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Associations Between Childhood Trauma Characteristics and Theory of Mind in Adults: Results From a Large, Diverse Sample

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Abstract

Theory of mind (ToM) is an essential social cognitive process encompassing abilities to represent and understand others' mental states. Although previous reports linked childhood trauma to social cognitive deficits, how *characteristics* of trauma exposure, such as subtype or timing, affect ToM remains unaddressed. Using data from a diverse adult sample (n = 2200), we tested whether exposure type and first exposure timing of common childhood trauma associated with ToM. Neither interpersonal loss (β = − 0.25, p = 0.170, [− 0.61, 0.10]) nor child maltreatment (β = − 0.21, p = 0.369, [− 0.66, 0.25]) was associated with lower ToM. There was no effect of timing of age at which trauma was experienced (F = 2.19, p = 0.087). While we did not identify age-dependent effects, future studies should examine links between timing or chronicity of prospectively reported childhood trauma and social cognition. Understanding of how childhood experiences shape ToM could reveal mechanisms underlying social cognition development and inform prevention efforts.

Keywords Social cognition · Theory of mind · Trauma · Sensitive periods

Introduction

Social cognition refers to learned cognitive capabilities applied to social situations, including emotion recognition and perception, attribution style, and mental inferencing [1–3]. Social-cognitive deficits are associated with a wide range of adverse physical and mental health outcomes [4–7]. Identifying key determinants of the development of social cognition broadens our understanding of disease etiology across health domains.

Theory of mind is defined as the ability to attribute mental states, such as emotions, desires, and beliefs, to oneself and others. As a higher-order social cognitive process, normative development of the theory of mind requires integrating other cognitive abilities, such as attention, memory, and language [8]. In recent years, there has been increasing interest in studying the causes of impairment in theory of mind, given its critical role in understanding how others think, predicting consequential behavior, and navigating complex day-to-day social interactions appropriately [9, 10]. The process of theory of mind development is complex; however, one of the most prevalent risk factors warranting careful consideration related to the development of theory of mind is traumatic exposure in childhood [11, 12].

Previous work has indicated that childhood trauma might disrupt social perceptions and emotion processing, which could obstruct the development of adaptive social behavior [13–15]. Prior studies on childhood trauma and theory of mind included heterogeneous samples and analyzed a wide range of trauma types. Two important themes have emerged from these findings. First, there is preliminary evidence for

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an association between exposure to childhood trauma and theory of mind deficits in both clinical [4–6, 16–18] and non-clinical adult populations [6, 19]. For example, a population-based study showed small effects of childhood trauma on social cognition, with Cohen's *d* ranging from under 0.1 (neglect) to 0.3 (physical abuse) [20]. Second, previous theoretical and empirical work suggests the plausibility that different types of childhood trauma, such as neglect versus abuse, might influence social cognitive domains, namely theory of mind, through distinct mechanisms. Empirically, the performance on emotion recognition tasks, a social cognitive domain highly correlated with theory of mind [21], was found to be different between physically abused children and neglected children [14]. A theoretical framework for pathways through which different types of childhood trauma operated have been articulated in the child development literature: on the one hand, neglect may limit opportunities for a child to learn to navigate social encounters through observing the behavior and reactions of others, thus reducing cognitive stimulation and social nurturing [22, 23]. On the other hand, child maltreatment, such as physical abuse or sexual abuse, may lead to a hypersensitive response to aversive stimuli, thereby altering neural circuits, similar to findings associated with fear learning [23].

Whereas the existing literature has substantially contributed to our understanding of how childhood trauma may influence the development of theory of mind, three questions remain unaddressed. First, how do various types of trauma, ranging from child maltreatment to family instability, differentially affect theory of mind development? Although previous studies have alluded to specific cognitive deficits due to different types of exposures, few studies have directly compared the effects of exposure type in one sample [24]. Moreover, while prior studies have shown that interpersonal losses, such as losing a parent or experiencing sudden changes in household structure, can have a profound impact on a child's cognitive development [25, 26], research linking experiences of interpersonal loss during childhood to the specific domain of theory of mind is scarce. Second, *when* might exposure to childhood trauma have the most powerful impact on theory of mind? In other words, it remains unknown whether sensitive periods exist for the effects of trauma on theory of mind development. Sensitive periods are specific windows of time during which human brain development is particularly plastic and, therefore, more responsive to life experiences [27, 28]. Several cognitive domains, such as face processing and language acquisition, have time-dependent growth and plasticity [29–31]. Theory of mind development may be more vulnerable to stressors occurring during specific periods in childhood or adolescence. Identifying whether there are sensitive periods and, if so, when they could occur can provide insight into *how* childhood trauma shapes adult social cognition and inform more targeted and effective intervention during specific stages of development.

