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Children's Sensitivity to Facial Emotional Expressions: The Mediating Roles of Maternal Warmth and Home Environment

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ABSTRACT

Children's ability to recognize emotions in the facial expressions of others is critical for their social functioning and self-regulation. Children exposed to adversity often show differences in their ability to recognize emotions. However, most prior research has relied on clinical or high-risk samples and focused on exposure to extreme forms of adversity, such as child maltreatment or serious deprivation. The present study utilized data from the Environmental Risk (E-Risk) Longitudinal Twin Study, an epidemiological cohort of 2232 British twins, to test whether (1) children growing up in households with lower versus higher socioeconomic status (SES) are less sensitive in their identification of emotions, controlling for child intelligence quotient (IQ) and sex, and, if so, (2) differences in parenting and household environment (maternal warmth, negative parenting, orderly homes, polyvictimization, or maternal depression) across lower versus higher SES households explains these differences. Results indicated that children living in higher versus lower-income households were more sensitive in identifying a range of facial emotions, even after accounting for child IQ and sex. Maternal warmth and the state of the children's homes, but not other factors, mediated this association. Additional within-family analyses showed that children whose mothers expressed more warmth when describing them, as compared to their same-sex twin, were also more sensitive to the recognition of negative emotions. Future research is needed to test whether enhanced maternal warmth or home environments can lead to improved emotion recognition among children.

1 | Introduction

Children's ability to recognize emotions in the facial expressions of others is critical for social functioning and self-regulation (Castro et al. 2018; Kohls et al. 2020; McKown et al. 2009; Trentacosta and Fine 2010). Children exposed to early adversity exhibit differences in their ability to recognize facial emotions (Bérubé et al. 2020; Pollak et al. 2000; Raver et al. 2015); however, prior findings have produced mixed and at times conflicting results. For example, young children exposed to more years in poverty

Summary

- Children growing up in households with higher versus lower socioeconomic status (SES) are more sensitive in their identification of emotions, controlling for intelligence quotient (IQ) and sex.
- Maternal warmth and the state of the children's homes explained this association. Childhood victimization was not associated with children's abilty to recognize emotions after controlling for sex and IQ.
- Within-family analyses showed that children whose mothers expressed more warmth when describing them, as compared to their same sex co-twin, were more sensitive to the recognition of negative emotions.

are less accurate in identifying the facial emotional expressions of others (Raver et al. 2015), while physically abused children tend to react more quickly and accurately to expressions of anger (Pollak et al. 2000). To date, most studies have focused on clinical or high-risk samples of children and less is known about how adversity may influence the development of children's emotion recognition across the socioeconomic status (SES) spectrum. As such, it is unknown whether maltreatment per se, versus associated conditions of poverty (e.g., household safety or parenting behaviors), influence emotion recognition during childhood. In addition, it is unclear whether these findings among high-risk samples extend to the larger population of children.

Children's ability to recognize the emotional expressions of others develops from infancy through early adolescence. Infants show preferential attention to expressive faces (Hoehl et al. 2008) and may be able to differentiate facial movements on the basis of valence (Shablack and Lindquist 2019; although see Ruba and Pollak 2020). Between the ages of 2 and 7, children become increasingly adept in their ability to infer the meaning of others' emotional expressions (Denham et al. 2012; Gao and Maurer 2009; Herba et al. 2006; Montirosso et al. 2010; Shablack and Lindquist 2019; Tonks et al. 2007; Widen and Russell 2008). Importantly, emotion recognition becomes more refined throughout later childhood and adolescence, with research indicating that the neural substrates involved in the processing of emotional cues are not adult-like until early adolescence (Batty and Taylor 2006). Moreover, task-specific variance (e.g., stimulus intensity) in emotion recognition has been documented (Riddell et al. 2024). For example, Gao and Maurer (2009) found that 5-year-old children recognize expressions of happiness as well as adults, regardless of the intensity of the emotional display. However, for expressions of fear, children's recognition abilities were not comparable to adults until the age of 10 when tested at a range of intensity levels.

Evidence suggests that both child-specific characteristics and the broader family context predict children's emotion recognition abilities. Children with greater cognitive abilities tend to demonstrate more accurate recognition of emotions (Bennett et al. 2005). Moreover, longitudinal studies demonstrate that cognitive abilities measured early in childhood continue to predict emotion recognition abilities in later childhood (Berzenski and Yates 2017). Within the broader family context, parents socialize emotion recognition development through modeling emotional expression and regulation, parent-child discussions of emotions, and their reactions to children's emotional displays (Eisenberg et al. 1998). As such, parents who are high in negative affect, or have blunted emotional reactions, such as parents who are depressed, tend to be less effective in scaffolding emotional development, therefore their children may demonstrate deficits in emotion recognition (Priel et al. 2020; Székely et al. 2014). Similarly, negative parenting behaviors, particularly harsh, intrusive, controlling, or insensitive behaviors, are associated with less overall accuracy on emotion recognition tasks (Kujawa et al. 2014). In contrast, positive parenting behaviors, such as expressions of positive emotions, empathy, and regard for the child (forms of maternal warmth), are linked to enhanced socialization of emotion and, in turn, better emotion recognition in children (Sadri and Yates 2024; Székely et al. 2014).

Research focused on high-risk or victimized children, such as maltreated children, finds relatively consistent evidence that these experiences are linked to alterations in emotion recognition (Assed et al. 2020; Bérubé et al. 2023; Camras et al. 1983, Camras et al. 1988; Koizumi and Takagishi 2014; Leist and Dadds 2009; Masten et al. 2008; Pears and Fisher 2005; Pollak and Kistler 2002; Pollak and Sinha 2002; Pollak et al. 2000; Pollak et al. 2009). Children exposed to physical violence, including physical abuse, demonstrate heightened sensitivity to expressions of anger as compared to non-maltreated or neglected children (Assed et al. 2020; Briggs-Gowan et al. 2016; Pollak et al. 2000; Schäfer et al. 2023). Studies of children with more varied adversity exposure (exposure to physical abuse, sexual abuse, prior institutionalization, and/or neglect) find that these children demonstrate deficits in emotion recognition, particularly for negative emotions, compared to non-exposed children (Camras et al. 1988; Fries and Pollak 2004; Moulson et al. 2009; Parker and Nelson 2005; Paine et al. 2023; Pears and Fisher 2005), although some studies show superior recognition of fear and sadness (Leist and Dadds 2009; Masten et al. 2008) or heightened perceived intensity of positive facial expressions (Gerin et al. 2024). Of note, the only study conducted to date with a large, population representative sample of young children found no association between maltreatment or adversity exposure and children's emotion recognition skills (Dunn et al. 2018), although the sample was predominantly middle to high income.

