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An Examination of Reward Probability as a Mediator of the Relationship between Trauma-Exposed Individuals and Cannabis and Alcohol Use

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An Examination of Reward Probability as a Mediator of the Relationship between Trauma-Exposed Individuals and Cannabis and Alcohol Use

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Abstract

Trauma-exposure and Posttraumatic stress (PTS) symptoms are frequently comorbid with problematic cannabis and alcohol use which is high among college students. Emerging research suggests the relationship between trauma and drug and alcohol use is due to the reinforcing effects of substances like alcohol and cannabis. Researchers have looked at behavioral economic theories of reward/reinforcement to see how reward deprivation plays a role in trauma and substance use. Reward deprivation associates with a person's ability to experience reward and availability of reward in the environment, as measured by the Reward Probability Index scales: *Reward Probability* and *Environmental suppression* (RPI; Carvalho et al., 2011). Based on these theories, substance use is connected to deficits in rewards in a substance-free environment. Research has found that low environmental rewards mediate the relationship between trauma and alcohol use problems (Acuff et al., 2018), but to the author's knowledge, no research has examined whether low environmental rewards mediate the link between trauma and cannabis use. The present cross-sectional study tested the hypothesis that reward deprivation, measured by the RPI, mediates the relationship between trauma/PTS and alcohol/cannabis use in college students directly exposed to trauma. Environmental suppression indirectly accounted for 58% of the relationship between PTS and cannabis use. Reward probability indirectly accounted for 11% of the relationship between trauma exposure and cannabis use. Environmental suppression indirectly accounted for 39% of the relationship between trauma exposure and cannabis use. Thus the RPI scales were able to explain part of the relationship between trauma/PTS and cannabis use. Results provide support for behavioral economic models of addiction and utility of the RPI in addiction research and treatment suggesting access to and the experience of reward may be beneficial in the treatment of trauma and substance use.

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Introduction

Substance Use Among College Students

Use of alcohol and cannabis is common among college students with an estimated 76% of students endorsing past-year alcohol use and 34% reporting past-year cannabis use (Bolin, Pate & McClintock, 2017). Per the 2019 National College Health Assessment, 58.4% of college students endorsed past-month alcohol use and 22.1% endorsed past-month cannabis use. Additionally, 5.9% of students report daily cannabis use, and 4.3% of students reporting daily alcohol use (Bolin et al., 2017). Daily cannabis use among college students has nearly doubled from 2.8% to 4.9%. over the last ten years (National Institute for Drug Abuse [NIDA], 2017.)

Substance Use Consequences Among College Students

Cannabis and alcohol use among college students associates with deleterious consequences including health risks, involvement in risky behavior, and functional impairment (Allen & Holder, 2013; Bolin et al., 2017). Cannabis use has been found to be associated with numerous negative consequences including poor academic performance, declines in cognitive functioning (i.e., deficits in psychomotor function, attention, sensory, working and verbal memory, free recall, inhibition decision making, and executive function; Phillips et. al., 2015; Suerken et al., 2016), and poor physical health (e.g., respiratory dysfunction, altered brain development and mental health problems such as depression, anxiety; Allen et al., 2013; Bolin et al., 2017; Suerken et al., 2016; Struble et al., 2019; Pearson et al., 2017).

Cannabis and alcohol use among college students adversely affects academic performance (i.e., lower GPA, Bolin et al., 2017) and associates with reduced academic efforts and motivation (Phillips et al., 2015). Prior research has linked cannabis and alcohol use to

reductions in time studying and class attendance, falling behind in schoolwork, and poor exam performance (Bolin et al., 2017; Suerken et al., 2016).

Both heavy drinking (greater than 4 to 5 drinks in one sitting) and cannabis use among students associates with numerous consequences related to health, social, legal and psychological variables that include injury and accidents, impaired driving and driving-related accidents, hangovers, addiction and dependence, job loss, death, property damage, fines and arrests, physical and sexual assault, risky sexual activity, interpersonal conflict, relational conflict, cognitive impairment and higher levels of sensation seeking (Martinez, Sher & Wood, 2014; Acuff et al., 2018(a); Joyner et al., 2016; Acuff et al., 2018(b); Suerken et al., 2016; Schultz et al., 2019; Caldeira et al., 2008, Pearson et al., 2017). Cannabis use has also been found to be a significant factor in increasing the risk of experiencing other substance-related problems and alcohol drug combinations with a 76% increase in drug and alcohol hospitalization due to overdosing among adults 18- to 24 years old (Caldiera et al., 2008; Meshesha et al., 2018).

Trauma Exposure Among College Students

Identifying risk factors for substance use is important for optimizing preventative and treatment efforts for this population. Trauma exposure is an important variable to consider in the understanding of alcohol and cannabis use among students. Recent estimates indicate that between 54% to 85% of students have experienced prior traumatic events (Boyraz & Granda, 2019). The rate of trauma exposure has remained consistently high over the years; a previous study of 1528 college students reported 85% of college students reported lifetime exposure and more than one exposure to traumatic events and 21% reported experiencing trauma during their time in college, and within the past 2 months (Frazier et al., 2009). A large number of these traumatic events occurred before students entered college that involved self, family, and/or close

friends surviving a life-threatening event, car accidents, witnessed or experienced family violence, unwanted sexual attention and sexual assault (Frazier et al., 2009). College students are seen as at-risk population for future traumatic events and retraumatizing events on campuses (Baynard & Cantor, 2004; Frazier et al., 2009). Read et al. (2011) found 66% of students reported a history of trauma exposure and 9% met the criteria for PTSD; the latter finding is consistent with prior research indicating rates of 1-10% for PTSD prevalence (Read et al., 2011; Read et al., 2014). These studies indicate that the prevalence of trauma exposure among college students has remained consistent over the past 10 plus years and can result in levels of posttraumatic stress (PTS) symptoms and a diagnosis of PTSD.

Trauma can be understood as a range of events that overwhelm an individual's capacity to cope and is characterized as involving threats of serious injury or death to self or someone close (Banyard & Cantor, 2004). Traumatic events may include exposure to accidents/natural disasters, war-related combat, sudden unexpected death of a loved one, life-threatening illnesses, physical assaults, sexual assaults, life-threatening events causing serious distress/injury, childhood abuse/family/domestic violence (emotional/verbal), and interpersonal violence. According to the Diagnostic and Statistical Manual of Mental Disorders (5th ed; DSM-5; American Psychiatric Association [APA], 2013), a traumatic event can be defined as:

> Exposure to actual or threatened death, serious injury, or sexual violence in one (or more) of the following ways: 1) directly experiencing the traumatic event(s), 2) witnessing, in person, the event(s) as it occurred to others, 3) learning that the traumatic event(s) occurred to a close family member or close friend (in cases of actual or threatened death of a family member or friend, the event(s) must have been violent or accidental), or 4) experiencing repeated or extreme exposure to aversive details of the traumatic event(s) (e.g., first

> responders collecting human remains; police officers repeatedly exposed to details of child abuse). Note: Criterion A4 does not apply to exposure through electronic media, television, movies, or pictures, unless this exposure is work-related. (APA, 2013, p. 271)

To expand on the above definition of trauma, May and Wisco (2016) did a systematic review of the research on trauma by examining the changes from the DSM-IV-TR to the DSM-5 definitions on exposure levels and proximity of events in the development of future PTSD. These authors evaluated the exposure levels of direct and indirect, or secondary trauma. May and Wisco (2016) defined direct exposure to trauma as first-hand experiencing a traumatic event or observing the traumatic event occurring to another. They defined indirect exposure as experiencing trauma via secondary narrative accounts, and work-related media reports or learning about traumatic events, or as the DSM-5 directly described it, as "repeated or extreme exposure to aversive details of traumatic events" (APA, 2013 p.271). This helps elucidate the complexities of what is trauma and how college students can be affected directly or indirectly by traumatic events before and after joining college.

Trauma Exposure Consequences: Risk Factor for Substance Use and Misuse

Trauma exposure may have many negative effects on students throughout college via impaired ability to cope with negative emotions, posttraumatic stress (PTS) symptoms, PTSD, overall academic functioning, and increased risk for drug and alcohol use (Banyard & Cantor, 2004; Read et al., 2016). Exposure creates risk for PTS/PTSD, but exposure and PTS/PTSD are separate constructs. A person exposed to trauma may not develop PTS/PTSD but still have similar consequences. Trauma exposure may present a risk for substance use problems as PTSD and Substance Use Disorder (SUD) have a high rate of co-occurrence (Haller & Chassin, 2014). Between 14-60% of adults and up to 20% of adolescents have PTSD and SUD comorbidity,

suggesting trauma exposure may be related to future substance misuse (Haller & Chassin, 2014). One theory that helps explain this relationship is the Self-Medication Hypothesis, which assumes that substance use in individuals affected by trauma reflects a coping mechanism where PTSD symptoms develop before substance misuse (Haller & Chassin, 2014). Research has supported the self-medication hypothesis by longitudinally monitoring trauma exposure and drug and alcohol use among adolescents through adulthood. Haller and Chassin (2014) found that participants were at significantly higher risk for drug and alcohol problems when exposed to trauma relative to those not exposed, and that PTSD symptoms were linked with alcohol and drug problems. Haller and Chassin (2014) found PTSD symptoms predicted higher future levels of substance misuse with cannabis being the most prevalent drug used with a 10% increase with each PTSD symptom. They also noted preexisting family adversity was related to PTSD and substance misuse and was a risk factor for trauma exposure, thereby increasing the chances of future substance abuse problems. A factor such as family adversity relates to childhood trauma and a broader aspect of trauma. Overall, their study helped substantiate the self-medication hypothesis by establishing a link between trauma exposure and future drug and alcohol misuse.

While a large number of trauma-exposed college students do not meet full PTSD criteria, they nonetheless experience PTS symptoms (approximately 30-35%) that puts them at increased risk for drug and alcohol use (Read et al., 2012). Read et al. (2012) examined the relationship between trauma exposure levels and posttraumatic stress symptoms (PTS) with substance misuse among college students. Students were categorized using the DSM-IV Criterion A trauma exposure (e.g., the sudden death of a loved one; physical assault; sexual assault; etc.) as no Criterion A exposure, Criterion A exposure but no significant PTSD symptoms, Partial PTSD, and full PTSD. Results revealed that full-PTSD participants suffered the most alcohol and drug

consequences over the other levels with partial PTSD falling just below full PTSD. Students with full PTSD and partial PTSD at the beginning of college had higher rates of substance abuse than students with other levels of trauma exposure and remained constant during the first year. Read et al. (2012) speculated that periods of stress like starting school, put these trauma-exposed students at risk because they have to cope with a new environment. Students classified as "No criterion A" had the lowest consequences and their substance use levels significantly differed from those meeting Criterion A and full PTSD symptoms. An interesting result of the study was that the full and partial PTSD students did not differ significantly showing higher consequences than the other two levels of trauma exposure. These results suggest that sub-thresholds (partial PTSD) students are at the same risk of experiencing substance misuse and consequences as are those with full PTSD symptoms.

