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Associations between Executive Functioning, Affect-regulation Drinking Motives, and Alcohol Use and Problems

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Abstract

Motivation to use alcohol to regulate positive and negative affect and deficits in cognitive control (i.e., executive functions; EFs) have both been associated with increased alcohol use and problems. Although dual process models predict that affect-driven motivations and cognitive control should interact to determine alcohol involvement and heavy drinking, this intersection has remained largely unexplored. The present study examined the extent to which effects of enhancement and coping drinking motives on alcohol use and alcohol-related consequences are moderated by individual differences in three theorized components of EF. We anticipated, in general, that drinking motives would more strongly predict alcohol use, heavy drinking, and alcohol-related consequences among individuals low versus high in cognitive control/EF. Participants ($N = 801$) completed a battery of nine EF tasks as well as measures of drinking motives, alcohol consumption, heavy drinking, and alcohol-related negative consequences. A baseline structural model indicated that (1) both enhancement motives and coping motives predicted alcohol use and heavy drinking; (2) both enhancement and coping motives exerted their effects on alcohol-related consequences both directly and indirectly via alcohol use; and (3) shifting/switching abilities were modestly positively associated with heavy drinking. Most important for the aims of the study, latent variable interaction analyses failed to provide consistent evidence that better EF abilities attenuate the effects of drinking motives on alcohol use and alcohol-related consequences, as predicted.

Keywords

drinking motives; executive functions; heavy drinking; alcohol-related consequences; latent variable modeling

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Why do some individuals engage in heavy and problematic drinking more than others? Empirical research provides evidence for the effects of two key constructs: (1) deficits in cognitive control or executive functions (EFs) (for reviews see Day, Kahler, Ahern, & Clark, 2015; Gierski et al., 2013), and (2) motivations to use alcohol for affect regulation (for review see Cooper, Kuntsche, Levitt, Barber, & Wolf, 2016). Dual process models (see

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Wiers et al., 2007) posit that not only should affect-driven motives and EFs[1] predict alcohol involvement and heavy drinking, but they should also interact, such that motives should be stronger predictors when top-down regulatory (cognitive) control is weak. To date, however, little research has directly examined the way these factors are inter-related and, consequently, potential interactions between drinking motives and EFs on alcohol involvement and alcohol-related consequences remain largely unexplored. The purpose of the present study was to test interactions between drinking motives and EFs in predicting alcohol use, heavy drinking, and alcohol-related consequences within an integrative theoretical framework.

A Motivational Perspective on Individual Differences in Alcohol-Related Behavior

As noted by Cooper (1994), understanding why and under what conditions people will consume alcohol requires consideration of specific motivational factors. In fact, drinking motives have been described as a "final common pathway to alcohol use through which the influence of more distal variables is mediated" (Cooper, Kuntsche, Levitt, Barber, & Wolf, 2016, p. 375). Cooper draws a distinction between alcohol consumption motivated by coping needs (i.e., behavior fueled by a need to reduce or regulate negative emotions) and that motivated by enhancement needs (i.e., behavior driven by a need to enhance positive mood or well-being). Behaviors driven by these two classes of motives are embedded in distinctive phenomenological and behavioral networks, and are associated with different personality profiles and consequences of use (Cooper, Frone, Russell, & Mudar, 1995; see Cooper et al., 2016, for review). Enhancement motives strongly predict alcohol use and heavy drinking within both cross-sectional and prospective study designs, but do not directly predict alcohol-related consequences when the effects of alcohol use per se are controlled (Cooper, 1994). Coping motives have shown less robust and reliable associations with alcohol use and heavy drinking per se, but have been shown to directly predict alcohol-related negative consequences over and above alcohol use (Cooper et al., 2016). Even though enhancement and coping motives were assumed to be trait-like in terms of their stability (Cooper et al., 2016), some studies have provided empirical support for the malleable nature of both of these motivations (e.g., Crutzen, Kuntsche, & Schelleman-Offermans, 2013).

EF and Individual Differences in Alcohol-Related Behavior

Recent theoretical perspectives also have stressed the contribution of individual differences in EF to alcohol consumption and alcohol-related problems (e.g., Gierski et al., 2013). EFs have been defined as higher-level cognitive control processes critical for self-regulation (Friedman & Miyake, 2016; Hofmann, Schmeichel, & Baddeley, 2012; Miyake & Friedman, 2012; Miyake et al., 2000). Specifically, EFs regulate initiation, direction and control of cognitive abilities such as attention and response control, behavioral and cognitive flexibility, and action planning and decision-making (see Diamond, 2013, for review;

[1]We acknowledge the theoretical (and functional) distinction between cognitive control and EF constructs. Because the tasks used here have been used to inform models of EF (Miyake et al., 2000; Miyake & Friedman, 2012), the term "EF" is used throughout the current work.

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Hofmann et al., 2012; Miyake et al., 2000; Stuss & Alexander, 2000). Increasingly, EF is conceptualized as a multifaceted or multidimensional construct (Friedman et al., 2008; Friedman, Miyake, Robinson, & Hewitt, 2011; Miyake & Friedman, 2012; Miyake et al., 2000). In particular, Miyake and colleagues have proposed that EF is comprised of three theoretically and empirically distinct, though related, component abilities: *inhibition* (the ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary), *updating* (the ability to actively manipulate relevant information in working memory), and *shifting* (the ability to shift or switch between tasks or mental sets). The current research incorporates this multifaceted EF model and utilizes the suite of nine EF tasks outlined by Miyake and Friedman (2012) to measure these three component abilities.

Considerable research has documented that deficits in response inhibition and working memory updating are associated with increased alcohol involvement. For example, such deficits can predict variability in the initiation of alcohol consumption among non-drinkers (Khurana et al., 2012; Peeters et al., 2015), as well as the quantity and frequency of alcohol consumption (e.g., Squeglia, Jacobus, Nguyen-Louie, & Tapert, 2014), heavy or problematic consumption (e.g., Squeglia et al., 2014), and alcohol-related problems among drinkers (e.g., Finn et al., 2009). By contrast, little is known concerning potential associations between shifting/switching abilities and alcohol involvement due to a paucity of studies examining this question (see Day et al., 2015). It is also important to acknowledge that a number of studies have failed to show associations between EFs and alcohol-related outcomes (e.g., Pieters, Burk, Vorst, Engels, & Wiers, 2014; Pieters, Burk, Vorst, Wiers, & Engels, 2012; Thush et al., 2008; van Deursen et al., 2015), raising concerns about the reliability of these effects and suggesting potential specificity (e.g., with particular EF measures) or moderator effects that should be examined.