Other settings that might hamper emotion recognition include low-resource neighborhoods and family environments. Within economically and socially stressed environments, children may have fewer opportunities for cognitive and emotional stimulation needed for normative emotion recognition development (Saitadze and Lalayants 2021; Sarsour et al. 2011). Children growing up in low versus higher income households may be exposed to fewer conversations about negative emotional situations (Lunkenheimer et al. 2007). Moreover, high poverty environments are more likely to be characterized as chaotic, dangerous, and disorganized (Vernon-Feagans et al. 2012). Children in disorderly or dangerous environments tend to have a wide range of poor child outcomes, including lower self-regulation, academic achievement, and language acquisition (Cooper and Stewart 2021; Garrett-Peters et al. 2016; Hicks et al. 2018; Vernon-Feagans et al. 2012). As a result, low SES children may have

less, or at least less consistent, exposure to normative emotional cues by which to learn how to accurately recognize emotional expressions, leading to hypo-vigilance, or an overall deficit in emotion recognition abilities.

However, another possibility is one of hypervigilance, whereby children living in poverty overly focus on non-verbal cues potentially related to threat (Maurer 2023). Stressors related to living in poverty have been linked to a greater frequency of negative and harsh interpersonal interactions (Dodge et al. 1994; Dotterer et al. 2012), which may cause children to be more likely to attribute ambiguous interactions and expressions as threats. Likewise, conditions associated with poverty may increase caregiver stress which may, in turn, decrease children's exposure to warmth from their caregivers (Davis-Kean 2005; Dodge et al. 1994), a known predictor of young children's positive social and emotional development (Berona et al. 2023). Caregiver warmth, and social support more broadly, can alternatively act as a buffer leading to positive outcomes for children exposed to adversity or poverty (Brown et al. 2020; Gerin et al. 2024; Skinner et al. 2022). Overall, extant findings suggest both hypo- and hypervigilant profiles of children's recognition of emotions are possible in the context of early adversity.

In a large cohort of children that span the entire range of SES in the UK, the present study sought to (1) describe differences in recognition sensitivity (ability to correctly identify emotions across a range of intensity) to facial expressions of emotions between children from families with lower versus higher SES and (2) test potential mechanisms that may explain why children from lower SES households would exhibit deficits in emotion recognition while controlling for relevant child-related characteristics. The study also offers the advantage of being able to leverage the within-family twin design to control, by design, for shared factors between children growing up in the same family, such as family SES, that may confound associations between exposure to childhood adversity and emotion recognition abilities. More specifically, we test whether differences in parenting (e.g., maternal warmth, negative parenting) and/or victimization experienced by children growing up in the same family account for differences between same-sex and same-age siblings in their emotion recognition abilities.

Children were participants in the Environmental Risk (E-Risk) Longitudinal Twin Study, an epidemiological cohort of 2232 twin children assessed prospectively at ages 5, 7, 10, and 12. The design of the E-Risk Study is well suited for examining SES influences on children's emotion recognition. First, the E-Risk sample is a population representative sample including children at all levels of SES, from poverty to wealth. Second, high-risk families were oversampled to ensure sufficient numbers of children growing up in high-risk environments. Third, in-depth assessments of the parenting and home environment obtained via multiple sources (parent report, observer ratings, geo-coded poverty indicators) allow for tests of potential mediating pathways that might explain why children from lower-SES backgrounds are more likely to exhibit emotion recognition difficulties. Finally, the inclusion of twins allows for testing sibling difference models to investigate whether differences in parenting *between children growing up in the same family* predicted differences in siblings' sensitivity to recognizing negative facial emotions.

We hypothesized that (1) children growing up in higher versus lower SES households would exhibit enhanced recognition sensitivity to emotional expressions (Raver et al. 2015), (2) this association would hold after accounting for children's intelligence quotient (IQ) and sex, both of which have been linked to emotion recognition (Olderbak et al. 2019; Schlegel et al. 2020), and (3) the association between high SES and enhanced children's emotion recognition sensitivity would be mediated by parenting and home environment factors (i.e., with less exposure to polyvictimization, greater maternal warmth, a more orderly home, less maternal depression, and less negative parenting accounting for this association).

2 | Method

2.1 | Participants

The E-Risk sample was drawn from a birth register of twins born in England and Wales in 1994–1995 (Trouton et al. 2002). Details about the sample have been reported previously (Moffitt and Team 2002). Briefly, the E-Risk sample was constructed in 1999–2000, when 1116 families with same-sex 5-year-old twins (93% of those eligible) participated in home-visit assessments. The full sample comprised 56% monozygotic (MZ; 100% shared genes) and 44% dizygotic (DZ; 50% shared genes) twin pairs; sex was evenly distributed within zygosity (49% male; see Table 1). Families were recruited to represent the UK population of families with newborns in the 1990s, based on (a) residential location throughout England and Wales and (b) mother's age (i.e., older mothers having twins via assisted reproduction were under-selected and teenage mothers with twins were over-selected). This sampling was used to (a) replace high-risk families who were selectively lost to the register via nonresponse and (b) ensure sufficient numbers of children growing up in high-risk environments.

The study sample represents the full range of SES conditions in the UK, as reflected in the families' distribution on the deciles of the UK government's 2007 Index of Multiple Deprivation, which ranks relative deprivation in British neighborhoods at an area level of roughly 1500 residents or 650 households. At age 5, 33% of children were living in low-SES households. As shown in Figure S1, approximately 10% of the E-Risk cohort falls into each of the index's 10% bands, suggesting that the cohort accurately reflects the socioeconomic distribution of households in the UK.

2.2 | Measures

2.2.1 | Emotion Recognition Paradigm

Children viewed four trials of each emotion category (angry, fearful, sad, and happy; 16 total) from Ekman's black-and-white set of facial stimuli (eight male and eight female models) (Ekman and Friesen 1976). Each trial consisted of 11 presentations of faces beginning with a neutral face (0%) that sequentially morphed with one emotion at increasing 10% increments and ended at a full expression of that emotion (100%; Figure 1a,b). Emotion recognition sensitivity scores were defined as the lowest morph for which the child correctly identified the emotion across four trials (angry, fearful, sad, and happy). A composite score for negative