Further Explanatory Variables for Trauma to Substance Use

The empirical work by Read et al. (2014) supports the self-medication hypothesis model, linking alcohol use with PTS symptoms and a person's coping styles. Coping strategies, defined as styles of addressing emerging conflicts and challenges, have been linked to PTS, psychological distress, and problematic drinking. Specifically, negative coping strategies (i.e., avoidance) have been linked to the development of PTSD and problematic drinking following trauma exposure. PTS symptoms among students at the time of enrolling in college predicted negative coping in years that followed.

The association between trauma exposure, PTS, and drug, and alcohol use has been supported by extant research, but specific substance misuse in college populations needs further exploration. Various models have proposed to explain this relationship. Derived from operant learning, Avant et al. (2011) propose that "substance use is negatively reinforced by avoidance of

negative emotions or reminders of traumatic experience…that temporary positive consequences (e.g., reduced inhibition, increased social confidence) of substance use can reinforce use" (p.540). Avant et al. (2011) found that women college students with a history of trauma, but with no difference in severity levels or PTSD diagnosis, were more likely to engage in drug and alcohol use; women diagnosed with PTSD reported a higher frequency of drinking days than those without PTSD. The avoidance PTSD symptom cluster tends to be associated with the most varied use of drugs, suggests that substance use in those exposed to trauma is related to the general avoidance of symptoms consistent with self-medication theory.

Broadened Definition of Trauma Exposure

Childhood trauma exposure (i.e., abuse, neglect) and lower levels of PTS symptoms is also linked to substance use. Berenz et al. (2016) completed a longitudinal study on the effects of interpersonal trauma (i.e., physical/sexual assault/abuse) on the alcohol use of male and female college students; they examined the effects of potentially traumatic events (PTEs) and PTSD symptoms on alcohol use. Their results showed pre-college PTEs were related to greater alcohol use for women but not for men. Men's pre-college PTEs with or without PTSD symptoms predicted initial alcohol consumption during the first semester and college-onset PTEs did not impact concurrent or subsequent alcohol use. However, women college-onset PTEs, above and beyond pre-college significantly predicted increased alcohol use at follow up assessments leading Berenz et al. (2016) to conclude that there is an association between posttraumatic events and alcohol consumption among women in college.

Substance use among young adults is linked with childhood exposure to adverse events such as maltreatment and dysfunctional living environments. Adverse childhood experiences (ACEs; Felitti et al., 1998) associate with a wide range of mental and behavioral health problems

including the prediction of substance use and other consequences including psychological symptoms (Shin, McDonald & Conley, 2018). Shin et al. (2018) found (a) multiple or cumulative exposure to ACEs increases the risk for substance use, and (b) young adults exposed to more than one or more ACEs and more severe ACEs were at higher risk for alcohol problems and other consequences. Individuals with high and multiple ACE exposures are more likely to be at risk than low ACEs with predominantly household dysfunction, community/emotional violence and that multiple exposures are most important in predicting later substance use.

Forster et al. (2018) examined the relationship between family-based ACEs and substance abuse among college students and found that 50% to 75% of those who used substances were exposed to ACEs. They reported that each ACE, except verbal and physical abuse, was positively correlated with substance abuse behaviors and that every additional ACE led to increased levels of substances used in the past year. These study results support a hypothesized linear dose-response relationship of added ACEs and each substance abuse behavior. Forster et al. (2018) concluded that family-based ACEs are strong predictors of substance misuse later in life and a key identifying tool for college substance use and misuse.

Behavioral Economic Reasons for Substance Use

Psychological concepts of operant conditioning and economic theories have been applied to the understanding of addiction as a function of the availability of reinforcement and rewards from the environment (Avant et al., 2011; Acuff et al., 2019). Addiction involves a person continuing to use a substance, despite damaging health and social consequences, due to the reinforcing properties of the substance on desired outcomes even though negative behavioral and resource-draining effects may occur (Acuff et al., 2019). Behavioral economics theories, postulated by Herman in 1974, “consider reinforcement in the context of the environment and

posit that the allocation of resources to an activity (response rate) is related to reinforcing properties of a given stimulus relative to the other available stimuli" (as cited in Acuff et al., 2019, p. 79). Behavioral economics has more recently been applied to the understanding of SUDs where substance use is seen as a consequence of reinforcement/reward which can be influenced further by trauma exposure (Acuff et al. 2018; Bickel et al., 2012; Bickel et al., 2014; Luciano et al, 2019; Meshesha et al., 2018).

This reinforcer pathology involves the high valuation and preference of a reinforcing commodity (i.e., drugs or alcohol) over other environmental rewards that have less immediate gratification value (Meshesha et al., 2018; Joyner et al., 2016; Bickel et al., 2014). The reinforcer pathology helps explain that substance misuse is related to beneficial negative effects easily obtained from their environment and perceived deficits in the availability of and access to alternative (possibly delayed) rewards that are substance-free (Acuff et al., 2018; Meshesha et al., 2018; Bickel et al., 2014). These theories suggest that substance use is connected to perceived deficits in a substance-free environment (Acuff et al., 2019). In a recent review, Acuff et al. (2019) elaborated on how substance-free reinforcement/reward affects drug and alcohol use and misuse and how it can be measured. They reviewed previous studies not only on animals of drug availability versus enriched living conditions but also of school children who were given more after school and evening alternative activities to encourage them to remain substance-free. They concluded that studies support an inverse relation of substance use with substance-free reinforcement/reward, that is, access and availability of alternative rewards in the environment are related to less drug and alcohol use and misuse. In their review, they concluded that the Reward Probability Index (RPI; Carvalho et al., 2011) is a useful measure of environmental reward and ability to experience reward for predicting substance use (Acuff et al., 2019).

The RPI is a behavioral self-report measure that was originally designed to examine how response-contingent positive reinforcement (RCPR) relates to depression. RCPR is defined as "an increase in the frequency of duration of a behavior as a result of the presentation of a reinforcer" (Carvalho et al., 2011, p. 250), which relates to the continued maintenance of depression characteristics as lacking environmental reinforcement leads to continued unhealthy behaviors. The RPI is based on the behavioral models that link reward deprivation (i.e., reduced RCPR) to the maintenance of depression. The models postulate four factors that lead to the cause and maintenance of decreased RCPRs: a decreased number of available events that an individual find reinforcing, an inability to utilize environmentally reinforcing events, an inability to experience rewarding events due to behavioral or social deficits, and a higher frequency of aversive events (Carvalho et al., 2011). The RPI was developed to measure factors of RCPR via two subscales: *Reward Probability* which relates to potentially reinforcing events and instrumental behaviors looking at ability to experience reward and *Environmental Suppressors,* which relates to availability or reinforcement and aversive and unpleasant experiences looking at availability or access to environmental rewards (Carvalho et al., 2011).

The availability of substance-free reward/reinforcement reduces individuals' use of drugs and alcohol through the availability of ability to experience rewards. Unfortunately, the risk for substance misuse in college populations is high because of the prevalence of illicit substances and rewarding social events involving drugs and alcohol on college campuses. Using the RPI, Joyner et al. (2016) examined the relationship between reward availability and reward experience ability, controlling for depression, and alcohol use among heavy-drinking college students. Results indicated that the total RPI score (sum of the two subscales) was predictive of the severity of alcohol-related problems, thus providing support for the assertion that reward

deprivation is a factor in alcohol-related problems. Environmental Suppression, not Reward Probability, significantly predicted AUDs. The lack of access/availability to rewarding experiences predicts problematic alcohol use in college students. College students appear to have the ability to experience rewards but have limited availability of /access to natural rewards in their environment resulting in more alcohol use (Joyner et al., 2016). They also point out that the Environmental Suppressor scale helps predict alcohol use possibly because of ease of access to these substances in college relative to other natural rewards. Their access to natural rewards may be limited due to such issues as poor adjustment in college, limited campus/community recreational activities, poor social skills, or socialization opportunities. College students then may have an intact ability to experience reward given access to it, but they appear to have limited access to natural rewards which may explain their problematic alcohol use and by offering substance-free rewards student substance use may decrease.

Individuals in environments with few rewarding alternatives to drinking alcohol may engage in risky drinking and substance use (Joyner et al., 2016). Meshesha et al. (2018) used the RPI to examine the relationship between substance-free reward deprivation among heavy drinking and drug-using college students. They categorized the students into heavy drinkers (HD), HD and cannabis users, and HD and polysubstance users. They found HD had an association with RPI total score over HD and cannabis and HD and polysubstance and for main effects results, drug use had a main effect on both subscales and the RPI total score. Looking at mean differences between groups they found that HD related to lower environmental suppressor to reward over HD and polysubstance and then HD and cannabis over HD and polysubstance use with HD connected to higher reward experience over HD and polysubstance use. This supports the behavioral economics model that substance use is related to deficits in natural rewards. Out

of the three substance groups, the study found HD and polysubstance was the most related to lower chances of rewarding environments and connected with diminished ability to experience reward relative to HD. Diminished ability to experience reward has been linked to alcohol and polysubstance use, which may reduce hedonic responses to natural rewards (Meshesha et al., 2018) common in individuals with trauma exposure and SUD (Vujanovic et al., 2017).

Deficits in reward probability helps explain the link between trauma exposure and substance abuse. The ability to experience natural rewards, reward functioning, can help a person to seek out positive and rewarding life events (i.e., food, sex, social interactions), however, this ability may be compromised by comorbid PTS and substance misuse (Vujanovic et al., 2017). Reward functioning is an important concept in trauma exposure and substance use because of their connections with anhedonia and a blunted reward response-ability. PTSD patients have been found to have deficits in reward functioning because of their anhedonia and blunted affect (Vujanovic et al., 2017). This is consistent with the results of Meshesha et al.'s (2018) study, which reported that those who abused substances had lower hedonic responses or the ability to experience reward. In a review, Vujanovic et al. (2017) found that reward responsiveness may negatively associate with avoidance clusters in PTSD. They concluded that deficits in reward functioning, common in those with SUD, is possibly due to anhedonia in individuals who show elevated cravings and substance use. Based on common features of PTSD and SUD, Vujanovic et al. (2017) documented evidence linking anhedonia symptoms, depressive symptoms, and future problematic alcohol use among those exposed to early life trauma. In summary, impairments in the ability to experience reward may be directly related to trauma exposure as it blunts hedonic responses to rewards and which in turn may lead to substance use.