Potential Role of EF in the Relationship between Drinking Motives and Alcohol Use

For decades, dual-process models intended to explain the influence of more impulsive/automatic versus more reflective/controlled processes on a range of phenomena have proliferated in social and cognitive psychology (e.g., see Chaiken & Trope, 1999). Recently, this integrative perspective has been applied to understand the initiation and maintenance of addictive behaviors, including alcohol use and heavy drinking (e.g., Deutsch & Stack, 2006; Wiers et al., 2007; Wiers & Stacy, 2006). Hofmann and colleagues (2008; 2009) proposed that two different information-processing systems, an automatic or impulsive system and a controlled or reflective system, interact in a competing manner to predict behavior and self-control outcomes. The impulsive system refers to immediate or spontaneous bottom-up information processing. In the case of addictive substances like alcohol, such bottom-up processes can develop as individuals learn to associate substance-related cues (e.g., images) with reward, ultimately leading to craving or wanting responses when such cues are present (see Robinson, Robinson, & Berridge, 2013). In contrast, the reflective system concerns the deliberate, top-down enactment of long-term goals and decisions, which has been shown to require higher-level mental control processes or EFs (Hofmann, Friese, & Strack, 2009)

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Initial models proposed a relationship between impulsive processes on the one hand and reflective processes on the other hand, in which the former are more predictive of alcohol involvement and other risk-taking behaviors when the latter are relatively weak (see Wiers et al., 2007; Wiers & Stacy, 2006). More recently, Hofmann and Van Dillen (2012) expanded this idea by arguing that immediate, automatic processes in the form of desires or temptations "may also emerge into consciousness, thus occupying limited working-memory resources" (p. 318) and undermining the representation of existing long-term goals (Hofmann & Van Dillen, 2012; Hofmann et al., 2012; Kavanagh, Andrade, & May, 2005). As a result, feelings of *wanting* and craving can escalate into highly motivationally relevant cognitions, leading to conscious action to satisfy the desire (see Hofmann & Kotabe, 2012; Hofmann & Van Dillen, 2012; Hofmann, Kotabe, Vohs & Baumeister, 2015). For example, the cognitive elaboration of strong motivations to drink (i.e., drinking motives) may consume cognitive resources needed to maintain drinking restraint standards. As a result, individuals low in EF and who have strong motivations to drink might be more likely to engage in motive-consistent behaviors.

Overview of the Present Study and Hypotheses

The proposed research examined the individual and combined effects of drinking motives and EFs on alcohol use (here, defined as the product of drinking frequency and quantity per week over the past 3 mo), heavy drinking, and alcohol-related consequences in a relatively large sample of individuals without patterns of very heavy drinking or alcohol use disorder. Consistent with previous work (Cooper, 1994; Cooper et al., 1995; Cooper et al., 2016; Kuntsche, Knibbe, Gmel, & Engels, 2005), enhancement motives were expected to be positively associated with alcohol use and heavy drinking but to be unassociated with alcohol-related consequences after controlling for alcohol use. In contrast, coping motives were expected to positively predict alcohol-related consequences over and above alcohol use, but to less strongly predict alcohol consumption. It was also expected that deficits in EF ability would be associated with inability to resist automatic behavioral tendencies to engage in heavy patterns of alcohol use, emerging here as a negative association between response inhibition and alcohol involvement. Likewise, to the extent that deficits in working memory updating might result in the inability to represent and shield long-term goals, as well as to shield attention and down-regulate impulses or desires for drinking (Hofmann et al., 2012; Hofmann et al., 2015), deficits in Updating-specific abilities were expected to positively predict alcohol involvement. Given the lack of prior evidence examining the association between shifting/switching abilities and alcohol use and consequences, no specific hypotheses were advanced for shifting-specific abilities.

Finally, we tested whether individual differences in EFs interact with drinking motives to predict alcohol use, heavy drinking, and alcohol-related consequences. It was expected that, in general, drinking motives would more strongly predict alcohol use and alcohol-related consequences among individuals low versus high in EF. This prediction was based on the logic that individuals high in EF are better able to resist conscious desires or cravings to drink. High EF resources are thought to facilitate the representation and monitoring of long-term goals and restraint standards (Hofmann et al., 2008, 2009, 2012), as well as the successful down-regulation of conscious desires (or craving cognitions) (Hofmann et al.,

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2015; see also Schmeichel & Tang, 2015). Additionally, high EF resources promote the ability to override behavioral tendencies to act consistently with the desire, whenever individuals are motivated to control their behavior (Hofmann, Adriaanse, Vohs, & Baumeister, 2014). Importantly, we believe that evidence showing that drinking motives predict alcohol use, heavy drinking and alcohol problems more strongly for individuals low in EFs would inform efforts to tailor intervention and treatment programs in the context of heavy and problematic drinking. For instance, impulsive individuals who engage in heavy/ problematic drinking motivated by enhancement or coping motives may benefit the most from interventions targeted to bolster their inhibition abilities, as well as their ability to utilize self-protecting strategies.

Method

Participants

The present study used baseline data from a large alcohol challenge experiment, which tested acute effects of alcohol on EF task performance. Recruiting and baseline screening procedures were conducted over a 5-year period between 2010 and 2014. Participants were recruited from the Columbia, MO community using mass emails, website announcements, classified ads and posted flyers. Interested individuals were interviewed via telephone to determine whether they met inclusion criteria, which included: age (21 to 35 years); absence of any condition contraindicating participation in an alcohol challenge (abstention; history of alcohol or drug treatment or other symptoms consistent with potential alcohol use disorder; alcohol-related arrests; other serious mental or physical illness; prescription medication other than oral contraception; pregnancy); absence of any condition that might make completion of laboratory tasks unusually difficult (colorblindness; primary language other than English; history of neurologic disease or trauma); recent consumption history (an average of 2–25 drinks per week; at least one heavy drinking occasion [defined as five or more and four or more alcoholic drinks in a single occasion for men and women, respectively] over the past year); and absence of symptoms of nicotine dependence. Participants received $35 for completing the baseline session and were paid $14/hr. for completion of the second (alcohol challenge) session.

An initial sample of 801 participants completed a battery of nine computerized EF tasks, along with measures of personality, alcohol sensitivity, family history of alcoholism, drinking motives, alcohol expectancies and extensive measures of alcohol use and negative consequences of drinking. Thirty-three participants (4.1%) were excluded because they had no valid data on EF tasks, mainly due to technical problems such as equipment malfunction. Also, four participants were eliminated because they had missing data across all items from the drinking motives measure. No age, sex, or race/ethnicity differences were found between included versus excluded participants (all ps > .05). The final sample included 764 participants; Table 1 summarizes the demographic characteristics of the final sample.

Materials and Measures

Executive Function Tasks—EFs were measured using a battery of nine lab-based EF tasks taken from Friedman et al. (2008), representing three experimental tasks from each of

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three theorized facets of EF (shifting, updating, and inhibition). Details on each of these tasks can be found in the Supplementary Materials section, and in previous reports (e.g., Fleming, Heintzelman, & Bartholow, 2016). Data trimming and transformation of EF task performance data followed the procedures outlined by Friedman and colleagues (Friedman et al., 2008; 2011). All EF tasks were scored such that higher scores reflect better EF abilities.

