NEW RESEARCH SUBSTANCE USE

Longitudinal Pathways From Maltreatment to Substance Use Through Delay Discounting During Adolescence and Into Young Adulthood

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Objective: Children and adolescents exposed to maltreatment are at a greater risk for substance use disorders in adulthood. However, developmental processes that explain how maltreatment experiences may influence substance use behaviors remain unclear. We investigated whether delay discounting (ie, the preference for immediate over delayed rewards), a critical indicator of self-regulation, serves as a key mechanism linking maltreatment and substance use. We used a developmental cascade model with a dimensional approach to test the direct and indirect effects of neglect and abuse on substance use during adolescence and across the transition from adolescence to young adulthood.

Method: The present study includes 167 adolescents (53% male; mean age = 14 years at time 1) who provided data on delay discounting and cigarette, alcohol, and cannabis use frequency across 5 time points (ages 14-18, approximately 1 year between assessments). At ages 18 to 19, adolescents provided reports of their exposure to maltreatment during adolescence (across ages 13-17).

Results: Using structural equation modeling, developmental cascade models tested whether the effects of neglect and abuse on cigarette, alcohol, and cannabis use were mediated through delay discounting over time. Our results indicate that adolescents exposed to neglect may be especially vulnerable to cannabis use over time via elevated delay discounting. Neglect experiences predicted greater cigarette use over time.

Conclusion: These findings underscore the critical role of delay discounting in prevention and intervention efforts aimed at mitigating the risks of substance use development among young people who have been exposed to neglect during adolescence.

Plain language summary: This study used a developmental cascade model to examine whether delay discounting (ie, choosing smaller, immediate rewards over larger rewards with a delay) may be a mechanism linking maltreatment and substance use (cigarette, alcohol, and cannabis use) during adolescence. One hundred sixty-seven adolescents aged 13-14 were assessed in a computerized delay discounting task across 5 time points over 6 years. Results indicated that adolescent neglect was associated with higher delay discounting, which in turn was associated with increased substance use, especially cannabis use. These findings highlight delay discounting as a potential intervention target to mitigate substance use risk in adolescents who have experienced neglect.

Key words: neglect; abuse; delay discounting; substance use; adolescence

JAACAP Open 2024;2(4):239-249.

Maltreatment is a pervasive, global problem[1] known to have cascading effects across development.[2] Maltreatment is both multidimensional and heterogeneous, including neglect, emotional maltreatment, physical abuse, and sexual abuse,[3] and these subtypes involve acts of omission (ie, reflecting the absence of caregiving necessary to minimally meet children's needs) or commission (ie, reflecting harmful behaviors or threat of harm by caregivers enacted upon children[4]). According to the Dimensional Model of Adversity and Psychopathology, these different conceptualizations may be distinguished by the nature of experiences that underlie them: deprivation and threat. The dimension of deprivation involves acts of omission such as neglect and poverty, whereas the dimension of threat involves acts of commission such as physical abuse, sexual abuse, and interpersonal abuse. Deprivation and threat are suggested to differentially affect neurodevelopment and behavior through unique mechanisms.[5]

Maltreatment has been found to affect competencies required for resolving developmentally relevant challenges,[6,7] which may have cascading consequences for later substance use. Delay discounting—the preference for immediate over delayed rewards—is an important component of self-regulation[8] that may be a key pathway from maltreatment exposure to substance use. Associations between delay discounting and substance initiation and use are robust,[9] and increases in delay discounting across adolescence may signify elevated risk of pathological substance use.[10]

Research examining the associations between maltreatment and delay discounting is scant. One cross-sectional

study demonstrated an indirect effect of cumulative maltreatment on high cigarette use among adults, via high delay discounting.[11] However, this study was limited in capturing the multidimensional nature of maltreatment and the developmental nature of maltreatment effects unfolding over time. Hence, the current study presents a longitudinal investigation of developmental pathways from neglect and abuse to delay discounting and substance use during adolescence and across the transition from adolescence to young adulthood, when both delay discounting and substance use are known to peak.[12] We focus on maltreatment experienced during adolescence, given the evidence that maltreatment occurring during adolescence is more strongly associated with later delinquency and substance use in young adulthood than maltreatment during childhood.[13,14] Furthermore, adolescence is a critical period of protracted development of prefrontal functioning[15] that underlies delay discounting decision making.[16]

Maltreatment exposure during adolescence is associated with concurrent and later substance use. Although some prior research did not examine neglect and abuse in the same study, exposure to neglect during adolescence was linked to cigarette, alcohol, and cannabis use in young adulthood,[13] and physical abuse during adolescence predicted increases in alcohol and cannabis use.[17] Other prior research investigating both neglect and abuse within the same study further indicated more consistent effects of neglect than abuse on young adult substance use.[18,19]

Within the addiction literature, delay discounting has been shown to be a trans-disease process that explains a range of chronic health problems including substance use.[20] Developmentally, there is evidence that delay discounting prospectively predicts the initiation and progression of substance use in adolescence.[21,22] Although research examining the associations between maltreatment and delay discounting is limited, a theoretical account is provided by the Competing Neurobehavioral Decision Systems (CNDS) theory, suggesting that the subcortical regions associated with the impulsive system and the prefrontal and parietal regions associated with the executive system in tandem contribute to delay-discounting decision making.[16] Maltreatment exposure may disrupt the neurobehavioral systems implicated by CNDS theory to impair decision making, such that dysregulation of these competing impulsive and executive systems facilitates the preference for smaller, immediate rewards over larger rewards with a temporal delay. On the 1 hand, deprivation, often experienced with physical neglect, has been observed to impede cognitive functioning and lead to more myopic decision making.[23] The neurobiological processes undergirding this association may be explained by research demonstrating that deprivation alters executive functioning.[5] Impairments to the executive system may lead to dysregulation of competing decision systems and bias decision making toward greater delay discounting.[24] On the other hand, threat, often experienced with abuse, may increase delay discounting via its effects on the impulsive system involved in emotional learning and dysregulation.[25] Developmental trajectories of adolescent brain development[15] suggest that the impulsive system develops earlier than the executive system of the CNDS. Thus, impairments from neglect may be especially detrimental during adolescence when development associated with the executive system is critical.