The third question is: can findings to date from clinical population studies be generalized to non-clinical populations? The majority of studies on the effects of childhood trauma on social cognitive functioning have been conducted in clinical cohorts, such as patients with schizophrenia or post-traumatic stress disorder [4–6, 17]. While studies on clinical cohorts are valuable, the findings in clinical populations may not necessarily generalize to population-based samples due to differences in severity of exposures, altered neurocircuitry, and comorbid conditions between patients and general populations [32, 33]. To address these questions, we designed an innovative approach by combining a large non-clinical sample, commonly used in epidemiologic research, with standard methodologies of social cognition studies, allowing us to unite the strengths of both fields. Specifically, we used a well-validated web recruitment site, www.TestMyBrain.org, that collects large datasets for behavioral experiments. Using this approach, we expanded on findings reported by Germine et al. [20]: whereas Germine et al. used a principal component analysis to investigate the effects of childhood trauma composites on multiple social cognitive domains, the current study separated the exposures into two overarching domains; child maltreatment and interpersonal loss. By focusing on timing- and domain-specific effects (rather than constructing a composite score combining effects across time points and domains, as Germine and colleagues did), we aimed to generate findings that could inform targeted prevention and treatment strategies by identifying people who are at higher risk of social cognitive deficits because they were exposed to either a specific form of adversity or within a specific period of time.

The primary aims of the current study were to: (1) determine which types of childhood trauma, if any, were associated with theory of mind deficits in adulthood; and (2) identify whether trauma exposures that occurred at different developmental stages were differentially associated with theory of mind. Consistent with the existing literature, we hypothesized that child maltreatment (such as verbal or physical abuse) would be more strongly associated with impaired theory of mind compared to other forms of adversity [7]. We also hypothesized that evidence for time-dependent effects of trauma exposure on theory of mind development would emerge in our analyses. However, given the dearth of literature, we did not have specific hypotheses regarding which time periods would be more salient.

Method

Web Administration and Sampling

TestMyBrain (TMB) is a citizen science website that uses crowdsourcing methodologies to collect large sample datasets for cognitive experiments [34]. People of all ages from any country worldwide participate in experiments by taking cognitive assessments adapted for the web. In exchange, participants receive feedback on their performance. No explicit advertising or recruitment is conducted. Over 2.5 million people from over 240 countries have participated in studies on TestMyBrain.org since its inception in 2008. Previous studies support that the reliability of data collected through the TestMyBrain website is comparable to data acquired using traditional methods [34]. Research on various domains of cognition using data from the TestMyBrain website has produced convergent results with studies in other population-based samples [35–37].

The current study is based on an analytic sample of 2200 adult participants who visited TestMyBrain between December 21, 2012, and December 2, 2013, and completed a test battery titled "The Social Mind and Life Experiences." This battery was described to the user as follows: "In this test, we look at your life experiences and aspects of your social brain." Each participant completed one or two social cognitive functioning measures and social affiliation, followed by the TestMyBrain Childhood Experiences Questionnaire. The Social Mind and Life Experiences battery included an objective instrument to assess theory of mind and other domains of social cognition, including face discrimination, facial memory, and self-reported social motivation, and perceived social support.

Participants provided informed consent before taking part in the study by ticking a box indicating that they agreed to participate. All consenting participants were subsequently prompted to answer questions about their age, gender, race and ethnicity, education, and native language. Participants were then given instructions about the experiment and prompted to proceed to the Reading the Mind in the Eyes test (RMET), beginning with one practice image (**Fig. 1**). The RMET is a well-validated, sensitive measure for mental inferencing and has demonstrated internal consistency and reliability across sexes [38, 39]. Upon completion of the practice answer, users were shown the correct answer and were told the practice was complete. Following the RMET, participants who reported they were 18 years of age or older were asked to participate in a TestMyBrain Childhood Experiences Questionnaire. Those not yet 18 years old were invited to participate in a different questionnaire with less sensitive questions about their everyday experiences. TestMyBrain collected no personally identifying information at any point. Thus, participation was entirely anonymous. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study and consent procedure received approval from the Harvard University Committee on the Use of Human Subjects in Research (CUHS).

