

Reward Processing Modulates the Association Between Trauma Exposure and Externalizing Psychopathology



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Abstract

Childhood adversity is common and strongly associated with risk for psychopathology. Identifying factors that buffer children from experiencing psychopathology following adversity is critical for developing more effective intervention approaches. In the present study, we examined several behavioral metrics of reward processing reflecting global approach motivation for reward and the degree to which reward responses scaled with reward value (i.e., behavioral sensitivity to reward value) as potential moderators of the association of multiple dimensions of adversity—including trauma, caregiver neglect, and food insecurity—with depression and externalizing psychopathology in a sample of youths ages 8 to 16 ($n = 132$). Trauma exposure and externalizing problems were positively associated at low and moderate levels of reward reactivity, but this association became nonsignificant at high levels of reward reactivity. Our findings extend prior work by demonstrating that high behavioral sensitivity to reward value may buffer against externalizing problems following exposure to trauma.

Keywords

child adversity, depression, developmental psychopathology, externalizing, reward processing, open data, open materials

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Childhood adversity—including physical and sexual abuse, witnessing domestic violence, and neglect—is common: One third to one half of children experience one or more forms of adversity before they reach adulthood (Finkelhor, Ormrod, & Turner, 2009; Finkelhor, Turner, Ormrod, & Hamby, 2009; McLaughlin et al., 2012). Childhood adversity is strongly related to the onset of internalizing and externalizing psychopathology (Clark, Caldwell, Power, & Stansfeld, 2010; Cohen, Brown, & Smaile, 2001; McLaughlin et al., 2012). Identifying protective factors that reduce the likelihood of psychopathology after exposure to adversity and underlying mechanisms may inform the development of novel prevention and early-intervention approaches. Reward processing—characterized as a complex set of behavioral, psychological, and neural responses that help enable an organism to alter behavior to achieve a reward (Olino, 2016)—may contribute to individual differences in vulnerability to psychopathology after

childhood adversity. Specifically, in one prior study (Dennison et al., 2016), elevated sensitivity to reward was shown to buffer against the development of adolescent depression after experiences of trauma in childhood although it is unclear whether this extends to other forms of adversity (e.g., deprivation) and other types of psychopathology known to be associated with disruptions in reward processing (e.g., externalizing problems). Alternatively, other work has suggested that disruptions in reward processing may be a mechanism linking some forms of adversity, particularly deprivation, with depression and social problems (Sheridan et al., 2018; Wismer Fries & Pollack, 2017). In the present study, we examined whether reward processing

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served as a moderator or mediator of the association of multiple types of childhood adversity with symptoms of depression and externalizing psychopathology.

Adversity and Reward Processing

Reward processing has been organized into several distinct constructs, including reward responsiveness, reward valuation, and reward learning (National Advisory Mental Health Council Workgroup on Changes to the Research Domain Criteria Matrix, 2018). Reward responsiveness refers to feelings of liking or enjoying rewards. Reward valuation is a measure of an organism's ability to assess the value of reward and increase effort to achieve the maximum reward; this construct is often referred to in the clinical literature as *approach motivation* (Dennison et al., 2019; Olino, 2016). Lastly, reward learning involves acquiring information about the environment that can help predict reward. We focused on several behavioral indicators of reward valuation or approach motivation to assess variation in reward-driven behavior as a mechanism linking experiences of a childhood adversity with symptoms of psychopathology.

Childhood adversity has been associated with alterations in reward processing at both behavioral and neural levels, but these associations vary depending on the type of adversity and reward-processing constructs measured. For example, children who experience deprivation—characterized by institutionalization, material deprivation, and neglect—consistently exhibit blunted approach motivation and reduced behavioral sensitivity to increasing reward value in behavioral tasks compared with control participants (Sheridan et al., 2018; Wismer Fries & Pollak, 2017) as well as reduced responsiveness to reward in the frontostriatal valuation network (i.e., ventral striatum, putamen, and pallidum; Boecker et al., 2014; Goff et al., 2013; Hanson, Hariri, & Williamson, 2015). These findings suggest that social and cognitive deprivation may alter the development of both approach motivation and reward responsiveness.

In contrast, findings from studies that examined reward processing after experiences of trauma in childhood (including sexual and physical abuse) are more mixed. For example, children who have experienced abuse have exhibited poor reward learning (Hanson et al., 2017) and blunted reward responsiveness in adulthood in the left putamen and left pallidum (Dillon et al., 2009) compared with control participants. Furthermore, children who have experienced trauma and neglect have exhibited blunted behavioral sensitivity to reward value compared with children without such histories (Guyer et al., 2006). Although these findings are consistent with patterns among children exposed to deprivation, other studies measuring reward processing in trauma-exposed youths have found no difference in

behavioral sensitivity to reward value (Dennison et al., 2016, 2019) or exaggerated rather than blunted ventral-striatum activation to rewarding stimuli (Dennison et al., 2016).

Although existing studies have demonstrated associations of specific types of childhood adversity with reward processing, they have not accounted for the high co-occurrence of multiple types of adversities (Green et al., 2010; McLaughlin et al., 2012). Thus, it remains unclear whether exposure to different types of adversity similarly influence reward processing or whether there is specificity among associations of particular adversity types with reward processing. Authors of recent conceptual models have argued that distinct forms of adversity may be associated with unique neurodevelopmental consequences (McLaughlin & Sheridan, 2016; McLaughlin, Sheridan, & Lambert, 2014; Sheridan & McLaughlin, 2014). Specifically, authors have proposed in these models that experiences involving threat (e.g., abuse and violence exposure) and deprivation have differential influences on aspects of emotional and cognitive development. Indeed, differential associations of threat and deprivation have been observed in relation to aversive learning (McLaughlin & Sheridan, 2016), threat-related information processing (Lambert, King, Monahan, & McLaughlin, 2017; Lambert, Sheridan, et al., 2017), and cognitive control (Lambert, King, et al., 2017; Sheridan et al., 2018), but it is unknown whether they have distinct associations with reward processing.

To date, the associations of specific forms of adversity with neural and behavioral reward processing have been examined in just one study. Dennison and colleagues (2019) explored differential associations of material deprivation (i.e., food insecurity), caregiver neglect, and trauma exposure with reward-related behavior and structural integrity of white-matter pathways in the frontostriatal valuation network. Behavioral results indicated that when all adversity types were examined simultaneously, only material deprivation was associated with blunted approach motivation. At the neural level, although all three types of adversity were associated with differences in the structural integrity of frontostriatal white-matter pathways, the specific pathways and patterns varied across adversity types. These findings provide initial evidence of differential associations of different types of adversity with behavioral and neural indices of reward processing.

Reward Processing and Psychopathology

Altered reward processing at behavioral and neural levels has also been linked to depression and externalizing psychopathology. Adolescents and adults with depression have exhibited blunted behavioral approach

motivation (Morris, Bylsma, Yaroslavsky, Kovacs, & Rottenberg, 2015), blunted behavioral sensitivity to reward value (Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008; Vrieze et al., 2013), and blunted neural response to reward in striatal regions (Forbes & Dahl, 2012; Luking, Pagliaccio, Luby, & Barch, 2016; Zhang, Chang, Guo, Zhang, & Wang, 2013). Moreover, reduced behavioral approach motivation and reduced neural response to reward in striatal regions have been observed in adolescents at risk for depression (Gotlib et al., 2010) as well as in adolescents with a diagnosis of depression (Fischer et al., 2019; Forbes, Shaw, & Dahl, 2007) and predicted the persistence of depression after treatment in adults (Vrieze et al., 2013). Furthermore, longitudinal studies have demonstrated that blunted neural responses to reward predict later emergence of depression in adolescence (Bress, Foti, Kotov, Klein, & Hajcak, 2013; Nelson, Perlman, Klein, Kotov, & Hajcak, 2016). Together, these findings implicate blunted reward processing as a developmental risk factor for depression.

