.11$, $p < 0.001$), anxiety symptoms ($\beta = 0.08$, $p < 0.001$), impulsivity ($\beta = 0.09$, $p < 0.001$), delinquency ($\beta = 0.13$, $p < 0.001$), and heavier weight categories ($\beta = 0.09$, $p = 0.001$), and PCG reported internalizing problems ($\beta = 0.14$, $p < 0.001$), externalizing problems ($\beta = 0.23$, $p < 0.001$), and attention problems ($\beta = 0.16$, $p < 0.001$). Higher number of ACEs was also associated with adolescent-reported depressive symptoms ($\beta = 0.07$, $p < 0.001$), anxiety symptoms ($\beta = 0.07$, $p < 0.001$), and impulsivity ($\beta = 0.07$, $p = 0.001$), and PCG reported internalizing problems ($\beta = 0.11$, $p < 0.001$), externalizing problems ($\beta = 0.07$, $p < 0.001$), and attention problems ($\beta = 0.05$, $p = 0.009$), but not adolescent-reported delinquency ($\beta = 0.01$, $p = 0.71$) nor weight categories ($\beta = 0.01$, $p = 0.63$).

As a follow-up analysis, we report individual regression results for unpredictability and ACEs separately in Table S7. Both environmental unpredictability and ACEs are significant predictors of all eight outcomes. In models with only ACEs as the sole predictor, ACEs do predict adolescent delinquency and BMI categories that were not significant when in the same model as environmental unpredictability. Additionally, these results show that both environmental unpredictability and ACEs account for similar variance.

3.2.2 | Individual Forms of Environmental Unpredictability

We also report multiple regression analyses using individual forms of environmental unpredictability in the adolescent

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TABLE 2 | Descriptive statistics adversity variables and youth outcomes for the full FFCWS birth cohort sample and the subset of families participating at the year 15 assessment.

	FFCWS full birth bohort sample			FFWCS age 15 participating sample		
Construct	***M* (SD)**	**Range**	***N***	***M* (SD)**	**Range**	***N***
Adversity measure						
Unpredictability dimensional index	0.58 (0.29)	0.00–1.75	4820	0.63 (0.28)	0.00–1.55	3595
Total ACEs	3.85 (1.42)	0.00–9.00	4898	4.08 (1.40)	0.00–9.00	3595
Individual forms of unpredictability by year						
Parental impulsivity						
Year 1	0.33 (0.22)	0.00–1.00	2932	0.33 (0.22)	0.00–1.00	2329
Year 3	0.34 (0.21)	0.00–1.00	4223	0.34 (0.20)	0.00–1.00	3333
Year 5	0.31 (0.19)	0.00–1.00	4292	0.31 (0.19)	0.00–1.00	3416
Family routines						
Year 3	0.13 (0.16)	0.00–1.00	3326	0.13 (0.16)	0.00–1.00	2757
Year 5	0.12 (0.15)	0.00–1.00	3004	0.12 (0.15)	0.00–1.00	2606
Year 9	0.14 (0.20)	0.00–1.00	3628	0.14 (0.20)	0.00–1.00	3360
Physical household chaos						
Year 3	0.24 (0.24)	0.00–1.00	3313	0.24 (0.24)	0.00–1.00	2749
Year 5	0.24 (0.25)	0.00–1.00	2991	0.24 (0.25)	0.00–1.00	2596
Year 9	0.20 (0.20)	0.00–1.00	3639	0.20 (0.20)	0.00–1.00	3362
Family chaos						
Year 9	0.22 (0.21)	0.00–1.00	3639	0.22 (0.21)	0.00–1.00	3357
Inconsistency in coparenting						
Year 1	0.17 (0.27)	0.00–1.00	3515	0.18 (0.27)	0.00–1.00	2768
Year 3	0.17 (0.26)	0.00–1.00	3936	0.18 (0.26)	0.00–1.00	3109
Year 5	0.18 (0.27)	0.00–1.00	3821	0.18 (0.26)	0.00–1.00	3059
Year 9	0.21 (0.31)	0.00–1.00	2715	0.21 (0.31)	0.00–1.00	2522
Childcare instability						
Year 1	0.07 (0.11)	0.00–0.80	4288	0.07 (0.11)	0.00–0.75	3335
Year 3	0.09 (0.11)	0.00–0.80	4165	0.09 (0.11)	0.00–0.80	3301
Family instability						
Year 1	0.06 (0.12)	0.00–0.75	4073	0.06 (0.12)	0.00–0.75	3143
Year 3	0.07 (0.12)	0.00–0.75	4005	0.07 (0.13)	0.00–0.75	3187
Year 5	0.11 (0.17)	0.00–1.00	3815	0.11 (0.17)	0.00–1.00	3138
Year 9	0.15 (0.21)	0.00–1.00	3321	0.15 (0.21)	0.00–1.00	3068
Residential instability						
Year 1	0.12 (0.14)	0.00–1.00	4457	0.12 (0.41)	0.00–1.00	3430
Year 3	0.11 (0.13)	0.00–0.95	4364	0.11 (0.13)	0.00–0.95	3415
Year 5	0.10 (0.13)	0.00–0.90	4293	0.10 (0.12)	0.00–0.90	3417
Year 9	0.12 (0.14)	0.00–1.00	3695	0.12 (0.14)	0.00–1.00	3327