The Present Study

By using a developmental cascade approach and multiple time-point data, the present study aimed to elucidate the predictive associations of both neglect and abuse with delay discounting and substance use as they unfold during adolescence and across the transition from adolescence to young adulthood ("young adulthood" hereafter). A cross-lagged panel mediation model was used to examine developmental processes with maltreatment as a predictor and delay discounting as a mediator linking maltreatment to substance use. The objectives of this study were 3-fold: (1) to estimate the direct effects of neglect and abuse on substance use; (2) to estimate the direct effects of neglect and abuse on delay discounting; and (3) to examine delay discounting as a mediating process between neglect and abuse during adolescence and substance use throughout adolescence and into young adulthood.

METHOD

Participants

The study sample was drawn from a longitudinal study of 167 adolescents who were between the ages of 13 and 14 at time 1 (mean [SD]) = 14.07 [0.53] years of age at time 1, mean [SD] = 15.05 [0.54] at time 2, mean [SD] = 16.07 [0.56] at time 3, mean [SD] = 17.01 [0.55] at time 4, mean [SD] = 18.39 [0.67] at time 5). The study was approved by the university's Institutional Review Board. Adolescents over the age of 18 provided written consent for their participation. For adolescents under the age of 18, primary caregivers provided written consent and adolescents provided written assent for their participation. The median annual family income ranged between $35,000 and $49,999. The primary caregivers consisted of 137 mothers, 21 fathers, and 9 others. Table 1 provides sample characteristics. Data collection was done from 2014 to 2019. Inclusion criteria included being

TABLE 1 Summary of Sociodemographic Characteristics

Characteristic	n	%
Adolescent sex		
Male	88	53
Female	79	47
Adolescent race		
White	130	78
Black	23	14
American Indian/Alaskan Native	2	1
Asian	1	1
More than 1 race	11	6
Adolescent ethnicity		
Latinx	4	2
Not Latinx	163	98
Parent education		
Without HS diploma	3	2
HS graduate (including GED)	54	32
Some college education	40	24
4-Year degree or more	70	42

GED = graduate equivalence degree; HS = high school.

between the ages of 13 and 14 at the time of recruitment and being able to see the computer display clearly with corrected vision. Exclusion criteria included claustrophobia, a history of head injury that resulted in a loss of consciousness for more than 10 minutes, orthodontia impairing image acquisition, and any other contraindications to magnetic resonance imaging because the larger study involved brain imaging. A total of 157 adolescents were recruited for their participation in the study at time 1, and an additional 10 adolescents were recruited for participation at time 2. Of a total sample of 167, 157 adolescents participated at time 1, 150 at time 2, 147 at time 3, 149 at time 4, and 126 at time 5.

Measures

Maltreatment. The Maltreatment and Abuse Chronology of Exposure (MACE)[26] scale was used to retrospectively evaluate neglect and abuse during adolescence. At times 5 and 6, young adults reported the ages at which they experienced neglect and abuse from age 13 to age 18. We computed a maltreatment severity composite (the maximum scores reported across times 5 and 6) using the guidelines of Teicher and Parigger.[26] Subscale scores were rescaled for a total possible scale score of 10 (with higher scores indicating greater maltreatment). The index of maltreatment of omission, that is, neglect, was calculated using an average of physical neglect (5 items) and emotional neglect (5 items). The index of maltreatment of commission, that is, abuse, was calculated using an average of parental verbal abuse (4 items), parental nonverbal abuse (6 items), parental physical maltreatment (6 items), and the familial and nonfamilial sexual abuse (7 items) subscales. Prior research demonstrates good reliability for each of the maltreatment subscales, and MACE has shown evidence of good validity.[26]

Delay Discounting. Adolescents' reward-dependent decision making was assessed using a computerized delay discounting task across 5 time points. Adolescents were given a series of hypothetical decisions in which they made intertemporal choices between immediate monetary rewards and larger monetary rewards ($1,000) with a delay. Individual discounting rates were computed using hyperbolic k values[27] and 4 delays (1 day, 1 week, 1 month, and 1 year). Nonsystematic discounting cases were excluded for violating the assumption of monotonic decreases in discounting function, and delay discounting rates at all time points were log transformed prior to estimating the model per Johnson and Bickel.[28] The model used here for delay discounting was developed by Mazur,[27] in which the association between reinforcing value and delay was found to be approximated by a hyperbola. Furthermore, this task has commonly been used in research on substance use disorders.[29] Specifically, it has been shown that the choice dynamic from the hyperbolic discounting model was reflected in the pattern of decisions made by many individuals with substance abuse problems.[29]

Substance Use. We used the maximum of adolescents' reports of 3 of the most commonly used substances (ie, cigarette, alcohol, and cannabis) at each time point. Adolescents were asked to report the frequency of their substance use (cigarette, alcohol, and cannabis use),[30] with responses ranging from 1 ("never used") to 6 ("usually use every day"). Higher scores were indicative of greater use.