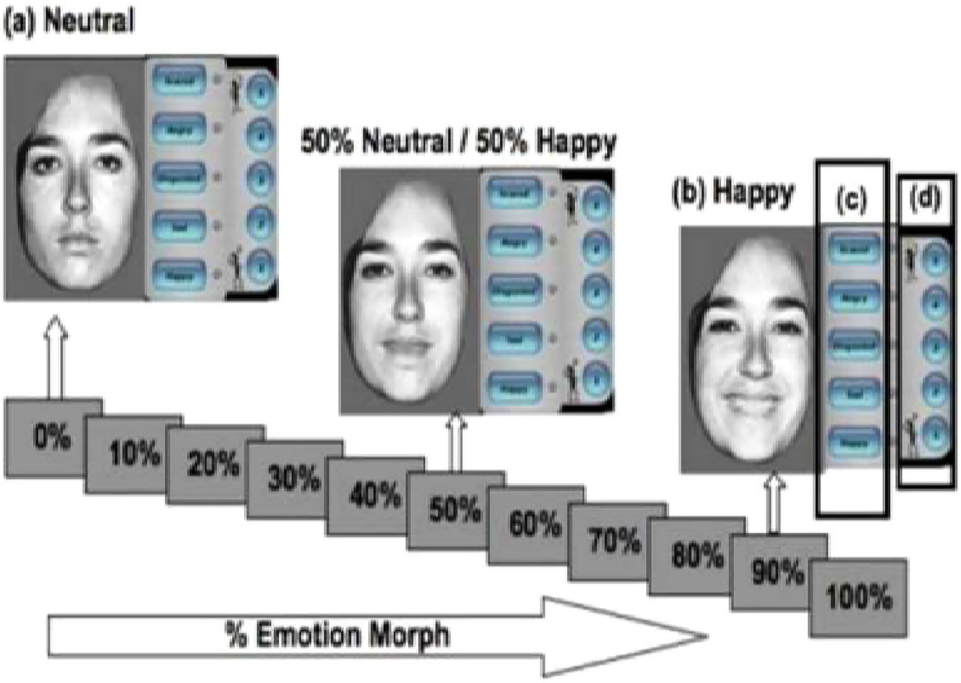

FIGURE 1 | Emotion recognition task.

emotion recognition was formed by averaging performance across the three negative emotion expressions (i.e., angry, fearful, sad). This task is similar to other emotion recognition sensitivity tasks used with children (Gao and Maurer 2009; Garcia and Tully 2020; Montirosso et al. 2010; Porter-Vignola et al. 2021).

2.2.2 | Childhood SES

Participants' family SES was assessed at child age 5 using a standardized composite of total household income, highest maternal/paternal education, and highest maternal/paternal occupation, which loaded significantly onto one latent factor (Trzesniewski et al. 2006).

2.2.3 | Polyvictimization

Lifetime exposure to several types of victimization was assessed repeatedly when the children were 5, 7, 10, and 12 years of age, and comprehensive dossiers were compiled for each child with cumulative information about exposure between birth and age 12 years to domestic violence between the mother and her partner; frequent bullying by peers; physical abuse by an adult; sexual abuse; emotional abuse/neglect; and physical neglect. The dossiers comprised reports from caregivers of victimization using questions based on the Multisite Child Development Project (Dodge et al. 1990; Lansford et al. 2002), recorded narratives of the caregiver interviews, recorded debriefings with research workers who had coded any indication of abuse and neglect at any of the successive home visits using the Home Observation for Measurement of the Environment (HOME; Bradley and Caldwell 1977), and information from clinicians whenever the study team made a child-protection referral. The dossiers were reviewed by two independent researchers and rated for the presence and severity (none/mild/severe) of each type of victimization. Interrater agreement between the coders exceeded 85% among the positive cases, and discrepantly coded cases were resolved by consensus review. Full details on this measure have been reported previously (Danese et al. 2016; Fisher et al. 2015).

2.2.4 | Maternal Warmth

Maternal warmth was assessed when the children were age 10 using a 5-minute speech sample (FMSS) from the mother to elicit expressed emotion about each child. Trained interviewers asked caregivers to describe each of their children ("For the next 5 minutes, I would like you to describe [child] to me; what is [child] like?"). The mother was encouraged to talk freely with few interruptions. However, if the mother found this difficult, the interviewer could aid the mother with a series of semi-structured probes, such as "In what ways would you like [child] to be different?" Interviews about each twin were separated in time by approximately 90 min. All interviews were audiotaped with the mother's consent. Two trained raters coded the audiotapes (inter-rater reliability = 0.90) according to guidelines adapted from the FMSS scoring manual and modified for use with preschool children (see also Sandberg et al. 2003). The raters underwent 2 weeks of training about coding expressed emotion. Interrater reliability was established by having the raters individually code audiotapes describing 40 children. The same rater coded both twins in the same family. The rater was blind to all other E-Risk Study data. A full description of the procedure is detailed elsewhere (Caspi et al. 2004). Maternal warmth was a global measure of the entire speech sample that captured the warmth expressed about the child during the speech and was coded 6-point scale, ranging from "high warmth" (5) and "moderately high warmth" (4) to "very little" (1) or "no" (0) warmth.

TABLE 1 | E-Risk study sample characteristics.

Sample characteristics	Full sample ($N = 2232$)	
	N	**%**
Sex		
Male	1092	49.00%
Female	1140	51.00%
Race/ethnicity		
White	2018	90.40%
Black	42	1.90%
Asian	89	4.00%
Mixed	9	0.40%
Zygosity		
Monozygotic	1246	56.00%
Dizygotic	986	44.00%
SES at age 5		
Low	742	33.24%
Medium	738	33.06%
High	752	33.69%
Index of multiple deprivation (2007)		
Decile 1 (most deprived)	196	10.46%
Decile 2	178	9.50%
Decile 3	226	12.06%
Decile 4	160	8.54%
Decile 5	188	10.03%
Decile 6	134	10.14%
Decile 7	188	10.03%
Decile 8	190	10.14%
Decile 9	194	10.35%
10 (least deprived)	220	11.74%

Note: Percentages may not equal 100 due to missing data. Index of multiple deprivation data was available for 1874 participants.

2.2.5 | Orderly Home

The state of the home, referred to here as "orderly home" (e.g., "Are visible rooms of the house clean?"), was obtained at the age 10 visit via the Coder's Impression Inventory (Kim-Cohen et al. 2006), which is based on two main inventories, the HOME (Bradley and Caldwell 1977) and the University of Washington Parenting Clinic questionnaire (Parent–Child Observations; Webster-Stratton 1998). The Inventory was rated immediately following the study visit by interviewers. Interviewers underwent 4-day training on the coding scheme. Higher scores reflected a more orderly, safe, and less crowded home environment.

2.2.6 | Negative Parenting

The quality of parenting was assessed at the age 10 visit by trained interviewers, who were blind to maternal psychopathology status, as part of the Coder's Impression Inventory as described above. The negative parenting scale included seven items and measured the extent to which each child experienced controlling, strict, harsh, negligent, inconsistent, or erratic parenting behaviors. High scores reflected more negative parenting. The internal consistency was 0.72 and the inter-rater reliability was 0.92.