(Continues)

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TABLE 2 | (Continued)

Construct	FFCWS full birth bohort sample			FFWCS age 15 participating sample		
	M (SD)	Range	*N*	*M* (SD)	Range	*N*
Parental employment instability						
Year 1	0.19 (0.18)	0.00–1.00	4679	0.19 (0.17)	0.00–1.00	3513
Year 3	0.17 (0.14)	0.00–0.76	4361	0.17 (0.13)	0.00–0.76	3413
Year 5	0.16 (0.14)	0.00–0.88	4282	0.16 (0.14)	0.00–0.88	3412
Year 9	0.17 (0.15)	0.00–1.00	3731	0.17 (0.15)	0.00–1.00	3340
Early childhood disruptive behavior						
Year 3 externalizing problems	0.62 (0.36)	0.00–1.91	3320	0.63 (0.35)	0.00–1.91	2754
Year 5 externalizing problems	0.44 (0.30)	0.00–2.00	2715	0.44 (0.29)	0.00–2.00	3052
Year 9 externalizing problems	0.18 (0.20)	0.00–2.00	3337	0.18 (0.20)	0.00–2.00	3122
Adolescent outcomes[a]						
Year 15 depressive symptoms	0.60 (0.60)	0.00–3.00	3437	0.60 (0.60)	0.00–3.00	3437
Year 15 anxiety symptoms	0.81 (0.65)	0.00–3.00	3437	0.81 (0.65)	0.00–3.00	3437
Year 15 impulsivity	2.47 (0.70)	1.00–4.00	3437	2.47 (0.70)	1.00–4.00	3437
Year 15 delinquency	1.11 (0.20)	1.00–3.08	3492	1.11 (0.20)	1.00–3.08	3492
Year 15 BMI[b]	23.86 (5.36)	13.23–49.60	3138	23.86 (5.36)	13.23–49.60	3138
Year 15 internalizing problems	0.26 (0.31)	0.00–1.88	3580	0.26 (0.31)	0.00–1.88	3580
Year 15 externalizing problems	0.22 (0.26)	0.00–1.80	3580	0.22 (0.26)	0.00–1.80	3580
Year 15 attention problems	0.37 (0.52)	0.00–2.00	3580	0.37 (0.52)	0.00–2.00	3580

[a]The descriptive statistics for the age 15 data are the same across the full sample and year 15 participating (as all year 15 data were used in year 15 analyses).
[b]Table reports continuous BMI descriptive statistics (*n*s of each BMI category are: underweight $n = 80$, healthy weight $n = 1878$; overweight $n = 593$; obese $n = 587$).

subsample (using data from families with both adolescent outcomes and individual forms of unpredictability data). Regression results are presented in Table 4. With regard to general patterns, higher levels of parental impulsivity, physical household chaos, and family chaos were associated with more adolescent problems for both adolescent- and PCG-reported outcomes; whereas, higher parental employment instability and coparenting inconsistency were associated with the PCG-reported adolescent problems. Childcare instability, family routines, family instability, and residential instability were uniquely associated with few youth outcomes.