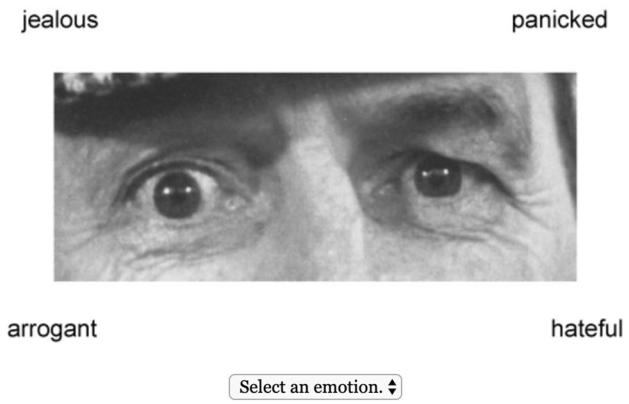

Fig. 1 An illustration of a trial of the RMET measure. Participants were asked to choose from a drop-down menu containing the four possible surrounding adjectives, which best describes the mental state reflected in the eye region's grayscale image. In this example, the correct answer is panicked. The user was subsequently shown a pop-up which states that the correct answer was 'panicked' and that no additional feedback will be given from this point forward in the test

Exclusions

We restricted our analyses to native English speakers and removed non-native English speakers (n = 1347; 35.3%) and missing responses for native language (n = 253; 7%). We decided to impose the language restriction for the following reasons: first, language ability and acquisition are fundamental to the development of theory of mind, and different processes of language acquisition during development may thus result in heterogeneity of theory of mind assessed using native versus non-native languages [40–44]. Additionally, the instrument used to measure theory of mind, RMET, heavily relies on vocabulary [45] and can be biased by cultural and language barriers [46].

Compared to people who were excluded due to missingness and other exclusion criteria, the analytic sample was more likely to include female, older, and White individuals, who perceived themselves as more socioeconomically disadvantaged and were born to parents whose education was limited to a high school degree (Supplemental Table S1). Individuals in the analytic sample were also more likely to have experienced verbal abuse, but less likely to have been exposed to parental divorce or parental

incarceration (Supplemental Table S1). As sample missingness was patterned by sociodemographic factors, bias may arise from a complete case analysis [47].

In the analyses of exposure timing and RMET scores, of the 1889 participants who reported exposure to trauma (Table 1), 338 participants did not report their age at exposure to child maltreatment; 94 participants omitted their ages at exposure to interpersonal loss. Thus, we further excluded them from the timing-focused analyses, which yielded a secondary analytic sample of 1457 participants.

Table 1 Distribution of demographic characteristics in the total TestMyBrain (TMB) analytic sample (n = 2200) and demographic characteristics by exposure childhood trauma

	Total sample	Exposed to any trauma		Exposed to any childhood maltreatment		Exposed to any interpersonal loss	
	N (%[A])	N (%[B])	*p* value[C]	N (%[B])	p value[C]	N (%[B])	*p* value[C]
Gender			0.75		0.575		0.469
Female	1458 (66.3)	1253 (66.3)		1186 (66.5)		629 (65.5)	
Male	742 (33.7)	636 (33.7)		597 (33.5)		332 (34.5)	
Age			**0.039**		0.018		**< 0.001**
18–25	919 (41.8)	773 (40.9)		725 (40.7)		424 (44.1)	
26–35	539 (24.5)	465 (24.6)		435 (24.4)		254 (26.4)	
36–45	293 (13.3)	267 (14.1)		256 (14.4)		134 (13.9)	
46–55	253 (11.5)	214 (11.3)		204 (11.4)		99 (10.3)	
56 +	196 (8.9)	170 (9.0)		163 (9.1)		50 (5.2)	
Race/ethnicity			**< 0.001**		**< 0.001**		**< 0.001**
Hispanic	104 (5.2)	97 (5.6)		92 (5.7)		60 (6.7)	
White	1637 (81.2)	1377 (79.6)		1293 (79.5)		696 (77.9)	
Black	88 (4.4)	81 (4.7)		73 (4.5)		51 (5.7)	
Other	187 (9.3)	174 (10.1)		169 (10.4)		86 (9.6)	
NA	184 (8.4)	160 (8.5)		156 (8.7)		68 (7.1)	
Education			**0.008**		0.053		**< 0.001**
Less than high school	14 (0.7)	12 (0.7)		12 (0.7)		5 (0.6)	
High school	309 (14.7)	280 (15.5)		264 (15.5)		194 (21.3)	
Some college	813 (38.6)	711 (39.3)		668 (39.2)		383 (42.1)	
College degree	523 (24.8)	436 (24.1)		409 (24.0)		183 (20.1)	
Masters or higher	448 (21.3)	370 (20.5)		353 (20.7)		144 (15.8)	
NA	93 (4.2)	80 (4.2)		77 (4.3)		52 (5.4)	
Parental education			**< 0.001**		**< 0.001**		**< 0.001**
Less than high school	126 (6.1)	117 (6.6)		116 (6.9)		65 (7.3)	
High school	787 (37.9)	709 (39.8)		668 (39.7)		398 (44.5)	
Some college	581 (27.9)	495 (27.8)		469 (27.9)		252 (28.2)	
College degree	323 (15.5)	257 (14.4)		243 (14.4)		96 (10.7)	
Masters or higher	262 (12.6)	204 (11.4)		188 (11.2)		83 (9.3)	
NA	121 (5.5)	107 (5.7)		99 (5.6)		67 (7)	
Perceived socioeconomic status			**< 0.001**		**< 0.001**		**< 0.001**
Much lower	185 (8.6)	181 (9.8)		172 (9.8)		142 (15.1)	
Lower	478 (22.2)	444 (24.0)		429 (24.5)		270 (28.6)	
Same	825 (38.3)	697 (37.6)		644 (36.8)		326 (34.6)	
Higher	531 (24.6)	420 (22.7)		394 (22.5)		160 (17.0)	
Much higher	136 (6.3)	111 (6.0)		109 (6.2)		45 (4.8)	
NA	45 (2.0)	36 (1.9)		35 (2)		18 (1.9)	