Shifting tasks: Tasks used to measure shifting included the color-shape task (Miyake, Emerson, Padilla, & Ahn, 2004), the category-switch task (adapted from Mayr & Kliegl, 2000), and the number-letter task (Rogers & Monsell, 1995). In each of these tasks, participants must use visual cues to determine which of a pair of decision rules to apply in classifying visual stimuli displayed on the computer monitor. For example, in the category-switch task, a heart cue signifies that the subsequent target word must be classified as describing something living vs. non-living, but a crossed-arrows cue signifies that the target word should be classified as larger or smaller than a soccer ball. The difference in response latency on trials when the decision rule repeats from the previous trial and those where the decision rule changes (i.e., switch trials) is the primary dependent measure (i.e., the *switch cost*).

Updating tasks: Working memory updating ability was measured using the spatial 2-back task (Friedman et al., 2008), the keep-track task (Yntema, 1963), and the letter memory task (Morris & Jones, 1990). These tasks require participants to constantly monitor, add and delete information from working memory. For example, in the keep-track task, participants are given three to five category labels (e.g., cities; animals), followed by sequences of 15 to 25 words describing category members (e.g., London; cow). At the end of each sequence, participants were required to tell the experimenter the last word that appeared from each of the categories. The dependent measure in each of these tasks was the proportion of items correctly identified or recalled across all trials.

Inhibition tasks: Response inhibition was assessed using the antisaccade task (adapted from Roberts, Hager, & Heron, 1994), the Stroop task (Stroop, 1935), and the stop-signal task (adapted from van den Wildenberg et al., 2006). On critical trials in each of these tasks, participants must overcome a prepotent or habitual response tendency in order to make an alternative response. For example, in the antisaccade task, participants had to inhibit the tendency to look at a square that appeared on one side of the screen in order to identify the random digit (1 through 9) that appeared very briefly on the opposite side. The dependent measure in the antisaccade task was the proportion of trials on which the digit was correctly identified; the dependent measure in the Stroop and stop-signal tasks was based on response latency.

Self-report Measures

Drinking Motives: Enhancement and coping motives were measured by two subscales taken from the Drinking Motives Questionnaire-Revised (DMQ-R; Cooper, 1994). Both scales have five items that describe coping (e.g., “I drink to forget my worries”) and enhancement (e.g., “I drink because I like the feeling”) reasons for alcohol consumption. For each item, participants were instructed to indicate the extent to which they typically drink for each of the stated reasons, on a response scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). In the current sample, one item from both factors – "To get high" (an enhancement items) and "Because I feel more self-confident/sure of myself" (a coping item) – cross-loaded onto the other factor, so those items were dropped. Internal reliability estimates based on the 4-item subscales were α = .77 for the enhancement scale, and α =.87 for the coping scale.

Alcohol use: Two items assessed quantity and frequency of alcohol use during the past 3 months. Respondents indicated the number of drinking occasions ("Think of all the times in the past three months when you had something to drink. How often have you had some kind of beverage containing alcohol?") using the following response scale: 0 (*I didn't drink in the past 3 months*), 1 (*1 time in the past three months*), 2 (*2 times in the past three months*), 3 (*About once a month*), 4 (*2 to 3 times a month*), 5 (*Once or twice a week*), 6 (*3–4 times a week*), 7 (*Nearly every day*), 8 (*Once a day*), and 9 (*twice a day or more*). Respondents also indicated the number of drinks typically consumed per occasion ("In the past three months, when you were drinking alcohol, how many drinks did you usually have on any one occasion?") using a response scale, in which 0 (*I did not drink in the past 3 months*), 1 (*1 drink*), 2 (2 *drinks*), 3 (*3 drinks*), 4 (*4 drinks*), 5 (*5 drinks*), 6 (*6 drinks*), 7 (*7 drinks*), 8 (*8 drinks*), 9 (*9 to 11 drinks*), and 10 (*12 or more drinks*). Frequency and quantity responses were recoded so that scores reflected per-week consumption, and scores from both items were multiplied to form an alcohol quantity/frequency composite (i.e., alcohol use). Values > 40 (< 2% of responses) were assigned the value 40 to ensure adequate distributional properties.

Heavy Drinking: Heavy drinking was measured with four items assessing the number of times in the past 30 days respondents, "got a little buzzed or light-headed on alcohol," "got drunk (speech was slurred or unsteady on your feet)," "had five or more drinks in a single sitting," and "had twelve or more drinks in a single sitting." Responses were made using a 9-point scale, where 0 = *not once in the past 30 days* and 8 = *every day*. Because items were relatively highly correlated (mean absolute value r = .61; range = .41 to .75), they were combined into a heavy drinking latent variable. Use of a composite has a number of advantages over a single heavy drinking item, including increased validity and reliability, precision and generalizability of the heavy drinking construct, and consistency with prior work (e.g., Martinez, Sher, & Wood, 2008).

Negative alcohol-related consequences: Respondents were asked to complete 24 items taken from the Young Adult Alcohol Problems Screening Test (Hurlbut & Sher, 1992), designed to assess their experience of adverse alcohol-related consequences across various life domains. Items were answered according to lifetime experience of alcohol-related consequences, using a response format in which respondents were able to select "Never," "Yes, but not in the past year," "Yes, in the past year but not the past three months," "Yes, in the past three months: once; twice; three times, or four times." The number of reported alcohol consequences experienced in the past 3 months were summed to create an alcohol problems variable with four levels: 0, 1–2, 3–4, and 5 or more alcohol-related consequences.

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Participants that reported never having experienced any alcohol-related consequences were excluded from subsequent analyses.

Procedure

After the initial telephone screening interview, eligible participants were invited for an initial laboratory session to complete the baseline assessments. The baseline assessment session lasted 3–4 hours. Each session was conducted between 9:00 A.M. and 1:00 P.M. in a private lab room. Participants provided informed consent and then completed the self-report measures, followed by the computerized EF tasks administered in a fixed, randomized order: stop-signal, spatial 2-back, category-switch, Stroop, keep track, color shape, antisaccade, letter memory, number letter. After completing the EF task battery, participants were paid and dismissed. All materials and procedures used in the current study were reviewed and approved by the University of Missouri Campus Institutional Review Board.

Data Analytic Approach

The Cook's D statistic (values > 1) was used to check for extreme multivariate observations but no cases were identified as multivariate outliers. A series of latent variable models using MPlus, version 7.3 (Muthén & Muthén, 1998–2012) was estimated using a stepwise estimation approach (Klein & Moosbrugger, 2000; Maslowsky, Jager, Hemken, 2014). Specifically, a number of measurement models were estimated, followed by estimation of two baseline structural models with distinct time frames for the outcome measures (i.e., [1] a model predicting 3-month typical alcohol use and alcohol-related consequences, which was modeled as a Poisson distributed count variable, and [2] a model predicting past-month heavy drinking), as well as 18 individual latent interaction models.