3.2.3 | Developmental Timing of Environmental Unpredictability

To address developmental timing of unpredictability, we also report multiple regression analyses using time-specific environmental unpredictability at ages 1, 3, 5, and 9 as predictors of adolescent outcomes in the adolescent subsample (using data from families with both adolescent outcomes and unpredictability data across the study assessment periods). Regression results are presented in Table 5. All outcomes were predicted by at least one individual time point. Adolescent-reported anxiety and depressive symptoms and weight categories were predicted by unpredictability in early life (anxiety: age 1, depression: ages 1 and 3, weight categories: age 1), whereas adolescent-reported delinquency was predicted by more recent unpredictability in middle childhood (age 9). Adolescent-reported impulsivity was predicted by both early life and more recent unpredictability (ages 1, 3, and 9). Parent-reported behavioral problems were predicted by unpredictability at most time points (internalizing and externalizing at all ages; attention problems at ages 3, 5, and 9).

3.2.4 | Sex-Specific Findings

We report multiple regression analyses for both boys and girls in Table S8. Environmental unpredictability was associated with outcomes for both boys and girls in seven of the eight outcomes. The one exception was found for BMI categories, where environmental unpredictability was associated with heavier weight categories in boys but not girls. ACEs were associated with depressive symptoms and internalizing and externalizing problems in both boys and girls; whereas anxiety symptoms, impulsivity, and attention problems were only associated with ACEs in boys but not girls. Similar to the overall findings, delinquency and BMI categories were not associated with ACEs in either boys or girls.

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TABLE 3 | Regression results examining ACEs, environmental unpredictability, and adolescent outcomes.

	Youth-reported outcomes											
	Depressive symptoms			Anxiety symptoms			Delinquency			Impulsivity		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*
Unpredictability	0.24 (0.05)	0.11	< 0.001***	0.19 (0.05)	0.08	< 0.001***	0.09 (0.02)	0.13	< 0.001***	0.24 (0.05)	0.09	< 0.001***
ACEs	0.03 (0.01)	0.07	< 0.001***	0.03 (0.01)	0.07	0.001***	0.02 (0.00)	0.01	0.71	0.03 (0.01)	0.07	0.001***
R^2	0.05			0.04			0.07			0.04		
N	3428			3428			3420			3428		
	Youth-reported outcome			Caregiver-reported outcomes								
	BMI categories			Internalizing problems			Externalizing problems			Attention problems		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*
Unpredictability	0.33 (0.10)	0.09	0.001***	0.15 (0.02)	0.14	< 0.001***	0.21 (0.02)	0.23	< 0.001***	0.31 (0.04)	0.16	< 0.001***
ACEs	0.01 (0.02)	0.01	0.63	0.02 (0.00)	0.11	< 0.001***	0.01 (0.00)	0.07	< 0.001***	0.02 (0.01)	0.05	0.008**
R^2	0.04			0.08			0.10			0.10		
N	3052			3420			3420			3420		

Note: City fixed effects are controlled for in the analysis. Additional covariates include marital status, family income, child sex, age, and race/ethnicity. Covariates are omitted for brevity. BMI categories regression models reflect ordinal regression with underweight youth excluded from the analysis; all other outcomes reflect linear regression models.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

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TABLE 4 | Regression results examining individual forms of environmental unpredictability and adolescent outcomes.