Although less work has examined associations of reward processing with externalizing psychopathology, several studies have shown that externalizing behaviors are associated with increased reactivity in neural valuation circuits, including the ventral striatum and caudate, in both adults (Buckholz et al., 2010) and adolescents (Bjork, Chen, Smith, & Hommer, 2010; Gatzke-Kopp et al., 2009). In addition, adolescents diagnosed with externalizing disorders failed to suppress reward-related neural activation after reward incentives were withdrawn from previously rewarded tasks (Gatzke-Kopp et al., 2009). In contrast, other studies have observed reduced cortical and ventral-striatal neural responsiveness to reward in children, adolescents, and adults who exhibit disinhibition and externalizing problems (Joyner et al., 2019; Plichta & Scheres, 2014; Scheres, Milham, Knutson, & Castellanos, 2007), which indicates that reduced sensitivity to reward may also be a risk factor for externalizing behaviors. Given mixed findings, it is unclear how individual differences in sensitivity to reward relate to externalizing psychopathology, and limited research has examined the associations of behavioral aspects of reward processing with externalizing psychopathology.

Reward Processing in the Association of Childhood Adversity With Psychopathology

Many studies have demonstrated that reward processing is related to both childhood adversity and later psychopathology; however, the role of reward processing in this association remains unclear. It could be that reward processing acts as a mediator whereby adversity leads

to atypical reward-system development, which in turn increases risk for psychopathology. For example, both behavioral (Sheridan et al., 2018) and neural aspects of reward responsiveness, including ventral-striatum response to reward anticipation and the integrity of frontostriatal white-matter tracts (Dennison et al., 2019; Hanson et al., 2015), have been shown to mediate the association between early-life deprivation (i.e., institutional rearing, food insecurity) and depression symptoms. A similar pattern has emerged for associations of externalizing psychopathology with reward learning: Hanson and colleagues (2017) found that lower levels of reward-related associative learning mediated the association between childhood trauma exposure and later externalizing problems.

On the other hand, differences in approach motivation or reward responsiveness might moderate associations of adversity with psychopathology. For example, high sensitivity to reward value may buffer against developing certain forms of psychopathology after childhood adversity. This possibility is supported by a prior study that showed an association between trauma exposure and depression only among youths who exhibited lower but not higher levels of behavioral sensitivity to reward value and neural responsiveness to reward (Dennison et al., 2016). In contrast, Gudiño, Nadeem, Kataoka, and Lau (2012) found that high levels of behavioral approach strengthened the association between youth exposure to violence and externalizing problems. These studies suggest that reward processing may serve as a moderator rather than a mediator of associations between adversity and psychopathology. However, existing evidence has come from a small number of studies focused on exposure to adversity involving threat (i.e., violence exposure).

Present Study

In the present study, we aimed to examine links among distinct forms of childhood adversity, reward processing, and depression and externalizing problems in children and adolescents. We extend prior work that has focused largely on single types of adversity by examining how multiple forms of adversity that reflect distinct underlying dimensions of experience (i.e., exposure to trauma, food insecurity, and neglect) influence approach motivation and behavioral sensitivity to reward value. We predicted that food insecurity and neglect (indicators of material and emotional deprivation, respectively) would be associated with lower levels of approach motivation and behavioral sensitivity to reward value. In contrast, we predicted that trauma exposure would be associated with higher approach motivation and behavioral sensitivity to reward value. Next, we

examined whether approach motivation and behavioral sensitivity to reward value were associated with symptoms of depression and externalizing psychopathology. Finally, we investigated whether these indicators of reward processing served as mediators or moderators of the association of adversity with depression and externalizing symptoms. We predicted that the association of adversity with depression and externalizing symptoms would be lower among youths with high behavioral sensitivity to reward value.

Method

Participants and Procedure

Children ages 8 to 16 and a parent or guardian were recruited to participate in a longitudinal study examining child trauma exposure, emotion regulation, and psychopathology. Recruitment occurred at after-school and prevention programs, adoption programs, food banks, domestic-violence shelters, parenting programs, medical clinics, and throughout the general community in Seattle, Washington, between January 2015 and June 2017. To increase the variability of trauma exposure in the sample, we recruited from neighborhoods with high levels of violence, clinics that served predominantly low-socioeconomic-status areas, and agencies that work with families who have been victims of violence (e.g., domestic-violence shelters, programs for parents mandated to receive intervention by Child Protective Services).

A total of 262 children completed the first study visit, during which inclusion and exclusion criteria were assessed. Inclusion criteria for trauma-exposed youths included exposure to physical or sexual abuse or direct witnessing of domestic violence. Children in the control group were matched on age, sex, and handedness with children exposed to trauma and had no exposure to maltreatment or other forms of interpersonal violence. Exclusion criteria included an IQ of less than 80, presence of a pervasive developmental delay, active psychotic symptoms or mania, active substance abuse, and presence of safety concerns (i.e., imminent suicidality).

The reward-processing task was administered at the second study visit. A total of 168 children met inclusion criteria for participation during this study visit; of these, 132 children successfully completed the reward-processing task (78.6%) and therefore constituted the analytic sample for the present study (for greater details on sample and structure of study visits, see the Supplemental Methods in the Supplemental Material available online).

All procedures were approved by the institutional review board at the University of Washington. Written

informed consent and assent were obtained from legal guardians and children, respectively. For sociodemographic characteristics of the final sample, see Table S1 in the Supplemental Material.

Materials and measures

Childhood adversity. We used multiple methods for assessing exposure and severity of childhood adversity (i.e., experiences of trauma, neglect, and food insecurity). Children participated in two interviews with trained staff and reported experiences of maltreatment and exposure to interpersonal violence using the Childhood Experiences of Care and Abuse (CECA) interview (Bifulco, Brown, & Harris, 1994) and the Violence Exposure Scale for Children–Revised (VEX-R; Raviv et al., 2001; Raviv, Raviv, Shimoni, Fox, & Leavitt, 1999). The CECA assesses experiences with caregivers, including experiences of physical and sexual abuse. We modified the interview to assess experiences of having witnessed violence between caregivers (i.e., domestic violence). Interrater reliability for maltreatment reports is excellent, and validation studies have indicated high agreement among siblings on maltreatment reports (Bifulco, Brown, Lillie, & Jarvis, 1997). The VEX-R assesses how often children have either personally experienced or witnessed various forms of violence. Children are presented with a cartoon depicting a child of the same sex either experiencing a violent scenario (e.g., “A person pushes or shoves Chris really hard”) or having witnessed the same violent scenario (e.g., “Chris sees a person push or shove another person really hard”). Using a Likert scale ranging from 0 (*never*) to 3 (*lots of times*), children then rate how often they have either personally experienced or witnessed that particular type of violence (e.g., “How many times has a person pushed or shoved you really hard?” “How many times have you seen a person push or shove another person really hard?”). The VEX-R has demonstrated good reliability and has been validated with children as young as second grade (Raviv et al., 2001; Raviv et al., 1999).