Plan of Analysis

We used structural equation modeling (SEM) to examine longitudinal associations among maltreatment, delay discounting, and substance use across adolescence and into young adulthood. To test the hypothesized indirect pathways from the predictor (ie, maltreatment) to the mediator (ie, delay discounting) and to the outcome (ie, substance use), we used the model indirect command in *Mplus*[31] to conduct bias-corrected bootstrapping tests of indirect effects using the 95% confidence interval.[32] We used maximum likelihood with robust standard errors (MLR), given that the substance use variables were slightly skewed and MLR is robust to non-normality.[33]

RESULTS

Correlations and descriptive statistics for all study variables are presented in Table 2. The rates of endorsement of abuse,

TABLE 2 Descriptive Statistics and Bivariate Correlations of Neglect, Abuse, Delay Discounting, Cigarette Use, Alcohol Use, and Cannabis Use

Part 1

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Mean	SD
1. Neglect T1[a]															1.81	2.35
2. Neglect T2[b]	0.98*														1.72	2.33
3. Neglect T3[b]	0.95*	0.97*													1.67	2.27
4. Neglect T4[d]	0.93*	0.94*	0.98*												1.66	2.24
5. Neglect T5[e]	0.92*	0.93*	0.97*	0.99*											1.67	2.23
6. Abuse T1	0.29*	0.28*	0.19*	0.18*	0.21*										1.16	1.64
7. Abuse T2	0.26*	0.26*	0.20*	0.19*	0.22*	0.95*									1.13	1.55
8. Abuse T3	0.26*	0.25*	0.20*	0.19*	0.22*	0.91*	0.96*								1.15	1.48
9. Abuse T4	0.25*	0.22*	0.17	0.18*	0.19*	0.87*	0.91*	0.95*							1.16	1.54
10. Abuse T5	0.17	0.14	0.08	0.12	0.12	0.77*	0.79*	0.85*	0.93*						1.06	1.38
11. DD T1	0.09	0.08	0.07	0.05	0.10	0.11	0.04	0.03	−0.05	0.06					−2.38	1.25
12. DD T2	0.39*	0.39*	0.37*	0.36*	0.36*	0.13	0.04	0.04	−0.03	0.07	0.53*				−2.51	1.16
13. DD T3	0.21*	0.21*	0.22*	0.20*	0.22*	0.13	0.02	0.02	−0.04	0.08	0.43*	0.67*			−2.77	1.02
14. DD T4	0.27*	0.28*	0.30*	0.29*	0.30*	0.10	−0.03	−0.02	−0.09	0.07	0.43*	0.63*	0.60*		−2.92	1.03
15. DD T5	0.38*	0.36*	0.33*	0.30*	0.32*	0.11	−0.08	−0.06	−0.13	0.10	0.55*	0.50*	0.54*	0.60*	−2.60	0.61

Part 2

Variable	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
1. Neglect T1	0.21*	0.15	0.21*	0.14	0.09	0.26*	0.15	0.16	0.23*	0.26*	0.16	0.21*	0.16	0.01	0.31*
2. Neglect T2	0.20*	0.15	0.21*	0.14	0.11	0.25*	0.15	0.16	0.23*	0.28*	0.16	0.22*	0.19*	0.01	0.30*
3. Neglect T3	0.22*	0.11	0.16	0.13	0.11	0.20*	0.13	0.14	0.21*	0.25*	0.15	0.19*	0.19*	−0.02	0.26*
4. Neglect T4	0.23*	0.12	0.15	0.13	0.13	0.18*	0.14	0.14	0.21*	0.23*	0.14	0.18*	0.18	−0.03	0.20*
5. Neglect T5	0.24*	0.10	0.15	0.13	0.12	0.18*	0.13	0.12	0.19*	0.20*	0.14	0.18*	0.17	−0.04	0.21*
6. Abuse T1	−0.10	−0.01	0.03	−0.06	0.04	0.08	0.04	0.09	0.00	0.07	0.13	0.12	−0.06	0.08	0.15
7. Abuse T2	−0.09	−0.04	−0.02	−0.10	0.04	0.03	−0.03	0.10	−0.01	0.01	0.13	0.11	−0.09	0.08	0.13
8. Abuse T3	−0.07	−0.06	−0.02	−0.09	0.04	0.03	−0.03	0.10	−0.05	0.00	0.13	0.06	−0.10	0.09	0.11
9. Abuse T4	−0.04	−0.02	−0.02	−0.04	0.06	0.03	0.04	0.10	−0.05	0.04	0.13	0.04	−0.06	0.11	0.08
10. Abuse T5	−0.05	−0.04	−0.06	−0.04	0.02	0.00	0.05	0.09	−0.04	0.01	0.07	−0.04	−0.08	0.13	−0.00
11. DD T1	0.06	0.01	−0.02	−0.02	0.06	0.01	0.02	0.06	0.03	0.06	0.12	0.12	0.04	0.07	0.22*
12. DD T2	0.03	0.07	−0.06	0.10	0.16	0.06	0.21*	0.21*	0.25*	0.23*	0.13	0.32*	0.16	0.09	0.27*
13. DD T3	0.06	0.02	−0.01	0.09	0.15	0.02	0.16	0.06	0.08	0.11	0.08	0.17	0.15	0.10	0.20
14. DD T4	0.04	0.06	−0.05	0.14	0.22*	−0.00	0.13	0.16	0.15	0.19*	0.23*	0.15	0.10	0.09	0.19
15. DD T5	0.12	0.04	0.06	0.03	0.05	0.08	0.11	0.10	0.10	0.13	0.12	0.05	0.02	0.07	0.10

Part 3

Variable	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	Mean	SD
16. Cig T1															1.63	0.94
17. Alc T1	0.48*														2.08	1.39

(*continued*)