	Youth-report outcomes											
	Depressive symptoms			Anxiety symptoms			Delinquency			Impulsivity		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
Parental impulsivity	0.08 (0.03)	0.06	0.045**	0.08 (0.03)	0.05	0.01*	0.02 (0.01)	0.05	0.02*	0.16 (0.03)	0.10	<0.001***
Family routines	−0.05 (0.03)	−0.03	0.12	−0.04 (0.04)	−0.02	0.34	−0.01 (0.01)	−0.01	0.45	−0.01 (0.04)	−0.00	0.86
Physical household chaos	0.08 (0.03)	0.06	0.003**	0.09 (0.03)	0.06	0.002**	0.02 (0.01)	0.04	0.04*	0.06 (0.03)	0.04	0.04*
Family chaos	0.15 (0.05)	0.05	0.005**	0.21 (0.06)	0.07	<0.001***	0.07 (0.02)	0.07	<0.001***	0.28 (0.06)	0.09	<0.001***
Coparenting inconsistency	0.05 (0.02)	0.05	0.005**	0.04 (0.02)	0.04	0.06	0.00 (0.01)	0.01	0.55	−0.01 (0.02)	−0.01	0.73
Childcare Instability	0.00 (0.07)	0.00	0.96	0.00 (0.07)	0.00	1.00	−0.01 (0.02)	−0.01	0.70	0.00 (0.08)	0.00	0.96
Family instability	0.06 (0.03)	0.04	0.06	0.02 (0.04)	0.01	0.61	0.03 (0.01)	0.06	0.004**	0.07 (0.04)	0.04	0.07
Residential instability	0.01 (0.03)	0.00	0.83	−0.03 (0.04)	−0.02	0.40	0.02 (0.01)	0.04	0.06	0.01 (0.04)	0.00	0.88
Employment instability	0.04 (0.03)	0.03	0.20	0.04 (0.04)	0.03	0.22	0.02 (0.01)	0.03	0.14	0.04 (0.04)	0.02	0.28
R^2	0.05			0.04			0.08			0.06		
N	3037			3037			3030			3037		
	Youth-reported outcome			Caregiver-reported outcomes								
	BMI categories			Internalizing problems			Externalizing problems			Attention problems		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
Parental impulsivity	0.13 (0.06)	0.05	0.04*	0.07 (0.01)	0.09	<0.001***	0.06 (0.01)	0.10	<0.001***	0.10 (0.02)	0.09	<0.001***
Family routines	0.01 (0.07)	0.00	0.93	0.00 (0.02)	0.00	0.98	−0.01 (0.01)	−0.02	0.37	−0.02 (0.03)	−0.01	0.54
Physical household chaos	0.18 (0.06)	0.08	0.002**	0.04 (0.01)	0.05	0.005**	0.04 (0.01)	0.08	<0.001***	0.02 (0.02)	0.02	0.35
Family chaos	0.10 (0.11)	0.02	0.41	0.14 (0.03)	0.10	<0.001***	0.16 (0.02)	0.13	<0.001***	0.29 (0.04)	0.12	<0.001***
Coparenting inconsistency	0.02 (0.04)	0.01	0.68	0.04 (0.01)	0.09	<0.001***	0.04 (0.01)	0.11	<0.001***	0.04 (0.01)	0.05	0.01*
Childcare instability	0.15 (0.14)	0.02	0.31	0.01 (0.03)	0.00	0.86	0.03 (0.03)	0.02	0.29	0.10 (0.05)	0.03	0.06
Family instability	0.09 (0.07)	0.03	0.21	0.00 (0.02)	0.00	0.96	0.02 (0.01)	0.03	0.09	0.05 (0.03)	0.04	0.08
Residential instability	−0.05 (0.07)	−0.02	0.48	0.03 (0.02)	0.03	0.11	0.03 (0.01)	0.04	0.04*	0.04 (0.03)	0.03	0.14
Employment instability	−0.04 (0.07)	−0.01	0.59	0.04 (0.02)	0.06	0.005**	0.04 (0.01)	0.06	0.002**	0.10 (0.03)	0.07	<0.001***
R^2	0.05			0.09			0.12			0.11		
N	2692			3029			3029			3029		

Note: City fixed effects controlled for in the analysis. Additional covariates include marital status, family income, child sex, age, and race/ethnicity. Covariates are omitted for brevity. BMI categories regression models reflect ordinal regression with underweight youth excluded from the analysis; all other outcomes reflect linear regression models.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

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TABLE 5 | Regression results examining developmental timing of environmental unpredictability and adolescent outcomes.

	Youth-reported outcomes											
	Depressive symptoms			Anxiety symptoms			Delinquency			Impulsivity		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
Year 1 unpredictability	0.48 (0.13)	0.08	<0.001***	0.42 (0.14)	0.06	0.003**	−0.02 (0.04)	−0.01	0.64	0.32 (0.15)	0.04	0.03*
Year 3 unpredictability	0.48 (0.16)	0.07	0.003**	0.23 (0.18)	0.03	0.20	0.07 (0.05)	0.03	0.16	0.39 (0.19)	0.05	0.04*
Year 5 unpredictability	0.21 (0.14)	0.04	0.12	0.21 (0.15)	0.03	0.16	0.15 (0.04)	0.08	0.001***	0.22 (0.16)	0.03	0.16
Year 9 unpredictability	0.20 (0.12)	0.03	0.10	0.25 (0.14)	0.04	0.06	0.17 (0.04)	0.08	<0.001***	0.45 (0.14)	0.06	0.002**
R^2	0.05			0.04			0.08			0.06		
N	2978			2978			2971			2978		
	Youth-reported outcome			Caregiver-reported outcomes								
	BMI categories			Internalizing problems			Externalizing problems			Attention problems		
	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p	B (SE)	β	p
Year 1 unpredictability	0.58 (0.27)	0.05	0.03*	0.22 (0.07)	0.07	0.001***	0.14 (0.05)	0.05	0.009**	0.20 (0.11)	0.04	0.06
Year 3 unpredictability	−0.13 (0.36)	−0.01	0.73	0.24 (0.08)	0.06	0.003**	0.22 (0.07)	0.07	0.001***	0.35 (0.14)	0.05	0.01*
Year 5 unpredictability	0.53 (0.29)	0.05	0.07	0.19 (0.07)	0.06	0.006**	0.27 (0.06)	0.11	<0.001***	0.43 (0.11)	0.08	<0.001***
Year 9 unpredictability	0.26 (0.27)	0.03	0.33	0.31 (0.06)	0.10	<0.001***	0.40 (0.05)	0.16	<0.001***	0.50 (0.11)	0.10	<0.001***
R^2	0.04			0.08			0.10			0.10		
N	2647			2970			2970			2970		