Children also completed two self-report measures: the Childhood Trauma Questionnaire (CTQ; Bernstein, Ahluvalia, Pogge, & Handelsman, 1997) and the University of California, Los Angeles, PTSD Reaction Index (PTSD-RI; Steinberg, Brymer, Decker, & Pynoos, 2004). The CTQ is a 28-item scale that assesses the frequency of maltreatment during childhood (i.e., physical, sexual, and emotional abuse). Validated CTQ thresholds for exposure to physical (≥ 8 on the physical abuse subscale), sexual (≥ 8 on the sexual abuse subscale), and emotional abuse (≥ 10 on the emotional abuse subscale; Walker et al., 1999) were applied in evaluating abuse exposure. The CTQ has excellent internal consistency, test–retest reliability, and convergent and discriminant

validity with interviews and clinician reports of maltreatment (Bernstein et al., 1997; Bernstein, Fink, Handelsman, Foote, & Lovejoy, 1994). The PTSD-RI includes a trauma screen that assesses exposure to many traumatic events, including physical abuse, sexual abuse, community violence, and domestic violence. The PTSD-RI has good internal consistency and convergent validity (Steinberg et al., 2013).

Caregivers completed two self-report measures: the Juvenile Victimization Questionnaire (JVQ) lifetime caregiver report (Finkelhor, Ormrod, Turner, & Hamby, 2005) and the caregiver version of the PTSD-RI. The JVQ is a 34-item measure that assesses exposure to crime, child maltreatment, peer and sibling victimization, sexual victimization, and witnessing or indirect victimization and has excellent psychometric properties, including test-retest reliability and construct validity (Finkelhor et al., 2005). Caregivers endorsed whether their child had experienced each event in the child's lifetime. Caregivers also completed the trauma screen included in the PTSD-RI, described above. A trained interviewer followed up with the caregiver if any form of abuse or domestic violence was endorsed to gather additional information about the experience.

Children were classified as experiencing physical or sexual abuse if it was endorsed by the child (on the CECA interview, PTSD-RI trauma screen, or above the validated CTQ threshold) or parent (on the JVQ or PTSD-RI trauma screen). Emotional abuse (above a validated threshold on the CECA or CTQ) and having witnessed domestic violence (on the VEX-R or PTSD-RI) were based on child report only. Interrater reliability was good for child and caregiver reports of abuse (82.0% agreement; $\kappa = .62$). Exposure to physical or sexual trauma or having witnessed domestic violence (referred to as *trauma exposure*) was coded using a binary present (1) or absent (0) score (Table 1). Trauma severity was measured by summing the total number of threat experiences (i.e., any instances of sexual or physical trauma, emotional abuse, or having witnessed domestic violence) endorsed by the child or caregiver.

Exposure to caregiver neglect was assessed using an eight-item self-report measure embedded in the CECA interview, which assesses the frequency of neglectful behaviors (Bifulco, Bernazzani, Moran, & Jacobs, 2005). Children completed this measure separately in reference to neglectful behaviors on the part of each caregiver for children living with two caregivers. We elected to use this measure rather than the emotional neglect subscale of the CTQ because this measure more closely aligns with accepted definitions of neglect (Straus & Kantor, 2005) by assessing neglectful behaviors (e.g., "[My mother] would leave me unsupervised before I

was 10 years old"). The neglect subscales exhibited acceptable internal consistency in this sample ($\alpha = .79$ for child report on the mother; $\alpha = .86$ for child report on the father). We selected the highest score for either parent to determine the overall neglect score, which was then turned into a binary score of present (1) or absent (0) according to the previously established cutoff scores linked to optimal sensitivity and specificity (≥ 22 for maternal neglect and ≥ 24 for paternal neglect; Bifulco et al., 2005). We used the highest sum from the neglect subscale for either parent to create a continuous neglect-severity score.

Food-insecurity exposure in the past 12 months was assessed using a set of four items taken from the short form of the U.S. Department of Agriculture's Food Security Scale (Blumberg, Bialostosky, Hamilton, & Briefel, 1999). These four items constitute a measure of food insecurity that has been validated and used in epidemiological surveys of youth psychopathology (e.g., McLaughlin et al., 2012). Children and their parent completed two dichotomous items indicating whether they had ever been hungry but did not eat because they could not afford enough food and whether they had ever eaten less than they thought they should because there was not enough money to buy food. Two additional items assessed how often adolescents and parents did not have enough money to buy food and could not afford to buy balanced meals in the past 12 months. Exposure to food insecurity was coded using a binary score of present (1) if the sum score was above 4 or absent (0) if the sum score was below 4. To create a food-insecurity severity variable, we summed the items on the food-insecurity subscale.

Depression symptoms. During the first study visit, children completed the Children's Depression Inventory-II (CDI-II; Kovacs, 2011), a widely used self-report measure of depression symptoms in children and adolescents. We focus on youth reports of depression symptoms because extensive evidence suggests that youths report more depressive symptoms on average than parents and that reports of internalizing symptoms from parents have lower validity than child reports (Aebi et al., 2017; Cantwell, Lewinsohn, Rohde, & Seeley, 1997; Moretti, Fine, Haley & Marriage, 1985). The CDI-II includes 28 items consisting of three statements each (e.g., "I am sad once in a while," "I am sad many times," "I am sad all the time") representing different levels of severity of a specific depression symptom. The 28 items were summed for each participant to derive a total score. The CDI-II has demonstrated good reliability and validity among children and adolescents (Bae, 2012). The CDI-II demonstrated excellent internal consistency in our sample (Cronbach's $\alpha = .883$)

Table 1. Associations of Adversity With Depression and Externalizing Problems

Adversity variable	β	SE	t	p
Depression symptoms				
Trauma exposure	0.38	1.09	$t(128) = 4.76$	.001
Trauma severity	0.49	0.15	$t(128) = 6.60$	.001
Neglect exposure	0.24	1.34	$t(128) = 2.82$	.006
Neglect severity	0.24	0.07	$t(128) = 2.82$	.006
Food-insecurity exposure	0.33	1.46	$t(128) = 4.07$	.001
Food-insecurity severity	0.34	0.32	$t(128) = 4.14$	.001
Depression symptoms (controlling for other adversity types)				
Trauma exposure	0.25	1.28	$t(126) = 2.71$	.008
Trauma severity	0.42	0.18	$t(126) = 4.70$	.001
Neglect exposure	0.09	1.36	$t(126) = 1.11$	.54
Neglect severity	0.00	0.07	$t(126) = 0.04$	.97
Food-insecurity exposure	0.20	1.57	$t(126) = 2.30$	.046
Food-insecurity severity	0.15	0.33	$t(126) = 1.89$	.06
Externalizing problems				
Trauma exposure	0.62	1.46	$t(128) = 8.92$	.001
Trauma severity	0.58	0.22	$t(128) = 8.21$	.001
Neglect exposure	0.36	2.01	$t(128) = 4.46$	.001
Neglect severity	0.42	0.10	$t(128) = 5.31$	.001
Food-insecurity exposure	0.32	2.31	$t(128) = 3.92$	.001
Food-insecurity severity	0.39	0.50	$t(128) = 4.78$	.001
Externalizing problems (controlling for other adversity types)				
Trauma exposure	0.53	1.73	$t(126) = 6.52$	.001
Trauma severity	0.43	0.25	$t(126) = 5.08$	.001
Neglect exposure	0.14	1.84	$t(126) = 1.86$	.07
Neglect severity	0.19	0.10	$t(126) = 2.39$	.04
Food-insecurity exposure	0.06	2.12	$t(126) = 0.83$	.41
Food-insecurity severity	0.17	0.47	$t(126) = 2.17$	.06

Note: All p values are corrected for false discovery rate across multiple comparisons.

