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**The Mediated Moderation Model of Depressive Symptoms, Alcohol Use and Consequences:
The Protective Role of Executive Function**

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Author Note

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Abstract

Background: Heavy episodic drinking (HED) and negative drinking consequences represent prevalent and serious health concerns for college students. Depressive symptoms may elevate students' risk for engaging in HED and experiencing negative consequences, but levels of risk may vary by executive function (EF) capabilities. Growing evidence suggests that EF deficits are associated with comorbid depressive symptoms and alcohol misuse. Nevertheless, little is known about unique and shared risks that depressive symptoms and EF may interactively pose for HED and negative drinking consequences.

Methods: To address these gaps, the study assessed depressive symptoms, multiple domains of EF via multi-method approach, HED, and negative drinking consequences in a sample of 446 undergraduate students. Mediated moderation models were conducted to examine associations between depressive symptoms and alcohol use behaviors and modulating roles of EF.

Results: Depressive symptoms, poor planning, and self-reported executive dysfunction were significantly associated with HED and negative drinking consequences. HED mediated the effect of depressive symptoms and executive dysfunction on negative consequences. A significant interaction effect indicated that better EF (i.e., low or average self-reported executive dysfunction) buffers the risk depressive symptoms confer for negative drinking consequences.

Conclusion: The current findings suggest that college students may present with different risk and resilience factors for HED and negative drinking consequences. Effective EF capabilities may be especially helpful for reducing students' risk for more serious drinking consequences.

Key words: Heavy episodic drinking, alcohol-related consequences, depression, executive function, emerging adulthood

The Mediated Moderation Model of Depressive Symptoms, Alcohol Use and Consequences: The Protective Role of Executive Function

Heavy episodic drinking (HED; consuming five or more drinks; Schulenberg et al., 2017) and related negative consequences (e.g., violence, risky sexual behaviors, drunk driving, injuries) present serious public health concerns for college students (Hingson et al., 2017; National Institute on Alcohol And Alcoholism, 2016; Villarosa et al., 2018). Depressive symptoms—another increasingly common behavioral health concern among college students (Chen & Jacobson, 2012)—have been associated with increased risk for HED and negative drinking consequences (Acuff et al., 2018; American College Health Association, 2015; Kenney et al., 2017). While some may dismiss HED as part of the “college experience,” research has demonstrated that comorbid depressive symptoms and alcohol misuse may impair their health and safety well beyond college (Chen & Jacobson, 2012; Deas & Brown, 2006). However, levels of risk for comorbidity may vary across individuals, as not every student with depressive symptoms engages in HED and experiences negative drinking consequences (Acuff et al., 2018; Geisner et al., 2012). This highlights the importance of researching factors that may modulate individual vulnerability (Archie et al., 2012; Connell et al., 2015; Gonzalez et al., 2011). An improved understanding of students’ risk and resilience may help inform efforts to identify and intervene with those suffering from depressive symptoms and at higher risk for alcohol misuse.

Individuals with depressive symptoms may excessively consume alcohol to manage negative affect when they lack effective self-regulation (Pompili & Laghi, 2017; Simone et al., 2019), which in turn may lead to more negative drinking consequences (Correia et al., 2012; Villarosa et al., 2018). While self-regulatory skills have been identified as important resilience factors against comorbid depressive symptoms and alcohol misuse among college students

(Borden et al., 2011; Desalu et al., 2019), evidence specifying neurocognitive profiles of such resilience is limited (Connell et al., 2015; Hermens et al., 2011). Executive function (EF) refers to neurocognitive processes involved in goal-directed regulation of thought, action, and emotion (Friedman & Miyake, 2017; Howard & Melhuish, 2017; Zelazo & Carlson, 2012). Growing research has illustrated how these distinct yet interdependent facets of EF may underlie self-regulation (Hofmann et al., 2012; Nigg, 2017) and contribute to better behavioral health, including less depressive symptoms (Hermens et al., 2011; Marazziti et al., 2010; Warren et al., 2021) and less alcohol misuse (Kim-Spoon et al., 2017; Mesman, 2015; Mochrie et al., 2020). In contrast, it is less clear what role EF plays in determining individuals' vulnerability to comorbidity. Further research is needed to clarify how different facets of EF may modulate the links among these prevalent health concerns among college students.

Depressive Symptoms and Alcohol Use and Consequences

Depressive symptoms have been associated with higher risks for HED and negative drinking consequences among college students both cross-sectionally (Archie et al., 2012; Desalu et al., 2019) and longitudinally (Acuff et al., 2018; Lamis et al., 2010). Because HED and negative drinking consequences often cooccur (Kuntsche et al., 2017), it is important to study both behaviors and their shared risks. Particularly, research has indicated that HED may often precede negative drinking consequences (Nourse et al., 2017), suggesting that HED may be the link connecting depressive symptoms to negative drinking consequences. However, while highly correlated, research has also shown that HED and negative drinking consequences are not inextricably connected (Borden et al., 2011; Ray et al., 2009). Not all heavy drinkers experience negative alcohol-related consequences and not all light drinkers avoid them (Borden et al., 2011; Ray et al., 2009). Instead, other factors (e.g., depressive symptoms, EF deficits) may contribute

to higher risk for negative drinking consequences (Borden et al., 2011; Desalu et al., 2019). Given the impact that HED and negative drinking consequences distinctly and concomitantly have on college students' health and safety, it is critical to understand potential unique and shared risk and protective factors for both behaviors. A more comprehensive model that includes depressive symptoms, HED, and negative drinking consequences may help clarify the relative weights of direct and indirect associations among these common yet dire health concerns affecting college students.