Measurement and baseline structural models were estimated using the robust maximum likelihood (MLR) estimator, a full information maximum-likelihood estimation method featuring robust standard errors (Muthén & Muthén, 1998–2012). Following the recommendations proposed by Hu and Bentler (1999), multiple data-model fit indices were used: χ^2 test, standardized root mean square residual (SRMR ≤ 0.08), root mean square error of approximation (RMSEA ≤ 0.06), comparative fit index (CFI ≥ 0.95), and Tucker-Lewis index (TLI ≥ 0.95). The maximum likelihood (ML) estimator with the percentile bootstrap confident intervals based on 10,000 bootstrap samples were used to detect significant indirect effects following recent recommendations in statistical mediation literature (Fritz, Taylor, MacKinnon, 2012; Hayes & Scharkow, 2013).

After fitting the measurement models and baseline structural model, a series of structural equation models with interactions between latent variables were estimated individually (one interaction at a time) by using the MLR estimator with a numerical integration algorithm based on the latent moderated structural equations method (LMS; Klein & Moosbruger, 2000). Given the lack of a reliable χ^2 statistic and traditional model fit statistics when applying the latent moderated structural equations method (LMS), log-likelihood ratio test statistic was used to evaluate adequacy of the nested latent interaction models. The log-likelihood ratio difference test (see Asparouhov & Muthén, 2013) and the Wald test when the value of the log-likelihood ratio difference test was negative were used (see Ito et al.,

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2015) for testing the significance of the latent interactions. Given the dramatic decrease in statistical power associated with testing interactions in nonexperimental research (McClelland & Judd, 1993), a problem not resolved entirely by use of a latent variable approach (Cham, West, Ma, & Aiken, 2012), the alpha level used to infer statistical significance of interaction tests was relaxed to $p < .10$. Finally, plots of interaction effects were used to estimate conditional effects at the 20th percentile and 80th percentile values on the distribution of factor scores of the moderating variables.

Results

Measurement Models

Comparing the correlated factors and the "nested" factors EF model—We first replicated the factor structure of the correlated factors EF model (Miyake et al., 2000) and the "nested" factors model of EFs (Friedman et al., 2008; 2011; Miyake & Friedman, 2012). Variances of the latent factors in both EF measurement models were constrained to 1 and factor means fixed to zero for model mathematical identification. Specifically, consistent with previous research (see Friedman et al., 2008; 2011; Miyake et al., 2000), the correlated factors EF model provided a very good fit to the observed data: χ^2 (24) = 47.81, $p = .0027$, CFI = .97, TLI = .95, RMSEA = .036, RMSEA 90% CI [0.021–0.051], SRMR = .029 (see Figure 1A). However, the stop-signal task had a nonsignificant factor loading (λ value = .052, $p = .340$) and thus, was not a statistically significant indicator of the Inhibition factor in the data. The Inhibition factor appears instead to be represented by antisaccade task performance. All other tasks yielded statistically significant factor loadings on the hypothesized latent constructs. Furthermore, both Updating and Shifting EF-related factors correlated significantly with the Inhibition factor (rs ≥ .52, all ps < .05), but failed to correlate significantly with each other ($r = .102$, $p = .080$), in clear contrast with previous work (Friedman et al., 2006; Friedman et al., 2011; Miyake et al., 2000).

The "nested" factors model of EFs also provided an acceptable fit to the observed data: χ^2 (21) = 38.62, $p = .011$, CFI = .97, TLI = .96, RMSEA = .033, RMSEA 90% CI [0.016–0.049], SRMR = .029 (see Figure 1B). Previous replications of the "nested" factors EF model have shown similar results (e.g., Fleming et al., 2016; Ito et al., 2015). Nevertheless, the Common EF factor failed to account for substantial (or significant) variance in the stop-signal task in these data, which implies that the stop-signal task does not measure the "Common EF" construct and does not share commonalities with the other EF tasks in the present study. All the other EF tasks yielded statistically reliable factor loadings on the hypothesized latent constructs.

Given the acceptable fit of both models, and consistent with recent advances in conceptualizing EF (Miyake & Friedman, 2012), we decided to include the "nested" factors EF model in the baseline structural model used for testing predicted relationships between EF and drinking motives and their effects on involvement in alcohol use and alcohol-related consequences.

Testing the structure of drinking motives: Enhancement and coping motives —A two-factor measurement model was estimated in which the two factors (enhancement

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motives and coping motives) were each measured by five indicators and allowed to covary. Model identification was accomplished both by constraining the variance of the factors to 1 and by fixing the factor means to zero. The two-factor measurement model did not provide initially an acceptable fit to the observed data: χ^2 (34) = 227.85, $p < .001$ CFI = .92, TLI = .89, RMSEA = .086, RMSEA 90% CI [0.076–0.097], SRMR = .068. Model modification indices (MIs) identified two cross-factor, statistically significant loadings. The item, "To get high" (an enhancement item), loaded on both factors, and likewise the item, "Because I feel more self-confident/sure of myself" (a coping item), also loaded on both factors. Given evidence of factorial complexity and for ease of interpretation, these two items were dropped from the final model. After removing the two items and allowing a correlated disturbance between two semantically similar items on the coping scale ("To forget my worries" and "To forget about my problems"), the two-factor measurement model fit the observed data extremely well: χ^2 (18) = 52.13, $p < .001$, CFI = .98, TLI = .97, RMSEA = .050, RMSEA 90% CI [0.034–0.066], SRMR = .027. As shown in Figure 2, the correlation between enhancement motives and coping motives ($r = .41$) and all factor loadings in the standardized solution (λ values ranging from 0.51 to 0.82) achieved significance at the level of $p < .05$. The modified two-factor model was included in the baseline structural model used in subsequent analyses.

Testing the structure of heavy drinking—The measurement model for heavy drinking involved one latent factor measured by four indicators. To mathematically identify this measurement model, we constrained one of the factor loadings equal to 1 and fixed the factor mean to zero. After freeing a correlated residual term between two semantically similar items ("In the past 30 days how many times have you had five or more drinks in a single sitting?" and "In the past 30 days, how many times have you had twelve (12) or more drinks at a single sitting?"), model fit was excellent: χ^2 (1) = 2.83, $p = .093$, CFI = 1.00, TLI = .99, RMSEA = .049, RMSEA 90% CI [0.000–0.120], SRMR = .007 (see Figure 3). The heavy drinking model was included as a dependent variable in the baseline model used to examine the relationships between variables, as well as to test individual interaction models involving drinking motives and EFs predicting heaving drinking.