Behavior Economics Linking Trauma to Substance Use

Theories consistent with the self-medication hypothesis help explain how substance use stems from a need to cope with PTS. Behavioral economics can complement the self-medication theory which fails to explain how trauma exposure reduces a person's ability to engage in alcohol-free reinforcing environments (Luciano et al., 2019). Luciano et al. (2019) investigated the relationships between trauma and alcohol use and coping-related drinking and the RPI's Environmental Suppressor subscale. The study determined the incremental utility of behavioral economic variables in predicting alcohol use. Results of the study support the self-medication hypothesis of motives behind drinking with coping predicting alcohol use, showing its importance in the relationship between trauma exposure and alcohol. While the RPI did not help explain the relationship beyond coping mechanisms for trauma to alcohol use, other behavioral economic measures, demand/consideration of future events/delay discounting did show an ability to predict or explain part of the relationship in alcohol misuse and use. One conclusion from this study is that the self-medication hypothesis connects alcohol use to negative reinforcement in coping with trauma symptoms. Results show concepts of behavioral economics relate to positive reinforcement with alcohol demand and negative reinforcement with coping. Deficits in the ability to delay reward support the reinforcer pathology theory in explaining the relationship between trauma and substance use (Luciano et al. 2019) and further demonstrate the importance of reward/reinforcement in the development of substance use problems.

The relationship between trauma exposure and substance use and misuse has been explained by the self-medication hypothesis with drinking to cope. Emerging research suggests the self-medication model lacks explanatory utility for the relationship between trauma exposure and substance misuse due to the positive reinforcing effects of substances (Acuff et al., 2018).

Acuff et al. (2018) connects trauma to the RPI through symptoms of avoidance and loss of the ability to experience pleasure due to impaired or damaged reward functioning and maladaptive cognitions. These PTS symptoms associate with a lack of availability to alternative and substance-free rewards in the environment leading to alcohol use. In particular, the DSM-5 (APA, 2013) PTSD criteria has two symptom clusters that relate to the RPI: avoidance symptoms and diminished interest in activities or inability to experience positive emotions (i.e., satisfaction). Acuff et al. (2018) believed reward deprivation is a risk factor for PTS symptoms and alcohol use. Their study showed evidence for the RPI's ability to explain trauma exposure and alcohol use. Alcohol use measures and PTS symptoms had a negative correlation with the access to environmental reward subscale of the RPI, meaning lower access to rewarding environments was linked with more drinking, problems, craving, and PTS symptoms but unfortunately the experience of reward subscale only correlated to drinks per week and craving. Through testing mediation models, Acuff et al. (2018) found only the access to environmental rewards subscale mediated the relationship between PTS symptoms and alcohol craving and problems with an indirect proportion of 52% and 39% respectively after controlling for drinks per week. This is the first study to find PTS symptoms had an inverse association with the availability of reward subscale of the RPI and reinforced research connecting alcohol use with PTS symptoms. The study found access to environmental rewards was a mediating variable in explaining the relationship between PTS symptoms and alcohol craving and problems, meaning a lack of access to reward is an important risk factor for trauma and alcohol use. Results provide support to the role of reward deprivation in alcohol use and misuse and also the utility of RPI in explaining the relationship to trauma over just the self-medication hypothesis. However, they did not find any support for the ability to experience reward subscale of the RPI in predicting

substance use which was surprising given results of prior research that show trauma and SUDs and criteria for PTSD symptoms lead to deficits in reward function and needs further exploring.

Present Study: RPI's Influence on Trauma to Substance Use

Trauma exposure and PTS are risk factors for problematic substance use and the prevalence of trauma exposure and substance use is high among college students. Substance (e.g., alcohol and cannabis) use occurs due to their reinforcing effects which help cope with PTS symptoms. Behavioral economic theories of reward/reinforcement can be used to examine how reward-deprivation plays a role in the relationship between trauma exposure, PTS symptoms, and substance use. Reward deprivation has been shown to be associated with the RPI scales: Reward Probability (a person's ability to experience reward) and Environmental Suppression (availability of/or access to reward in the environment). These two RPI subscales have been found to be related to common symptoms associated with traumatic exposure as avoidant behavior (of potentially rewarding behaviors) and mal-adaptive cognitions (difficulty with experiencing positive emotions). Promising research found connections between trauma exposure and substance use using reward deprivation showing the utility of the RPI as a valid measure to explain why the relationship exists (Acuff et al., 2018; Joyner et al. 2016; Meshesha et al., 2018).

This study will expand on prior research that investigated if reward deprivation mediates the relationship of PTS symptoms and trauma exposure with alcohol and cannabis use. The study hypotheses are that (a) RPI subscales (i.e., Reward Probability, Environmental Suppressor) will partially mediate the relationship between trauma/PTS and alcohol and (b) RPI subscales will partially mediate the relationship between trauma/PTS and cannabis use. Based on prior research not finding utility for the reward probability sub-scale in this relationship, the ACEs was used as a supplemental measure for trauma exposure.

Methods

Procedure

Participants were recruited through undergraduate psychology classes who had completed an online assessment battery of self-report questionnaires measuring issues related to mental health and drug-alcohol use. West Chester University students from various undergraduate Psychology classes completed a Qualtrics survey either through SONA-Systems or an emailed link from their instructors. Participants were either required to participate in research as part of needing research credits for class requirements or given the opportunity of participating in this research for extra credit. Students were notified of the opportunity to participate in this online research project and were able to review the study requirements (e.g., completion of 60 minutes of self-report questionnaires focused on drug-alcohol use and trauma exposure) through their Sona Systems account. Participants decided whether or not to enroll after reading the abstract and description of the study. There were no prescreening or inclusion/exclusion criteria required for enrollment. This study was administered online through the Sona Systems program. After completion of the study, two research credits (or extra credit) were awarded to students through Sona Systems. Study procedures were approved by the West Chester University Institutional Review Board.

Participants

Initially, 734 participants enrolled into the study and completed some portion of the questionnaires. However, data from 128 participants were excluded because of (a) their failure to endorse the informed consent form (n = 2), (b) failure to respond to many items (n = 18), (c) for completing the survey in less than 15 minutes (n = 46) on the assumption that these participants clicked through the responses without reading questions, and (d) for incorrectly answering 2 out

of 3 “dummy” questions (*n* = 62), which were included in the assessment battery as a validity check. The dummy questions specified that participants should select a specific response to verify that they are reading each question (i.e., “Please select option 3, strongly agree, to verify that you are actually reading each questionnaire carefully”).

This sample was further broken down (*n* = 387) based on requirements for the analysis that restricted focus to participants who endorsed direct trauma exposure (i.e., “happened to me”) on at least one of the items from the a trauma exposure questionnaire (LEC-5 list) excluding those who did not endorse this restriction. The prevalence of direct trauma exposure (Table 1) picked for this study include exposure to: natural disaster (*n* = 127, 32.8%), fire or explosion (*n* = 25, 6.5%), transportation accident (*n* = 228, 58.9%), serious accident at work home or during recreational activity (*n* = 67, 17.3%), exposure to toxic substance (*n* = 8, 2.1%), physical assault (*n* = 77, 19.9%), assault with a weapon (*n* = 12, 3.1%), sexual assault (*n* = 64, 16.5%), other unwanted or uncomfortable sexual experience (*n* = 128, 33.1%), combat or exposure to a war-zone (*n* = 3, 0.8%), captivity (kidnapped, abducted, held hostage) (*n* = 2, 0.5%), life-threatening illness or injury (*n* = 31, 8%), severe human suffering (*n* = 16, 4.1%), sudden violent death (*n* = 15, 3.9%), sudden accidental death (*n* = 12, 3.1%), serious injury, harm, or death you caused to someone else (*n* = 5, 1.3%), any other very stressful event or experience (*n* = 195, 50.4%). The final sample chosen for analysis included 79 men (20.4%) and 307 women (79.3%) with the average age of 19.76 years (*SD* = 2.318, range = 18-39).

Participants in this study (Table 2) identified as American Indian or Alaska Native (*n* = 2, 0.5%), Asian or Asian American (*n* = 14, 3.6%), Black or African American (*n* = 52, 13.4%), Hispanic or Latino/a (*n* = 28, 7.2%), Non-Hispanic White (*n* = 280, 72.4%) and Other (*n* = 10, 2.6%).

Measures

The **Alcohol Use Disorders Identification Test (AUDIT; Fleming et al., 1991)** is a 10-item self-report screening tool developed by the World Health Organization (WHO) to assess alcohol consumption, drinking behaviors, and alcohol-related problems. It is a simple and effective method to screen for unhealthy and problematic alcohol use and a potential disorder. Participants answer questions with a 0 to 4 scale where questions 1-3 query alcohol consumption (i.e., *"how often do you have a drink containing alcohol");* questions 4-6 query alcohol dependence (i.e., *"how often during the last year have you found that you were not able to stop drinking once you had started"*); questions 7-10 query alcohol problems (i.e., *"have you or someone else been injured because of your drinking"*); and questions 9-10 querying last-year alcohol use (i.e., 0 points = no, 2 points = yes, but not in the last year and 4 points = yes, during the last year). Total AUDIT scores are derived by summing items with a score of 8 or more indicating hazardous or harmful alcohol use. The AUDIT has been shown to be a valid alcohol screening tool in the identification of DSM-5 alcohol use disorder symptoms in college students and shown to have a decent ability to diagnose college students (Hagman, 2016). The Cronbach's alpha in this study was .86.

The **Cannabis Use Disorder Identification Test-R (CUDIT; Adamson et al., 2010)** is an 8-item screening tool for problematic cannabis use that assesses the severity of use, dependence, and related problems associated with cannabis use within the last six months. This is a shorter version of the original measure with superior psychometric properties that has utility as a brief assessment instrument. Participants answer questions with a 0 to 4 scale where questions 1 asks (i.e., *"how often do you use cannabis")* about frequency in a month and question 2 asking (i.e., *"how often do you use cannabis", "how many hours were you "stoned*"

on a typical day when you had been using cannabis") in hour increments up to 7 hours or more. Questions 3-7 are answered on a 5-point Likert scale (i.e., 0 = *never* to 4 = *daily or almost daily*; i.e., *"how often in the past 6 months have you* had a *problem with your memory or concentration after using cannabis"*); with item 8 querying cessation considerations (i.e., "*have you ever thought about cutting down, or stopping your use of cannabis*") during the prior 6 months. Total CUDIT scores are derived by summing the ratings for the 8 items, with a score of 8 or more indicating hazardous use and a score of 12 indicating cannabis use disorder. The CUDIT-R is a reliable and valid measure in screening to identify college students at risk cannabis use (Schultz et al., 2019). The Cronbach's alpha in this study was .88.