Externalizing symptoms. During the first study visit, children and caregivers completed the Youth Self-Report (YSR) and Child Behavior Checklist (CBCL), respectively (Achenbach, 1991). The YSR and CBCL scales are among the most widely used measures of youth emotional and behavioral problems and use extensive normative data to generate age-standardized estimates of symptom severity. The externalizing composite includes rule-breaking behaviors (e.g., “sets fires,” “runs away”) and aggressive behaviors (e.g., “disobeys at home/school,” “gets into fights”). We examined both youth- and parent-reported externalizing problems given that parents have been shown to provide unique information with regard to youth externalizing problems (Bird, Gould, & Staghezza, 1992; Grills & Ollendick, 2002). The T scores were calculated, and we created a combined report by using the highest reported T score on either the YSR or CBCL externalizing composite.

Reward-processing task. Participants completed a child-friendly, computer-based version of the monetary-incentive-delay (MID) task that depicts cartoon animal piñatas (Helfinstein et al., 2013; see Fig. S1 in the Supplemental Material). Each piñata contains a variable number of stars (zero, one, two, or four). The children are instructed to hit the piñata as quickly as possible to earn the stars within and that the number of stars they earn will determine whether they receive a monetary prize. On each trial, children make a speeded response to a target in order to earn the stars inside the piñata. Each trial is composed of three stages: anticipation, response, and feedback. In the anticipation stage, children see a cue indicating the size of the potential reward (number of stars within the piñata) for that trial. The bottom portion of the piñata containing the stars is revealed at the top of the screen, but the children cannot yet hit it. In the response stage, children can earn

the stars for that trial by responding quickly once the target reappears. The piñata drops to the middle of the screen, and children press the spacebar on a keyboard to hit the piñata. In the outcome stage, children see and hear feedback indicating whether their response was fast enough to receive the reward. For successful trials (i.e., hits), the piñata cracks open, and the stars are deposited in a basket at the bottom of the screen. On unsuccessful trials (i.e., misses), children see the intact piñata swing to the side of the screen with the stars still inside. The task was designed to be visually appealing and engaging for children. To incentivize performance, all children were told they would receive \$10 of bonus money if they earned enough stars. After completion, all children received the \$10 irrespective of performance.

Before the task, participants played a practice round of 22 trials. During this practice task, the response window for responding to the target piñata was 250 to 300 ms. Performance on the practice task was used to determine the length of the response window during which the participant could respond to the target in the final task, consistent with prior work (Helfinstein et al., 2013); for greater details, see the Supplemental Methods in the Supplemental Material. This was done to make the final task equally challenging for all children at the beginning of the task despite individual differences in processing speed or baseline reaction time. However, once the task commenced, display time was no longer manipulated on the basis of the participant's performance during the task, meaning that children had the opportunity to improve their performance throughout the task. During the task, the cue first appeared for 1,500 ms, followed by a cue-free anticipatory period that varied between 1,000 and 2,000 ms. The target appeared for a variable duration based on performance on the practice trials (for details, see the Supplemental Methods), followed by a delay period with a duration such that the target period and delay period combined to a total of 1,500 ms. Finally, the feedback appeared for 1,500 ms. The task consisted of six task runs of 22 trials each, for a total of 132 trials. Trials were divided evenly between the four incentive levels for a total of 33 trials at each incentive level. Data for 13 subjects were removed from the analyses because there were no responses on the 0-star trials, indicating that the task was not completed as directed.

Statistical analysis

All analyses were performed using the R software environment (Version 4.0.2; R Core Team, 2020; code and output are in the Supplemental Material). Our goal was to examine whether each type of adversity (trauma, caregiver neglect, and food insecurity) had unique associations with reward processing. Thus, we tested for

the main effects of the three adversity-exposure and adversity-severity measures in separate models. We then examined two adjusted models: one including all adversity-exposure variables and one including all adversity-severity variables simultaneously to evaluate whether the associations were specific to particular forms of adversity but not others. This follows recommendations for examining unique contributions of distinct dimensions of adversity (McLaughlin & Sheridan, 2016).

We used linear regression to examine associations among adversity measures, behavioral indicators of reward processing, and psychopathology symptoms. First, we measured approach motivation using the total number of stars earned on the piñata task. Consistent with the definition of approach motivation as involving the regulation of behaviors that result in reward achievement (Olino, 2016) and prior studies in which this task was used (Dennison et al., 2019), we interpreted the total number of stars earned on the behavioral reward task to indicate the child's effortful engagement with the task, and ability to regulate their behavior to achieve the maximum reward (i.e., a global index of motivation to obtain reward). We also examined behavioral sensitivity to reward value—a distinct metric of approach motivation—by calculating differences in reaction time (RT) to high-reward trials (i.e., four stars) compared with the low- and no-reward trials (i.e., zero, one, and two stars), averaged across all trials in the task. This construct measures the degree to which children modulate their behavior in response to varying reward value on a trial-by-trial basis and has been used in both child and adult studies of reward processing (Guyer et al., 2006; Olino, 2016; Pizzagalli et al., 2009; van Hulst et al., 2015). A positive score indicated greater behavioral sensitivity to reward value (i.e., faster RT on high-reward compared with low- or no-reward trials). Next, we tested direct associations between behavioral measures of reward processing and depression and externalizing symptoms. All main-effect analyses included age and sex as covariates, and standardized betas are reported. We used the *p.adjust* function in R to run false discovery rate (FDR) corrections for multiple comparisons for each hypothesis in which multiple tests were performed (i.e., when we examined both an adversity exposure and severity variable as predictors of the same outcome) per standard procedure (Benjamini & Yekutieli, 2001). FDR-corrected *p* values are reported throughout.

Mediation analyses. In cases in which we observed significant associations between adversity and reward processing and between reward processing and either depression or externalizing symptoms (i.e., a and b paths), we used mediation to explore indirect effects.

These models were used to determine whether behavioral measures of reward processing were underlying mechanisms that explain (i.e., mediate) associations between adversity and depression or externalizing symptoms. All indirect effects were tested using bootstrapped standard errors (10,000 draws) in the mediation package in R, and 95% confidence intervals (CI) are reported. Sex and age were included as covariates.

Moderation analyses. Next, we used linear regression to test our hypothesis that reward processing moderates the association between adversity and depression and externalizing psychopathology. Main effects, covariates, and interaction terms were entered simultaneously, and standardized regression coefficients are reported. Significant interactions were probed with simple-slopes analysis at the mean and at 2 *SD* and 1 *SD* above and below the mean of the moderator variable following McCabe, Kim, and King's (2018) guidelines for testing regions of significance. This procedure uses regression parameters to create individual simple-slopes plots at various values of the moderator (i.e., behavioral sensitivity to reward value); simple-slopes effects, observed data, and confidence intervals are displayed.

Results

Preliminary Analyses

Demographic information, means, and standard deviations for age, reward-processing variables, and internalizing and externalizing psychopathology measures by exposure to adversity type are presented in Table S1 in the Supplemental Material. Table S2 presents Pearson correlations among all variables of interest.