2.2.7 | Maternal Depression

At the age-10 assessment, mothers' major depressive disorder (MDD) was assessed by a trained clinician using the Diagnostic Interview Schedule (Robins et al. 1995) according to DSM-IV (American Psychiatric Association 1994) criteria. Mothers who met criteria for MDD at any time over the past 5 years were then asked to refer to the Life History Calendar (LHC) to specify the timing of their depressive episodes. If mothers did not meet criteria for MDD in the past 5 years, their score on all reference periods was entered as zero. The LHC is a reliable visual method for recalling the occurrence, timing, and duration of life events, including psychopathology (Caspi et al. 1996). Specifically, the reliability of recalling depressive episodes using the LHC method was separately evaluated using a 1-month test–retest and determined to be high at 93% (Kim-Cohen et al. 2006). Here a dichotomous variable reflecting any maternal depression in the past 5 years was derived. The prevalence of maternal 5-year MDD was 37%, which is comparable to other population-based samples of similar aged women in the UK (Abel et al. 2019) and likely reflects the oversampling of high-risk families.

2.2.8 | Children's IQ

Children's IQ was tested at age 5 years using a short form of the Wechsler Preschool and Primary Scale of Intelligence—Revised (WPPSI; Wechsler 1990). Using two subtests (Vocabulary and Block Design), children's IQs were prorated following procedures described by Sattler (1992, 998–1004) and then standardized with a mean of 100 and a standard deviation of 15.

2.3 | Procedures

Initial home visits were conducted when the children were aged 5, with follow-up home visits occurred when children were aged 7 years (98% participation), 10 years (96%), and 12 years (96%). Home visits at ages 5, 7, 10, and 12 included assessments with participants as well as their primary caretaker. Each twin participant was assessed by a different interviewer. The Joint South London and Maudsley and the Institute of Psychiatry NHS Research Ethics Committee approved each phase of the study. Parents gave written informed consent, and twins gave assent at each assessment.

During the age-10 home visits, children completed an emotion recognition sensitivity task via a PC laptop computer with a touch-sensitive screen. Upon viewing each facial morph presentation, children were asked to identify the emotion via written labels including the four target emotions and a filler option (i.e., disgust; Figure 1c), which served to decrease the likelihood of correct guesses. This task was administered in less than 20 min on average.

TABLE 2 | Descriptive statistics for main study variables.

Variables	Full sample ($N = 2232$)					
	n	**Mean/%**	**SD**	**Range**	**Skew**	**Kurtosis**
Covariates						
IQ at age 5	2210	95.79	14.46	52–145	0.02	2.87
Emotion sensitivity at age 10						
Anger	2120	38.91	15.41	10–100	0.54	3.18
Fear	2097	38.48	14.11	10–100	0.58	3.76
Sadness	2108	32.43	16.33	10–100	0.84	3.73
Happiness	2122	19.95	9.00	10–77	1.71	7.25
Negative emotion composite	2082	36.62	9.82	13–79	0.57	3.44
Parenting variables						
Maternal depression	2132	38.43%	—	0–1	—	—
Polyvictimization	2232	0.36	0.72	0–5	2.54	10.67
Maternal warmth	2100	3.66	0.91	1–5	−0.31	2.92
Orderly home	2130	6.83	1.86	0–8	−1.78	5.49
Negative parenting	2132	0.84	1.63	0–12	2.89	13.13

2.3.1 | Statistical Analyses

Our analyses proceeded in three steps. First, we tested for bivariate associations between children's facial emotion recognition sensitivity and childhood polyvictimization, IQ, and sex that have been observed in prior studies and examined whether there was a graded association between family SES and children's emotion recognition. Second, we applied multiple regressions to test whether the relation between SES and emotion recognition held after accounting for children's IQ and sex. Third, we estimated parallel mediation models in a structural equation modeling (SEM) framework to test whether the association between SES and emotion recognition was mediated by parenting or household characteristics. Finally, a twin-difference design was used to test whether differences in parenting experienced between children in the same family, including levels of maternal warmth, negative parenting, and exposure to polyvictimization, predicted differences in siblings' sensitivity to recognizing negative facial emotions. This approach (where for twin i with sibling j: $OUTCOME_i - OUTCOME_j = \beta_0 + \beta_1{*}(Warmth_i - Warmth_j) + \varepsilon_i$) holds constant, by design, family-level factors such as family income and orderly home, as well as shared genetic factors, that may otherwise confound associations.

SEM and twin difference models were fitted in Mplus Version 8 (Muthén and Muthén 1998–2017) using full information maximum likelihood (FIML) estimation to handle missing data (Raykov 2005). FIML performs equally well, and is often better than multiple imputation techniques, with respect to correcting bias in estimates and recovering known population parameters (Lee and Shi 2021). Missing data posed minimal threat to the results due to high retention rates in E-Risk (over 95% response rate across data collection points).

The COMPLEX option in Mplus was used to compute adjusted standard error estimates and correct for the non-independence of observations since children in our study were nested within families (Odgers et al. 2009). Consistent with prior research (Koizumi and Takagishi 2014; Leist and Dadds 2009; Pollak and Sinha 2002), separate regression analyses were conducted for children's responses to each of the four emotions (i.e., angry, fearful, sad, happy). For the mediation analyses, separate models were fit for negative (average recognition sensitivity to anger, fear, and sadness) and positive (happiness) emotion recognition sensitivity. Eighteen participants were excluded from the analyses due to technical difficulties or failure to complete the emotion recognition task. To address potential non-normality and ensure robust inference, bias-corrected bootstrap estimation with 10,000 samples was used to generate confidence intervals and standard errors for all models.

3 | Results

3.1 | Descriptive Analyses

Descriptive statistics for the main study variables are reported in Table 2. Children varied in their recognition sensitivity across emotions, with children, on average, being most sensitive when identifying happiness ($m = 19.95$, $sd = 9.00$) and least sensitive when identifying anger ($m = 38.91$, $sd = 15.41$). The extent of polyvictimization ranged from 0 to 5, with 73.5% of the sample experiencing no victimization, 20.1% experiencing 1 form of severe victimization, and 6.4% experiencing two or more types of severe victimization.

Bivariate correlations among children's emotion recognition sensitivity scores and potential predictors are presented in Table 3. Overall, age-5 IQ, age-5 SES, age-10 maternal warmth, and age-10 orderly home were significantly and negatively associated with recognition sensitivity scores for all four of the individual emotions and the composite of the negative emotions, such that

TABLE 3 | Correlations among children's emotion recognition and main predictors.