The Role of Executive function

As a neurocognitive foundation of self-regulation, EF may play a notable role in college students' ability to manage alcohol use and consequences (Day et al., 2015; Kim-Spoon et al., 2017). Investigating EF's role in behavioral health may be particularly salient among undergraduate populations because the frontal-parietal neural network underlying EF continues to develop into emerging adulthood (Johnson et al., 2009; Lebel & Beaulieu, 2011; Silveira et al., 2020). In addition to environmental risk factors (e.g., campus culture, peer groups), developing neural circuitry during this transitional period from adolescence to emerging adulthood may present increased vulnerability for risky drinking behaviors as well as opportunities for intervention (Hermens, Lagopoulos, et al., 2013; Shnitko et al., 2019; Silveira et al., 2020). Therefore, an improved understanding of EF's contributions to college students' alcohol use may inform targets of assessment and intervention.

Extant literature has indicated significant associations between distinct facets of EF and alcohol use. For instance, higher working memory has been related to greater awareness and control of alcohol use behaviors (Blume et al., 2005; Houben et al., 2011). Similarly, better attention skills have been linked to better regulation of and recovery from alcohol misuse (Blume

et al., 2005). Among college students, attention regulation difficulties have been associated with greater risk for HED and negative drinking consequences (Mesman, 2015; Mochrie et al., 2020). Better planning capabilities have been linked to decreased HED among college students (Black & Mullan, 2015) and alcohol dependent patients (Rupp et al., 2012). Moreover, self-reported executive dysfunction in everyday life have similarly been associated with greater risk for alcohol misuse among adolescents and emerging adults (Silveira et al., 2020). A review of research examining the role of EF in adolescents and emerging adults' alcohol use has indicated that its moderating effect may be more consistent and stronger than its direct contribution (Kim-Spoon et al., 2017). Therefore, EF may be conceptualized as a regulatory system that modulates levels of individual vulnerability to alcohol misuse (Kim-Spoon et al., 2017). Importantly, its effect may vary across different domains (e.g., attention, working memory; Kim-Spoon et al., 2017; Lees et al., 2019) and mental constructs (i.e., performance-based, cognitive efficiency vs. self-reported successes in goal pursuits; Toplak et al., 2013). Ongoing research examining EF's direct and interactive contributions is needed to elucidate its role in HED and negative drinking consequences among college students.

Furthermore, EF may be especially compromised among individuals with comorbid depressive symptoms and alcohol misuse. Notably, emerging adults with comorbid depressive symptoms and HED exhibited greater neurocognitive deficits than healthy controls (Hermens, Lee, et al., 2013) or those with either condition alone (Connell et al., 2015). Although these findings provide some insight into the neurocognitive underpinnings of comorbid depressive symptoms and HED, no clear conclusion can be drawn about the functions of EF in a broader spectrum of college students' alcohol-related experiences. Given both concurrent and separate occurrences of HED and negative drinking consequences, risk and resilience factors associated

with these outcomes should be collectively examined in a model. Overall, more research is needed to elucidate the modulating function of EF in the relation among depressive symptoms, alcohol use, and consequences among college students (Kim-Spoon et al., 2017).

Present Study

The present study aimed to investigate how depressive symptoms and EF interact to determine risk levels for HED and negative drinking consequences among college students. Consistent with the existing theoretical framework and empirical evidence, we conceptualized a mediated moderation model where EF would moderate the relations between depressive symptoms and alcohol use, and HED would mediate the association between risk factors (i.e., depressive symptoms and poor EF) and negative drinking consequences (see Figure 1; Morgan-Lopez & MacKinnon, 2006). We hypothesized that: (a) depressive symptoms would be associated with more HED and negative drinking consequences; (b) better EF (e.g., attention, cognitive flexibility, working memory, planning, self-reported global EF) would weaken the relation between depressive symptoms and HED; (c) better EF would weaken the relation between depressive symptoms and negative consequences; and (d) HED would mediate the direct and interactive effect of depressive symptoms and EF on negative drinking consequences.

Methods

Participants

The present study draws data from a larger cross-sectional research project examining risk and protective factors for college students' behavioral health. Participants included 446 undergraduate students from a public university in the Northeastern United States ($N_{\text{Males}} = 178$, $M_{\text{age}} = 18.8$ years). Over half of the participants (63.9%) were in their first year of undergraduate study.

Measures

Performance-Based EF Measures

Well-validated performance-based instruments were selected to assess multiple domains of EF: attention, cognitive flexibility, working memory, and planning.

Berg Card Sorting Task (BCST). Modeled after the Wisconsin Card Sorting Task (Stuss et al., 2000), the BCST was administered via the PEBL computer software (Mueller & Piper, 2014) to measure attention regulation and cognitive flexibility. Percentages of non-perseveration (inattention) and perseveration (cognitive inflexibility) errors were utilized in subsequent analyses (Barceló & Knight, 2002; Delis et al., 1992). The BCST has acceptable test-retest reliability ($r = .45$), which provides adequate relative consistency within the context of performance-based EF measures, given known limitations in capturing EF (e.g., task novelty, practice effects; Piper et al., 2015).