Adversity and psychopathology

When examined as separate predictors, all measures of adversity exposure and severity were associated with greater depression symptoms and externalizing problems ($ps < .01$; Table 1). When examined simultaneously, trauma exposure and severity and food-insecurity exposure remained significantly associated with depression symptoms; trauma exposure and severity and neglect severity remained significant predictors of externalizing symptoms ($ps < .05$; Table 1).

Adversity and reward processing

When examined independently, trauma exposure ($\beta = -0.25, p < .01$) and severity ($\beta = -0.23, p < .01$) were associated with fewer total stars earned on the reward-processing task (Figs. 1a and 1b) but were not

associated with behavioral sensitivity to reward value ($ps > .05$). Caregiver neglect and neglect severity were not associated with total stars earned or behavioral sensitivity to reward value (Figs. 1c and 1d; $ps > .05$). Both food-insecurity exposure ($\beta = -0.17, p < .05$) and severity ($\beta = -0.19, p < .05$) were associated with fewer total stars earned on the reward-processing task (Figs. 1e and 1f) but were not associated with behavioral sensitivity to reward value ($ps > .05$).

In a model including all adversity types, both trauma exposure ($\beta = -0.27, p < .05$) and severity ($\beta = -0.25, p < .05$) remained significant predictors of fewer total stars earned on the reward-processing task. All remaining adversity variables became or remained unassociated with total stars earned and behavioral sensitivity to reward value ($ps > .05$).

Reward processing and psychopathology

Fewer total stars earned on the reward-processing task was positively associated with depression symptoms (see Fig. S2a in the Supplemental Material; $\beta = -0.19, p < .05$) and externalizing symptoms (see Fig. S2b; $\beta = -0.22, p < .05$). Behavioral sensitivity to reward value was unassociated with either depression or externalizing symptoms ($ps > .05$).

Reward processing as a mediator

We examined the indirect effect of reward processing on the association between adversity and psychopathology outcome in which a and b paths were both significant. Thus, we examined the indirect effect of total stars earned on the associations of trauma exposure and severity with depression and externalizing symptoms. Total stars did not emerge as a significant mediator of the effect of trauma exposure ($b = 0.32, 95\% \text{ CI} = [-0.28, 1.32]$) or severity ($b = 0.03, 95\% \text{ CI} = [-0.04, 0.17]$) on depression symptoms or the effect of trauma exposure ($b = 0.31, 95\% \text{ CI} [-0.33, 1.51]$) or severity ($b = 0.06, 95\% \text{ CI} = [-0.05, 0.21]$) on externalizing symptoms ($ps > .05$).

We also examined the indirect effect of total stars earned on the associations of food-insecurity exposure and severity with depression and externalizing symptoms. Total stars earned on the reward-processing task was not a significant mediator of the effect of food-insecurity exposure ($b = 0.41, 95\% \text{ CI} [-0.14, 1.75]$) or severity ($b = 0.10, 95\% \text{ CI} = [-0.04, 0.38]$) on depression symptoms or the effect of food-insecurity exposure ($b = 0.81, 95\% \text{ CI} = [-0.04, 3.05]$) or severity ($b = 0.18, 95\% \text{ CI} = [0.00, 0.65]$) on externalizing symptoms ($ps > .05$).

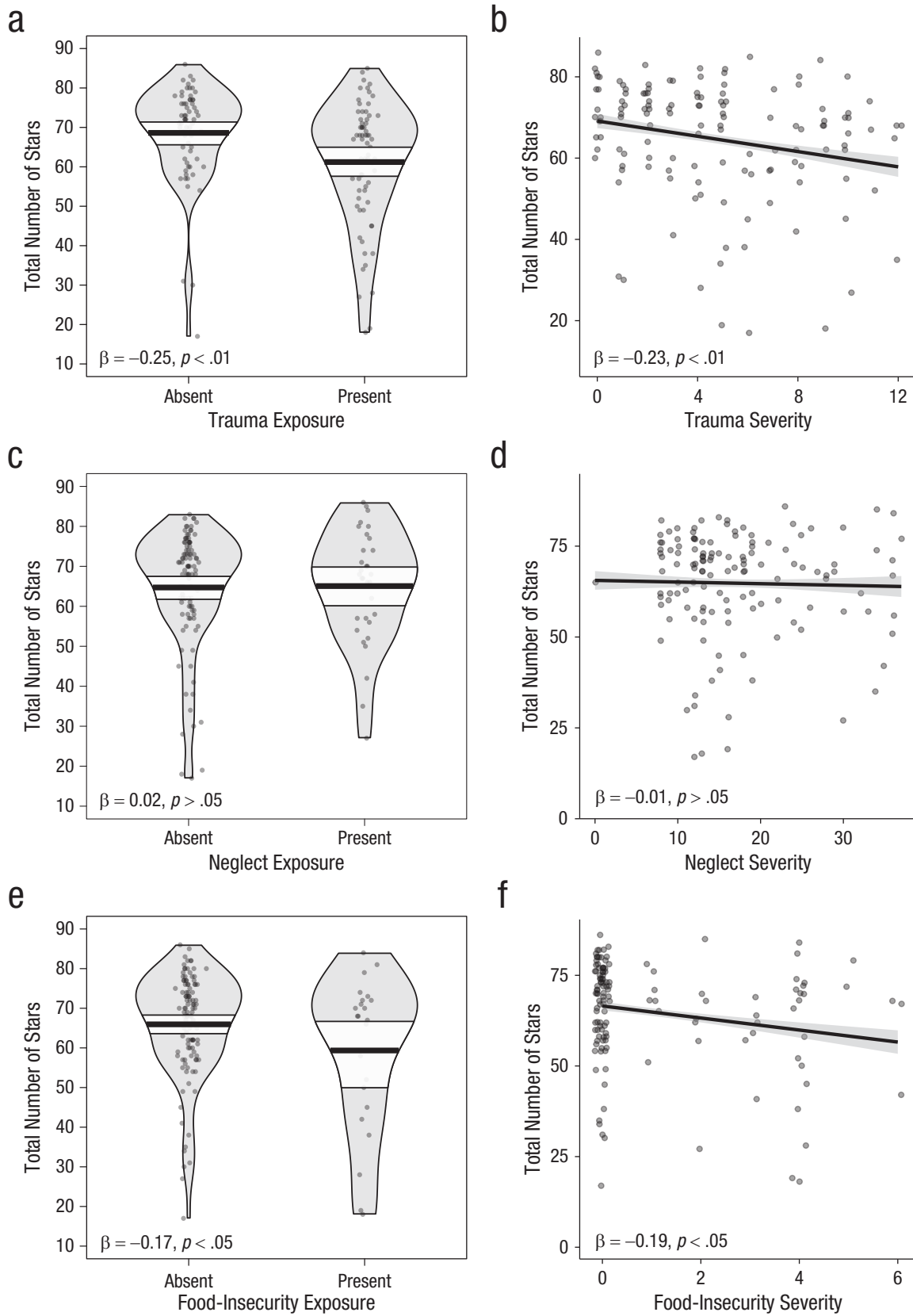


Fig. 1. (continued on next page)

Fig. 1. Exposure to and severity of childhood trauma, neglect, and food insecurity as they relate to behavioral-reward approach motivation (i.e., the total number of stars earned on the reward-processing task). The violin plots show the relationship between the total number of stars earned and exposure to (a) trauma, (c) neglect, and (e) food insecurity. The thick line in the middle of each plot indicates the mean; the thin lines above and below indicate the top and bottom of the interquartile range, respectively; and the lines at the top and bottom of the plot indicate the maximum and minimum values, respectively. The shaded area represents the probability density. The scatterplots (with best-fitting regression lines) show the relationship between the total number of stars earned and the severity of (b) trauma, (d) neglect, and (f) food insecurity. The shaded area above and below the regression line represents the 95% confidence interval. In both type of graphs, each dot represents a single participant. The p values reported are corrected for false discovery rate.