TABLE 2 Continued

Part 3

Variable	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	Mean	SD
18. Can T1	0.59*	0.50*													2.19	1.22
19. Cig T2	0.55*	0.56*	0.42*												2.68	1.39
20. Alc T2	0.24*	0.58*	0.17*	0.49*											3.45	1.36
21. Can T2	0.41*	0.48*	0.63*	0.51*	0.39*										0.00	0.74
22. Cig T3	0.58*	0.46*	0.41*	0.72*	0.36*	0.37*									0.00	0.75
23. Alc T3	0.21*	0.51*	0.24*	0.30*	0.66*	0.28*	0.25*								1.91	1.02
24. Can T3	0.37*	0.44*	0.39*	0.45*	0.45*	0.68*	0.36*	0.43*							1.59	1.11
25. Cig T4	0.36*	0.41*	0.30*	0.46*	0.36*	0.42*	0.65*	0.29*	0.45*						1.59	0.98
26. Alc T4	0.15	0.42*	0.16	0.29*	0.59*	0.18*	0.28*	0.72*	0.32*	0.42*					2.32	1.06
27. Can T4	0.25*	0.46*	0.37*	0.42*	0.45*	0.52*	0.42*	0.46*	0.74*	0.59*	0.47*				2.03	1.48
28. Cig T5	0.36*	0.36*	0.31*	0.47*	0.35*	0.28*	0.58*	0.33*	0.44*	0.75*	0.41*	0.58*			1.87	1.30
29. Alc T5	0.00	0.00	0.03	0.18	0.41*	0.11	0.25*	0.48*	0.27*	0.33*	0.60*	0.30*	0.34*		3.02	1.12
30. Can T5	0.31*	0.31*	0.38*	0.35*	0.37*	0.46*	0.38*	0.32*	0.51*	0.53*	0.53*	0.69*	0.51*	0.46*	2.60	1.63

Note: *Alc = alcohol use; Can = cannabis use; Cig = cigarette use; DD = delay discounting; T = time.*
**p ≤ .05.*

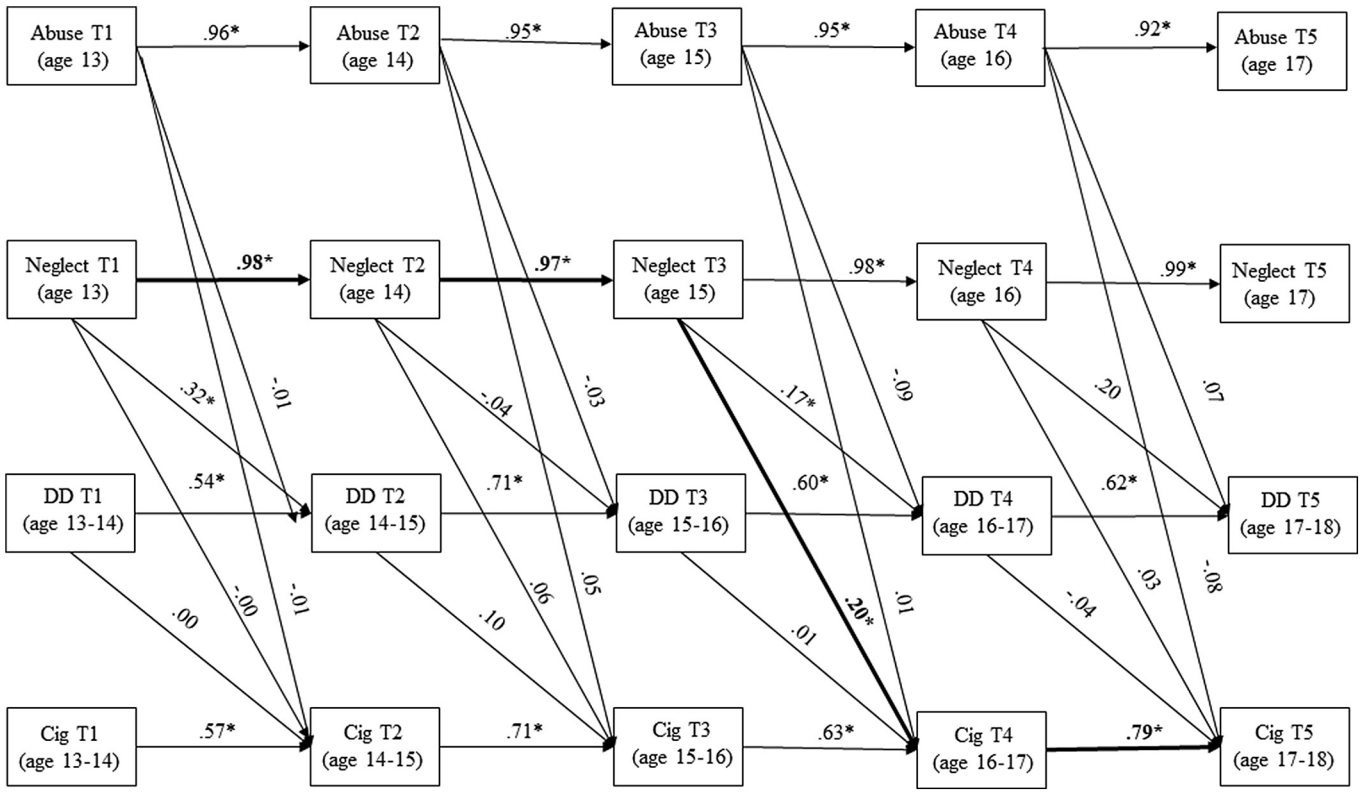
neglect, and substance use for each time are presented in Tables S1 and S2, available online. We used multivariate general linear modeling (GLM) to test for the effects of demographic covariates on the model with neglect and abuse, delay discounting, and substance use study variables, and found no significant effects of age (p = .37), race (p = .51; White vs other racial categories, ie, Black, American Indian/Native American, Asian, or more than 1 race), or sex (p = .62) on study variables. We used full information maximum likelihood (FIML)[34] for handling cases with missing data. FIML allows all available data to be included regardless of the pattern of missingness, and FIML estimates are generally superior to those obtained with listwise deletion or other ad hoc methods, even when the missing at random (MAR) assumption is not fully met.[35]