The **Life Events Checklist for the DSM-5 (LEC-5; Weathers et al., 2013)** is a 16-item self-report measure that queries exposure to potentially traumatic events in the participants lifetime that may result in distress or PTSD, including an additional 1-item category of trauma exposure that is considered by the participant to be an extremely stressful event and not included in the first 16 items. For this measure participants indicate the proximity of trauma exposure (i.e., *"happened to me", "witnessed it", "learned about it", "part of my job", "not sure", or "doesn't apply"*); among the 17 trauma categories (i.e., *"natural disaster", "transportation accident", "physical assault", sexual assault", "sudden accidental death"*). The present study restricted focus to participants that endorsed direct trauma exposure (i.e., *"happened to me"*) on at least one of the items from the LEC-5 list, excluding participants with no prior trauma.

The **Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5; Weathers et al., 2013)** is a 20-item self-report measure that assesses PTSD symptom severity in a manner consistent with the DSM-5. Participants rate the extent to which they experience symptom severity on a 5-point scale (0 = *not at all* to 4 = *extremely*) over the past month. Examples of

items include *"loss of interest in activities that you used to enjoy", "avoiding memories, thoughts, or feelings related to the stressful experience", "avoiding external reminders of the stressful."* Ratings are summed to derive a total score with scores between 31-33 or higher indicating problematic PTS symptoms. This measure has been deemed valid and reliable in identifying PTSD symptoms severity in college students based on research collected by the National Center for PTSD (Blevins et al., 2015). The study had Cronbach's alpha of .95.

The **Adverse Childhood Experiences Questionnaire (ACEs; Felitti et al., 1998)** is a 10-item self-report measure that assesses childhood exposure to adverse events and trauma before the age of 18. This measure was used to broaden the inclusion of trauma exposure beyond the restrictive definition outlined in the DSM-5 definition of trauma (5th ed; DSM-5; American Psychiatric Association [APA], 2013). This scale is divided into ACEs that represent physical and emotional neglect, household mental illness, domestic violence, divorce, separation, substance use, and incarceration of a family member. Participants rate on a yes or no scale corresponding to ACEs exposed to before they were 18 years old. Examples of items include i.e., "*did a parent or other adult in the household often swear at you, insult you, put you down, or humiliate you", "did you often feel that you didn't have enough to eat, had to wear dirty clothes and had no one to protect you."* The number of yes answers is the ACE score with higher scores meaning more consequences and complications later in life. This scale had a Cronbach's alpha of .70.

The **Reward Probability Index (RPI; Carvalho et al., 2011)** is a 20-item Likert scale used to assess reward deprivation through two designed subscales, *environmental suppression* (i.e., access to or availability of rewarding opportunities within one's environment) and *reward probability* (ability to experience reward). This scale assesses environmental rewards to

approximate response-contingent positive reinforcements. Participants answer questions based on a 4-point scale (i.e., 1 = *strongly disagree*; 4 = *strongly agree*). The reward probability subscale asks questions related to a person's ability to experience reward, pleasure, or achievement when a reward is obtained (i.e., "*I have many interests that bring me pleasure", "I have the abilities to obtain pleasure in my life"*) which are potentially reinforcing events and instrumental behaviors. The environmental suppressor subscale is used to assess obstacles to obtaining or engaging in rewarding activities (i.e., *"my behaviors often have negative consequences", "I have had many unpleasant experiences"*), which relate to aversive and unpleasant experiences and availability of reinforcement. Higher scores across both these subscales reflect healthier functioning and suggest an increased potential for engaging in rewarding activities and increased capacity to experience reward. Lower scores reflect impoverishment in the potential for access to and experience of rewarding activities. Each sub-scale has strong internal consistency ($\alpha = .90$) and had excellent two-week test-retest reliability (scale 1, $r = .68$; scale 2: $r = .69$; Carvalho et al. (2011). Validity studies have demonstrated scores on the RPI to strongly associate with daily diary reports of activity engagement and enjoyment among undergraduate students (Carvalho et al., 2011). The Cronbach's alpha in this study was .88 for the reward probability subscale and .82 for the environmental suppressor subscale.

Data Analysis Plan

A simple mediation model was used to determine if reward deprivation (i.e., RPI subscales) mediated the relationship between trauma and substance use. The Hayes PROCESS macro for SPSS version 24 (Soltis et al., 2018; Acuff et al., 2018) was employed for mediation analyses. The add-on macro improves on the older Baron and Kenny (1986) path analysis

mediation model of a.b.c pathways which required the Sobel test (1982) to test for the significance of indirect effects. The Hayes PROCESS macro computes the direct and indirect effects of a model and uses bootstrapping confidence intervals to test the significance of mediation effects which is regarded as a superior solution to the Sobel test (Zettle, Rains & Hayes, 2011). Essentially, this approach evaluated whether a relationship between two variables exists through a mediator. The present study's purpose was to examine if trauma-exposure and PTS (i.e., PCL-5, ACEs) operated fully or in part through an intervening variable (i.e., RPI subscales) to explain substance use and misuse (i.e., CUDIT, AUDIT).

According to Hayes (2012) described the simple mediation model used in this study as follows. If X = trauma (influence variable), Y = alcohol and cannabis use (outcome variable), M (mediator variable) = a reward deprivation subscale, then

> X is modeled to influence Y directly as well as indirectly through a single intermediary or [a] mediator variable M located in between X and Y with…direct and indirect effects of X are derived from two linear models, one estimating M from X and a second one estimating Y from both X and M. (Hayes, 2012, p.6)

According to Hayes (2012), the simple mediation models requires computing three path coefficients c', a and b based on two regression analyses with three variables Y (outcome), X (influence) variable, and M (mediator): $M' = i1 + b(X)$, and $Y' = i2 + c'(X) + a(M)$, where M' and Y' and M' are predicted scores and i_s are the intercept constants, and a, b, and c are regression coefficients. The Total effect of the influence variable $C = c' + ab$, where the direct effect is denoted by c' and the indirect effects by ab, a measure of the effects of X on Y through the mediator M. Mediation effects are inferred when the value of ab is not equal to zero. There is no requirement that C should be equal to zero.

Hayes PROCESS allows interpretation of the indirect effects through computing .95 confidence intervals using 5,000 bootstrapped samples. If the interval that does not include zero, then the mediation effect is regarded as significant (Soltis et al., 2018; Hayes, 2012). Hayes PROCESS also gives the ratio of the indirect effect to the total effect and can be calculated into a percentage to give the amount of the effect that happened indirectly through the mediating variable (Voss et al., 2018). Bivariate correlations were also conducted to make sure core variables had associations with each other given prior research on trauma and substance use and misuse among college students.

In this study, eight models were tested for mediation with PTS symptoms, trauma exposure (ACEs) as influence variables, alcohol and cannabis use as outcome variables, and each of the RPI subscales as mediator variables in separate analyses.

Results

Descriptive Statistics and Bivariate Correlations among Variable

Participant descriptive statistics are summarized in Table 3. The average PTS symptoms score was 22.20 (*SD* = 16.95) and the average number of ACEs endorsed was 1.87 (*SD* = 1.93). Independent samples *t*-test revealed PCL-5 and ACE scores to be significantly different between males and females. Females evidenced higher PCL-5 scores (*M* = 23.09, SD = 17.23) relative to males (*M* = 18.75, *SD* = 15.65; *t* (384) = -2.03, *p* = .04, *d* = .26). Females also evidenced greater exposure to ACES (*M* =1.98, *SD* = 1.97) relative to males (*M* = 1.36, *SD* = 1.69; *t* (341) = -2.38, *p* = .02, *d* = .34). No other sex-related differences were observed for the study variables. The average score for alcohol use and cannabis use was 6.46 (*SD* = 5.03) and 4.22 (*SD* = 5.59). The reward probability scale had an average of 33.06 (*SD* = 5.18) and the environmental suppressor scale had an average of 23.79 (*SD* = 4.74). Correlations between all variables of interest (i.e., AUDIT, CUDIT, PCL-5, ACEs) were all significant in the assumed positive direction (see Table 3). These variables correlated negatively with both the environmental suppressor scale and the reward probability scale of the RPI. The reward probability subscale did have significant correlations, but these were lower with trauma and substance use while the environmental suppressor scale had higher correlations with trauma and substance use which may help to explain the future mediation analysis (see Figure 1. for the mediation analysis further explaining this concept).

RPI subscales as Mediators for Trauma Exposure and PTS to Alcohol Use Severity

In the four models that hypothesized mediation effects for the relationship between trauma exposure (ACE) and PTS symptoms (PCL-5), and alcohol use (AUDIT), none of the models had significant mediation with either subscale of the RPI (see Table 4 [ACE] and Table 5

[PCL-5]). The relationship between ACE scores and alcohol use (see Figure 1.A) was not mediated by the RPI-reward probability scale. The ACE score predicted the reward probability subscale and was significant with path a (unstandardized *b* = -.58 [.15], *t* (309) = -3.86, *p* = .0001), while reward probability to the AUDIT score was not significant in path b (unstandardized *b* = -.005, [.06], *t* (308) = -.08, *p* = .94) with ACEs to AUDIT score being significant in the c' path (direct effect) (unstandardized *b* = .61 [.17], *t* (308) = 3.66, *p* = .0003) and the c path (total effect) significant (unstandardized *b* = .62 [.16], *t* (309) = 3.77, *p* = .0002). Overall, the model did not show a significant mediation effect (unstandardized indirect effect = .003 [se = .04], 95% CI [-.07, .08]).

The relationship between ACE score and alcohol use (see Figure 1.B) was not mediated by environmental suppression. The ACE score predicted the environmental suppressor subscale and was significant with path a (unstandardized *b* = -1.04 [.12], *t* (309) = -8.49, *p* = .001), environmental suppressor to the AUDIT score was not significant in path b (unstandardized *b* = -.06, [.08], *t* (308) = -.76, *p* = .45) with ACEs to AUDIT score being significant in the c' path (direct effect) (unstandardized *b* = .56 [.18], *t* (309) = 3.06, *p* = .0024) and the c path (total effect) significant (unstandardized *b* = .62 [.16], *t* (309) = 3.77, *p* = .0002). Overall, the model did not show a significant mediation effect (unstandardized indirect effect = .06 [.07], 95% CI [-.08, .20]).

The relationship between PCL-5 score and alcohol use (see Figure 1.C) was not mediated by reward probability. The PCL-5 score predicted the reward probability subscale and was significant with path a (unstandardized *b* = -.11 [.02], *t* (352) = -7.28, *p* = .001), reward probability to the AUDIT score was not significant in path b (unstandardized *b* = .07, [.06], *t* (351) = -1.12, *p* = .26) with PCL-5 to AUDIT score being significant in the c' path (direct effect)

(unstandardized *b* = .08 [.02], *t* (351) = 4.43, *p* = .001) and the c path (total effect) significant (unstandardized *b* = .08 [.02], *t* (352) = 4.32, *p* = .001). Overall, the model did not show significant a mediation effect (unstandardized indirect effect = -.01 [.01], 95% CI [-.02, .01]).