Digit Span (DS). The DS Forward and Backward scales of the WAIS-IV were used to measure working memory (Wechsler et al., 2008). Forward and Backward raw scores were summed to create a total DS performance score. The two-week test-retest reliability for the DS is .83 and the average split-half reliability is .93 (Wechsler et al., 2008).

Tower of London Task (TOL). Administered using the PEBL computer software (Mueller & Piper, 2014), the TOL was used to measure planning capabilities. An aggregate score representing both success rate (i.e., number of total moves) and average planning time was used to represent planning capabilities (Berg & Byrd, 2002). The TOL has acceptable test-retest reliability ($r = .35$) within the context of performance-based EF measures (Piper et al., 2015).

Self-Reported EF Measure

The Behavior Rating Inventory of Executive Function: Adult Self-Report (BRIEF-A;

Roth et al., 2014) was used to assess EF in daily life. The BRIEF is the most commonly used self-report scale of EF and provides an ecologically valid indicator of goal-directed, problem-solving behaviors in everyday life (Roth et al., 2014; Silveira et al., 2020; Toplak et al., 2013). Participants rated each of 75 items on a 3-point Likert scale (1 = *never* and 3 = *often*). A summary score, the Global Executive Composite (GEC), was formed by first calculating gender-combined scores for nine EF domains (e.g., inhibit, shift, working memory, plan) and subsequently summing these indices. Higher BRIEF GEC scores indicate greater global executive dysfunction. Within this sample, the BRIEF GEC demonstrated high internal reliability ($\alpha = .82$).

Depressive Symptoms

The Center for Epidemiologic Studies Depression Scale – Revised (CESD-R; Eaton et al., 2004) was used to assess depressive symptoms. Participants were asked to rate their feelings and behaviors in the past week (e.g., “I felt sad”) on a 5-point Likert scale (0 = *not at all or less than 1 day* and 4 = *nearly every day for 2 weeks*). A total score was formed by summing responses to each of the 20 questions; summed scores ≥ 16 indicate clinical levels of depressive symptoms (Eaton et al., 2004). Within this sample, the CESD-R demonstrated high internal reliability ($\alpha = .94$).

Alcohol Use and Consequences

Participants were instructed to report how many times they engaged in HED in the past two weeks. To measure the range of negative drinking consequences, this study used a 24-item alcohol-related consequences questionnaire developed by Barnett et al. (2014). In developing this questionnaire, Barnett et al. (2014) combined items shared across multiple established measures of drinking consequences. We made minor adjustments to the questionnaire to focus on

immediate behavioral outcomes of alcohol use, including risky sexual behaviors, that have been known to endanger college students' health and safety (Looby et al., 2019; National Institute on Alcohol And Alcoholism, 2016). Specifically, one item was removed from the original measure (i.e., "had problems with schoolwork"); one item was added to this questionnaire (i.e., "Have taken advantage of another person sexually"). Participants rated whether they had experienced any of the consequences during or after drinking alcohol within the past week (0 = *no* and 1 = *yes*). A total score was formed by summing responses to the items belonging to the negative drinking consequences scale. Within the sample, the scale demonstrated high internal reliability ($\alpha = .96$).

Procedure

Participants were recruited through the undergraduate research pool system. Following the informed consent process, participants completed self-report questionnaires on a computer. Afterwards, a trained research assistant administered the neurocognitive measures of EF in the following order: BCST, TOL, and DS. Upon conclusion of all tasks, the participants received partial credits toward a research participation requirement in certain psychology courses. All procedures were approved by the university's Institutional Review Board.

Data Screening and Missing Data Analysis

All variables of interest were assessed for univariate and multivariate normality. Skewness and kurtosis exceeded acceptable ranges ($< \pm 2.0$; Gravetter & Wallnau, 2014) and several univariate and multivariate outliers ($z > \pm 3.3$) were detected. Despite winsorization, a small number of univariate and multivariate outliers (less than 7% of cases per variable; i.e., TOL, BCST, negative drinking consequences) continued to be present. The assumption of linearity was upheld, and no issues of multicollinearity were detected (Tolerance $> .2$; VIF $<$

5.0). Examination of the residual plots indicated a potential mild violation of the homogeneity of variance assumption, which may have produced biased standard errors. The rates of missing data were found to be less than 10% across all variables. Composite scores were only calculated for individuals missing less than 10% of the item-level data points per scale (i.e., CESD-R, BRIEF-A, negative drinking consequences). As such, of the 446 participants, 3 were omitted from BRIEF-A scoring and 1, from CESD-R scoring due to too many missing items. To handle remaining missing data, we used full information maximum likelihood (FIML) to increase power and reduce parameter biases (Collins et al., 2001; Enders, 2008).

Data Analytic Plan

Descriptive statistics and zero-order correlations were computed using SPSS 26. We conducted mediated moderation models using Mplus 6.12 (Muthén & Muthén, 2010) and assessed indirect effects via the MODEL INDIRECT command. Self-reported age and male gender were included as a covariate in all models based on their documented associations with alcohol use behaviors (Kenney et al., 2018; Schnetzer et al., 2013). A power analysis conducted via the G*Power 3.0 computer program (Erdfelder et al., 2009; Faul et al., 2007) indicated good power (96%) to detect a small to medium effect size ($r^2 = .19$; Conner et al., 2009; Lees et al., 2019) in a regression model.