Reward processing as a moderator

Depression symptoms. Neither total stars earned nor behavioral sensitivity to reward value moderated the association between any of the adversity exposure or severity variables and depression symptoms ($ps > .05$).

Externalizing symptoms. Total stars earned did not moderate the association between any of the adversity exposure or severity variables and externalizing symptoms ($ps > .05$).

Behavioral sensitivity to reward value moderated the association between trauma exposure and externalizing symptoms ($\beta = -0.27$, $SE = 0.03$, $t(126) = -2.30$, 95% CI = $[-0.11, -0.01]$, $p < .05$; Table 2); this interaction remained significant after controlling for other adversity exposure types ($\beta = -0.29$, $SE = 0.03$, $t(124) = -2.52$, 95% CI = $[-0.12, -0.01]$, $p < .05$; Table 2). Simple-slopes analysis revealed that the association between trauma exposure and externalizing symptoms was positive and significant at low and moderate levels of reward reactivity

but became nonsignificant at high levels of sensitivity to reward value across the sample (Fig. 2).

Discussion

Exposure to trauma and food insecurity—as well as the severity of these adverse early experiences—were associated with lower approach motivation (i.e., worse overall performance on the reward-processing task). Trauma exposure and severity of traumatic experiences were associated with lower approach motivation even after controlling for other types of adversity. Low approach motivation was associated with higher symptoms of depression and externalizing problems but did not mediate the association of any form of adversity with psychopathology. Instead, we found that behavioral sensitivity to reward value—faster responses on trials associated with high relative to low reward—moderated the association of trauma with externalizing symptoms. Specifically, trauma exposure was associated with greater externalizing symptoms in youths with low

Table 2. Prediction of Externalizing Symptoms by Reward Reactivity and Trauma Exposure

Variable	β	SE	t	95% CI
Trauma exposure ^a				
Intercept	0.00	3.72	$t(126) = 15.39^{**}$	[49.84, 64.55]
Trauma exposure	0.66	1.51	$t(126) = 9.34^{**}$	[11.10, 17.07]
Reward reactivity	0.26	0.02	$t(126) = 2.25^*$	[0.01, 0.09]
Age	-0.16	0.28	$t(126) = -2.36^*$	[-1.20, -0.11]
Sex	0.00	1.48	$t(126) = 0.03$	[-2.88, 2.97]
Trauma Exposure \times Reward Reactivity	-0.27	0.03	$t(126) = -2.30^*$	[-0.11, -0.01]
Trauma exposure (controlling for other adversity exposures) ^b				
Intercept	0.00	3.67	$t(124) = 15.54^{**}$	[49.79, 64.33]
Trauma exposure	0.58	1.74	$t(124) = 7.01^{**}$	[8.74, 15.63]
Neglect exposure	0.15	1.81	$t(124) = 1.99^*$	[0.02, 7.19]
Food-insecurity exposure	0.08	2.12	$t(124) = 1.03$	[-2.01, 6.38]
Reward reactivity	0.26	0.02	$t(124) = 2.31^*$	[0.01, 0.09]
Age	-0.16	0.27	$t(124) = -2.41^*$	[-1.20, -0.12]
Sex	0.00	1.46	$t(124) = -0.13$	[-2.94, 2.84]
Trauma Exposure \times Reward Reactivity	-0.29	0.03	$t(124) = -2.52^*$	[-0.12, -0.01]

^aModel $R^2 = .43$, $F(5, 126) = 18.66$, $p < .001$. ^bModel $R^2 = .45$, $F(7, 124) = 14.38$, $p < .001$.

* $p < .05$. ** $p < .001$.

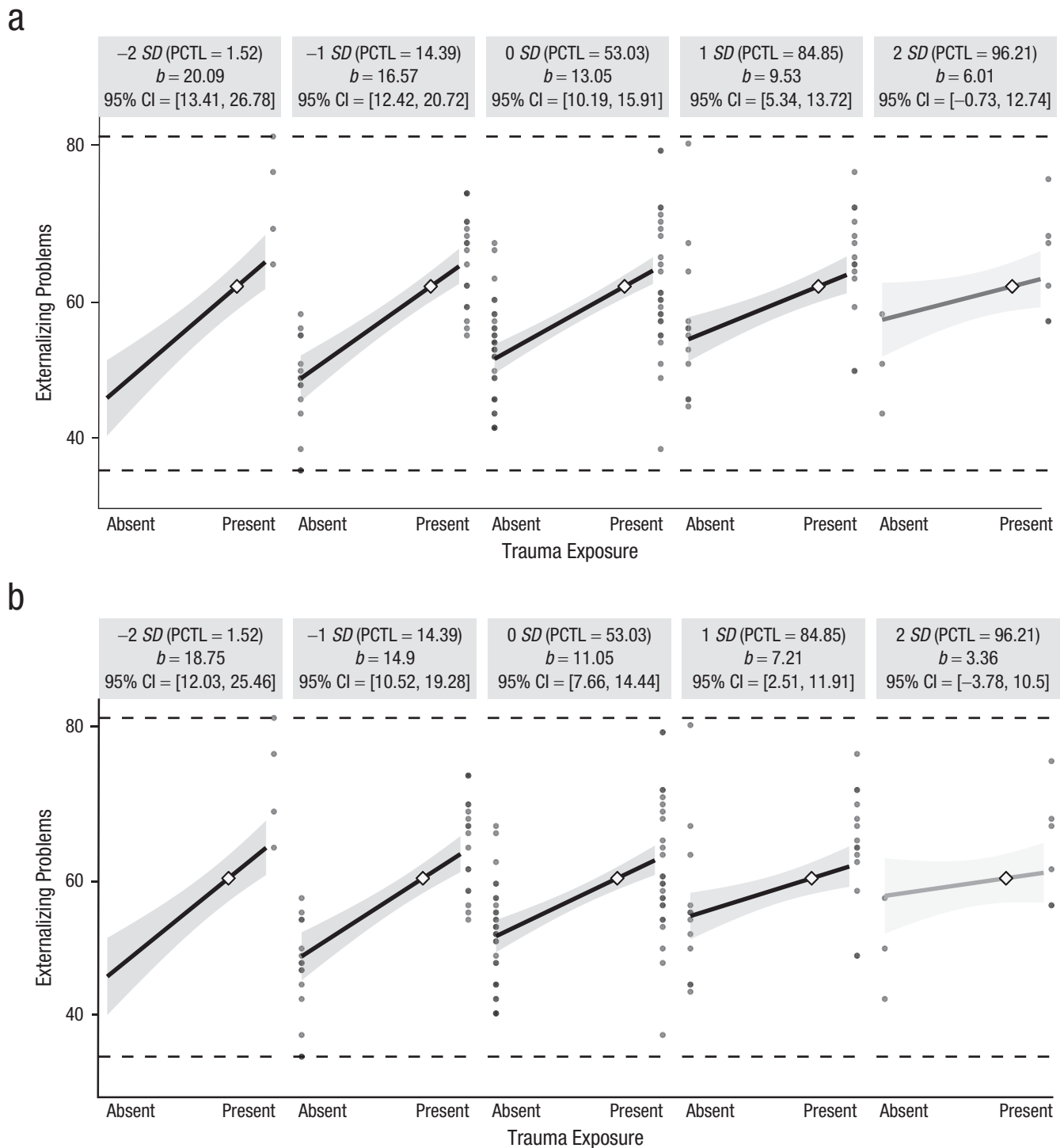


Fig. 2. Association between the presence or absence of exposure to trauma and externalizing problems (a) after controlling for age and sex and (b) after controlling for age and sex as well as exposure to neglect and food insecurity, with reward reactivity as a moderator. Simple slopes are provided for levels of the moderator at the mean and at 1 SD and 2 SD above and below the mean. The shaded area above and below the regression line represents the computed 95% confidence interval (CI), the dashed horizontal lines indicate the maximum and minimum values of the outcome, and the diamond indicates the crossover point. Each dot represents a single participant. PCTL = percentile.