The relationship between PCL-5 score and alcohol use (see Figure 1.D) was not mediated by environmental suppression. The PCL-5 score predicted the environmental suppressor subscale and was significant with path a (unstandardized *b* = -.18 [.01], *t* (352) = -14.85, *p* = .001), environmental suppressor to the AUDIT score was not significant in path b (unstandardized *b* = -.04, [.08], *t* (351) = -.44, *p* = .66) with PCL to AUDIT score being significant in the c' path (direct effect) (unstandardized *b* = .07 [.02], *t* (351) = 3.11, *p* = .002) and the c path (total effect) significant (unstandardized *b* = .08 [.02], *t* (352) = 4.32, *p* = .001). Overall, the model did not show a significant mediation effect (unstandardized indirect effect = .01 [.01], 95% CI [-.02, .03]).

RPI Subscales as Mediators for Trauma Exposure and PTS to Cannabis Use Severity

In the four models that hypothesized mediating effects for the relationship between trauma exposure (ACEs) and PTS symptoms (PCL-5) and cannabis use (CUDIT), there was evidence of significant mediation with reward probability and environmental suppression in three models (see Table 4 and Table 5). The relationship between PCL-5 score and cannabis use (see Figure 1.E) was not mediated by reward probability. The PCL-5 score predicted the reward probability subscale and was significant with path a (unstandardized *b* = -.12 [.02], *t* (346) = -7.67, *p* = .001), while reward probability to the CUDIT score was not significant in path b (unstandardized *b* = -.10, [.06], *t* (345) = -1.70, *p* = .09) with PCL to CUDIT score being significant in the c' path (direct effect) (unstandardized *b* = .06 [.02], *t* (345) = 3.26, *p* = .001) and the c path (total effect) significant (unstandardized *b* = .07 [.02], *t* (346) = 4.21, *p* = .001).

Overall, the model did not show a significant mediation effect (unstandardized indirect effect = .01 [.01], 95% CI [-.002, .03]).

The relationship between PCL-5 score and cannabis use (see Figure 1. F) was mediated by environmental suppression. The PCL-5 score predicted the environmental suppressor subscale and was significant with path a (unstandardized *b* = -.17 [.01], *t* (346) = -14.61, *p* = .001), as well as environmental suppressor to the CUDIT score being significant in path b (unstandardized *b* = -.25, [.08], *t* (345) = -3.13, *p* = .002) with PCL-5 to CUDIT score being nonsignificant in the c' path (direct effect) (unstandardized *b* = .03 [.02], *t* (345) = 1.42, *p* = .16) and the c path (total effect) significant (unstandardized *b* = .07 [.02], *t* (346) = 4.21, *p* = .001). Overall, the model showed a significant mediation effect (unstandardized indirect effect = .04 [.01], 95% CI [.02, .07]). The environmental suppressor subscale indirectly accounted for 58% ([indirect effect/Total Effect] *100) of the relationship between PCL-5 score and cannabis use.

The relationship between ACE scores and cannabis use (see Figure 1.G) was mediated by reward probability. The ACE scores predicted the reward probability subscale and was significant with path a (unstandardized *b* = -.60 [.15], *t* (303) = -3.95, *p* = .0001), and reward probability to the CUDIT score being significant in path b (unstandardized *b* = -.12, [.06], *t* (302) = -2.02, *p* = .04) with ACE to CUDIT scores being significant in the c' path (direct effect) (unstandardized *b* = .59 [.16], *t* (302) = 3.64, *p* = .0003) and the c path (total effect) significant (unstandardized *b* = .66 [.16], *t* (303) = 4.17, *p* = .001). Overall, the model showed a significant mediation effect (unstandardized indirect effect = .07 [.04], 95% CI [.01, .16]). The reward probability subscale indirectly accounted for 11% of the relationship between ACEs score and cannabis use.

The relationship between ACE scores and cannabis use (see Figure 1.H) was mediated by environmental suppression. The ACE scores predicted the environmental suppressor subscale and was significant with path a (unstandardized *b* = -1.02 [.12], *t* (303) = -8.55, *p* = .001), as well as environmental suppressor to the CUDIT score being significant in path b (unstandardized *b* = -.26, [.08], *t* (302) = -3.39, *p* = .001) with ACEs to CUDIT score being significant in the c' path (direct effect) (unstandardized *b* = .40 [.17], *t* (302) = 2.31, *p* = .02) and the c path (total effect) significant (unstandardized *b* = .66 [.16], *t* (303) = 4.17, *p* = .001). Overall, the model showed a significant mediation effect (unstandardized indirect effect = .26 [.08], 95% CI [.11, .45]). The environmental suppressor subscale indirectly accounted for 39% of the relationship between ACE and cannabis use.

Discussion

This study expanded on prior research that found reward deprivation, as measured by the RPI scale, as a factor in explaining the relationship between trauma and substance use in trauma-exposed college students. Trauma is a common risk factor for future substance use and prior explanations of coping for distress do not provide a complete explanation. Acuff et al. (2018) found PTS symptoms and alcohol use were mediated by reward deprivation. Through mediation models, this study is one of the first to examine if reward deprivation acts as a mediating influence in the relationship of trauma exposure and PTS symptoms with cannabis use in college students.

All participants in the sample endorsed direct exposure to at least one traumatic experience. Cannabis and alcohol use and a broadned trauma measure (ACEs: child abuse and neglect) were then examined. Consistent with prior research, the cannabis and alcohol use were positively correlated with ACE and PCL-5 (PTS) scores (Avant et al., 2011; Forster et al., 2018; Haller & Chassin, 2014; Read et al., 2012; Shin et al., 2018). The trauma measures were both negatively correlated with both subscales of the RPI. This shows support for the Acuff et al. (2018) finding that PTS symptoms have an inverse relation with access to environmental rewards. Correlations also showed a stronger association than previous research between the trauma measures and the reward probability subscale giving support to its potential mediating ability and usage with supplemental trauma measures. Both RPI subscales negatively correlated with alcohol and cannabis use meaning cannabis and alcohol scores were lower with higher RPI scores, findings which were consistent with prior research (Acuff et al. 2019; Luciano et al., 2019; Meshesha et al., 2018). Thus, students who reported having lower levels of access to

environmental rewards and the ability to experience reward tended to also report higher levels of trauma and greater use of substances.

Contrary to the hypothesis, none of the RPI subscales mediated the relationship between PTS symptoms, trauma exposure, and alcohol use. Consistent with Acuff et al.'s (2018) finding, reward probability did not explain the relationship between PTS symptoms and alcohol use. The ability to experience reward did not explain PTS scores and alcohol use, so other factors may play a role such as coping for distress or reward probability may not relate to the construct of addiction in a reinforcing/rewarding manner. This sample of college students may not have the same complications as those with higher levels of PTS symptoms that include deficits in reward functioning due to anhedonia or blunted affect and less reward response (Acuff et al., 2018; Vujanovic et al., 2017). The current sample had PTS symptom scores that are not clinically significant which may explain why deficits in the ability to experience reward did not mediate the relationship between trauma and alcohol use. Thus, replicating the study in a clinical sample with higher levels of PTS symptoms and a higher probability of anhedonia characteristics, reward probability is important.

The hypothesis that the relationship between broader trauma exposure (i.e., childhood trauma: abuse, neglect, measured by ACE) and alcohol use would be mediated by reward probability was not supported. Thus, the ability to experience reward did not explain the relationship between ACE scores and alcohol use; this result is surprising given the common consequence of trauma symptomology is alcohol misuse. Those with trauma symptoms are likely to have mal-adaptive cognitions which makes it difficult for them to experience positive emotions putting them at risk for using drinking as a coping mechanism (Read et al. 2014). Also, those with PTS symptoms and trauma exposure may be anhedonic and thus unable to enjoy

experiences without alcohol. Alcohol, however, may not relate to the reward probability sub-scale because in college environments alcohol may help students to cope with distress and allows them to go out and engage in social activities, but it does not alter their inability to experience reward. The scores on the reward probability scale were high suggesting that the sampled college students did not report having trouble experiencing reward. In other words, it appears that reward probability is possibly more related to coping for distress as suggested by the self-medication hypothesis.

The environmental suppressor scale did not mediate the relationship between PTS symptoms and alcohol use, a finding inconsistent with previous research by Acuff et al. (2018). This may be due to the choice of alcohol measure used in this study. The AUDIT measure is a quick clinical tool for possible Alcohol Use Disorder symptoms, alcohol problems, and possible interventions. It may not be a comprehensive enough for use with college students. Other researchers used more comprehensive measures of alcohol use (i.e., Brief Young Adult Alcohol Consequences Questionnaire, B-YAACQ; Kahler, Strong & Read, 2005) that may be more suitable for use in college populations (Acuff et al., 2018; Joyner et al., 2016; Meshesha et al., 2018). Those measures are more specific in their assessment and give more opportunity for the variability of responses to drinking behaviors. Using a broader definition of trauma exposure (by using ACEs) also did not help in finding support for the hypothesis that the environmental suppressor scale would mediate the relationship between ACE and alcohol use. This is a surprising finding given that prior research has found the environmental suppressor scale to mediate the relationship between trauma and alcohol use (Acuff et al., 2018). Other possible reasons for lack of access to environmental rewards may not have mediated the relationship include the high availability of alcohol-related activities in college and not having other

substance-free awards that are as socially rewarding as drinking (Joyner et al., 2016; Meshesha et al., 2018; Wilkinson & Ivsins, 2017).

Interestingly, when the hypotheses about the mediation effects of RPI sub-scales were tested on the relationship between trauma and cannabis, significant mediation effects were found for both scales. However, this was only found when expanding on trauma measures with the ACE, a broadened measure of trauma exposure. Reward deprivation only through a lack of access to rewards in the environment seem to have played a role in explaining why those with PTS symptoms engaged in cannabis use. The reasoning behind this may be specific to the use of cannabis as opposed to alcohol. Alcohol use may be more for social engagement, that is, for going out with peers, looking for rewards like popularity, fitting in, peer approval and peer pressure, and sexual activity (DiGuiseppi et al., 2018; Albert & Steinberg, 2011; Wilkinson & Ivsins, 2017). Alcohol motives may also be related to avoidance clusters of PTSD, depressive symptoms, and/or mal-adaptive cognitions of past events like parties or social gatherings always believed to be negative experiences or provide negative reinforcement from past traumas (Dalgleish & Werner-Seidler, 2014). Cannabis may be used in a different way than alcohol as it may be used to achieve a more relaxed social and/or personal experience that is not the same as the motives for the outward social aspects of drinking. Cannabis users may use it for feeling a more positive sense of well-being, and happiness, and feel less anxious about coping, stress and depression or to be social in groups (Allen and Holder, 2013). The difference in motives for the usage of these substances may be help understand the differences in results with the RPI scales.