Note: City fixed effects are controlled for in the analysis. Additional covariates include marital status, family income, child sex, age, and race/ethnicity. Covariates are omitted for brevity. BMI categories regression models reflect ordinal regression with underweight youth excluded from the analysis; all other outcomes reflect linear regression models.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

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3.2.5 | Bidirectional Associations Between Child Behavior and Unpredictability

Results using the full FFCWS analytic sample from the random-intercept cross-lagged panel model (Hamaker et al. 2015) assessing bidirectional associations among child externalizing problems and unpredictability at ages 3, 5, and 9 years old are depicted in Figure 1 ($N = 4648$; e.g., families with both the dimensional index and childhood externalizing problems). First, at the between-persons level, there is a positive association between environmental unpredictability and child externalizing problems ($\beta = 0.43$, $p < 0.001$). At the within-persons level, the cross-lagged effect of child externalizing problems was associated with greater changes in environmental unpredictability from age 3 to age 5 ($\beta = 0.10$, $p < 0.001$) and age 5 to age 9 ($\beta = 0.10$, $p < 0.001$). The cross-lagged effect of environmental unpredictability was associated with greater changes in child externalizing problems from age 3 to age 5 ($\beta = 0.06$, $p = 0.008$) but not from age 5 to age 9 ($\beta = 0.07$, $p = 0.087$).

4 | Discussion

Greater levels of environmental unpredictability throughout childhood as measured by the dimensional index were associated with poorer adolescent mental health and behavioral problems. Our findings are consistent with previous research investigations of unpredictability and chaos indices and mental health and behavioral problems (Doom et al. 2016; McGinnis et al. 2022). Our findings are also consistent with previous work on chaos and child health within the FFCWS during early childhood (at ages 3 and 5) (Kamp Dush et al. 2013). Notably, our index of unpredictability extends previous work and is broader in scope with regard to capturing unpredictability across multiple ecological levels and timescales than previous investigations.

Unstable resources have been posited to contribute to the development of an unpredictability schema that may underlie risk-taking and impulsivity (Ross and Hill 2002). Consistent with previous research (Kidd et al. 2013), greater impulsivity in unpredictable environments may reflect rational decision-making given the uncertainty of future events, thus prioritizing more immediate rewards. These impulsive, quick response strategies may also underlie some of the other behavioral and developmental outcome findings, including increased delinquency and higher weight categories during adolescence. With regard to internalizing problems, unpredictability may undermine self-efficacy and emotion-regulation skills, and in turn, deficits in these skills may contribute to depressive and anxiety symptoms.

We also examined the effects of individual forms of unpredictability on adolescent mental health and behavioral problems. Our exploratory hypothesis of more proximal forms of unpredictability being associated with adolescent outcomes was partially supported. However, more complex patterns of findings among the individual forms of unpredictability emerged as a combination of proximity of ecological level, timescale,