	Anger	Fear	Sadness	Negative composite	Happiness
SES	−0.07***	−0.11***	−0.06**	−0.12***	−0.13***
	[−0.11, −0.03]	[−0.15, −0.06]	[−0.10, −0.01]	[−0.17, −0.08]	[−0.18, −0.09]
IQ	−0.09***	−0.13***	−0.08***	−0.16***	−0.20***
	[−0.13, −0.05]	[−0.17, −0.09]	[−0.12, −0.03]	[−0.20, −0.12]	[−0.24, −0.16]
Female	−0.05*	−0.03	−0.08***	−0.09***	−0.03
	[−0.09, −0.01]	[−0.07, 0.02]	[−0.12, −0.04]	[−0.13, −0.04]	[−0.07, 0.02]
Maternal warmth	−0.09***	−0.06**	−0.05*	−0.11***	−0.08***
	[−0.13, −0.05]	[−0.11, −0.02]	[−0.09, −0.01]	[−0.15, −0.06]	[−0.12, −0.03]
Orderly home	−0.08***	−0.07**	−0.08***	−0.12***	−0.09***
	[−0.12, −0.03]	[−0.12, −0.03]	[−0.12, −0.03]	[−0.16, −0.07]	[−0.13, −0.04]
Negative parenting	0.06**	0.05*	0.06**	0.09***	0.11***
	[0.02, 0.10]	[<0.01, 0.08]	[0.02, 0.11]	[0.05, 0.13]	[0.07, 0.15]
Polyvictimization	0.03	0.04*	0.03	0.06**	0.08***
	[−0.01, 0.08]	[<0.01, 0.09]	[−0.01, 0.08]	[0.02, 0.10]	[0.04, 0.12]
Maternal depression	0.01	−0.02	0.01	<0.01	<0.01
	[−0.04, 0.05]	[−0.06, 0.02]	[−0.03, 0.05]	[−0.04, 0.04]	[−0.05, 0.04]

Note: $N = 2232$. $^{*}p < 0.05$; $^{**}p < 0.01$, $^{***}p < 0.001$. Lower emotion recognition scores reflect quicker correct identification of emotions, as such higher SES is associated with quicker correct identification of emotions (i.e., greater emotion recognition). Presented estimates are *r*-coefficients with 95% confidence intervals. Abbreviations: IQ, intelligence quotient; SES, socioeconomic status.

children with higher SES, higher IQ, mothers who expressed more warmth toward them, and those from more orderly homes correctly identified the target emotion more quickly (*r*s = −0.05 to −0.20). Girls were significantly quicker to correctly identify anger and sadness than boys (*r*s = −0.05 to −0.08). Children whose parents reported negative parenting behaviors were significantly slower to correctly identify all emotions (*r*s = 0.05 to 0.11). Polyvictimization was significantly associated with poorer emotion recognition as measured by the negative emotion composite ($r = 0.06$), as well as happiness and fear recognition sensitivity scores (*r*s = 0.04 to 0.08). Maternal depression was not associated with children's performance for any of the individual emotions or the composite of the three negative emotions (see Table S1 for correlations among main predictors).

Behavioral genetic analyses indicated that 23.5% of the variation in children's emotion recognition abilities (i.e., average emotion recognition sensitivity across all four emotions) could be attributed to additive genetic factors, whereas the remaining 76.5% was attributable to environmental factors (common environment, unique environment, and error).

3.2 | SES and Children's Facial Emotion Recognition

Figure 2 contrasts the levels of emotion sensitivity recognition among children growing up in high, medium, and low SES families. Children from higher SES families identified facial emotions more quickly than those from lower SES families across all four emotions. They were also faster at identifying fear and sadness compared to children from middle SES families. Additionally, children from middle SES families identified happiness more quickly than those from lower SES families. All effect sizes were small ($\eta_p^2 = 0.005$ to 0.018). The association between family SES and the negative emotion recognition composite is presented in Figure 3, again showing that children from higher SES families identified negative emotions more quickly than children from lower and middle SES families (small effect size, $\eta_p^2 = 0.018$). As illustrated in Table 4, Model 1, mean recognition sensitivity scores for all four emotions and the negative emotion composite differed significantly by SES, such that higher SES was associated with greater recognition sensitivity to facial expressions of emotion, with associations ranging from 0.06 to 0.13. Next, in Model 2, SES continued to be a significant predictor of sensitivity to fear, happiness, and the negative emotion composite, even after accounting for IQ and sex. For anger and sadness, the association between SES and emotion recognition was reduced to non-significance, with higher IQ measured at age 5 and being female predicting greater sensitivity to the recognition of both emotions at age 10. Childhood IQ was the most consistent and robust predictor of children's recognition across all emotions and, along with sex, fully accounted for the association between SES and the recognition of anger and sadness.

3.3 | Mediational Pathways to Emotion Recognition

We estimated parallel mediation models in a SEM framework to test the direct effect of SES on children's emotion recognition sensitivity while accounting for the indirect effect(s) of SES on emotion recognition sensitivity through maternal warmth,

TABLE 4 | Regression results for emotion recognition.

	Model 1				Model 2			
	b **[95% CI]**	***SE***	***β***	***p***	***b*** **[95% CI]**	***SE***	***β***	***p***
Anger								
SES	−1.36 [−2.20, −0.52]	0.43	−0.07	**<0.01**	−0.84 [−1.72, 0.04]	0.45	−0.05	0.06
IQ					−0.08 [−0.13, −0.03]	0.03	−0.07	**<0.01**
Female					−1.47 [−2.86, −0.08]	0.71	−0.05	**0.04**
Fear								
SES	−1.81 [−2.58, −1.04]	0.39	−0.11	**<0.01**	−1.14 [−1.97, −0.31]	0.42	−0.07	**<0.01**
IQ					−0.10 [−0.15, −0.06]	0.02	−0.10	**<0.01**
Female					−0.67 [−1.93, 0.60]	0.65	−0.02	0.30
Sadness								
SES	−1.13 [−1.97, −0.29]	0.43	−0.06	**0.01**	−0.65 [−1.55, 0.25]	0.46	−0.03	0.16
IQ					−0.07 [−0.12, −0.02]	0.03	−0.06	**<0.01**
Female					−2.60 [−3.99, −1.20]	0.71	−0.08	**<0.01**
Happiness								
SES	−1.48 [−2.01, −0.95]	0.27	−0.13	**<0.01**	−0.78 [−1.31, −0.24]	0.27	−0.07	**<0.01**
IQ					−0.11 [−0.14, −0.08]	0.02	−0.17	**<0.01**
Female					−0.43 [−1.26, 0.40]	0.42	−0.02	0.31
Negative composite								
SES	−1.48 [−2.01, −0.95]	0.28	−0.12	**<0.01**	−0.89 [−1.47, −0.31]	0.30	−0.07	**<0.01**
IQ					−0.09 [−0.12, −0.06]	0.02	−0.13	**<0.01**
Female					−1.69 [−2.57, −0.80]	0.45	−0.09	**<0.01**

Note: $N = 2232$. Significant estimates at $p < 0.05$ are in bold with 95% confidence intervals (CIs) for the unstandardized coefficient (*b*). Model 1 tests the bivariate association between SES and children's emotion recognition. Model 2 tests this association while controlling for child IQ and sex. We clustered on family ID to account for the non-independence of twin observations.