In partial support of the hypothesis, the relationship between PTS symptoms and cannabis use was mediated by environmental suppression. Environmental suppression accounted for a moderate to a large amount of the total effect with 58% due to indirect effects. This

subscale, therefore, maybe a strong predictor for use in cannabis addiction research and treatment/interventions. It also may help explain that those who are exposed to trauma and have a lack of access to alternatives for a variety of reasons (i.e., poor social skills, self-regulatory abilities, monetary resources; Acuff et al., 2018) or lack of opportunities in the environment or engaging in avoidance from past trauma may seek out cannabis because of its availability on campuses and for its immediate reward/reinforcing properties. Contrary to the hypothesis but not surprising given prior research on alcohol, substance use, and trauma, reward probability did not serve as a mediator for the relationship between PTS symptoms and cannabis use. The reasoning behind this relates to the self-medication theory of coping for distress discussed above in the alcohol section. Cannabis may be used to cope with distress from trauma, but not due to an inability to experience reward similar to the reasoning behind alcohol for coping.

When using ACE to assess trauma exposure broadly, both RPI subscales mediated the relationship between trauma exposure and cannabis use. Reward probability accounted for a small portion of the total effect with 11% due to indirect effects. Furthermore, environmental suppression also mediated the relationship between ACEs and cannabis use. Environmental suppression accounted for a small to moderate proportion of the total effect with 39% due to indirect effects. The inclusion of the ACE was relevant as two-thirds of the sample had at least one ACE and even one ACE can predict future substance use (Forster et al., 2018). Although the analysis with PCL-5 and reward probability did not reach significance as a mediator, it was interesting that by broadening the focus of traumas (using ACE), mediation effects became significant. The ACE measures trauma that affect individuals as a child and can result in trauma and chronic stress responses as an adult, aspects that may be missed by the DSM-5 categories of trauma. Berenz et al. (2016) mentioned students come to college with prior exposure to

potentially traumatic events (PTE) which predicts future substance use. Such aspects are also not included on the DSM-5 exposure list. The ACE has items to measure neglect (not enough food, clean clothes, stable environment), verbal and physical abuse, parental substance use even divorce, and incarcerated relatives. These traumas may be related more to the ability to experience reward due to this childhood specificity because ACE scores have been found to be correlated with poor mental health (anxiety, depression, PTSD), risky behavior, drug use and poor future outcomes (Shinn et al., 2018; Forster et al., 2018; Felitti et al., 1998). Given that ACE scores have been found to predict future drug use, they may also shed light on childhood traumas missed by the PTS symptoms checklist and identification categories in the DSM-5, that lead to cannabis use (APA, 2013). The mental health consequences of anxiety and depression that are linked with ACEs may well relate to reward probability because it was developed to measure response-contingent positive reinforcement and the inability to experience rewards with depressed individuals. Also, by measuring childhood trauma exposure, it may be possible to understand why people may have trouble experiencing rewards; it is possible people with childhood trauma exposure also lacked an environment with positive reinforcements and rewards. The readily available and inviting environment of college cannabis use and its reinforcing properties could provide a way to obtain immediate rewards and help fill a void created by prior difficulties in experiencing rewards.

When utilizing the ACE to determine trauma exposure the environmental suppressor subscale had a more significant mediation effect than the reward probability scale. This would make sense given current results with PTS symptoms and prior research that shows only finding significant mediation with environmental suppression (Acuff et al., 2018). This gives support for helping to predict future substance use among those exposed to trauma and who lack access or

have low availability to reward in their environment. The environmental suppressor scale is a stronger mediating variable over the other subscale possibly due to the environmental context. Colleges have easily accessible drugs and alcohol and therefore easily attainable rewarding environments and activities with less substance-free rewards for those who may or may not have had rewarding environments in childhood or adolescents. Traumatized students may not have grown up to have or to seek alternative positive reward/reinforcements and so in the easily accessible drug and alcohol world of college, these quick rewards are the positive reinforcement they choose. Also due to convenience and lack of alternative rewarding experiences, residence halls, and common areas on college campuses are considered high-risk areas for frequent substance consumption (Wilkinson & Ivisins, 2017). Boredom may play a central role in contributing to substance use at college campuses that normalize party culture and lack substance-free rewards/reinforcement (Magidson et al., 2020; Wilkinson & Ivisins, 2017). Both RPI subscales have a mediating effect when trauma is measured broadly to include childhood exposure to traumatic events in relation to cannabis use. Thus, it is important to highlight possible childhood trauma risks or identify more trauma than the DSM-5 characterizes to help prevent future consequences. Environments are important for understanding the relationship between trauma and substance use as an early negative environment may cause future substance use. Trauma, in general, may also have a connection to cannabis use and a lack of access to more positive substance-free rewards due to readily available cannabis as an easy rewarding/reinforcing factor. This may be due to higher difficulties of alternative rewards to achieve the same goals as college campuses are pretty restrictive and lacking in easy alternatives to partying.

Limitations

To the author's knowledge, this is the only known study to expand on prior research and include cannabis use with behavioral economic theories of reward deprivation in explaining the relationship between trauma exposure, PTS symptoms and substance use. Through the analysis of the results, support for reinforcement/reward principles as a resilience factor for future cannabis use were found on both subscales of the RPI. This is encouraging for future implications in substance use detection and treatment. However, the generalizability of the results to other populations/college campuses is limited. The most obvious limitation is our use of a sample of college students. Colleges students are a representative and unique sample to test these variables but cause limitations to generalizability. Research suggests a large percentage of college students 54% to 85% (Boyraz & Granda, 2019) report trauma exposure, which in this sample was consistent with 63% of our narrowed down sample endorsing traumatic exposure to at least one event. This may also have been higher if the endorsement of trauma was expanded to more than just direct trauma-exposure to indirect trauma-exposure which May and Wisco (2016) report has the potential to also fulfill high levels of PTS symptoms. According to the U.S. Department of Veteran Affairs, about 60% of men and 50% of women have been exposed to at least one traumatic event in their lives. While college student trauma-exposure may be representative of other populations, the unique aspects of college student availability of drugs and alcohol may not make it as generalizable to other non-college populations. This sample was also predominately Non-Hispanic White with over 70% and mainly female with 80%, which would make the study biased especially as females showed significantly higher means for trauma exposure than males and therefore less generalizable to other populations who may express consequences to trauma differently (Forster et al., 2018; Berenz et al., 2016).

Other limitations relate to the process of collecting data. The data was collected through an online survey service where college students did the study for course credit instead of diagnostic clinical interviews. This may cause the results to be less accurate due to the nature of self-reporting, which may have led to fake or inflated answers. The questionnaires also involved some sensitive information that participants may have lied about or felt hesitant to answer honestly. The choice of measures for alcohol and cannabis use also may have limited the study. The CUDIT is based on the AUDIT which was mentioned earlier as a quick clinical tool for measuring more diagnosable features. Other studies assessing similar constructs used more robust and diverse measures of drug and alcohol use which may have yielded a more accurate picture of substance use among college students.

The study's cross-sectional design with associations among variables and significant mediation also need to be looked at with caution in the ability to prove directional causality. As Acuff et al. (2018) discussed the directionality of the mediation analysis, due to the cross-sectional nature may be more bidirectional than working as a mediating variable. However, mediation models in the current study were specified due to empirical literature suggesting that trauma precedes substance use (Berenz et al., 2016; Forster et al., 2018) and because our measure of trauma assessed events that occurred in childhood while our substance use scale assessed current substance use occurring in young adulthood. Still, retrospective reports of childhood experiences may be impacted by current perceptions. Our cross-section data is not equipped to draw definitive conclusions about the direction of effects. Future research should build upon the results found in the current study by testing these modules longitudinally. In addition, as trauma may lead to lower levels of desire to be social or active this may lead to lower levels on the environmental suppressor scale due to the nature of trauma symptoms and

not necessarily the lack of access to reward in a college environment. Based on the PTSD cluster symptomology described in the DSM-5 (APA, 2013) with anhedonia expressions and lack of ability of stimulation from other experiences and the high ability of drugs to serve as reinforcers in rewarding experiences, lower levels of the reward probability subscale should have shown more connection to the two other variables. It only showed a small connection and may have been less directionally associated with what research would hint at and serve another purpose such as coping for distress.

Lastly, the RPI scale itself may have some limitations in predicting or associating with trauma and substance use through behavioral economic frameworks of reward/reinforcement. This may be due to its development for depression and connection with behavioral activation therapies for depression instead of development for a behavioral economic theory of addiction. More recently though, behavioral activation for addiction is getting evidence of utility in addiction treatment and identification (Martinez-Vispo et al., 2018). Luciano et al. (2018) described the RPI as not using an approach based on behavioral economics in both subscales but only the environmental suppressor scale which relates to important behavioral models in addiction. The environmental suppressor scale did have significance with a series of studies dealing with addiction and trauma which supports the thoughts that the one scale was useful and showed potential for addiction as found in this study. The results of this study partially counter that the reward probability subscale is useful for addiction with support of significance to cannabis with reward probability as a mediator in the relationship to broadened trauma but only to a small effect showing possible limitations of the whole RPI scale.

Directions for Future Research and Implications

Future research needs to focus on more specific trauma and examine whether childhood abuse or neglect or community violence causes reward deprivation. Also trying to find a more balanced sample and more diverse drug and alcohol measures may lead to better results with the RPI. Overall, some of the direct implications of this study are that the RPI scale can be seen as an emerging predictor in addiction pathology and the consequences of trauma exposure. Treatment efforts are to be focused on improving the ability to access substance-free rewards for those struggling with the consequences of trauma exposure and addiction. The concepts of behavioral activation which focus on giving rewarding experiences different from substance use have emerged as an option for addiction (Martinez-Vispo et al., 2018). Behavioral activation encourages increasing activities that result in experiences of positive environmental reinforcement which can reduce depression symptoms and increase positive thoughts and feelings (Gawrysiak et al., 2009). Possibly, behavioral activation to encourage seeking healthy rewards can also be applied in the treatment of trauma and substance use because depression symptoms are comorbid with trauma (Gawrysiak et al., 2009).

Engaging in substance-free behavior with scheduled substance-free activities (i.e., sports, church, yardwork/housework) helps increase positive reinforcement and lower substance use in a variety of economic settings (Martinez-Vispo et al., 2018; Magidson et al., 2020). Essentially activities that cause greater pleasure lead to less substance use over frequency of access and availability (Magidson et al., 2017). This may help understand part of the problem on college campuses which do not have enough meaningful alternatives to substance use activities. Engagement in substance-free rewarding activities can help reduce or lessen substance use. The

RPI scale, as it measures the ability to experience reward and lack of access/ availability to reward which are risk factors for substance use, can be useful in identification and treatment.