Cell contents include total analytic sample frequency as well as frequency and percent by demographic group and exposure status. Percentages represent those out of the total analytic sample (n = 2200) regardless of exposure status. A: Percentages represent the proportion of participants in the analytic sample regardless of trauma exposure; B: Percentages represent the proportion of participants among who were exposed by trauma exposure; C: Chi-squared tests were performed to examine whether the distribution of demographic covariates was significantly different by reports of trauma exposure

Measures

Theory of Mind

Theory of mind was measured with the Reading the Mind in the Eyes test (RMET), which is the measure currently recommended by the National Institute of Mental Health (NIMH) to assess mental and emotional perspectives [48]. The RMET is one of the most popular adult measures for theory of mind ability. It has been validated across adult populations of different races and has been shown to capture a wide range of social cognitive impairments reliably [49]. Low scores have been associated with various psychiatric conditions, such as antisocial personality disorder, bipolar disorder, and autism spectrum disorder [50–52]. In this test, participants were shown 36 Gy-scale images of the eye regions of human faces and were asked to select which of four complex-emotion words best described each pair of eyes' mental state. The four adjectives were presented, one at each corner of the image of the eyes (Fig. 1). These images included the eyes of both genders [39]. The highest total possible score was 36, representing the sum of correct emotion identifications. Scores below 22 are considered to indicate some degree of impairment, whereas scores between 26 and 30 are considered within the normal range, and scores above 30 are considered to be above average [49].

Childhood Trauma

The TestMyBrain Childhood Experiences Questionnaire assessed retrospective self-report experiences of childhood trauma birth to 17 years of age. This 25-item questionnaire was adapted from three established measures of childhood adversity and trauma exposure commonly used in epidemiological studies: (1) the Adverse Childhood Experiences Scale [53]; (2) Conflict Tactics Scale [54]; and (3) Composite International Diagnostic Interview [55]. The questionnaire has been used in prior research to study the effects of childhood adversity on social cognition and social affiliation [20]. An abridged version appears in the Supplemental Materials. Participants who reported being exposed to childhood trauma only at age 18 were dropped from the analysis, as we wanted to restrict the analysis to those that experienced trauma before adulthood.

The current study focused on two types of childhood trauma—childhood maltreatment and interpersonal loss—as described in detail below. These two domains were chosen because they mirror sub-classifications of trauma exposure used by the World Health Organization (WHO) World Mental Health Survey and in previous studies on trauma and stress-related disorders [56–58]. Participants were initially asked if each traumatic event occurred. For each traumatic event endorsed, participants reported their age (in years) of their first exposure. Using this data, we created three categories for age at first exposure, which were aligned with previous research [27, 59, 60]: early childhood (age 0–5 years), middle childhood (ages 6–10 years), and adolescence (ages 11–17). A main objective of this study was to test the existence of a sensitive period of childhood trauma on adult theory of mind ability. Therefore, categories were constructed to align with prior literature and capture a developmental window during which social cognitive development may be more easily modifiable in response to traumatic exposure. In comparison to including age of exposure as a continuous variable, the categorization of exposure age allowed us to test sensitive period hypothesis that there were nonlinear associations with theory of mind. Exposure to child maltreatment was determined by at least one affirmative response ("yes") to any of five items: (1) domestic violence; (2) physical abuse; (3) fear of abuse; (4) verbal abuse; and (5) sexual abuse. Exposure to interpersonal loss was determined by at least one affirmative response to any of the three items, which ascertained participants' experiences with: (1) parental death; (2) parental divorce; (3) parental imprisonment or incarceration of a parent or caregiver (see Supplemental Materials for specific items and details about the coding of childhood trauma items).