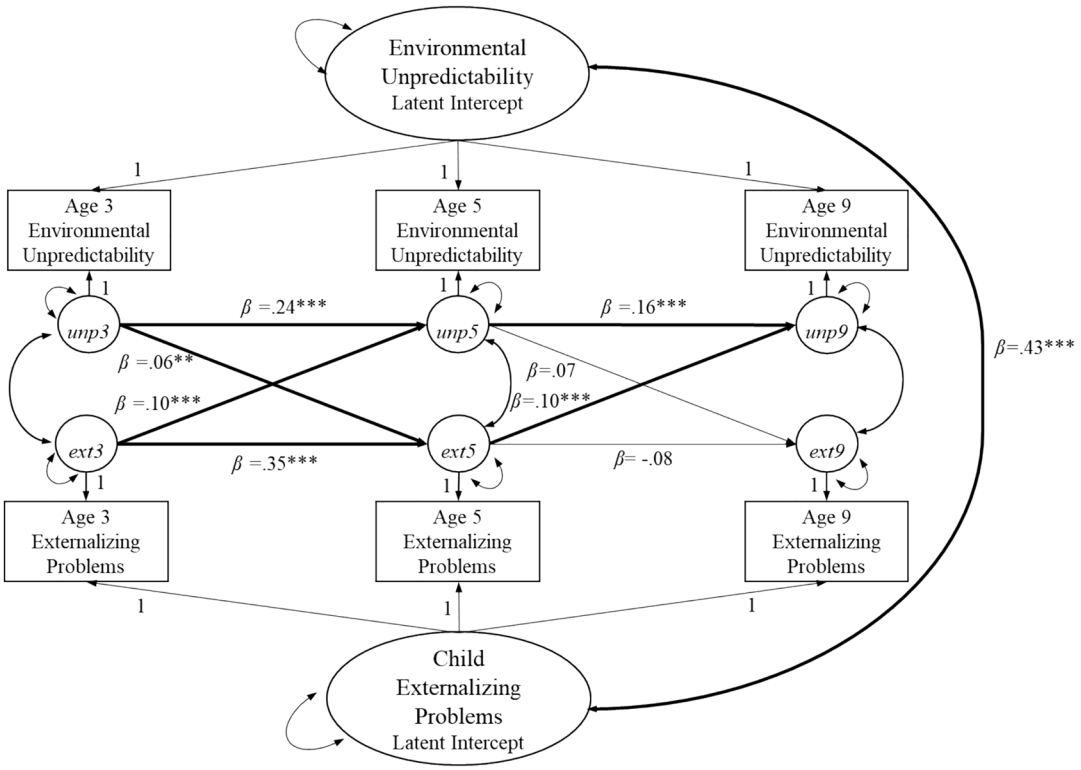

FIGURE 1 | Random-intercept cross-lagged panel model testing bidirectional associations among childhood externalizing problems and environmental unpredictability. Standardized coefficients are depicted in the figure. Model Fit $\chi^2(101) = 3.83.90$, $p < 0.001$, CFI = 0.95, RMSEA = 0.03. $N = 4648$. Covariates (omitted from figure for brevity) include child sex, race/ethnicity, family income, parental marital status at birth, and city fixed effects. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

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and reporter. Across adolescent-reported outcomes, parental impulsivity, family chaos, and physical household chaos were the most commonly associated individual forms reflecting types of unpredictability that are both proximal (e.g., in the family context) and more frequent, daily experiences. However, it is noted that the family routines measure does not reflect this same general pattern. Family instability, a proximal influence measured on a more long-term scale of family structure transitions, was largely not associated with youth-reported outcomes, which may suggest the need to consider the timescale at which unpredictability unfolds across development. In addition to associations with the same set of proximal forms of unpredictability found for adolescent-reported outcomes, forms of unpredictability in the child's mesosystem (e.g., caregiver co-parent inconsistency) and exosystem (e.g., employment instability) were associated with caregiver-reported outcomes. This pattern of findings may reflect the fact that the caregiver is directly embedded and influenced by unpredictability in these systems themselves (e.g., proximal to the parent, but more distal to the child). There were few findings for the individual role of residential instability in the regression results despite bivariate correlations with all youth outcomes; residential instability was correlated with all other forms of unpredictability, suggesting these effects may operate through other forms of unpredictability. There were no individual findings with regard to childcare instability, which may be a function of being a form of unpredictability only measured earlier in life that does not continue to exert effects in adolescence. The findings for individual forms of unpredictability should be interpreted with caution given the methodological challenges associated with isolating individual effects of co-occurring forms of adversity (Smith and Pollak 2021). With few exceptions, individual forms of unpredictability were correlated with one another, supporting an underlying unpredictability dimension as forms of unpredictability often co-occur and likely spill over into other ecological contexts.