Results

Descriptive statistics and the results of correlation analyses are presented in Table 1. Of the full sample, 32.9% ($N = 147$) reported at least one episode of HED in the past two weeks, and 32.7% ($N = 146$) experienced one or more negative drinking consequence in the past week. Younger and male students reported more HED, while female students reported more depressive symptoms. Higher levels of depressive symptoms were correlated with greater self-reported

executive dysfunction (BRIEF), more HED, and more drinking consequences. Better planning capabilities (TOL) were correlated with fewer drinking consequences, and greater self-reported executive dysfunction were related to more HED and negative drinking consequences. Better cognitive flexibility (BCST perseveration error) and planning capabilities (TOL) were correlated with better attention regulation (BCST non-perseveration error).

Mediated moderation models examined the direct, indirect, and interactive associations linking depressive symptoms, EF, HED, and negative drinking consequences; models were run separately for each domain of EF. In a model examining the effect of planning capabilities (Figure 2), depressive symptoms were significantly associated with more HED, $\beta = 0.17$, $SE = 0.05$, $p < .001$, and HED in turn was associated with more negative drinking consequences, $\beta = 0.39$, $SE = 0.05$, $p < .001$. Depressive symptoms were also significantly associated with more negative consequences, $\beta = 0.15$, $SE = 0.04$, $p < .001$. In contrast, as hypothesized, better planning was associated with fewer negative consequences, $\beta = -0.14$, $SE = 0.05$, $p = .002$. Interactive effects of depressive symptoms and planning were not statistically significant. Among covariates, male gender was significantly associated with more HED, $\beta = 0.25$, $SE = 0.05$, $p < .001$. Given the significant paths linking depressive symptoms, HED, and negative drinking consequences, the indirect (i.e., mediation) effect was assessed. HED significantly mediated the indirect association between depressive symptoms and negative drinking consequences, $\beta = 0.07$, $SE = 0.02$, $p = .001$.

In a mediated moderation model examining the effect of self-reported executive dysfunction (Figure 3), more executive dysfunction was significantly associated with more HED, $\beta = 0.13$, $SE = 0.05$, $p = .016$, and HED in turn was associated with more negative drinking consequences, $\beta = 0.40$, $SE = 0.05$, $p < .001$. Depressive symptoms were also significantly

associated with more drinking consequences, $\beta = 0.16$, $SE = 0.07$, $p = .023$. Given the significant paths linking executive dysfunction, HED, and negative drinking consequences, the indirect effect was assessed. HED significantly mediated the indirect association between executive dysfunction and drinking consequences, $\beta = 0.05$, $SE = 0.02$, $p = .028$. Lastly, executive dysfunction significantly moderated the association between depressive symptoms and negative drinking consequences, $\beta = -0.11$, $SE = 0.05$, $p = .022$. Analyses of conditional effects showed that depressive symptoms were only significantly associated with drinking consequences at low, $B = 0.41$, $SE = 0.16$, $p = .009$, and average, $B = 0.26$, $SE = 0.12$, $p = .02$, levels of executive dysfunction, but not at high levels, $B = 0.11$, $SE = 0.10$, $p = .28$ (see Figure 4).

Neither direct nor interactive effects of inattention (BCST non-perseveration errors), cognitive inflexibility (BCST perseveration errors), and working memory (Digit Span) were significant in their respective models. The significant associations between depressive symptoms, HED, and drinking consequences were comparable to those demonstrated in the aforementioned models and thus, were omitted to avoid redundancy.

Discussion

The present study investigated the roles of executive function (EF) in modulating levels of risk that depressive symptoms may confer for alcohol use and consequences. Of note, the study used both performance-based and self-report measures to capture multiple interrelated yet distinct domains of EF and examined their contributions to emerging adult college students' risk for alcohol misuse. Moreover, we used a more comprehensive, mediated moderation model to clarify unique and shared risk and protective factors for heavy episodic drinking (HED) and negative drinking consequences (e.g., fights, injuries, trouble with authority). This analytic approach helped elucidate how depressive symptoms and domains of EF may distinctly and

interactively relate to students' negative alcohol related experiences, and how much of the risk may be transmitted through excessive drinking.

Direct and Indirect Effects of Depressive Symptoms and EF

Our data indicated that depressive symptoms may represent a ubiquitous risk factor for both HED and negative drinking consequences. In the mediated moderation model including planning capabilities (TOL), college students with more depressive symptoms appeared to experience more negative consequences by engaging in more HED. Furthermore, higher levels of depressive symptoms were directly associated with more negative consequences above and beyond the effect of HED, which supports the notion that alcohol use and consequences may be related but separate phenomena (Borden et al., 2011). While students with depressive symptoms may frequently experience negative drinking consequences in the aftermath of HED, the range of consequences they experience may vary by the severity of depressive symptoms. It is also possible that students may engage in risky drinking behaviors without necessarily consuming a large amount of alcohol. This result replicates and expands upon prior findings (Borden et al., 2011; Desalu et al., 2019) by demonstrating the role of depressive symptoms as an independent and shared risk factor for HED and negative drinking consequences among college students.