Covariates

We included the following covariates in all multiple regression models: gender (male/female); participant age at time of testing (in years); race and ethnicity (Hispanic, White, Black, other); highest attained education (less than high school, high school, some college, college completion, master's, doctorate); highest attained parental education (same categories as highest attained education); and self-perceived childhood socioeconomic status compared to the average household for other families in the same part of the country (much lower, lower, same, higher, much higher). These covariates were selected since they capture constructs that have been routinely included in prior studies, because each has been linked to some degree to childhood trauma exposure, social cognition, or both [17, 41, 61, 62, 67].

Previous studies have shown that gender, race/ethnicity, and measures of socioeconomic status such as education and parental education may be linked to different patterns of trauma exposure [41, 61, 62]. For example, prior reports have found that child maltreatment disproportionally affects the black and Hispanic populations [63, 64]. Moreover, these factors may also have an impact on the development of theory of mind [41, 61, 62]. Racial/ethnic differences were also identified in the literature, largely due to biases of the existing measurements that were developed primarily for White populations [65]. Because these covariates could potentially be causes of differences in trauma exposure and theory of

mind, they would open a back-door path between the exposure and the outcome in our analyses, and lead to a spurious association [66]. To minimize these potential sources of confounding, we adjusted for all the listed covariates above in all analyses.

Missing Data

To reduce potential bias and minimize loss of power due to item non-response variables, we conducted all analyses using a multiply imputed dataset among all native English speakers for the covariates included in the models using the MICE package in R [68]. All exposure, covariate, and outcome information were included in the imputation models. Combined estimates from 20 imputed datasets were reported for all subsequent analyses. Results of a complete case analysis are also presented, for comparison.

Statistical Analysis

We first conducted univariate and bivariate analyses to examine the distribution of covariates and trauma exposure in the total analytic sample. For the primary analyses, we fit a set of multiple linear regression models to determine whether exposure to each trauma type (child maltreatment versus interpersonal loss) and the timing of first exposure were associated with theory of mind. With Model 1, we tested for the presence versus absence of exposure to any trauma, childhood maltreatment, or interpersonal loss in the primary analytic sample to identify any potential association with RMET scores. Model 2 examined the potential time-dependent effects of trauma by assessing the impact of age at first exposure to each trauma type (coded as 1 = early childhood (ages 0–5), 2 = middle childhood (ages 6–10), 3 = adolescence (ages 11–17), versus 0 = never exposed to any trauma, as the referent group) in the secondary analytic sample (n = 1457). The age variable examined in Model 2, age at first exposure, differs from the age covariate which is the participant age at the time of responding to the survey.

In secondary analyses, we repeated the analyses described above but focused on distinctions between the five items of childhood maltreatment and the three interpersonal loss exposures. To see if the effect of traumatic exposure on theory of mind differed by gender, we also tested interactions between gender and traumatic exposure for each trauma type. All analyses were performed in *R*.

Results

Sample Characteristics and Distribution of Exposure to Trauma and RMET Scores

Our analytic sample was predominantly comprised of women (66.3%, n = 1458) and White (81.2%) young adults between the ages of 18 and 25 years old (41.8%) (Table 1). The mean RMET score in the analytical sample was 28.3 (SD = 3.99), within the normal range. The RMET scores were patterned by gender, race and ethnicity, education, and parental education. Specifically, RMET scores were higher in females, Whites, and people with higher levels of education.

Most participants (85.8%) reported experiencing some type of childhood trauma, with most of those in the total analytic sample reporting child maltreatment (80.0%) and roughly half (58.4%) of those reporting experiences of interpersonal loss. The prevalence of exposure to any trauma and interpersonal loss was higher in younger adult participants (ages 18–25) than older participants (ages 26–60), White, and better-educated participants. In addition, exposure to child maltreatment was more prevalent among White participants with parents whose education was limited to a high school degree (Table 1).

As shown in Table 2, the most frequently reported trauma subtypes were verbal abuse (48.7%), physical abuse (45.4%), and fear of abuse (40.9%); parental death was the least reported (9.3%). The age of initial exposure varied by trauma type. For instance, the first occurrence of parental death was more commonly reported in adolescence (ages 11–17), while first occurrences of physical and verbal abuse were more widely reported throughout early and middle childhood (ages 0–5, and ages 6–10 respectively) (Table 2).