Mediation Models With Neglect, Abuse, Delay Discounting, and Substance Use

Cigarette Use. The model with neglect, abuse, delay discounting, and cigarette use demonstrated acceptable model fits (χ^2 = 218.04, df = 124, p <. 001, root mean square error of approximation [RMSEA] = 0.07, comparative fit index [CFI] = 0.98). As can be seen in Figure 1, the autoregressive effects of neglect, abuse, delay discounting, and cigarette use were significant. Neglect at time 1 significantly predicted delay discounting at time 2 (controlling for the effects of delay discounting at time 1). Specifically, greater neglect at time 1 was associated with greater delay discounting at time 2. In addition, neglect at time 3 significantly predicted delay discounting at time 4 (controlling for the earlier effects of delay discounting), such that greater neglect was associated with greater delay discounting. In addition, neglect at time 3 significantly predicted cigarette use at time 4 (controlling for the earlier effects of cigarette use), such that greater neglect was associated with greater cigarette use. However, abuse did not significantly predict delay discounting or cigarette use at any time point, and delay discounting did not significantly predict cigarette use at any time point. There was a significant indirect effect from neglect at time 1 to cigarette use at time 5 via neglect at time 2 and time 3 (controlling for earlier effects of neglect) and cigarette use at time 4 (controlling for earlier effects of cigarette use), such that greater neglect was associated with greater cigarette use (95% CI = 0.03-0.30). However, delay discounting did not mediate this effect.

Alcohol Use. Results from the model with neglect and abuse, delay discounting, and alcohol use demonstrated acceptable model fits (χ^2 = 199.65, df = 124, p < .001, RMSEA = 0.06, CFI = 0.98). As can be seen in Figure 2,

FIGURE 1 A Developmental Cascade Model of Neglect, Abuse, Delay Discounting, and Cigarette Use



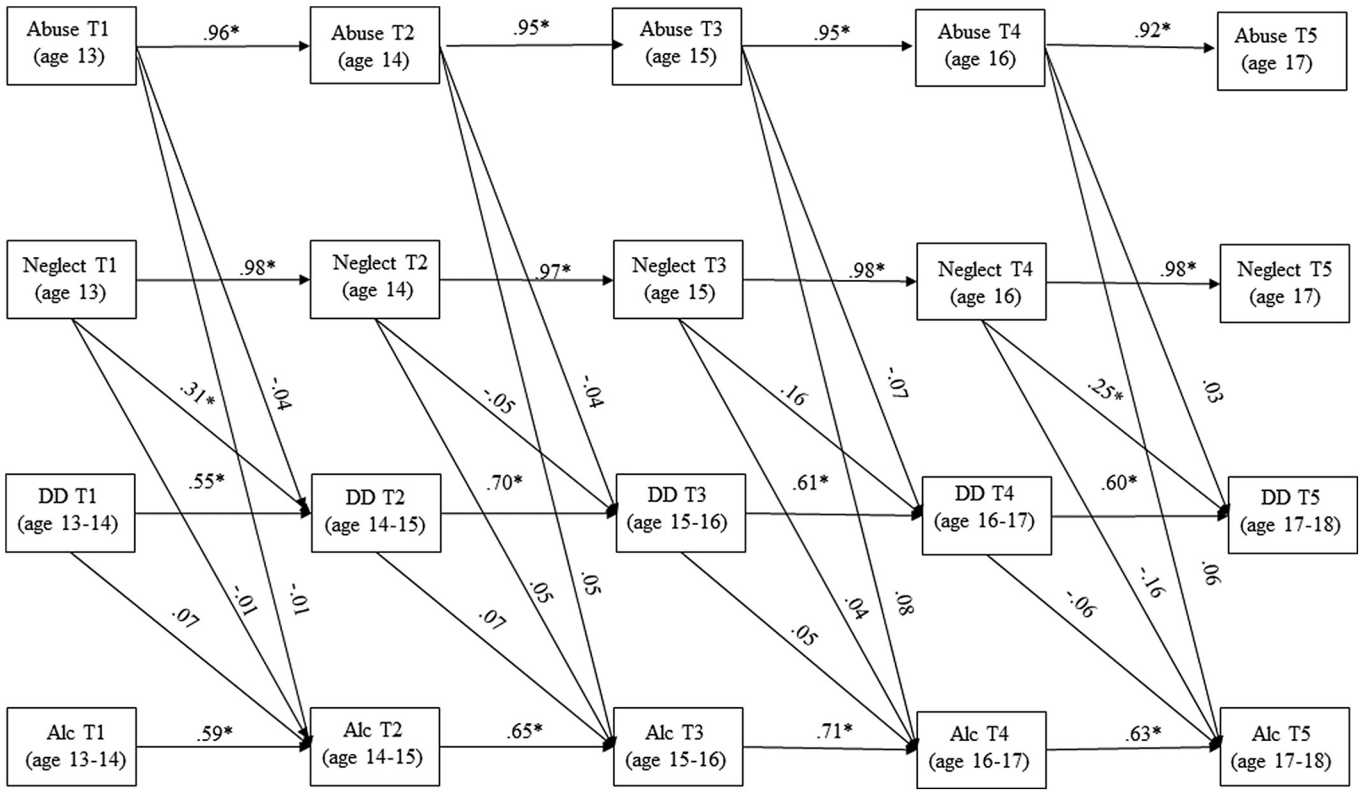
Note: *Significant indirect effects pathway are shown in boldface type. Standardized estimates are reported in the figure. Concurrent correlations were estimated but not reported in the figure for clarity of presentation (r = –0.13 to .33 for abuse ↔ neglect; r = –0.11 to 0.01 for abuse ↔ DD; r = –0.22 to 0.03 for abuse ↔ cigarette use; r = –.01 to 0.20 for neglect ↔ DD; r = –0.13 to 0.19 for neglect ↔ cigarette use; r = –0.09 to 0.22 for DD ↔ cigarette use). Cig = cigarette use; DD = delay discounting; T = time.*
**p < .05*