Structural or Substantive Models[2]

Main effects of drinking motives and EFs on alcohol use and alcohol-related consequences—The standardized structural model is depicted in Figure 4, which is consistent with the a priori hypothesized theoretical relationships between EFs, drinking motives, alcohol use and alcohol-related consequences. Sex and age were included as covariates in the model. By inspecting model parameters, both enhancement motives (b = 2.00, $SE = .36$, $\beta = .25$, $p < .001$) and coping motives (b = .89, $SE = .38$, $\beta = .11$, $p = .018$) predicted typical alcohol consumption. Furthermore, the effects of enhancement motives on alcohol-related consequences were mediated by consumption (product term $ab = 0.080$, SE

[2]It is possible that the predicted interactions between EFs and drinking motives on alcohol use, heavy drinking and alcohol-related consequences would differ for individuals who have experienced negative alcohol-related consequences, as these individuals might be more motivated to control their drinking. A set of ancillary models examining predicted associations and interactions among the subset of individuals who have experienced at least one negative consequence in the past 3 months are presented in the Supplementary Materials section.

= .02, $p < .001$). Similarly, the effects of coping motives were mediated by alcohol consumption (*ab* = .035, *SE* = .02, $p = .022$), and both enhancement motives and coping motives directly predicted alcohol-related consequences over and above alcohol consumption (b = .12, *SE* = .05, β = .10, $p = .024$ and b = .17, *SE* = .04, β = .14, $p < .001$, respectively). Contrary to our general expectations, however, EF facets did not predict either alcohol use or alcohol-related consequences, with the exception of the Shifting facet, which marginally (positively) predicted alcohol use (b = .63, *SE* = .35, β = .08, $p = .068$). The model accounted for 22% of the variance in alcohol use, $R^2 = .22$, $p < .001$. Supplementary analyses using drinking frequency as the dependent measure led to very similar conclusions, with three exceptions: coping motives did not directly predict drinking frequency, the Shifting facet did not predict drinking frequency, and frequency of alcohol use did not mediate the effects of coping motives on alcohol-related problems.

Main effects of drinking motives and EFs on heavy drinking—The standardized structural model predicting heavy drinking from EFs and drinking motives is depicted in Figure 5. All effects in this structural model were also estimated controlling for sex and age. Overall, the baseline structural model fit the observed data quite well: χ^2 (200) = 450.65, $p < .001$, CFI = .95, TLI = .94, RMSEA = .041, RMSEA 90% CI [0.036–0.045], SRMR = .039. Both enhancement motives (b = .33, *SE* = .042, β = .37, $p < .001$) and coping motives (b = .08, *SE* = .038, β = .10, $p = .025$) predicted heavy drinking, as did the Shifting facet (b = .10, *SE* = .04, β = .11, $p = .011$). No other EF facets predicted heavy drinking. The model accounted for 32% of the variance in heavy drinking, $R^2 = .32$, $p < .001$.

Interaction of drinking motives × EFs—A total of 18 interaction models were estimated between EF (Common EF, Shifting-specific, and Updating-specific factors) and drinking motives (enhancement motives or coping motives): 12 interaction models were estimated on alcohol use and on alcohol-related consequences after controlling for alcohol consumption and 6 additional models were estimated on heavy drinking. As previously mentioned, the interactions were individually tested one at a time, following standard procedures in the SEM literature of testing model parameters of interest individually. Table 2 summarizes model fit indices for all measurement models and baseline structural models.

In general, we predicted that enhancement and coping motives would more strongly predict alcohol use, heavy drinking and alcohol-related consequences among individuals low vs. high in EFs. Out of 12 interactions tested predicting alcohol use and alcohol-related consequences, only one was statistically significant at the level of $p < .10$. Particularly, enhancement motives interacted with Updating-specific (b = −.75, χ^2 (1) = 2.83, $p = .093$) to predict alcohol use. However, two out of six interaction effects predicting heavy drinking were statistically significant at the level of $p < .10$. Specifically, enhancement motives interacted with Common EF ($b = 0.08$, χ^2 (1) = 3.42, $p = .064$) and with Updating-specific ($b = -.07$, χ^2 (1) = 3.53, $p = .060$) to predict heavy drinking. Plotting these three interactions revealed no consistent pattern of the predicted interactions. As shown in Figure 6, consistent with our expectations, enhancement motives more strongly predicted alcohol use among individuals low in updating-specific abilities ($b = 2.75$, *SE* = 0.65, z = 4.21, $p < .001$) than among those high in updating-specific abilities ($b = 1.26$, *SE* = 0.55, z = 2.28, $p = .023$).

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Contrary to our expectations, enhancement motives more strongly predicted heavy drinking among individuals high in Common EF (b = .42, SE = 0.06, z = 6.56, p < .001) compared to those low in Common EF abilities (b = .26, SE = 0.06, z = 4.51, p < .001), as can be seen in Figure 7. Consistent with our expectations, however, enhancement motives more strongly predicted heavy drinking among individuals low in updating-specific abilities (b = .39, SE = 0.05, z = 7.72, p < .001) than among those high in updating-specific abilities (b = .25, SE = 0.06, z = 4.16, p < .001), as can be seen in Figure 8.

Discussion

The purpose of the present study was to test a theoretical and conceptual model examining the individual and joint effects of drinking motives and EFs on alcohol use, heavy drinking, and alcohol-related consequences using a latent variable modeling approach. Based on prior research and theory (e.g., Hofmann et al., 2014, 2015; Schmeichel & Tang, 2015), it was predicted that drinking motives and EFs would interact to predict alcohol-related outcomes, such that drinking motives would be stronger predictors among individuals with relatively weak EF abilities. However, findings related to this prediction were generally weak in magnitude (i.e., small effect sizes) and inconsistent. Our models showed that enhancement motives more strongly predicted heavy drinking among individuals high vs. low in Common EF abilities but that enhancement motives more strongly predicted alcohol use and heavy drinking among those low vs. high in Updating-specific abilities. Not only are these interaction results inconsistent, but their empirical strength and theoretical meaning is weakened by the fact that these interactions were but three out of a total of 18 tested. Thus, the current results provide little support for the hypothesis that individual differences in EFs moderate the effects of drinking motives on alcohol use and alcohol-related consequences.

The failure to find compelling evidence for the predicted interactions in this study may be attributable to the fact that interaction effects between drinking motives and EFs may depend upon a third variable – motivation to control drinking. This notion is consistent with dual-process theories of addiction (see Wiers et al., 2007; Wiers & Stacy, 2006) and recent published research (e.g., van Deursen et al., 2015; Tahaney, Kantner, Palfai, 2014). As suggested by Wiers and colleagues (2007), “there are two crucial factors which determine whether the impulse to drink or use drugs is followed or controlled: ability to inhibit (or to redirect attention or goals) and motivation to do so” (p. 271). According to this perspective, effects of drinking motives on alcohol use and consequences may depend on EF resources only when individuals are highly motivated to control their drinking. When there is no pressing need to regulate one’s drinking, it stands to reason that affect-driven motives would predict drinking independently of self-regulatory abilities. Unfortunately, the current dataset did not include variables related to motivation to control drinking. Thus, future research is needed to empirically test the plausibility of this notion.