Overall, there was considerable variability in the degree of correlation between individual trauma subtypes (r = 0.01–0.79). Specifically, some maltreatment subtypes were highly and positively correlated (e.g., verbal abuse and sexual abuse, r = 0.70), while other types, such as violence between caregivers, had little correlation with other subtypes of maltreatment (r = 0.01–0.22). The correlations among the subtypes of interpersonal loss were weak to moderate (r = 0.30–0.58). Between maltreatment and interpersonal loss subtypes, correlations ranged from r = 0.09 to 0.79, with parental death and verbal abuse being the most strongly correlated (Supplemental Table S2).

Association between Adversity and RMET Scores

As shown in Table 3, results from Model 1 suggested no association between exposure to any trauma ($\beta = -0.34$,

Table 2 Distribution of reported exposure to specific trauma types in the secondary analytic sample (n = 1457) and by age at first exposure

Trauma exposure	Age at first exposure (category)									
	Exposed		Age at first exposure (year)		Ages 0–5		Ages 6–10		Ages 11–17	
	N	% [A]	Mean	SD	N	%[B]	N	%[B]	N	%[B]
Child Maltreatment	1165	80.0	6.21	3.83	610	52.4	380	32.6	175	15.0
Violence between caregivers	382	26.2	6.07	3.93	189	49.4	149	38.9	44	11.5
Physical Abuse	662	45.4	7.05	4.08	299	45.0	223	33.6	140	21.1
Fear of Abuse	596	40.9	6.56	3.79	303	50.8	199	33.4	94	15.8
Sexual Abuse	367	25.2	8.31	4.00	108	29.2	150	40.5	109	29.5
Verbal Abuse	709	48.7	7.53	3.86	257	36.3	282	39.8	170	24.0
Interpersonal Loss	851	58.4	7.59	5.02	344	40.4	226	26.6	281	33.0
Parental Death	136	9.3	10.46	4.68	24	15.3	39	24.8	73	46.5
Parental Divorce	724	49.7	7.54	5.19	305	40.2	172	22.7	247	32.5
Parental Incarceration	162	11.1	8.70	4.65	43	25.4	62	36.7	57	33.7

Cell contents include exposure frequency and percent by adverse experience and initial exposure age. A: Percentages represent the portion out of the secondary analytic sample, those that reported an age at exposure (n = 1457). B: Percentages represent the portion out of those exposed to that type of trauma with a reported age at exposure

Table 3 Results of linear regression models examining associations between characteristics of exposure to trauma and RMET scores

	Any Trauma				Maltreatment				Interpersonal loss			
	Beta	LL	UL	p-value	Beta	LL	UL	p-value	Beta	LL	UL	p-value
Model 1: presence of exposure												
Exposure to any trauma	− 0.34	− 0.84	0.17	0.189	− 0.21	− 0.66	0.25	0.369	− 0.25	− 0.61	0.10	0.170
Model 2: age at first exposure												
Ages 0–5	− 0.29	− 0.86	0.28	0.308	− 0.13	− 0.68	0.42	0.635	− 0.38	− 0.89	0.14	0.529
Ages 6–10	**− 0.65**	**− 1.28**	**− 0.01**	**0.045**	− 0.43	− 1.03	0.17	0.164	− 0.39	− 0.98	0.21	0.524
Ages 11–17	− 0.70	− 1.41	0.01	0.053	− 0.49	− 1.24	0.25	0.196	− 0.53	− 1.06	0.01	0.105

Model 1 is the association between trauma type (exposed versus unexposed) and Reading the Mind in the Eyes test (RMET) score in the primary analytic sample (n = 2200). Model 2 is the association between the trauma type by age group of first exposure and RMET score in the secondary analytic sample (n = 1457). In this model, the referent group was those never exposed to any trauma. Maltreatment trauma types include: domestic violence, physical abuse, fear of abuse, sexual abuse, and verbal abuse. Interpersonal loss types include: parental death, parental divorce, and parental incarceration. Cell entries are the betas, confidence intervals, and p-values examining the effect of each traumatic event. LL refers to lower confidence level. UL refers to upper confidence level. Significant values are p-values < 0.05.

p = 0.189, 95% CI [− 0.84, 0.17]), child maltreatment (β = − 0.21, p = 0.369, 95% CI [− 0.66, 0.25]), or interpersonal loss (β = − 0.25, p = 0.170, 95% CI [− 0.61, 0.10]) and theory of mind after adjusting for covariates.

For Model 2, we found no evidence for an overall effect of age at the first exposure, as indicated by an omnibus F-test comparing the fit of the models with versus without the exposure age variable (F = 2.19, p = 0.087). Similarly, for maltreatment (F = 0.95, p = 0.418) and interpersonal loss (F = 1.15, p = 0.328), age at the first exposure did not seem to have an overall effect. None of the individual age groups had significant findings in relation to the Reading the Mind in the Eyes score.