the autoregressive effects of neglect, abuse, delay discounting, and alcohol use were significant. Neglect at time 1 significantly predicted delay discounting at time 2 (controlling for the effects of delay discounting at time 1). Specifically, greater neglect at time 1 was associated with greater delay discounting at time 2. In addition, neglect at time 3 significantly predicted delay discounting at time 4 (controlling for the earlier effects of delay discounting), such that greater neglect was associated with greater delay discounting. However, delay discounting did not significantly predict alcohol use at any time point. Abuse did not significantly predict delay discounting or alcohol use at any time point. There were no significant indirect effects from neglect or abuse at time 1 to alcohol use at time 5.

Cannabis Use. Results from the model with neglect and abuse, delay discounting, and cannabis use demonstrated acceptable model fits ($\chi^2 = 218.47$, $df = 124$, $p < .001$, RMSEA = 0.07, CFI = 0.98). As can be seen in Figure 3, the autoregressive effects of neglect, abuse, delay discounting, and cannabis use were significant. Neglect at time 1 significantly predicted delay discounting at time 2 (controlling for the effects of delay discounting at time 1). Specifically, greater neglect at time 1 was associated with greater delay discounting at time 2. In addition, neglect at time 3 significantly predicted delay discounting at time 4 (controlling for the effects of delay discounting), such that greater neglect was associated with greater delay discounting. Delay discounting at time 2 significantly predicted cannabis use at time 3 (controlling for the earlier effects of cannabis use), such that greater delay discounting was associated with greater cannabis use. However, abuse did not significantly predict delay discounting at any time point or cannabis use at any time point.

The indirect effect from time 1 neglect to time 2 delay discounting to time 3 cannabis use to time 4 cannabis use to time 5 cannabis use was significant (95% CI = 0.01-0.05). Neglect at time 1 significantly predicted subsequent delay discounting at time 2 (controlling for the effects of delay discounting at time 1), which significantly predicted subsequent cannabis use at times 3, 4, and 5 (controlling for the earlier effects of cannabis use). Specifically, greater

FIGURE 2 A Developmental Cascade Model of Neglect, Abuse, Delay Discounting, and Alcohol Use



Note: *Standardized estimates are reported in the figure. Concurrent correlations were estimated but not reported in the figure for clarity of presentation (r = –0.13 to 0.32 for abuse ↔ neglect; r = –0.11 to 0.03 for abuse ↔ DD; r = –0.02 to 0.14 for abuse ↔ alcohol use; r = –0.02 to 0.20 for neglect ↔ DD; r = –0.17 to 0.14 for neglect ↔ alcohol use; r = –0.16 to 0.25 for DD ↔ alcohol use). Alc = alcohol use; DD = delay discounting; T = time.*
*p < .05.

neglect at time 1 was associated with greater delay discounting at time 2, which was associated with greater cannabis use at time 3, which then was associated with greater cannabis use at time 4, which was associated with greater cannabis use at time 5.