Additionally, poor planning was found to be a significant risk factor for negative drinking consequences above and beyond the effect of depressive symptoms. Planning is a higher-order neurocognitive construct that helps to organize behavior necessary to self-regulate and attain salient goals (e.g., anticipating future events, formulating and executing tasks; Luciana et al., 2009; Roth et al., 2013; Valls-Serrano et al., 2016). Therefore, during alcohol use, better planning capabilities may have enabled students to prepare and organize their drinking behaviors to avoid negative consequences (Valls-Serrano et al., 2016). In contrast, planning was unrelated

to HED. This finding is notable and should be understood in the context of college student populations. In the U.S., HED during college is often normalized as a rite of passage (Schulenberg et al., 2017; Wrye & Pruitt, 2017) and thus, may not be perceived as adverse and risky as negative drinking consequences. Therefore, among college students, planning capabilities may not be as relevant to HED engagement but may help reduce their risk for engaging in risky, regrettable behaviors upon drinking. To our knowledge, this is the first study to link performance-based planning capabilities with negative drinking consequences among college students. While this is consistent with prior findings documenting the protective effects of better planning among alcohol and other substance use patients (Moriyama et al., 2002; Valls-Serrano et al., 2016), the demonstrated link in this context and population is still novel and requires replications.

As hypothesized, self-reported executive dysfunction (BRIEF) were associated with more HED, which in turn was related to more negative drinking consequences. The direct and indirect associations between executive dysfunction and alcohol use and consequences complement prior findings that have identified these self-reported difficulties as a significant risk factor for alcohol misuse (Liu et al., 2016; Silveira et al., 2020). Further, our result extends these findings by showing that executive dysfunction in the real-life settings may indirectly contribute to more serious drinking consequences through increased alcohol consumption, and that these links are significant beyond the effect of depressive symptoms. Thus, while similar in direction, the impact of self-reported EF difficulties in everyday life appears more salient and pervasive than that of performance-based planning capabilities.

Interactive Effects of Depressive Symptoms and EF

Furthermore, our data indicated that self-reported executive dysfunction may moderate

the association between depressive symptoms and negative drinking consequences. Specifically, better abilities to problem-solve and execute goal-directed behaviors in everyday life appeared to reduce the risk that depressive symptoms may pose for negative drinking experiences. This finding is consistent with prior research that has linked EF deficits with greater alcohol use (Day et al., 2015; Wetherill et al., 2013). It further adds to the literature by highlighting the function of EF as a resilience factor for college students at risk for comorbid depressive symptoms and alcohol misuse. However, examination of the simple slopes also suggests that at very high levels of depressive symptoms, better EF may no longer buffer the heightened risk for negative consequences. Additionally, it is notable that in our sample the moderating effect of executive dysfunction was not mediated by HED; rather, it was significantly related to negative drinking consequences beyond the effect of HED. This may suggest that among college students, for whom HED is often normalized (Schulenberg et al., 2017; Wrye & Pruitt, 2017), EF is particularly salient for understanding the risk of more serious consequences related to drinking. In sum, while depressive symptoms appear to be a potent risk factor for alcohol misuse, better EF may modulate the deleterious impact of poor mood and help students avoid negative consequences related to alcohol use.

Lastly, it is important to note that performance-based indices of attention regulation, cognitive flexibility, and working memory displayed no significant associations with alcohol use and consequences, and that only the direct effect of performance-based planning capabilities was significant. Although these findings contradict our hypotheses, differences in results involving performance-based EF measures vs. the BRIEF are not entirely surprising. Research has noted important distinctions between performance-based EF measures and self-rated scales (e.g., BRIEF; Toplak et al., 2013). The BRIEF may provide information about successes in daily goal

pursuits and thus, may be more ecologically salient and reflective of subjective distress and impairment (Denckla, 2002; Løvstad et al., 2016; McAuley et al., 2010; O'Rourke et al., 2018). In contrast, performance-based measures may offer more objective estimates of cognitive efficiency and executive capabilities (Roth et al., 2013; Toplak et al., 2013), but may be more easily influenced by state-dependent factors (e.g., fatigue; Hsu et al., 2014; Lavie, 2005; Nicholls et al., 2005). Considering these distinctions between performance-based EF and the BRIEF, our results suggest that the BRIEF may be particularly useful for understanding emerging adult college students' risk for alcohol use and consequences.

Clinical Implications and Future Directions

Although EF tends to remain stable across time, growing evidence supports that it may be responsive to intervention (Friedman & Miyake, 2017; Zelazo & Carlson, 2012). Researchers have proposed that relative stability of one's environment may be the reason why individual differences in EF remain constant across development (Friedman & Miyake, 2017; Zelazo & Carlson, 2012). A wealth of research has documented incredible plasticity and susceptibility of the human brain to environmental influences during periods of growth (Kolb et al., 2013; Zelazo & Carlson, 2012). The transition from adolescence to emerging adulthood marks an important period of prefrontal maturation (Johnson et al., 2009; Lebel & Beaulieu, 2011; Silveira et al., 2020). It is yet to be known whether EF would be prone to change during emerging adulthood; however, research has indicated that EF training programs (e.g., planning) may help reduce alcohol misuse among both college students (Black & Mullan, 2015) and alcohol dependent patients (Rupp et al., 2012). Although continued research is needed, efforts to reduce HED and negative drinking consequences on college campuses should consider assessing and helping to enhance students' daily EF skills (e.g., planning, organization). Such training programs may be

especially critical for students who are also struggling with depressive symptoms and thus, are at higher risk for alcohol misuse. Future research should examine whether emerging adults' EF can benefit from psychoeducation and goal management training and whether these effects would transfer to improved affect and behavioral regulation in drinking situations.