The secondary analysis exploring the interaction between gender and trauma exposure on RMET scores revealed that among female participants, exposure to any trauma was linked to lower RMET scores ($\beta_{trauma} = -0.76$, p-value = 0.016, 95% CI [− 1.37, − 0.14]). However, male participants exposed to any childhood trauma on average had higher RMET scores compared to unexposed male participants ($\beta_{trauma\ x\ male} = 1.22$, p-value = 0.017, 95% CI [0.22, 2.26]). In Model 2, the interaction between gender and timing of trauma exposure also suggested that for male participants, exposure to childhood trauma during ages 0–5 was associated with higher RMET scores ($\beta_{trauma\ 0–5\ yrs\ x\ male} = 1.46$, p-value = 0.009, 95% CI [0.37,

2.55]). Specifically, among male participants, experiences of interpersonal loss between the ages of 0–5 were associated with better RMET performance ($\beta_{\text{loss 0–5 yrs x male}} = 1.25$, p-value = 0.011, 95% CI [0.28, 2.22]). No other age groups had significant findings in relation to the Reading the Mind in the Eyes score. Results are presented in Table S4 and Figure S2.

No effect of developmental timing was identified in the follow-up analyses either (Supplemental Materials Table S5).

Discussion

Using data from a diverse population-based sample, we examined how features of exposure to childhood trauma may be associated with theory of mind in adulthood. The main finding from this study is that exposure to childhood trauma is not simply associated with adult theory of mind. Additionally, there was no evidence of a sensitive period effect for trauma on theory of mind. Our results are congruent with those of another large, population-based prospective study, which showed a lack of association between developmental timing effects on emotion recognition, another social cognition domain [69].

Interestingly, the lack of association between child maltreatment and theory of mind in our study does not align with findings from several other studies demonstrating that exposure to child maltreatment, specifically physical and sexual abuse, had a robust association with theory of mind ability [5, 13, 17, 21]. The divergence could potentially be explained by differences in study samples: most previous studies focused on associations among patients with clinical diagnoses of psychiatric disorders (such as bipolar disorder, schizophrenia, and post-traumatic stress disorder), who might have been exposed to more extreme forms of maltreatment.

Another source of discrepancy is the differences between measures used between studies: as noted in a previous report, the measure of theory of mind in our study, RMET, focuses on measuring emotion perception [70], whereas other measures of theory of mind, such as the short story or false belief test focus on measuring one's mental inferencing ability. In other words, the RMET captures the comprehension dimension of theory of mind, but not prediction. Conversely, short story and false belief tests primarily measure one's ability to predict another's future behavior or reaction. Nonetheless, the RMET is a widespread social cognitive metric and has been validated for remote administration. We were not able to assess the severity of child maltreatment in our study, and thus the effects of maltreatment might have been heterogeneous, especially given the wide range of resilience represented in a large non-clinical sample.

A perhaps counterintuitive finding emerged in the secondary analysis: trauma exposure was associated with higher theory of mind among male participants. We offer three possible explanations. First, there could be residual confounding by unmeasured sociodemographic characteristics. For example, if the male participants in our sample who were exposed to childhood had higher levels of social support than the unexposed male participants, then we would expect a positive association between trauma and theory of mind, because of confounding by social support.

Second, childhood trauma may differentially impact the cognitive development of men and women. Similar findings were identified in a prior study: in a US cohort of adolescents, among male participants, traumatic stress exposure was associated with better emotion identification abilities, but the trauma exposed female participants had lower emotion identification abilities [71]. The differences in social cognition development following traumatic experiences may reflect different patterns of response to stress and psychopathology among male versus female individuals or differences in the severity of abuse experienced by participants of different sexes. Specifically, trauma exposure in early life may lead to higher levels of internalizing symptoms in women and higher externalizing symptoms in men [72]. Differences in psychopathology can in return cause alterations in emotional processing: externalizing symptoms may not be linked to decreased accuracy in emotion-labeling, whereas internalizing symptoms could impair children's abilities to recognize happiness and anger [73]. However, given that results on gender-based differences in the effect of trauma on social cognition remain inconsistent, this finding needs to be further explored in large, prospective cohorts to further tease apart the mechanisms at play.

Third, childhood adversity exposure may also have some promotive health effects. Related work from our group and others has empirically shown that some individuals develop positive stress-adapted skills in response to traumatic exposure [74, 75]. That is, stressful conditions may evoke an ability that is advantageous to survival, which in turn promotes success. In this way, childhood adversity may operate at times as a kind of plasticity factor [76]. Our result of young males exposed to interpersonal loss was linked to higher RMET scores aligns with the idea that early-life stress increases the risk for atypical neural circuit development. However, atypical development does not necessarily imply deficiency [77]. For example, child neglect due to interpersonal loss may have increased anxiety and bias toward recognizing negative facial expressions (e.g., fear or anger), thus heightening vigilance that could promote beneficial stress-adapted skills to survive in adverse environments.