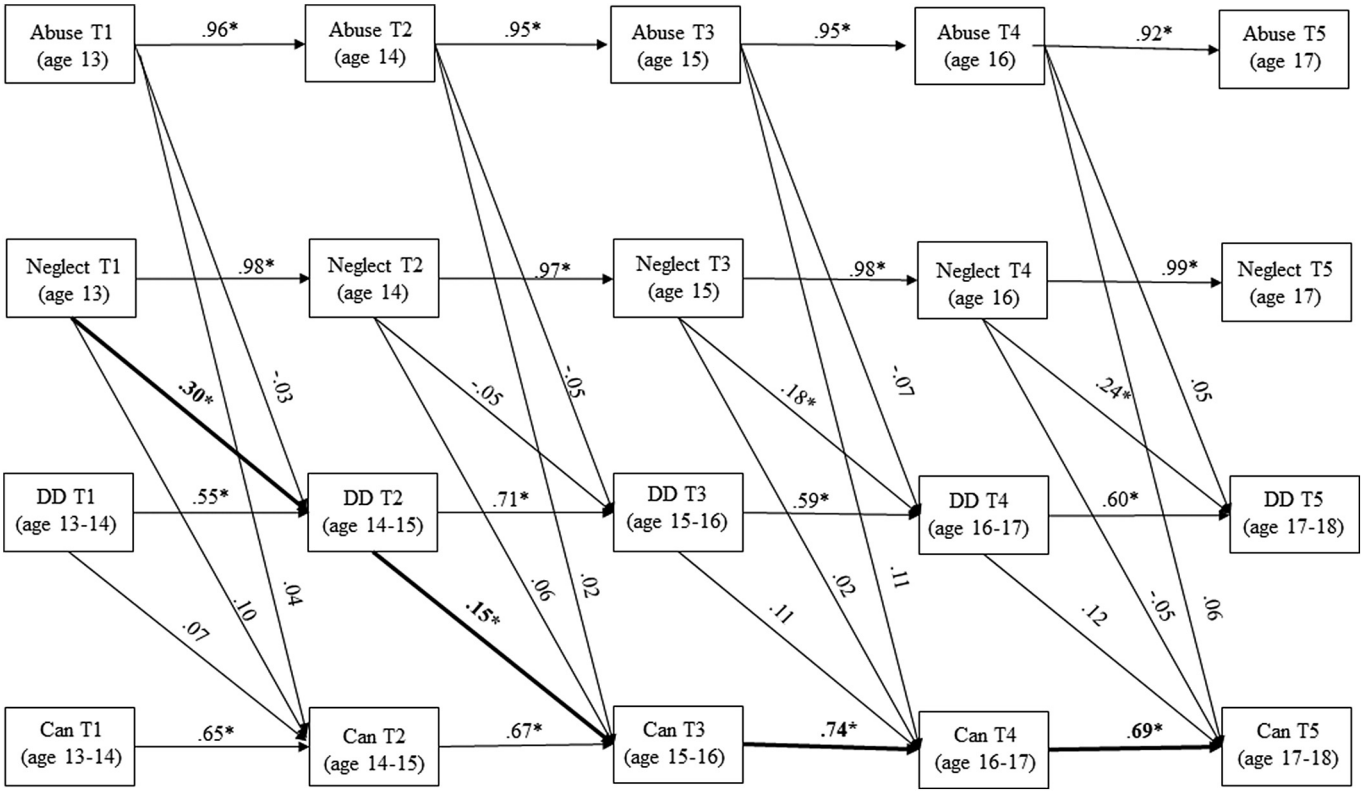
DISCUSSION

Extant research demonstrates the link between maltreatment and substance use, yet the underlying mechanisms are not clearly understood. We tested the Dimensional Model of Adversity and Psychopathology to examine the effects of maltreatment of omission (neglect) and commission (abuse) subtypes occurring during adolescence,[3] which are characterized by the unique nature of experiences that underlie them: deprivation and threat, respectively.[25] Our results suggest that deprivation (neglect) experiences, rather than threat (abuse) experiences, elevate vulnerability to substance use directly and indirectly through delay discounting during adolescence.

There is a dearth of literature isolating the effects of exposure to maltreatment during adolescence on substance use. However, 1 study examined the effects of adolescent exposure to neglect and abuse on the number of substances used, including alcohol, cannabis, and hard drugs.[18] Consistent with the significant effects of neglect on cigarette use found in the present study, this previous study found that the neglect subdimensions, including inadequate support and monitoring from parents/caregivers during adolescence, were associated with substance use in young adulthood; however, abuse subdimensions (ie, physical, sexual, and emotional abuse) did not predict substance use behaviors. Another study indicated that greater neglect and sexual abuse, but not physical abuse, during adolescence were associated with greater illicit drug use (ranging from cannabis to heroin) during young adulthood.[19] The present study advances our understanding of the developmental processes that link maltreatment experiences during adolescence and substance use by demonstrating significant direct effects of neglect on cigarette use and significant indirect effects of neglect on cannabis use via delay discounting.

Supporting the theoretical perspectives positing that differing dimensions of maltreatment have unique

FIGURE 3 A Developmental Cascade Model of Neglect, Abuse, Delay Discounting, and Cannabis Use



Note: *Significant indirect effects pathway are shown in boldface type. Standardized estimates are reported in the figure. Concurrent correlations were estimated but not reported in the figure for clarity of presentation (r = –0.13 to 0.32 for abuse ↔ neglect; r = –0.10 to 0.03 for abuse ↔ DD; r = –0.18 to 0.02 for abuse ↔ cannabis use; r = –0.03 to 0.20 for neglect ↔ DD; r = –0.13 to 0.19 for neglect ↔ cannabis use; r = –0.10 to 0.08 for DD ↔ cannabis use). Can = cannabis use; DD = delay discounting; T = time.*

*p < .05.

effects,[36,37] our findings suggest that experiences of neglect, rather than abuse, render young people more susceptible to greater delay discounting. Specifically, greater exposure to neglect (representing caregivers' failure to meet physical and emotional needs) occurring during early adolescence was related to biased decision making during middle adolescence, shown by the heightened preference for smaller, sooner rewards over larger, later rewards. Prior research has demonstrated that scarcity impairs cognitive functioning[23] by altering frontoparietal executive functioning.[38] These impairments to the executive system may lead to dysregulation of competing decision systems that bias decision making preferences toward myopic over reflective decisions.[23] Drawing from the Dimensional Model of Adversity and Psychopathology,[5] we expected that maltreatment experiences would predict delay-discounting decision making because threat (abuse) would affect the impulsive system, whereas deprivation (neglect) would affect the executive system of the CNDS.[16] Our results suggest that deprivation exerts stronger effects than threat on delay discounting. One explanation may be the nature of adolescent brain development: unlike the limbic brain system, which matures rapidly and peaks around middle adolescence, the prefrontal brain system matures at a slower rate throughout adolescence,[15] thus leaving it with a prolonged window for vulnerability to deprivation effects.