Abbreviations: IQ, intelligence quotient; SES, socioeconomic status.

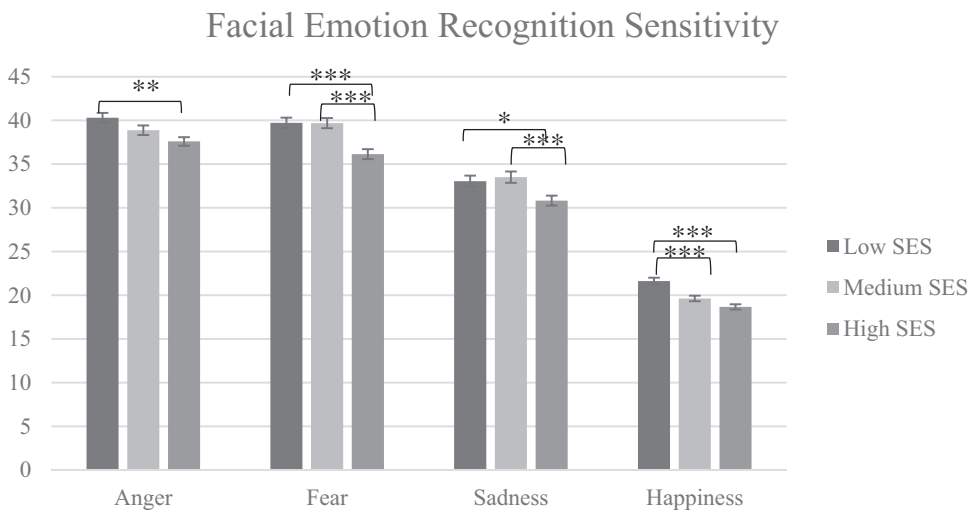

FIGURE 2 | SES gradient for recognition of facial emotional expressions. $N = 2232$. Error bars indicate standard errors. Multiple comparisons were adjusted using the Bonferroni method. Higher socioeconomic status (SES) was associated with quicker correct identification of emotions (i.e., greater emotion recognition). Effect sizes were small, ranging from $\eta_p^2 = 0.005$ for anger and sadness to $\eta_p^2 = 0.018$ for happiness. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

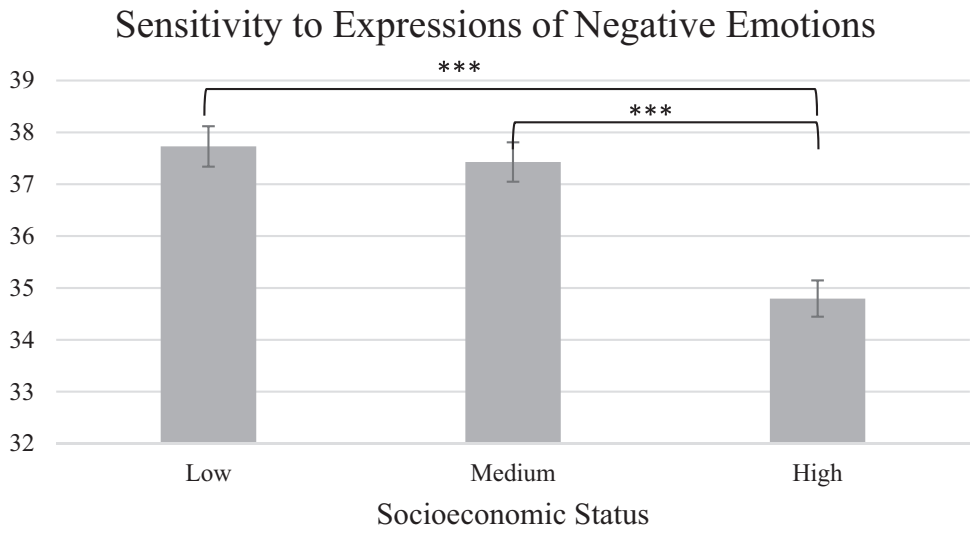

FIGURE 3 | SES gradient for recognition of facial expressions of negative emotions. $N = 2232$. Error bars indicate standard errors. Multiple comparisons were adjusted using the Bonferroni method. Higher socioeconomic status (SES) was associated with quicker correct identification of emotions (i.e., greater emotion recognition), a small effect size, $\eta_p^2 = 0.018$. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

orderly home, and/or negative parenting. We initially hypothesized that polyvictimization and maternal depression would mediate this association. However, polyvictimization was only associated with three of the five emotion recognition measures (fear, the negative composite, and happiness) and these associations did not hold after accounting for IQ and sex (Table S2, see also Table S3). Maternal depression failed to demonstrate any statistically significant associations with the outcomes. Overall, we found little evidence of an association between adversity exposure and children's emotion recognition.

To test for mediation, first, we evaluated whether the association between family SES and negative emotion recognition was explained by three separate mediators: maternal warmth, orderly home, and negative parenting. Three main paths were simultaneously estimated: paths a1-3, the association between SES (the predictor) and each of the mediators; paths b1-3, the association between each of the mediators and negative emotion recognition (the outcome); and path c', the association between SES (the predictor) and negative emotion recognition (the outcome), adjusted for each of the mediators. We also included IQ as a covariate in the model given the robust association between IQ and children's emotion recognition.