Limitations

The present study used a convenience sample of college students enrolled in psychology courses. These sample characteristics may reduce the generalizability of our results to populations outside college settings. Nevertheless, the number of students reporting HED (33%) or clinically notable levels of depressive symptoms (34.5%; CESD-R \geq 16; Eaton et al., 2004) in our sample were roughly comparable to the rates observed in the national samples of emerging adults (CDC, 2012; Gress-Smith et al., 2015). To our knowledge, the rates of alcohol-related consequences on a weekly basis in college populations is unknown. Overall, such comparability of depressive symptoms and HED reported in our sample may indicate its relative generalizability to emerging adult college populations in the U.S.

Additionally, the measures utilized in the current study relied on a relatively small timeframe for determining HED and negative drinking consequences. It is possible that capturing only the past one to two weeks of alcohol use and consequences may not have accurately captured students' typical behaviors. Given the overall length and complexity of the larger project assessing various aspects of college students' health, more involved measures of alcohol use (e.g., timeline follow-back, diary) were unfeasible. Instead, we aimed to reduce inaccurate recalls or social desirability bias by offering relatively short timeframe questions that can be answered anonymously (Davis et al., 2010). Follow-up work should consider longer timeframe observational and self-report measures of alcohol use to more comprehensively track college

students' drinking behaviors. Moreover, the EF measures used in this study were not counterbalanced; thus, the order of test administration could have potentially influenced students' performance (Brooks, 2012). Future research should consider randomizing the order of EF test administration to minimize the carryover effects (Brooks, 2012). Lastly, the cross-sectional nature of the data limits our ability to make causal inferences. Our findings should be replicated in longitudinal data.

Conclusion

The present study provides evidence that EF may protect college students with depressive symptoms from experiencing more negative drinking consequences. Although further investigation is necessary, our findings underscore the importance of promoting EF development to mitigate behavioral health risks among students. Prevention and intervention endeavors targeting depression and alcohol misuse on college campuses may benefit from assessment and training of EF skills, particularly in the context of students' daily behavioral regulation.

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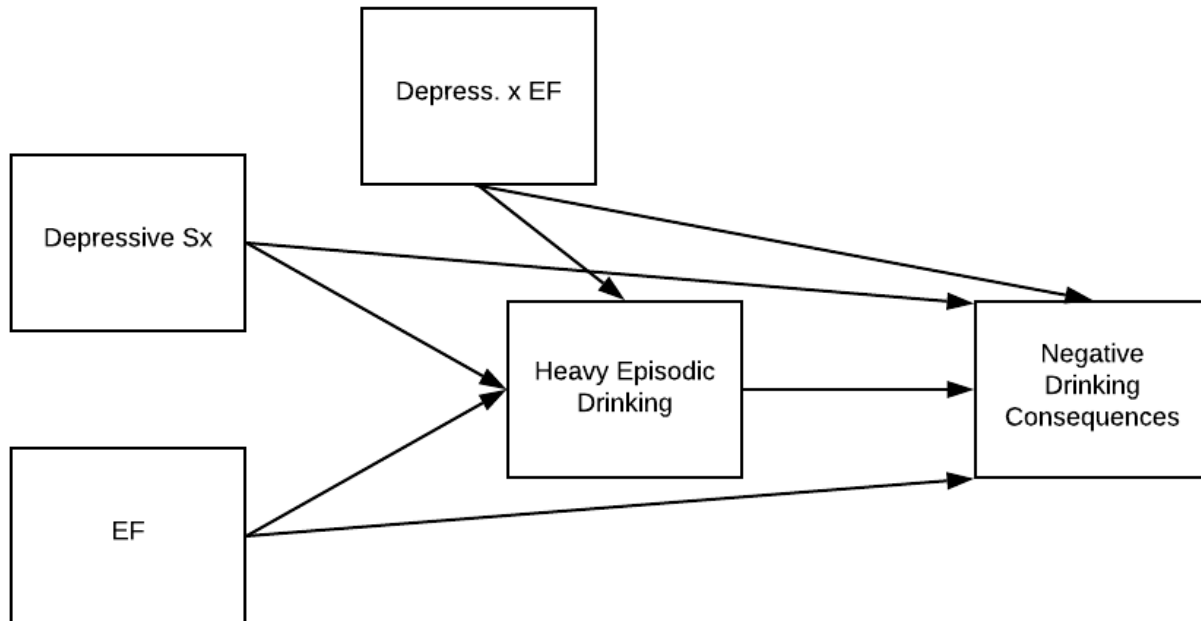
Table 1*Descriptive Statistics and Correlations (N = 446)*

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9
1. Male	N = 178; 40%										
2. Age	18.80	1.19	.09								
3. Heavy episodic drinking in the past two weeks	0.77 (0, 6)	1.58	.23 **	.10 *							
4. Negative alcohol-related consequences in the past week	0.97 (0, 7)	1.65	.07	-.04	.41 **						
5. Depressive symptoms	14.49	12.69	-.15 **	-.06	.14 *	.22 **					
6. BCST preservation error rates	0.14	0.06	-.01	-.01	-.03	.01	.04				
7. BCST non-preservation error rates	0.10	0.09	.03	.01	.05	.06	.09	.20 **			
8. TOL Performance	-0.01	1.46	.07	.08	.02	-.14 **	-.03	-.07	-.13 **		
9. DS Total Performance	18.39	3.35	.12 *	.01	-.03	.00	.02	-.06	-.03	.04	
10. BRIEF GEC	113.11	24.04	-.07	-.07	.17 **	.22 **	.66 **	.01	-.02	-.09	-.04