Our study has several strengths worth noting. First, by administering measures remotely via an innovative citizen-science based approach, we provided total anonymity to

respondents, thereby maximizing the likelihood of honest retrospective reporting. Second, the survey design also lessened potential participant bias as the title and description of the test battery did not reveal the assessment content. In other words, the test battery participants selected did not indicate that they would be asked explicitly about childhood trauma, thus minimizing self-selection bias. Third, the current study complements existing research on trauma and social cognition in clinical samples by examining specific links between characteristics of trauma during childhood and theory of mind development using a large population-based sample of native English speakers. Compared to previous clinical studies, findings from the current study may be more generalizable across populations.

We also recognize that our study has several limitations. First, although retrospective self-reporting is a standard method used in large population-based samples, it is subject to memory bias or recall error. As shown in recent research, there can be poor agreement between retrospective and prospective childhood trauma reports [78]. As prospective and retrospective reporting may identify different groups of individuals, findings from future prospective studies are needed to elucidate whether we might observe different patterns of associations with theory of mind development across the two groups. Second, there was substantial missingness in the initial age of maltreatment occurrence, which limited our analysis of time-dependent trauma effects, especially for exposures that were likely more chronic in their occurrence. Specifically, participants were least likely to report age of onset for reoccurring exposures such as child maltreatment, particularly physical abuse (56%), in contrast to single-event trauma, such as parental death, parental divorce, and parental incarceration, which had rates of completion as high as 90%. Similar missing data patterns for age at exposure were observed in another study with repeated, prolonged, and developmentally adverse traumatic experiences throughout childhood, such as verbal abuse, physical abuse, and fear of abuse [79]. Additionally, it is important to note that childhood neglect was excluded from this study as the number of participant response to the neglect-related items was substantially above (32%) the recommended threshold of missingness for imputation (20%). While the multiple imputation approach to addressing missing data used in our study reduces potential bias and loss of efficacy, it is important to note that the approach assumes that the data were missing at random, the missing random variables followed certain parametric distributions conditionally, and the imputation models were correctly specified. These assumptions are not empirically verifiable and therefore the results should be interpreted with the assumptions in mind. It is possible participants were able to recall the childhood experience of maltreatment, but were uncertain about their age at initial occurrence because of the repeated chronic exposure to one or multiple types of trauma. Repeated exposure to trauma would likely have a more significant impact on theory of mind and be linked to a lower ability than single instances [80]. Future research should investigate the specific effect of repeated child maltreatment compared to repeated cases of interpersonal loss. Lastly, a web-based approach may induce selection bias and impact the magnitude of estimated associations between childhood trauma and theory of mind. People who have struggled with deficits in cognitive abilities may choose to participate in seeking validation for their personal experiences.

In summary, to ascertain the developmentally sensitive effects of exposure more accurately to childhood trauma on social cognition, future population-based studies with repeated prospective reporting of childhood trauma are needed, where more characteristics of the exposure events are documented, such as ages at exposure and total number of exposed occasions.

Summary

Previous studies have shown that exposure to childhood trauma negatively impacts social cognitive functioning in adulthood. A core social cognitive ability is theory of mind, which supports a person's ability to interpret and understand others' thoughts, feelings, and emotions as well as contribute to cultivating personal relationships and successfully navigating through social interactions and society. To understand how exposure to specific characteristics of childhood trauma affects theory of mind development, we examined a multidimensional model comprised of trauma subtype and age at first trauma exposure in a large, diverse adult sample. Multiple linear regression models revealed that childhood exposure to interpersonal loss, but not child maltreatment, was moderately associated with lower theory of mind. This suggests a bias from less frequent and/or varied social cognitive stimulation and modeling, which may impede theory of mind development and result in lower theory of mind in adulthood. We did not identify any age-dependent effect of first exposure on theory of mind; however, future studies should include additional factors, such as frequency of traumatic incidents and relationship to the offending individual, to further disentangle the impact of trauma features. Null findings in large population-based samples make important contributions to the field by differentiating between evidence from clinical groups and findings in population-based samples, the latter of which may have broader public health implications. Hence, this study highlights the importance of generating and interpreting results across study samples to understand whether findings and subsequent interventional efforts from clinical samples are generalizable to a

larger population. Investigating characteristics of exposure to trauma during childhood with social cognitive domains, such as theory of mind, is key to understanding risk factors for theory of mind deficits and guiding future prevention or intervention efforts.

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Data Availability The data and code that support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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