Results for the negative emotion composite are shown in Figure 4. The direct effect of SES on children's recognition sensitivity to negative emotions (path c) was no longer significant once the mediational pathways were estimated (the effect size reduces by 0.04; the p value changed from <0.01 to 0.10). The indirect effect of SES on negative emotion recognition (path a*path

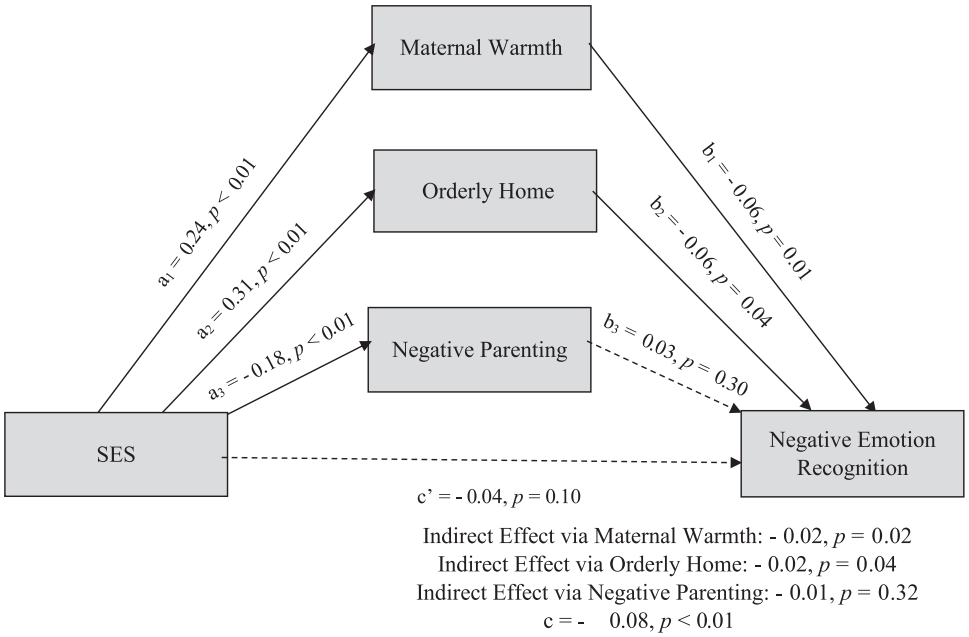

FIGURE 4 | Parallel mediation model for negative emotion recognition. $N = 2232$. SES, socioeconomic status. All results are presented including IQ as a covariate. Standardized coefficients are presented. The three mediators were allowed to correlate, not depicted here. Indirect effects were tested using bias-corrected bootstrap estimation with 10,000 samples. Model fit: $\chi^2 = 29.16$, df = 3, comparative fit index = 0.95, root mean square of approximation = 0.06 [0.04, 0.08], standardize root mean square residual = 0.03. We clustered on family ID to account for the non-independence of twin observations.

b) was significant for maternal warmth (standardized coefficient = −0.02, $p = 0.02$, a small effect size), orderly home (standardized coefficient = −0.02, $p = 0.04$, a small effect size), but not for negative parenting ($p = 0.32$). Overall, the mediators accounted for 47.3% of the variance of the total effect of SES on negative emotion recognition.

Second, for happiness, we tested whether the association between family SES and recognition of happiness was explained by maternal warmth, orderly home, and/or negative parenting using the same analyses described above for the composite. Results are shown in Figure 5. The direct effect of SES on children's recognition sensitivity to happiness (path c) remained statistically significant even after adjusting for maternal warmth, orderly home, and negative parenting. Moreover, the indirect effect (path a*path b) was not significant for any of the mediators, suggesting the association between higher SES and enhanced recognition for happiness is not mediated via maternal warmth, orderly home, or negative parenting.

All findings were replicated when substituting the neighborhood Index of Multiple Deprivation (IMD) deciles for family SES in both the positive and negative emotion recognition mediation models (see Figure S2).

3.4 | Within-Family Analyses

Twin difference models tested whether differences in parenting (levels of maternal warmth, negative parenting, and exposure to polyvictimization) experienced between same-age and same-sex children *growing up in the same family* predicted differences in siblings' sensitivity to recognizing negative facial emotions. This approach holds constant fixed family-level factors, such as family income and orderly home, as well as shared genetic factors.

Children whose mothers expressed more warmth when describing them were more sensitive to the recognition of negative emotions than their sibling about whom the mother expressed less warmth ($r = -0.06$, $p = 0.01$; DZ twins: $r = -0.03$, $p = 0.41$; MZ twins: $r = -0.09$, $p < 0.01$). No significant associations between sibling differences in negative parenting or polyvictimization and emotion recognition sensitivity emerged.

4 | Discussion

Findings from this study add in three ways to what is known about connections between children's emotion recognition and childhood adversity. First, results show an SES gradient in emotion recognition, with children in higher versus lower SES homes exhibiting enhanced recognition of facial emotions. When identifying negative emotions, no differences were found between children from low versus middle SES homes, while children from low SES homes were slower than children in both middle and high SES homes in their recognition of happiness. Second, mediation analyses indicate that child IQ, maternal warmth, and the state of children's homes may explain observed differences in facial emotion recognition between children from higher versus middle to lower SES households. Third, contrary to prior studies drawn from high-risk samples (e.g., maltreated children), we did not observe a robust association between victimization during childhood and emotion recognition. That is, among this large representative sample, there was no evidence that polyvictimization (or maternal depression) was associated with children's ability to recognize facial emotional expressions after accounting for

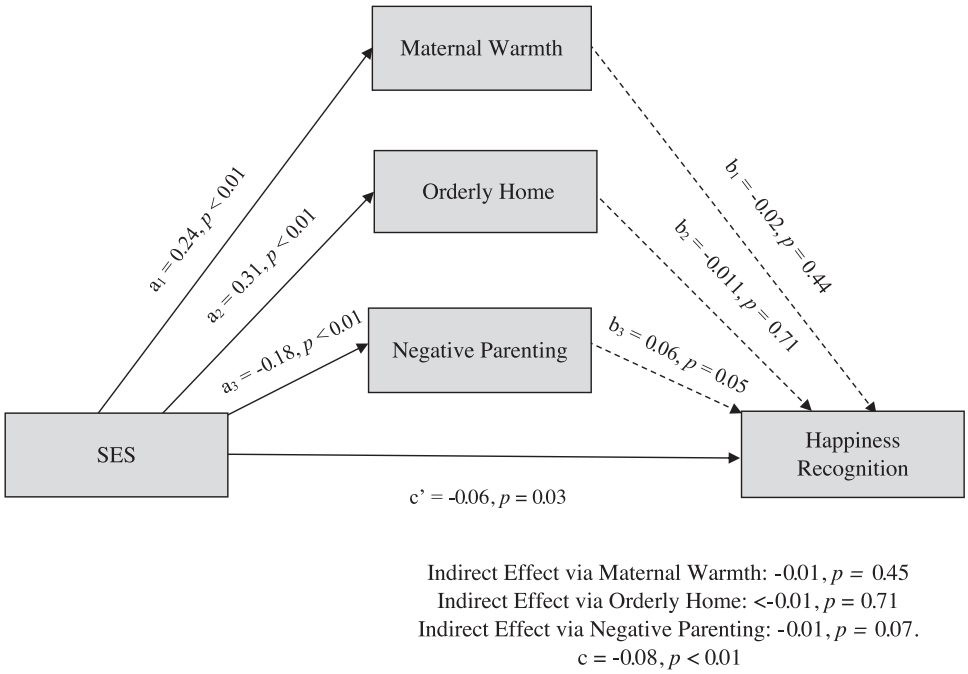

FIGURE 5 | Parallel mediation model for positive emotion recognition. $N = 2232$. SES, socioeconomic status. All results are presented including IQ as a covariate. Standardized coefficients are presented. The mediators were allowed to correlate, not depicted here. Indirect effects were tested using bias-corrected bootstrap estimation with 10,000 samples. Model fit: $\chi^2 = 29.17$, df = 3, comparative fit index = 0.95, root mean square of approximation = 0.06 [0.04, 0.08], standardize root mean square residual = 0.03. We clustered on family ID to account for the non-independence of twin observations.

child IQ and sex, in keeping with previous work with population-representative community samples (Dunn et al. 2018). This was true when we used a broad measure of polyvictimization and when we replicated our analyses using a more severe measure of victimization between birth and 10 years of age only.