Note. Minimum and maximum values are reported in (.). * $p < .05$, ** $p < .01$

Figure 1

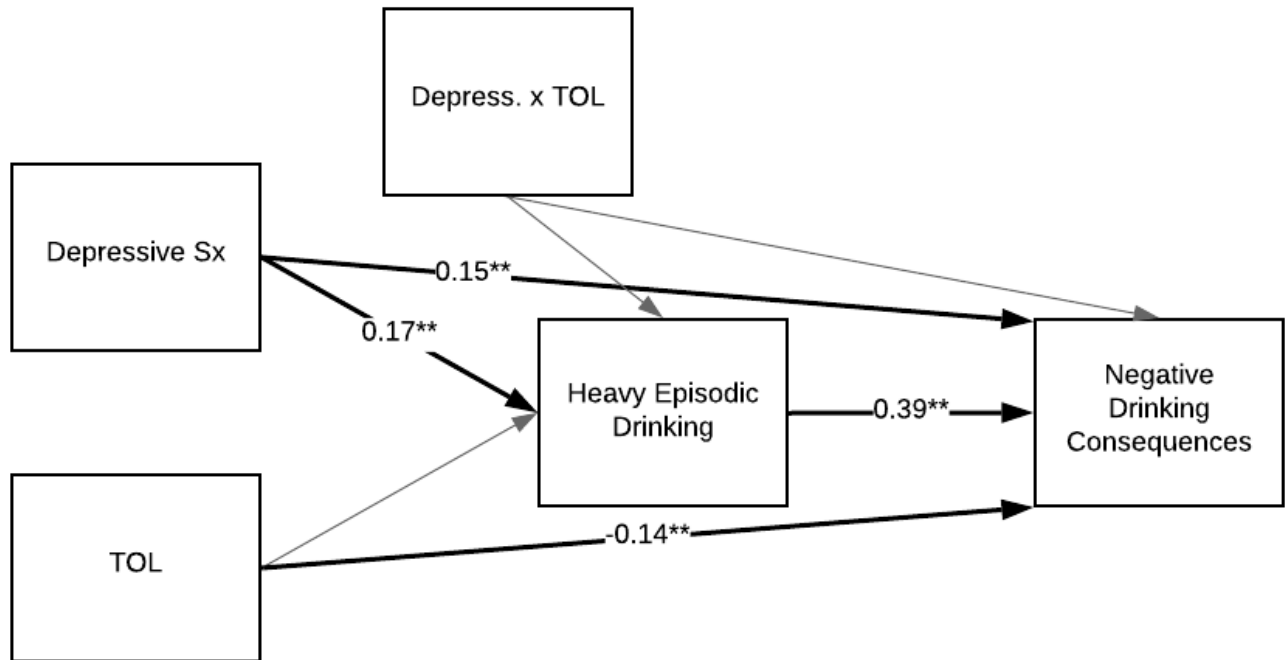
The Proposed Mediated Moderation Model Examining Direct, Indirect, and Interactive Relations among Depressive Symptoms, EF, HED, and Negative Drinking Consequences



Note. Depressive Sx or Depress. = Depressive Symptoms; EF = Executive function.

Figure 2

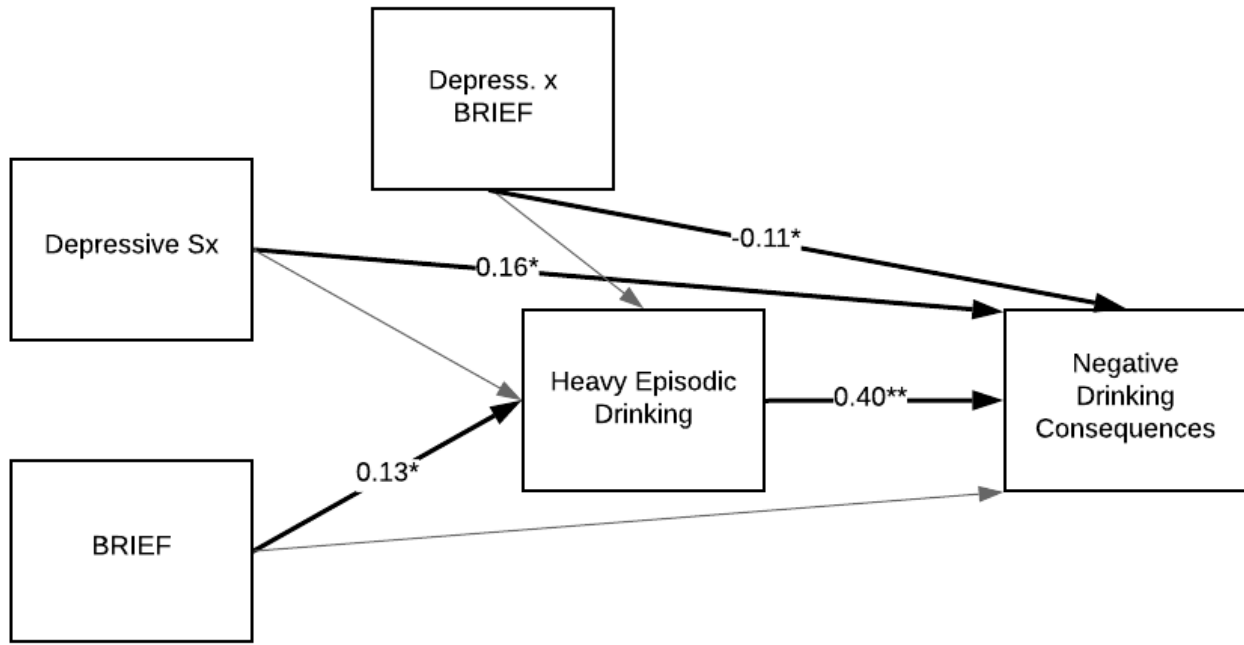
Mediated Moderation Model of Depressive Symptoms and Planning Regressed on Alcohol Use and Consequences