to moderate levels of behavioral sensitivity to reward, but this association was no longer significant among children with high levels of sensitivity to reward value.

Thus, higher behavioral sensitivity to reward value may buffer against externalizing problems among children who have experienced trauma.

Multiple forms of adversity exposure were associated with blunted behavioral approach motivation, characterized by fewer total stars earned on the behavioral reward task. We extend prior work by demonstrating an association between both trauma exposure and trauma severity with blunted approach motivation. Previous work that examined childhood trauma exposure and reward processing has produced mixed findings. Some studies have not found an association between trauma exposure and approach motivation or behavioral sensitivity to reward value (Dennison et al., 2016, 2019), and others have found that trauma-exposed youths exhibit low behavioral sensitivity to reward value (Guyer, 2006) as well as both blunted behavioral reward approach motivation and lower levels of reward learning over successive reward trials (Hanson et al., 2017). Because our sample was recruited to capture a more severe range of trauma exposure than many prior studies, it may be that associations between trauma exposure and reward processing emerge only at severe levels of trauma. Children exposed to severe trauma experience greater inconsistency in parenting behavior characterized by more punishment and lower levels of positive reinforcement (Pollak, 2015; Shackman et al., 2010). Over time, low levels of positive reinforcement or inconsistency in reinforcement may result in lower levels of reward-seeking behavior because of uncertainty about whether actions will produce reinforcement. Associations of childhood trauma with blunted approach motivation remained significant after controlling for other forms of adversity.

In addition, we replicated a prior study (Dennison et al., 2019) in which it was demonstrated that food-insecurity exposure and severity of food insecurity are associated with blunted approach motivation. It is feasible that uncertainty surrounding the ability to obtain food when hungry could have a direct impact on how reward-processing systems develop. Indeed, recurrent lack of reinforcement (i.e., food) following hunger cues may alter a child's sense that their behavior can influence the likelihood of reward and eventually may generalize to other contexts. Given that the link between food-insecurity exposure and severity and reward processing was no longer significant after adjusting for co-occurring forms of adversity, in contrast with a prior study in which this association persisted after such controls (Dennison et al., 2019), further studies are needed in large samples across a wide range of adversity severity to clarify distinct and overlapping associations between adversity type and approach-motivation behaviors.

In contrast to some previous studies, we found no associations of neglect with blunted reward processing. Sheridan and colleagues (2018) found that children who were raised in deprived institutional settings had

blunted behavioral sensitivity to reward value using the same task used in the current study, a pattern mirrored in other recent studies of children adopted internationally (Wisner Fries & Pollak, 2017). Variation in findings may arise from differing sample characteristics and severity of neglect. For example, previous studies in which this link was observed involved children who experienced extreme deprivation as a result of institutional rearing, whereas our sample was recruited from the community and involved neglect that was almost certainly less severe. Note that a prior study using the same task and measure of neglect also failed to observe an association between neglect and reward-processing behaviors (Dennison et al., 2019). It may be that only relatively extreme forms of emotional and cognitive neglect are associated with blunted approach motivation and behavioral sensitivity to reward. Alternatively, deprivation may have stronger associations with responsiveness to reward (i.e., feelings of liking or enjoying reward). Indeed, institutional rearing and emotional neglect in a community sample have both been associated with blunted ventral-striatum activation in response to reward (Goff et al., 2013; Hanson et al., 2015).

More broadly, these findings suggest that experiences of both threat and deprivation may produce reductions in behaviors reflecting approach motivation during childhood and adolescence. Although prior work examining these forms of adversity in relation to neural markers of reward responsiveness have produced mixed findings—with trauma associated with elevated ventral striatum response to reward (Dennison et al., 2016) and deprivation associated with blunted responses (Goff et al., 2013; Hanson et al., 2015)—these findings suggest that motivation and the organization of behavior to pursue reward may be influenced in a similar way by multiple forms of adversity. Children who experience both threat and deprivation experience lower levels of positive emotion in their caregiving relationships (Anthony, Paine, & Shelton, 2019; Bugental, Blue, & Lewis, 1990; Burgess & Conger, 1978; Kavanagh, Youngblade, Reid, & Fagot, 1988; Oldershaw, Walters, & Hall, 1986; Shackman et al., 2010; Trickett & Kuczynski, 1986). Moreover, children raised in these types of adverse early environments may be less able to reliably elicit rewards from their environment—either affection and soothing from caregivers in the case of trauma and neglect or primary reinforcers (i.e., food) in the case of food insecurity. This reduced contingency between child behavior and the ability to obtain rewards may culminate in blunted approach motivation later in development. Given that this pattern of lower approach motivation appears to be shared across multiple forms of threat and deprivation, it may be a promising target for early interventions aimed at preventing the emergence of psychopathology in children who have

experienced adversity (McLaughlin, DeCross, Jovanovic, & Tottenham, 2019).

Lower levels of global approach motivation on the task were associated with higher levels of both depression symptoms and externalizing problems, consistent with this conceptualization of low approach motivation as a transdiagnostic risk factor. This pattern is consistent with an accumulating body of work on blunted reward responsiveness and motivation to pursue reward in children and adolescents with depression (Forbes & Dahl, 2012; Morris et al., 2015; Pizzagalli et al., 2008; Vrieze et al., 2013; Zhang et al., 2013). In contrast, prior work on reward processing and externalizing problems is decidedly mixed; some studies have found elevated behavioral (Gudiño et al., 2012; Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008) and neural (Bjork et al., 2010; Buckholtz et al., 2010; Gatzke-Kopp et al., 2009) responses to reward in children and adolescents with externalizing problems, and others have found the opposite—that blunted neural responsiveness to reward is associated with externalizing problems (Plichta & Scheres, 2014; Scheres et al., 2007). Our findings are more consistent with the latter findings on neural hypo-responsivity to reward and extend this prior work by demonstrating that lower *behavioral* sensitivity to reward is also associated with externalizing problems.

Some theoretical models posit that individuals with externalizing problems exhibit disruptions in dopamine-related neural reward processing (i.e., reduced dopamine release in response to reward anticipation), which may lead to blunted neural and behavioral responsiveness to reward (Sagvolden, Johansen, Aase, & Russell, 2005; Tripp & Wickens, 2008). Note that blunted responsiveness to reward anticipation is associated with behavioral impulsivity and externalizing problems (Scheres et al., 2007; Ströhle et al., 2008). Increased impulsivity may subsequently lead to increased engagement in risky behaviors, in part because more normative rewards do not elicit patterns of neural response sufficient to produce motivational salience, thus leading youths to pursue highly potent incentives (e.g., drugs, alcohol, risky sexual activity); indeed, these types of high-risk behaviors (i.e., drug use, aggressive behavior, illegal activity) are common among youths with externalizing problems (Fergusson, Horwood, & Ridder, 2007).