Neglect also represents financial and material scarcity in that children experiencing physical neglect often do not have access to nutrition, clothing, hygiene, supervision, and medical attention from their caregivers.[39] Furthermore, children who experience emotional neglect experience less quality time with caregivers and receive less emotional support from them. The unmet physical and emotional needs characteristic of neglect may impose cognitive strain,[23] biasing the preference for smaller, immediate rewards over long-term gains.[29] Furthermore, our results identified delay discounting as a mediating factor that explains the link between neglect and cannabis use over time. The finding has important public health implications, given the dramatic increases in recreational cannabis use, with

cannabis use by young adults at the highest historic levels.[40] Our findings suggest that interventions targeting delay discounting during adolescence may prevent the onset or deter the progression of cannabis use during adolescence and into young adulthood. Research demonstrates that delay discounting is profoundly context dependent and changeable, and it can be reduced with mindfulness-based trainings and with future-oriented manipulations.[41,42] It is promising that, despite the deleterious effects of neglect on cannabis use, delay discounting behavioral interventions may be capable of mitigating these risks.

Extant literature suggests a significant association between delay discounting and addictive behaviors in general.[43] However, research examining the associations among delay discounting and cigarette, alcohol, and cannabis use in a non-clinical sample of adolescents is limited. Our data showed some significant correlations between delay discounting and the frequency of cigarette, alcohol, and cannabis use concurrently and longitudinally (Table 2). However, systematic examination of developmental cascading effects of maltreatment on substance use, while controlling for the autoregressive effects of previous levels, revealed more prominent longitudinal associations between delay discounting and cannabis use than cigarette and alcohol use. Similarly, prior findings from a study of delay discounting among young adults who frequently use cannabis suggest that heightened delay discounting is associated with cannabis dependence.[44] Another study examining delay discounting among a non-clinical sample of college students demonstrated that greater delay discounting was associated with earlier initiation of cannabis use.[45] As such, our finding extends prior research to highlight the importance of delay discounting in predicting the initiation and progression of cannabis use among adolescents and young adults.

Young people exposed to neglect may be motivated to use cannabis as a coping mechanism. Furthermore, motives to use substances may vary by substance type and maltreatment history. One study examining the motives behind cannabis use in young adults found that those exposed to maltreatment are more likely to experience deficits in emotion regulation and tend to use cannabis as a coping strategy (ie, "to forget your worries"). In turn, coping motives significantly mediated the association between maltreatment and cannabis problems.[46] Taken with the present study findings, adolescents who have experienced neglect may favor cannabis as a coping mechanism over other commonly used substances, given its psychoactive effects, and those individuals with delay discounting impairments may be especially vulnerable.

The findings of the present study should be interpreted while considering its limitations. First, several of the study variables involved self-report (eg, maltreatment, cigarette, alcohol, and cannabis use). Although self-report seems to be appropriate for assessing sensitive and private information such as maltreatment experiences and substance use behaviors, future research would be strengthened by using additional informants to help mitigate measurement bias. Second, neglect and abuse were assessed retrospectively and may have been subject to recall bias or to stigma resulting in underreporting. However, prior research indicates that both self-report and case records capture unique information about maltreatment and demonstrates high concordance between self-reported neglect and emotional abuse and case records.[47] Additionally, self-reported maltreatment is a strong predictor of later psychopathology.[48] Finally, although the majority of adolescents in the current sample were White, this is representative of the area in which the data were collected. The current sample represents Appalachian adolescents from economically marginalized backgrounds, a wide range of socioeconomic statuses, and higher rates of maltreatment than the national average.[49] However, these findings should be replicated in other samples with more diverse demographic backgrounds (including race and ethnicity) to evaluate the generalizability.

Although the current study focused on delay discounting, research has evidenced other mechanisms such as peer relationships and educational achievement, as mediators between maltreatment and substance use that warrant future research.[50] In addition, given that the onset of maltreatment exposure may precede adolescence, future work should examine whether there are differences between those who were exposed to maltreatment prior to adolescence and those who were not, aiming to elucidate the cumulative effects of maltreatment.

The present study makes a valuable contribution to the extant literature on adolescent substance use. The results revealed the developmental processes whereby maltreatment occurring during adolescence is related to the development of delay discounting and substance use over time. Our findings suggest that neglect and delay discounting confer risk for cannabis use during adolescence and into young adulthood. The significant mediation effects of delay discounting further suggest that preventive efforts and interventions intended to minimize delay discounting among adolescents who have experienced neglect may deter later cannabis use.

CRediT authorship contribution statement

Kristin M. Peviani: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Claudia Clinchard:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis.

Warren K. Bickel: Writing – review & editing, Investigation, Conceptualization. **Brooks Casas:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Jungmeen Kim-Spoon:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Conceptualization.

This article is part of a special series devoted to the subject of substance use, featuring topics relevant to child and adolescent behavioral health, including genetics, neuroscience, epidemiology, measurement, prevention, and treatment. This special series is edited by Guest Editor Kevin M. Gray, MD, *JAACAP Open* Deputy Editor Kara S. Bagot, MD, *JAACAP* Deputy Editor Mary Fristad, PhD, ABPP, *JAACAP* and *JAACAP Open* Associate Editor Robert R. Althoff, MD, PhD, *JAACAP Open* Editor Manpreet K. Singh, MD, MS, and Editor-in-Chief Douglas K. Novins, MD.

Accepted March 6, 2024.

This article was reviewed under and accepted by Ad Hoc Editor Kevin M. Gray, MD.

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This work was supported by the National Institute on Drug Abuse grant (R01 DA036017 to Jungmeen Kim-Spoon and Brooks Casas).

The research was performed with permission from the Virginia Tech Institutional Review Board.

The authors thank the former and current members of the JK Lifespan Development Lab at Virginia Tech for their help with data collection. The authors are grateful to the adolescents and parents who participated in the study.

Disclosure: Drs. Peviani, Bickel, Casas, and Kim-Spoon and Ms. Clinchard have reported no biomedical financial interests or potential conflicts of interest.

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https://doi.org/10.1016/j.jaacop.2024.02.003

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