Future research may benefit from examining efforts parents use to protect children from more distal forms of unpredictability. Although the individual forms of unpredictability were correlated with one another in this study, there may be unique patterns of proximal versus distal forms of unpredictability that emerge within families. Future research should seek to disentangle whether more distal unpredictability spills over into creating more instability within proximal family environments or whether parents increase efforts to maintain stability within the family context and provide greater structure to promote resilience in the face of adversity. Higher levels of structure and limit-setting following early life adversity have been found to protect against deficits in emotion regulation difficulties in early childhood (Koss et al. 2020).

There were significant differences by both family structure at birth and race and ethnicity in the level of environmental unpredictability across childhood. Existing research in the FFCWS demonstrates that children born to unmarried parents are more likely to experience multiple family transitions over the course of childhood and adolescence (Gold et al. 2020). The present investigation extends this previous research. We found that being born to unmarried parents was associated with higher environmental unpredictability across most individual forms of unpredictability that may place children at risk for cascading unpredictability across time and type. The racial and ethnic differences suggest that unpredictability at multiple ecological levels may be a source of perpetuating inequities particularly among Black families. Further, we note that the race and ethnicity differences should be interpreted with caution as the sampling strategy reflects a higher prevalence of unmarried and low-income families that may limit generalizability.

Our child sex-specific analyses show that unpredictability was associated with more mental health and behavioral problems for both boys and girls for all outcomes except BMI weight categories. Additionally, rates of exposure to unpredictability (as measured by the dimensional index) did not differ by child sex. Collectively, these results suggest no child sex differences in the rates nor how youth are impacted by environmental unpredictability despite independent main effects of child sex contributing to different levels of mental health and behavioral problems. We also did not find sex differences in the number of total ACEs experienced, which is in contrast to previous research finding adult females report more ACEs than their male counterparts (Haahr-Pedersen et al. 2020).

Our findings with regard to developmental timing demonstrate that exposure during infancy, early childhood, middle childhood, and preadolescence was associated with heightened mental health and behavioral problems during adolescence; however, specific timing effects varied by outcome and reporter. Caregiver-reported outcomes were associated with unpredictability at every developmental period. This may be due to shared method variance as caregiver reports were the primary source used in the creation of the unpredictability index. With regard to youth-reported outcomes, four of the five youth-reported outcomes (e.g., depressive symptoms, anxiety symptoms, impulsivity, BMI categories) were significantly associated with the age 1 unpredictability dimensional index consistent with an early experiences or sensitive period model. Youth-reported behavioral problems (impulsivity, delinquency) were associated with year 9 unpredictability supporting a recency model for disruptive behaviors. Impulsivity was the only youth-reported outcome to be associated with both early (age 1 and 3) and recent (age 9) experiences. These findings are in line with the complex associations among developmental timing, adversity, and psychopathology in existing research. For example, evidence for cumulative and more recent maltreatment was found predicting youth psychopathology in a cohort of children from England (Dunn et al. 2018). Whereas exposure to violence very early in life, consistent with a sensitive period model, was found to predict externalizing problems in a different cohort study from the Netherlands; importantly, these effects grew in magnitude across childhood providing evidence for unfolding, latent effects (Dunn et al. 2020). In past empirical work within the FFCWS, the effect of harsh parenting on psychopathology demonstrates a sensitive period during middle childhood; however, neglect appears to operate under an accumulation model (Dunn et al. 2023). Future research is needed to disentangle the complexity in timing effects.

The findings from our random-intercept cross-lagged panel models provide support for the bidirectional, transactional associations between child behavior and environmental

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unpredictability. In particular, we found that disruptive child behavior contributed to subsequent increases in environmental unpredictability across childhood. These findings are consistent with previous research that found children's ADHD genetic risk was associated with household chaos (Agnew-Blais et al. 2022). The cross-lagged effect from unpredictability to subsequent increases in externalizing problems was present from ages 3 to 5 years old but was attenuated when examining ages 5 to 9 years old, which may in part be due to the longer measurement lag (e.g., a 2 year lag vs. a 4 year lag) as longer measurement lags are known to attenuate effects over time.

There is a lack of consensus regarding definitions of environmental unpredictability (Young et al. 2020). Evolutionary developmental models define unpredictability as variation in environmental harshness (Ellis et al. 2009; McLaughlin et al. 2021). Informed by a bioecological perspective on environmental stability and instability (Bronfenbrenner and Evans 2000; Bronfenbrenner and Morris 2006), we extend our operationalization of unpredictability beyond variation in harshness to also include forms of variation in children's daily life and transitions and instability across childhood that may directly constitute risk as well as those that may disrupt processes that promote competence.