Despite the associations of adversity exposure and severity with lower approach motivation, which in turn predicted higher symptoms of both depression and externalizing psychopathology, approach motivation did not mediate the association between adversity and psychopathology. Prior studies that have found evidence of mediation have focused on neural measures of reward responsiveness (Hanson et al., 2015), frontostriatal white-matter integrity (Dennison et al., 2016), or measures of associative learning (Hanson et al.,

2017). Thus, it may be that the aspects of reward-related behavior studied here function as moderators rather than mediators of the association between adversity and psychopathology.

Indeed, behavioral sensitivity to reward value moderated the association of trauma exposure with externalizing psychopathology. Specifically, trauma exposure was positively associated with externalizing problems in children with low to moderate levels of sensitivity to reward value but not among children with high levels of reward sensitivity. This pattern of findings suggests that high sensitivity to reward value may buffer against externalizing problems in children who have experienced trauma. These findings extend a prior finding from our laboratory (Dennison et al., 2016) in which we used a similar task; trauma exposure was related to depression in adolescents with low levels of behavioral sensitivity to reward value but not those with high sensitivity to reward value. Youths exposed to trauma may be at particularly increased risk for engaging in externalizing behaviors for several reasons. Childhood trauma exposure is associated with increases in emotional reactivity and negative affect (Glaser, van Os, Portegijs, & Myin-Germeys, 2006; Heleniak, Jenness, Stoep, McCauley, & McLaughlin, 2016; McCrory et al., 2011; McCrory et al., 2013; McLaughlin, Peverill, Gold, Alves, & Sheridan, 2015) as well as difficulties with emotion regulation (Hébert, Langevin, & Oussaïd, 2018; Heleniak et al., 2016; Lambert, King, et al., 2017).

Impulsive responses to negative emotion (sometimes referred to as negative urgency) are one form of emotion-regulation difficulty commonly observed in children exposed to trauma that in turn increases risk for externalizing problems (Heleniak et al., 2016; Wardell, Strang, & Hendershot, 2016). These impulsive responses to negative emotion may lead to risky behaviors (e.g., substance use, unsafe sex) during periods of distress for youths who have experienced trauma. In contrast, heightened sensitivity to reward may reduce the need for more potent incentives to stimulate motivational salience to pursue rewards, effectively buffering against externalizing problems in trauma-exposed youths. Instead, trauma-exposed youths with heightened reward sensitivity may experience motivation to pursue more normative and naturally occurring rewards in the environment (i.e., adaptive peer relationships, extracurricular activities, positive interpersonal feedback), thus reducing the impulse to engage in externalizing behaviors in response to distress or negative affect.

We did not replicate findings from a prior study (Dennison et al., 2016) that showed a protective effect of high behavioral sensitivity to reward value and neural responsiveness to reward on depression symptoms after childhood physical or sexual abuse in a smaller sample of adolescents. Note that Dennison et al. (2016)

found that effect in a sample of youths ages 14 to 19, whereas the age range of our analytic sample was 8 to 16. This is noteworthy because the average age of onset of depression (and other mood disorders) occurs in the early or mid teenage years, whereas externalizing problems, such as conduct and impulse-control problems, exhibit a younger average age of onset (Kessler et al., 2005; Kessler et al., 2007). Thus, Dennison and colleagues' sample was well suited to detect associations of reward processing with maltreatment and depression, whereas we were likely better suited to detect associations of reward processing with maltreatment and externalizing problems given our younger sample. Future studies should study these constructs in a sample spanning a larger age range (e.g., 8–18 years) to ensure a sample composition adequate to assess potential associations of reward processing with maltreatment history and depression and externalizing problems.

The present study had several notable limitations. Because of the cross-sectional nature of our study, the directionality of the associations cannot be determined. Future studies should reassess psychopathology symptoms at a later time point in order to measure the predictive power of reward processing as it relates to the development of psychopathology. In addition, future studies should seek to further elaborate on these pathways by considering neural pathways associated with reward processing. Congruence between effects of behavioral and neural measures of reward processing would offer further support for this construct as a hopeful target for future intervention approaches. Furthermore, the reward-processing task used primarily assessed approach motivation and sensitivity to reward value. However, there are other components of reward processing that may be implicated in the association between early-life adversity and later psychopathology outcomes (Olino, 2016), such as reward responsiveness and reward learning. In addition, our task did not include loss of reward trials, so we were unable to determine whether response to punishment moderated the association between adversity and psychopathology. Furthermore, although it is common practice to use RT-difference scores to assess individual differences in behavioral sensitivity to reward (Guyer et al., 2006; Olino, 2016; Pizzagalli et al., 2009; van Hulst et al., 2015), low test–retest reliability of RT in behavioral tasks is a potential limitation of this approach (Balota & Yap, 2011).

Finally, as it relates to the dimensional model of adversity (McLaughlin & Sheridan, 2016), in cases in which we hypothesized differential impacts of different forms of adversity on reward processing outcomes, we instead demonstrate that both deprivation and threat have similar effects on broad reward-processing performance. Furthermore, we did not find any moderating effects of

behavioral sensitivity to reward value on associations of food-insecurity exposure with either depression or externalizing symptoms as hypothesized. Note that our sample was recruited for extreme trauma exposure. We had many fewer participants who met criteria for food-insecurity exposure compared with trauma exposure (Table S1 in the Supplemental Material), and of those who did, many also met criteria for trauma exposure. Thus, we may not have been well powered to detect differential effects of trauma exposure and food-insecurity exposure.

Conclusion

Childhood exposure to trauma and food insecurity are associated with blunted approach motivation in a behavioral reward-processing task. Although blunted approach motivation was associated with higher levels of depression and externalizing symptoms, it did not mediate the association of childhood adversity with psychopathology. In contrast, behavioral sensitivity to reward value moderated the association of trauma exposure with externalizing problems such that the association of trauma with externalizing problems was absent in children with high behavioral sensitivity to reward value. Thus, sensitivity to reward value may be protective against externalizing problems in trauma-exposed youths. Our findings provide insight into the development of reward-processing behaviors that may confer risk or resilience for psychopathology following experiences of adversity in childhood and suggest targets for intervention that could improve psychopathology among these vulnerable populations.

Transparency

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Author Contributions

S. W. Kasperek and K. A. McLaughlin developed the study concept. All of the authors contributed to the study design. Testing and data collection were performed by past research staff members and graduate students. S. W. Kasperek and J. L. Jenness performed the data analysis and interpretation under the supervision of K. A. McLaughlin. S. W. Kasperek drafted the manuscript, and J. L. Jenness and K. A. McLaughlin provided critical revisions. All of the authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Open Practices

All data and materials have been made publicly available via OSF and can be accessed at <https://osf.io/tgkqd>. The complete Open Practices Disclosure for this article can be found at <http://journals.sagepub.com/doi/suppl/10.1177/2167702620933570>. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at <https://www.psychologicalscience.org/publications/badges>.



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Supplemental Material

Additional supporting information can be found at <http://journals.sagepub.com/doi/suppl/10.1177/2167702620933570>

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