Results suggest that reduced access to environmental rewards, and in a small part ability to experience reward, are risk factors in cannabis use among those exposed to trauma. This reinforcer pathology basis for substance use is important as it expands on the lack of an explanation in the self-medication theory of coping for distress as the reason for substance use. This will help future research to target interventions for students struggling with alcohol and cannabis use through increased access to rewarding substance-free environments, which in turn, may help reduce problematic substance use. The push for understanding addiction pathology through reward reinforcement is an important emerging field that is supported through this work.

Summary

PTS symptoms are frequently comorbid with problematic substance use. Emerging research suggests that the relationship between PTS symptoms and alcohol use can be explained through behavioral economic principles of a reinforcer pathology through reward deprivation. The current study expanded on this concept by adding a supplemental measure of trauma and by including cannabis use as a study variable. Reward deprivation, measured by the RPI, explained the relationship between trauma exposure, PTS symptoms, and cannabis use. Results provide support for the expanded use of the RPI in addiction research as a measure for the behavioral economic theory of reinforcer pathology among those with PTSD and SUD. Future work in this area would benefit by specifying trauma exposure and including childhood adversity measures to be more inclusive of trauma definitions. Additionally, more nuanced use of substance use assessment measures (i.e., motives, diagnoses) will aid in the future exploration on the role of reward deprivation in relation to PTS and alcohol and cannabis use.

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Appendix A

Tables and Figure

Table 1

Direct Trauma Exposure of Participants

	Whole Sample
LEC Categories *n* (%)	387
Natural Disaster	127 (32.8%)
Fire or Explosion	25 (6.5%)
Transportation Accident	228 (58.9%)
Serious Accident	67 (17.3%)
Exposure to Toxic substance	8 (2.1%)
Physical Assault	77 (19.9%)
Assault with Weapon	12 (3.1%)
Sexual Assault	64 (16.5%)
Unwanted Sexual Experience	128 (33.1)
Combat-Warzone Exposure	3 (0.8%)
Captivity- Kidnapped	2 (0.5%)
Life Threatening Illness-injury	31 (8%)
Severe Human Suffering	16 (4.1%)
Sudden Violent Death	15 (3.9%)
Sudden Accidental Death	12 (3.1%)
Serious Injury/ Harm you Caused to Someone	5 (1.3%)
Very Stressful Event/ Experience	195 (50.4%)

Note. This study restricted focus of participants to those who endorsed at least one direct trauma exposure (i.e., “happened to me) on the Life Events Checklist.

Table 2
Sample Characteristics

Demographics	Whole Sample
Age (year), *n*	387
Mean (SD)	19.76 (2.318)
Range	18-39
Ethnicity, *n* (%)	387
Non-Hispanic White	280 (72.4%)
Black or African-American	52 (13.4%)
Hispanic or Latina/o	28 (7.2%)
Asian-American or Asian	14 (3.6%)
Other	10 (2.6%)
American Indian/Alaskan	2 (0.5%)
Sex, *n* (%)	387
Female	307 (79.3%)
Male	79 (20.4%)

Table 3

Sample Size, Mean, Standard Deviation and correlations between variables

Variable	N	Mean	Standard Deviation	1	2	3	4	5
1.PCL-5 Score	387	22.20	16.95	-				
2.ACEs Score	344	1.87	1.93	.439	-			
3.AUDIT Score	354	6.46	5.83	.224	.210	-		
4.CUDIT Score	348	4.22	5.59	.221	.233	.235	-	
5.Reward Probability Subscale	387	33.06	5.18	-.360	-.22	-.027	-.166	-
6.Environmental Access Subscale	387	23.79	4.74	-.615	-.446	-.157	-.246	.485

Note: $p < .01$
PCL-5-scores measure Posttraumatic symptoms

Table 4

Summary of Single Mediation Models for Cannabis and Alcohol Use with ACE as the Influence Variable

Mediator Variable	N	a path(se)	b path(se)	c path(se)	c' path(se)	Indirect Effect with 95% confidence interval
			Alcohol (AUDIT)			
Reward Probability	311	-.58(.15)*	-.005(.06)	.62(.16)*	.61(.17)*	.003 [-.07, .08]
Environmental Suppressor	311	-1.04(.12)*	-.06(.08)	.62(.16)*	.56(.18)*	.06 [-.08, .20]
			Cannabis (CUDIT)			
Reward Probability	305	-.60(.15)*	-.12(.06)*	.66(.16)*	.59(.16)*	.07 **[.01, .16]**
Environmental Suppressor	305	-1.02(.12)*	-.26(.08)*	.66(.16)*	.40(.17)*	.26 **[.11, .45]**

Note.
a = path coefficient from ACE to the mediator (RPI subscales); b = path coefficient from the mediator to the outcome variable (AUDIT/CUDIT-measuring alcohol and cannabis use); c = direct path coefficient from the influence variable to the outcome variable (total effect: not including the mediator); c' = indirect path coefficient from the influence variable to the outcome variable through the mediator; se = standard error). Bolded text represents the significant mediation models tested through the bootstrapped .95 confidence intervals with lower and upper limits in brackets and the bootstrapped standardized indirect effect shown outside the parenthesis.
* $p < .05$

Table 5

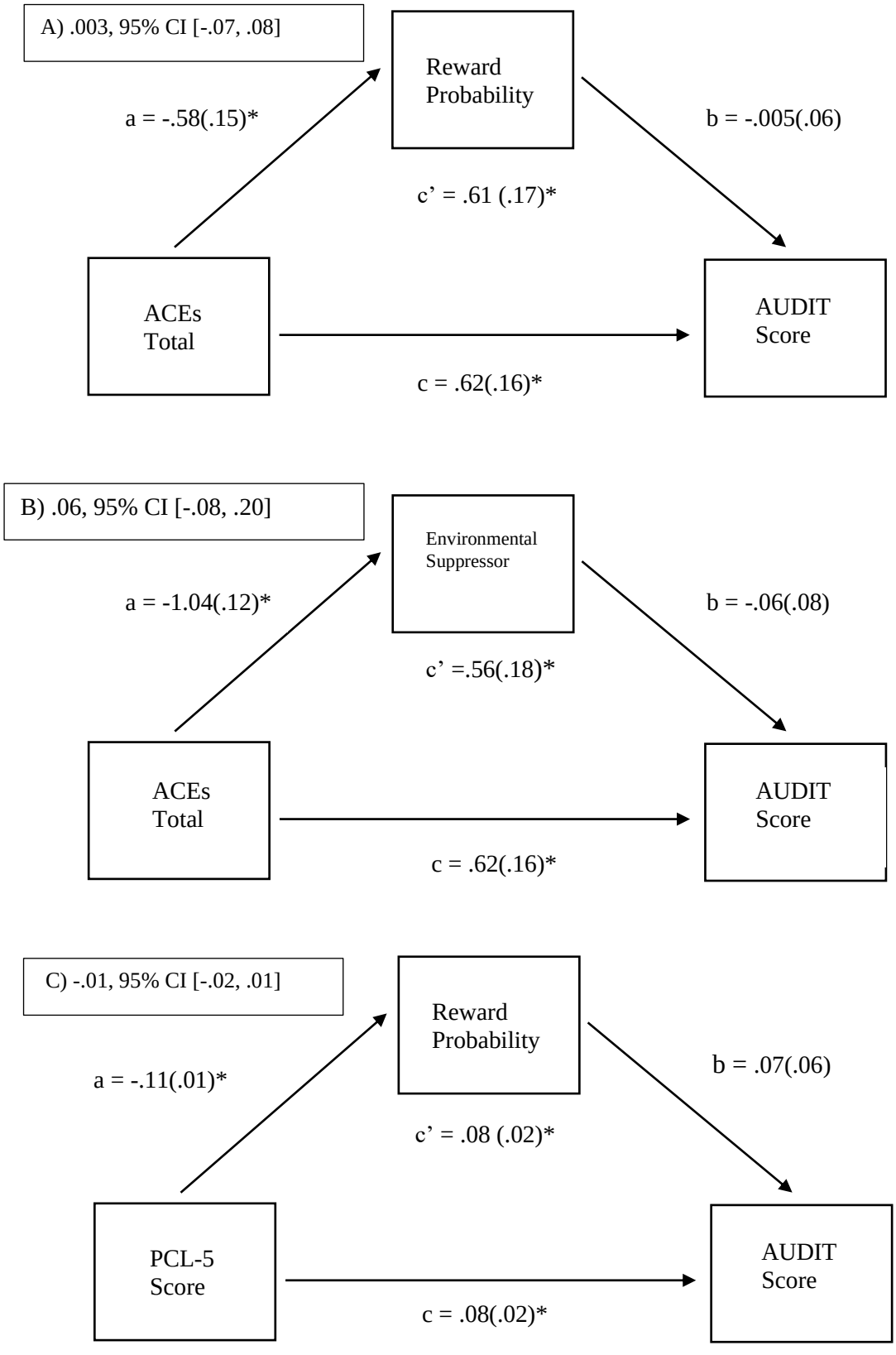
Summary of Single Mediation Models for Cannabis and Alcohol Use with PTS as the Influence Variable

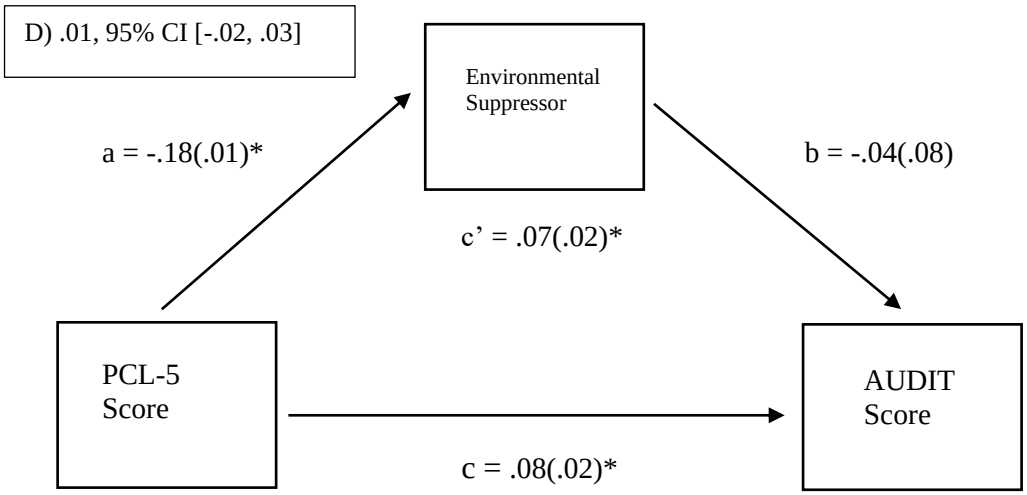
Mediator Variable	*n*	a path(se)	b path(se)	c path(se)	c' path(se)	Indirect Effect with 95% confidence interval
			Alcohol (AUDIT)			
Reward Probability	354	-.11(.01)*	.07(.06)	.08(.02)*	.08(.02)*	-.01[-.02, .01]
Environmental Suppressor	354	-.18(.01)*	-.04(.08)	.08(.02)*	.07(.02)*	.01[-.02, .03]
			Cannabis (CUDIT)			
Reward Probability	348	-.12(.02)*	-.10(.06)	.07(.02)*	.06(.02)*	.01 [-.002, .03]
Environmental Suppressor	348	-.17(.01)*	-.25(.08)*	.07(.02)*	.03(.02)	.04 **[.02, .07]**