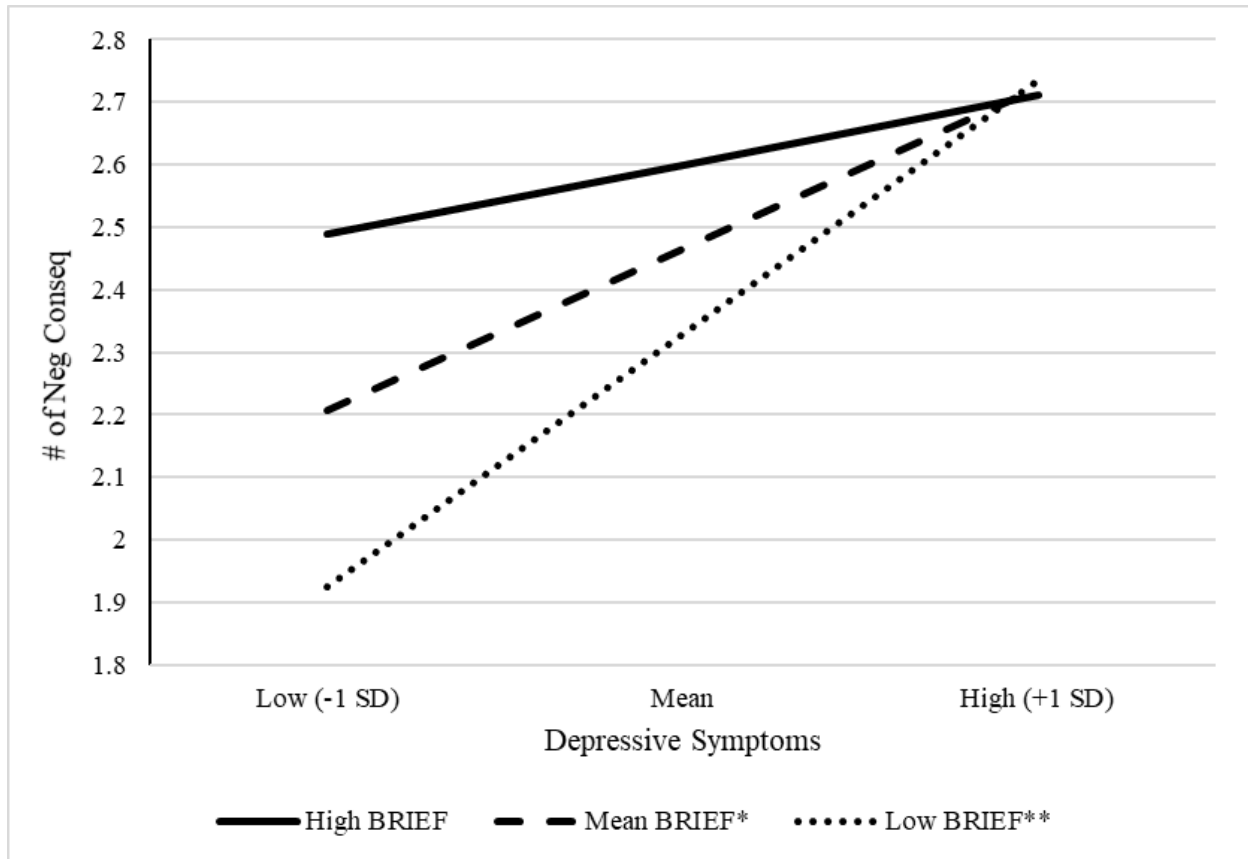
Note. Paths depicted (light gray and black) were specified in the full model. Only statistically significant standardized coefficients are depicted to aid readability. * $p < .05$ ** $p < .01$

Figure 3

The Mediated Moderation Model of Depressive Symptoms and Self-Reported Executive Dysfunction Regressed on Alcohol Use and Consequences



Note. Paths depicted (light gray and black) were specified in the full model. Only statistically significant standardized coefficients are depicted to aid readability. * $p < .05$ ** $p < .01$

Figure 4*Moderating Effects of Global Executive Dysfunction*

Note. Conditional effects of depressive symptoms on negative drinking consequences at high (1 SD above the mean), average, and low (1 SD below the mean) levels of BRIEF GEC (higher scores indicate greater executive dysfunction). The relation between depressive symptoms and negative drinking consequences is only significant among participants who exhibited low and average levels of executive dysfunction. Alpha significance is notated as follows: * $p < .05$, ** $p < .01$.