Importantly, our unpredictability findings were net of total ACE scores, highlighting the unique role of unpredictability as a form of childhood adversity and the need to expand conceptualizations of adversity. Unsurprisingly, ACEs and our dimensional index of environmental unpredictability were significantly correlated. Measurement of ACEs consists of multiple adverse experiences that may include both direct and indirect forms of unpredictability. For example, parental divorce as an ACE was a specific type of family transition that was also captured within our broader family instability measure; although our measure accounted for greater variation in the types of instability (multiple partner entrances and exits) that may occur within contemporary families but typically are not captured by items simply asking if parents have divorced. Indirectly, ACEs such as parental substance use or parental mental illness may increase environmental unpredictability through variations and disruptions in parenting and parental work. Our goal was to characterize the degree to which children experience environmental unpredictability and its role in understanding adolescent health and wellbeing in relation to a prominent current child adversity model (e.g., ACEs).

The current study is not without limitations. As stated above, there is shared method variance between the unpredictability measures and caregiver-reported outcomes. The findings in this study are based on a population-based birth cohort (1998–2000) born in large, urban US cities, resulting in a sample with socioeconomic, family structure, and racial and ethnic diversity. These results may not generalize beyond this population (e.g., unpredictability experienced in rural populations). Additionally, not all items and constructs were assessed at each time point due to both missing data and changes in developmentally relevant contexts. Missing data rates varied across time (e.g., study attrition) and reporter (e.g., changes in family structure, no in-home assessment). This resulted in sample sizes that varied across some outcomes and analyses. As the study measurement of unpredictability spanned from infancy through preadolescence, this is consistent with the changing nature of youth's environmental microsystems. For example, once children enter the school age years, instability in childcare settings may be a less relevant source of environmental unpredictability. The goal of this study was to capture developmentally relevant forms of environmental unpredictability, and the use of longitudinal POMS scoring allowed for placing a variety of different forms of environmental unpredictability on similar scaling. Because of these changing environmental contexts, we created an index that reflected various forms of environmental unpredictability from infancy to preadolescence available in the prospective study data. As such, the timing analyses should be interpreted with caution as the forms of unpredictability or specific items used to score the data varied somewhat across each developmental period. This longitudinal approach to creating a dimensional index of unpredictability that spanned across childhood also increased comparability to ACEs, which typically reflect any adversity prior to adulthood. There are also limitations in the creation of the ACEs scoring. The scoring based on CPS involvement reflects contact not substantiated claims, potentially adding additional measurement error into the ACEs index. Similarly, the CTS measure does not reflect legal definitions of child abuse but is consistent with investigations of ACEs within the FFCWS (Jimenez et al. 2016). Despite being similar to other investigations that construct measures of ACEs from prospective studies using the CTS, the prevalence of experiencing any psychological and physical aggression by parents was high in this sample.

Scholars note the need to incorporate both objective and subjective experiences into research on childhood adversity (Bronfenbrenner and Morris 2006; Smith and Pollak 2021). The majority of the measures included in the index of unpredictability reflect objective measures (e.g., occurrence of family and residential transitions, number of caregiving arrangements). Some of the measures used in our unpredictability construct do reflect subjective experiences (e.g., family chaos, work schedule stress, coparenting inconsistency) although we do not differentiate between the role of objective and subjective experiences in this investigation.

These findings have important implications for the study of adversity and health and well-being, highlighting the need to expand investigations to include aspects of environmental unpredictability. These findings also have the potential to inform policies, interventions, and preventions to reduce environmental unpredictability experienced by children. The results examining the role of specific individual forms of unpredictability suggest that these efforts may need to target multiple different forms of unpredictability to reduce the adverse effects for youth. Findings demonstrate that environmental unpredictability shapes multiple aspects of adolescents' mental health and behavioral problems.

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Data Availability Statement

The data and materials necessary to reproduce the analyses and replicate the findings presented here are publicly accessible; FFCWS data and materials are publicly available at: https://ffcws.princeton.edu/. The analytic code necessary to reproduce the analyses presented in this paper is not publicly accessible and the analyses presented here were not preregistered.

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