In contrast to the generally well-accepted idea that EF deficits predispose to alcohol use and negative alcohol-related consequences (e.g., Day et al., 2015; Gierski et al., 2013; Gustavson et al., 2017), EFs showed surprisingly little association overall with alcohol use, heavy drinking and consequences in the current sample. This lack of association is unlikely attributable to low statistical power, given that the present study included a larger sample

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than many previous studies (see Day et al., 2015). Specifically, only shifting/switching abilities were found to be associated with heavy drinking, and this association ran in the opposite direction to the EF-deficit hypothesis of alcohol abuse (Gierski et al., 2013); that is, better shifting ability was associated with more heavy drinking.

Careful consideration of the literature suggests, however, that this finding is generally consistent with recent theorizing (Miyake & Friedman, 2012) and empirical evidence (Friedman et al., 2007; Friedman et al., 2011; Herd, Hazy, Chatham, Brant, & Friedman, 2014; Young et al., 2009) suggesting that shifting-specific abilities may be uniquely positively associated with characteristics likely to undermine successful self-control. Specifically, as reported by Herd et al. (2014), better shifting-specific abilities were associated with deficits in self-restraint abilities during early childhood (Friedman et al., 2011), with indices of behavioral disinhibition (substance use, conduct disorder ADHD, and novelty seeking) at ages 12 and 17 (Young et al., 2009), and with smaller decrements in attention problems between ages 7 to 14 (Friedman et al., 2007). In addition, Friedman and colleagues (Friedman et al., 2007; Friedman et al., 2011; Herd et al., 2014) have shown that shifting-specific abilities and "Common EF" have opposing effects on several behavioral outcomes. These different effects have been interpreted by Friedman, Miyake and colleagues in light of the "stability–flexibility tradeoff" between EF abilities (Herd et al., 2014; see also Friedman & Miyake, 2016; Miyake & Friedman, 2012), initially described by Goschke (2000). As Miyake and Friedman (2012) clearly put it, "the ability to actively maintain a single task goal may indeed be a force that makes it difficult for individuals to flexibly switch to a different goal" (p. 12). In this line, and consistent with the 'goal shifting' hypothesis proposed by Hofmann et al. (2012), individuals high in shifting/switching abilities may, on the one hand, change the focus of their attention more easily to tempting goals (more flexibility) and, on the other hand, have more difficulty in maintaining and shielding their long-term self-control goals (less stability). This imbalance between high flexibility and low stability may impair self-control in some contexts and promote involvement in problematic behaviors such as heavy and problematic drinking.

In contrast to the mostly null findings related to EFs and alcohol involvement, and consistent with existing empirical research (see Cooper et al., 2016; Kuntsche et al., 2005, for an overview), enhancement motives were strongly (and coping motives less strongly) associated with alcohol use and heavy drinking (e.g., Cooper, 1994; Cooper et al., 2016). Furthermore, alcohol use mediated the relationship between enhancement motives and alcohol-related consequences in accordance with previous research (e.g., Cooper, 1994; Cooper et al., 1995; Magid, MacLean, & Colder, 2007; Merrill, Wardell, Read, 2014). Similarly, alcohol use mediated the relationship between coping motives and alcohol-related consequences. These results suggest that individuals who drink to enhance or drink to cope are likely to experience alcohol-related consequences because of how much they drink. Unlike in previous research (e.g., Cooper et al., 1995; Kuntsche et al., 2008; Magid et al., 2007; Merrill et al., 2014), both enhancement motives and coping motives directly predicted alcohol-related consequences independently of alcohol use. This finding suggests that the experience of alcohol-related consequences among individuals who drink for these reasons cannot be accounted for by their alcohol consumption alone but rather represents a unique

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process over and above quantity of consumption alone (see Cooper, 1994; Cooper et al., 2016).

Limitations

Findings from the current analyses should be considered in light of several limitations of the study. First, the larger study from which the current data were drawn was not designed to test the hypotheses investigated here. This has important implications for the sampling frame and, ultimately, the range of responses on a number of key variables. As described previously, because participants were recruited for an alcohol challenge experiment, individuals were excluded from participating in the study if they indicated during screening any symptoms consistent with potential alcohol use disorder, any history of substance abuse treatment or alcohol-related arrests or of neurologic disease or trauma, or if they reported either abstention or consistently very heavy drinking (> 25 drinks per week on average). Arguably, exclusion of individuals with these characteristics attenuated the range of both alcohol involvement and EF abilities in the sample, thereby limiting our ability to detect predicted associations. Moreover, given that those individuals with moderate and less problematic drinking might be less motivated to control their drinking, the sample used in the current study might not be the most appropriate to test the hypothesized predictions. In addition, despite the fact that participants completed a relatively exhaustive battery of laboratory EF tasks, the number of trials in each of those tasks had to be shortened, relative to usual administration procedures.[3] This may have exacerbated the well-known problem of low internal reliabilities of EF tasks (see Ito et al., 2015; Miyake et al., 2000), which could have contributed to the null effects obtained for Common EF and Updating-specific abilities predicting alcohol use and alcohol-related consequences.

Moreover, while not a limitation per se, our use of multiple indicators of each of the three EF facets is unusual in this literature, in that the majority of previous studies investigating associations between EF and alcohol involvement have operationalized EF using performance on a single task (see Day et al., 2015). It could be that some of the individual tasks used to inform the latent EF factors reported here would show associations with alcohol involvement consistent with those in previous reports. However, investigating associations with latent variables has numerous advantages over any single-task approach (e.g., see Burgess, 1997; Miyake et al., 2000), and therefore even if such single-task associations can be demonstrated they arguably are more reflective of the esoteric properties of individual tasks than of the underlying construct of interest (i.e., EF).