We hypothesized, and found, that children growing up in higher versus lower SES households would exhibit enhanced recognition sensitivity to emotional expressions. Importantly, we expected that poverty would be a key contributor to reductions in emotion recognition, such that children from low SES households would have poorer emotion recognition relative to children from middle or high SES households. However, across negative emotion types, children in the low SES tertile demonstrated similar emotion recognition skills to children in the middle SES tertile. As such, our findings suggest that children from higher SES households may have enhanced sensitivity to emotions relative to other children. This study identified potential mediators of the association between SES and children's emotion recognition to better understand how higher SES may canalize differences in processing emotional information. Overall, maternal warmth and orderly homes, but not negative parenting, polyvictimization, or maternal depression, mediated the association between SES and children's emotion recognition, specifically their recognition of negative emotions. When leveraging the sibling difference study design, we also found evidence that maternal warmth was uniquely associated with children's abilities to accurately identify facial emotions, as differences in maternal warmth between children living in the same family (and sharing exposures to the same family SES and exposure to unsafe, disorganized homes) were associated with observed differences on the facial emotion recognition task. Taken together, these findings suggest that maternal warmth and home conditions may uniquely influence young children's development of facial emotion recognition skills. Maternal warmth has previously been linked to both SES (Davis-Kean 2005; Dodge et al. 1994; Liu et al. 2023) and children's emotional functioning (Berona et al. 2023). Similarly, younger children residing in safe, organized homes tend to be more accurate in identifying negative expressions of emotion (Raver et al. 2015). Of note, in addition to maternal warmth and the home atmosphere, IQ was a robust and consistent predictor of children's emotion recognition. This finding is in keeping with previous research (Schlegel et al. 2020) and aligns with the conceptualization of emotion recognition as a sensory-cognitive ability that partly draws on individual differences in intelligence. Results from the present study extend previous findings by suggesting that greater maternal warmth and home atmospheres that are safer and less crowded may account, in part, for the greater emotion recognition displayed by children growing up in higher SES homes.

Some limitations of this study point to possible directions for future research. First, this is an observational longitudinal study and while we find that factors such as SES and IQ at age 5 uniquely predict children's emotional recognition at age 10, we are not able to address causation with this design. Future research that targets potentially modifiable factors included in our analysis are required to address these questions. Second, we assume that findings can be generalized from twins to the population of singletons. Some studies suggest that twins may be more similar than singleton siblings in their facial emotion recognition (Anokhin et al. 2010); however, our results are consistent with previous findings in singletons demonstrating the predictive role of SES on children's emotion recognition (Raver et al. 2015). Third, our

facial emotion recognition task captured multiple emotion types but was limited to a single computer-based task paradigm. Future research using multi-modal (e.g., vocal emotion recognition; Amorim et al. 2021) and more dynamic assessments of emotion recognition (e.g., videos of emotional expressions; Halberstadt et al. 2022) across contexts is required to fully capture children's abilities. Fourth, the predictive utility of children's facial emotion skills should be tested in future work as prior research suggests that, among low-SES children, those who display greater accuracy and sensitivity in their emotion recognition skills also fare better on a wide range of outcomes, including social functioning, academic competence, and behavioral functioning (Corcoran et al. 2018; Nix et al. 2013; Schultz et al. 2001). Finally, the mediation effects observed in this study were small. This is not unexpected, as prior work has shown that the main effects of low SES and other forms of adversity on emotion recognition tend to be modest, a finding we also replicated (Gerin et al. 2024; Koizumi and Takagishi 2014; Pollak et al. 2009; Raver et al. 2015). Mediated effects, particularly those involving multiple mediators and covariates, as in the present study, are expected to be even smaller (Walters 2019). Although small effects can still have meaningful implications (Carey et al. 2023), it is also possible that there are additional, unexamined pathways through which SES may influence emotion recognition. Identifying and investigating these alternative mechanisms represents an important direction for future research.

With these limitations in mind, findings from this study point to ways that children's emotion recognition may be influenced by SES, namely, via the influence that socioeconomic conditions may have on maternal warmth and the state of the home. Intervention efforts to improve children's emotion recognition, such as the emotion-based prevention program (Izard et al. 2004) and Tuning in to Kids program (Havighurst et al. 2025), have yielded promising results. The Tuning in to Kids program, in particular, targets children's emotion recognition by improving parental socialization of emotion. Our findings support the importance of parent and family factors on children's emotion recognition and suggest potential additional intervention targets. Future intervention and experimental studies are required to test whether modifications of these aspects of caregiving and the home environment can lead to improved emotion recognition among children, and in turn, improved social and emotional functioning.

Author Contributions

Helen M. Milojevich: conceptualization, methodology, formal analysis, data curation, writing – original draft, writing – review and editing, visualization. **Kelli L. Dickerson**: methodology, formal analysis, validation, writing – original draft, writing – review and editing. **Louise Arseneault**: methodology, writing – review and editing. **Avshalom Caspi**: conceptualization, methodology, funding acquisition, investigation, project administration, resources, supervision, writing – review and editing. **Julia Kim-Cohen**: conceptualization, data curation, formal analysis, methodology, writing – review and editing. **Andrea Danese**: conceptualization, writing – review and editing. **Terrie E. Moffitt**: conceptualization, methodology, funding acquisition, investigation, project administration, resources, supervision, writing – review and editing. **Candice L. Odgers**: conceptualization, methodology, investigation, project administration, resources, supervision, writing – original draft, writing – review and editing.

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Ethics Statement

The Joint South London and Maudsley and the Institute of Psychiatry Research Ethics Committee approved each phase of the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The dataset reported in the current article is not publicly available due to lack of informed consent and ethical approval for open access but is available upon request by qualified scientists. Requests require a concept paper describing the purpose of data access, ethical approval at the applicant's institution, and provision for secure data access (for further details, see here: https://eriskstudy.com/data-access/).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting File 1: desc70077-sup-0001-SuppMat.docx