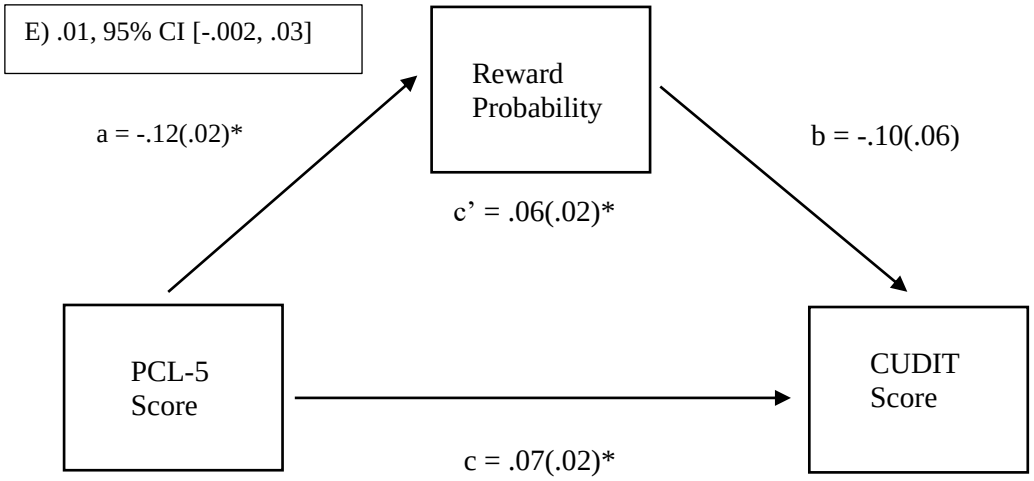
Note. a = path coefficient from PTS symptoms to the mediator (RPI subscales); b = path coefficient from the mediator to the outcome variable (AUDIT/CUDIT-measuring alcohol and cannabis use); c = direct path coefficient from the influence variable to the outcome variable (total effect: not including the mediator); c' = indirect path coefficient from the influence variable to the outcome variable through the mediator; se = standard error). Bolded text represents the significant mediation models tested through the bootstrapped .95 confidence intervals with lower and upper limits in brackets and the bootstrapped standardized indirect effect shown outside the parenthesis.
* $p < .05$
PCL-5 scores measure Posttraumatic symptoms

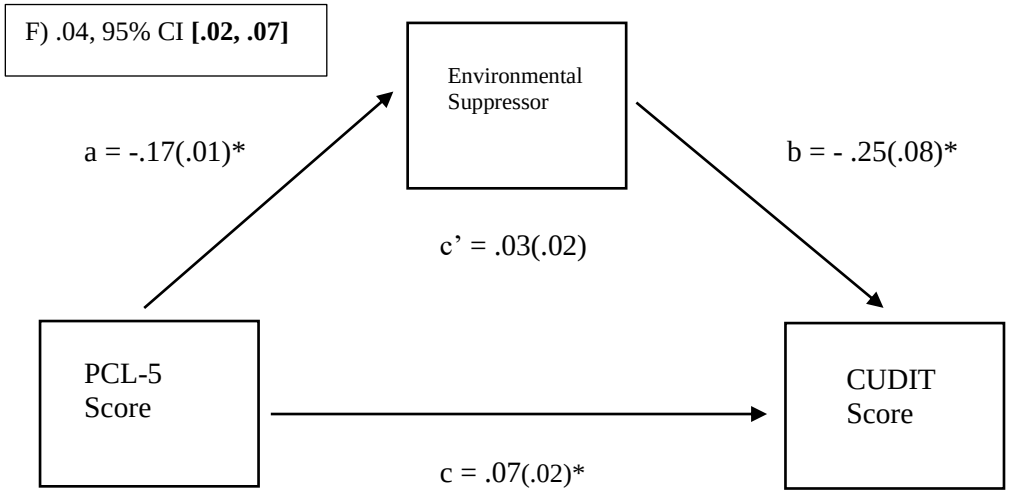
Figure 1

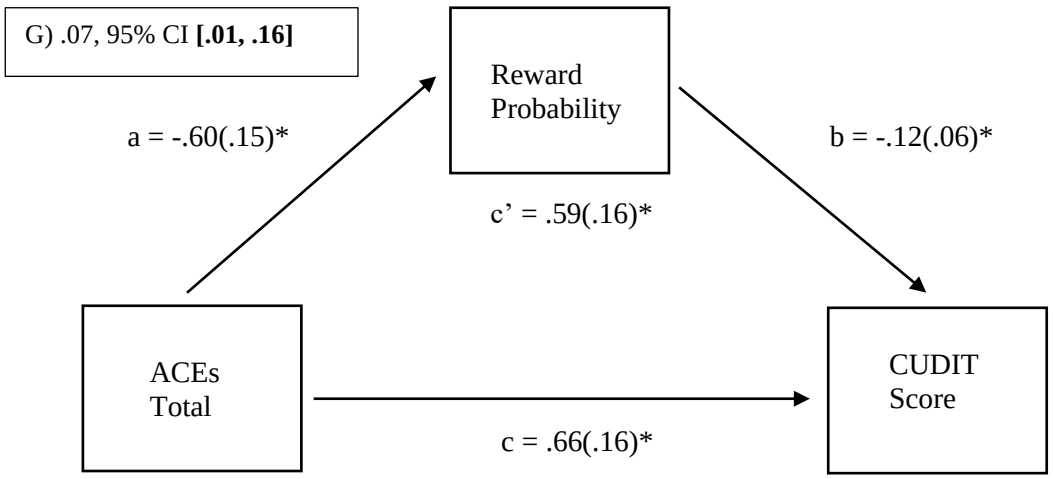
Summary of Final Single Mediation Models Significant and Insignificant

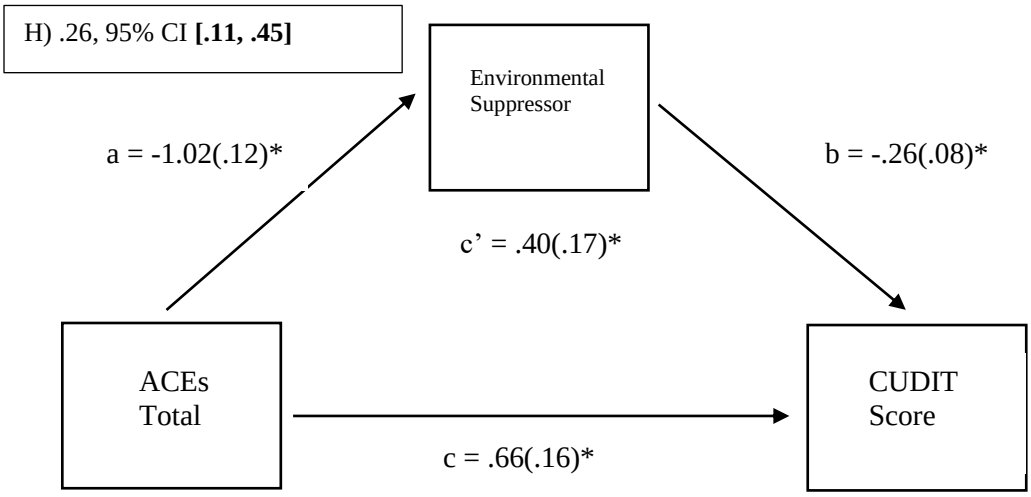



D) .01, 95% CI [-.02, .03]
Environmental Suppressor
a = -.18(.01)*
b = -.04(.08)
c' = .07(.02)*
PCL-5 Score
AUDIT Score
c = .08(.02)*


E) .01, 95% CI [-.002, .03]
Reward Probability
a = -.12(.02)*
b = -.10(.06)
c' = .06(.02)*
PCL-5 Score
CUDIT Score
c = .07(.02)*


F) .04, 95% CI **[.02, .07]**
Environmental Suppressor
a = -.17(.01)*
b = - .25(.08)*
c' = .03(.02)
PCL-5 Score
CUDIT Score
c = .07(.02)*





Note: Summary of significant and insignificant final single mediator model paths related to the RPI scales mediating the relationship between trauma (PCL-5/ACEs) and alcohol (AUDIT) and cannabis use (CUDIT). Through the bootstrap confidence intervals significant mediation was seen through three models all with bolded indirect effect. (F) Environmental Suppressor was a significant mediator in the relationship between PCL-5 and ACEs scores and CUDIT scores model, (G) ACEs-CUDIT model and Reward Probability was a significant mediator of the relationship between ACEs scores and CUDIT score, (H) ACEs-CUDIT model was a significant mediator in the relationship between ACEs-CUDIT model and Environmental Suppressor.
$p < .05$. *

Appendix B

WCU IRB Approval Form

Office of Research and Sponsored Programs | West Chester University | Wayne Hall
West Chester, PA 19383 | 610-436-3557 | www.wcupa.edu

TO: Michael Gawrysiak & Research Team
FROM: Nicole M. Cattano, Ph.D.
Co-Chair, WCU Institutional Review Board (IRB)
DATE: 2/10/2020

Protocol ID #
20191008E – R1

Project Title: Risk and Protective Factors Associated with Drug-Alcohol Use Among College Students: Examining Trauma Exposure and Posttraumatic Stress - REVISION

Date of Approval for Revision/Amendment: 2/20/2020**

☐ **Expedited Approval**

The submitted amendment/revision to this previously approved expedited study does not elevate the study risk. As a result, the amendments are approved for implementation. Any revisions to this protocol that are needed will require approval by the WCU IRB. Upon completion of the project, you are expected to submit appropriate closure documentation. Please see www.wcupa.edu/research/irb.aspx for more information.

Any adverse reaction by a research subject is to be reported immediately through the Office of Research and Sponsored Programs via email at irb@wcupa.edu.

Signature:

Co-Chair of WCU IRB

WCU Institutional Review Board (IRB)
IORG#: IORG0004242
IRB#: IRB00005030
FWA#: FWA00014155