Conclusion

In conclusion, the present study provides some interesting and provocative findings about the effects of EFs on alcohol use and heavy drinking and their role as moderators of the relationship between drinking motives, alcohol use, heavy drinking and alcohol-related

[3]The EF tasks were shortened for two reasons. First, in addition to the 9-task EF battery, participants completed a number of other behavioral and self-report tasks during their lab visits, and therefore fatigue was a key concern. Second, it was important to the goals of the larger study that participants be able to complete subsets of the EF tasks before their blood alcohol concentration peaked during the second, alcohol challenge lab session (not reported here). Therefore, reducing the duration of the EF tasks was determined to be necessary.

consequences. The present study not only replicated previously reported patterns of associations between drinking motives and alcohol involvement in a large community sample, but also found that (1) better shifting/switching abilities may constitute a risk factor for engaging in heavy drinking and (2) individual differences in EFs failed to consistently moderate the effects of enhancement and coping motives on alcohol use, heavy drinking, and alcohol-related consequences.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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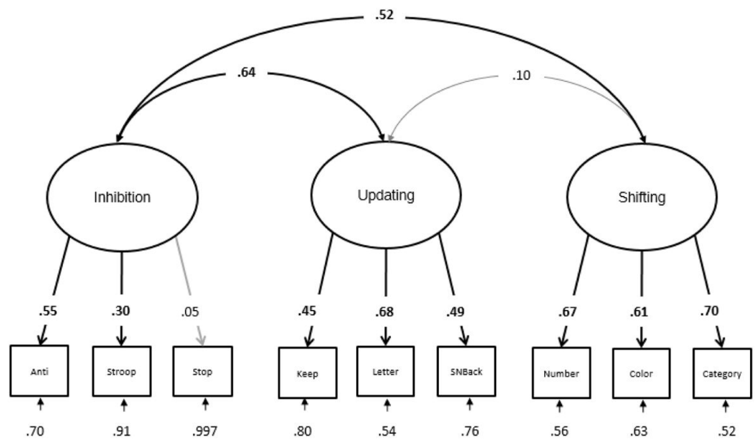

Figure 1A

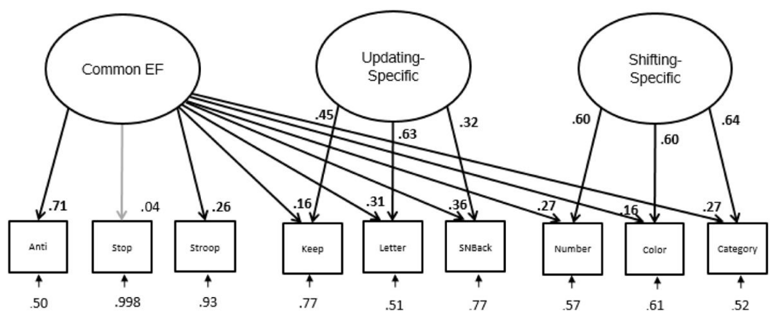

Figure 1B

Figure 1.

Figure 1A. The diagram depicts the correlated EF factors measurement model, which assumes three correlated EF latent factors (Inhibition, Updating, and Shifting), each measured by three manifest EF tasks. All significant standardized paths at the level $p < .05$ are shown in black solid lines. Anti = Antisaccade; Stop = Stop-signal; Keep = Keep track; Letter = Letter memory; SNBack = Spatial-2-back; Number = Number-letter; Color = Color-shape; Category = Category switch.

Figure 1B. The diagram depicts the “nested” EF factors measurement model, which assumes a Common EF latent factor measured by nine manifest EF tasks and two latent-specific EF factors (Updating-specific and Shifting-specific), each measured by three manifest EF tasks. All significant standardized paths at the level $p < .05$ are shown in black solid lines. Anti = Antisaccade; Stop = Stop-signal; Keep = Keep track; Letter = Letter memory; SNBack = Spatial-2-back; Number = Number-letter; Color = Color-shape; Category = Category switch.

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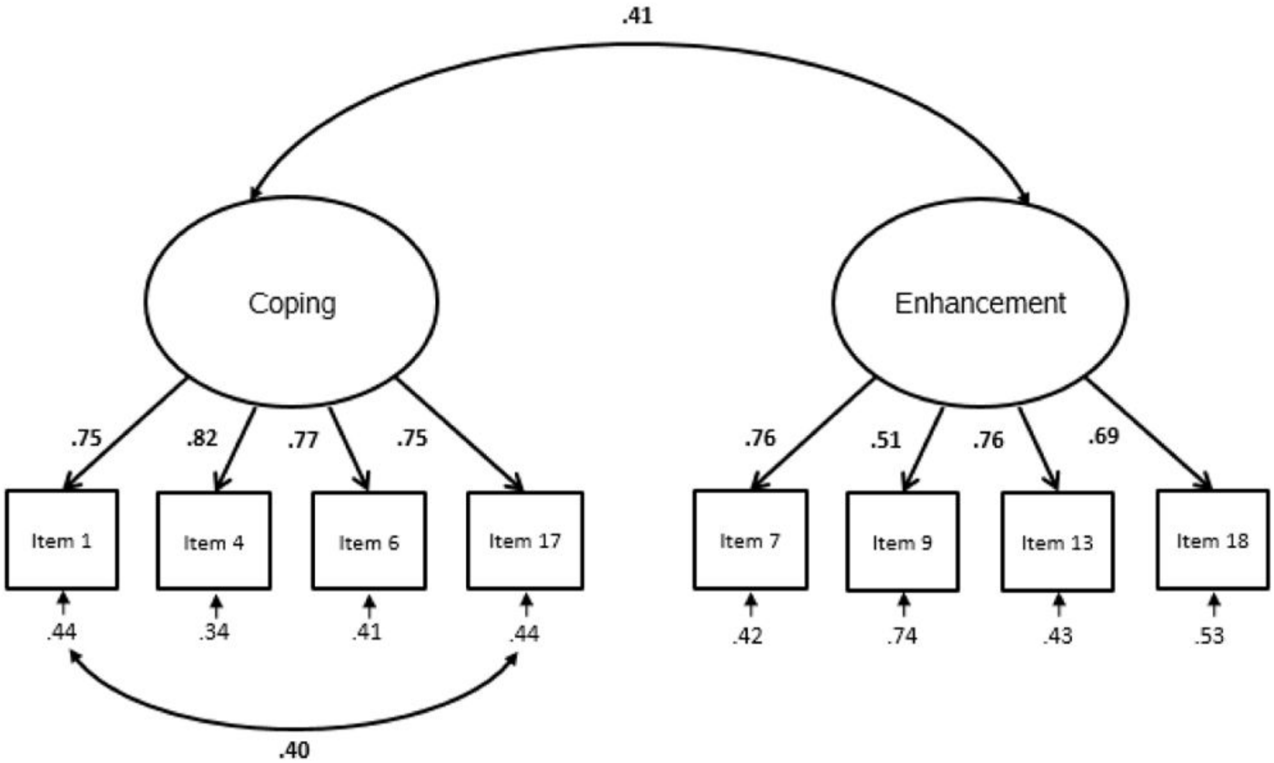

Figure 2.

The diagram depicts the two-factor measurement model, which assumes both coping motives and enhancement motives as correlated latent variables, each informed by responses on four indicators. All significant standardized paths at the level $p < .05$ are shown in black solid lines.

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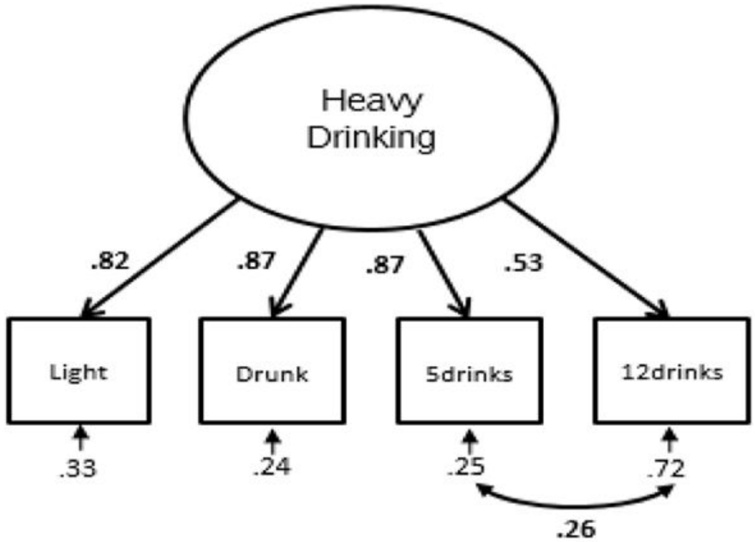

Figure 3.

The diagram depicts the one-factor measurement model, which assumes heavy drinking latent variable measured by responses on four indicators. All significant standardized paths at the level $p < .05$ are shown in black solid lines. Light = little buzzed or light-headed on alcohol; Drunk = drunk (e.g., speech was slurred or unsteady on your feet) on alcohol; 5drinks = 5 or more drinks in a single sitting; 12drinks = 12 or more drinks in a single sitting.

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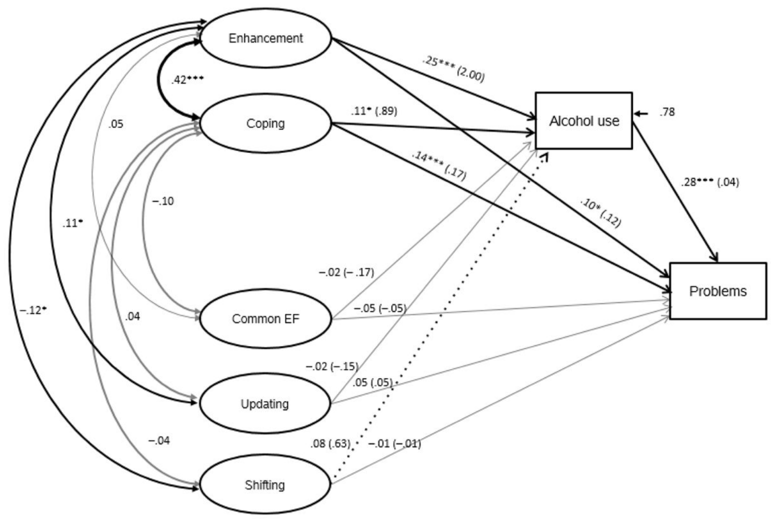

Figure 4.

The diagram depicts the standardized solution (unstandardized path coefficients are given with parentheses) of the structural equation model, including the hypothesized relationships between Common EF, Shifting-specific, and Updating-specific factors and Enhancement motives and Coping motives predicting alcohol use and alcohol-related consequences. Problems = alcohol-related consequences. Black solid paths illustrate significant standardized coefficients at the level of $p < .05$. Dashed paths represent marginally significant coefficients at the level of $p < .10$.

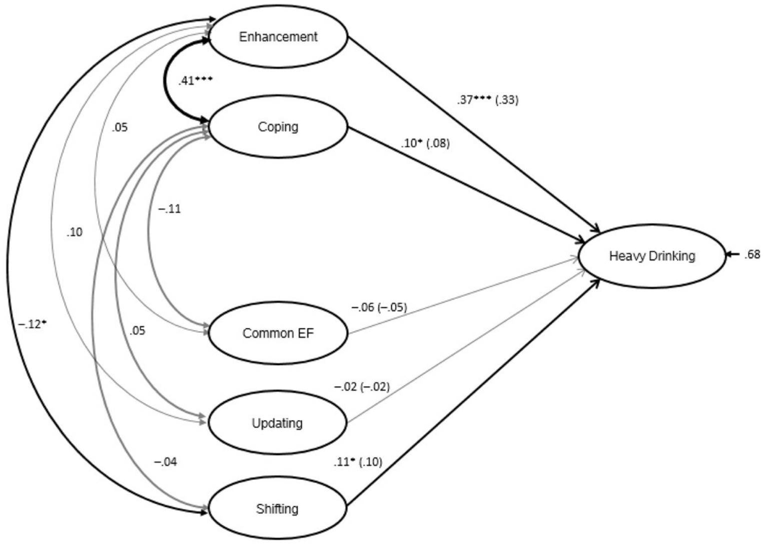

Figure 5.

The diagram depicts the standardized solution (unstandardized path coefficients are given with parentheses) of the structural equation model, including the hypothesized relationships between Common EF, Shifting-specific, and Updating-specific factors and Enhancement motives and Coping motives predicting heavy drinking. Black solid paths illustrate significant standardized coefficients at the level of $p < .05$.

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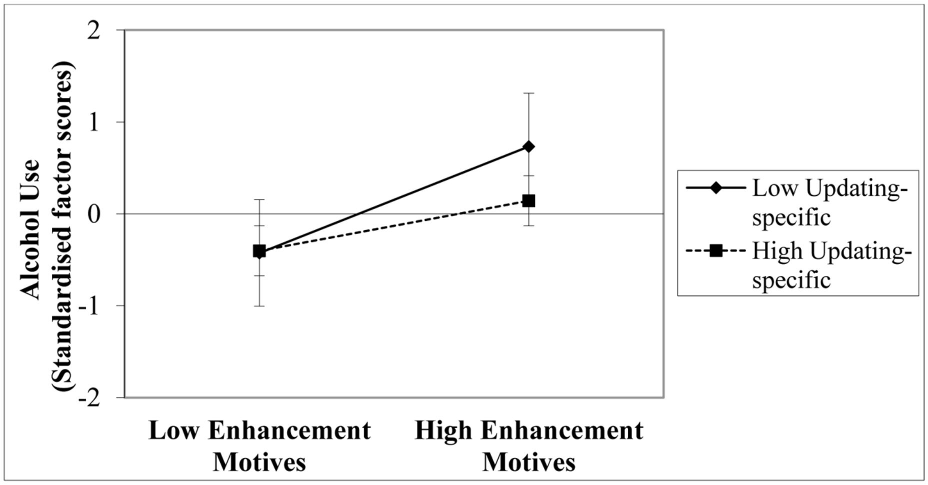

Figure 6.

Enhancement motives × Updating-specific factor interaction on alcohol use (standardized factor scores). Conditional effects were estimated at the 20th percentile and 80th percentile values on the distribution of factor scores of the moderating variable.

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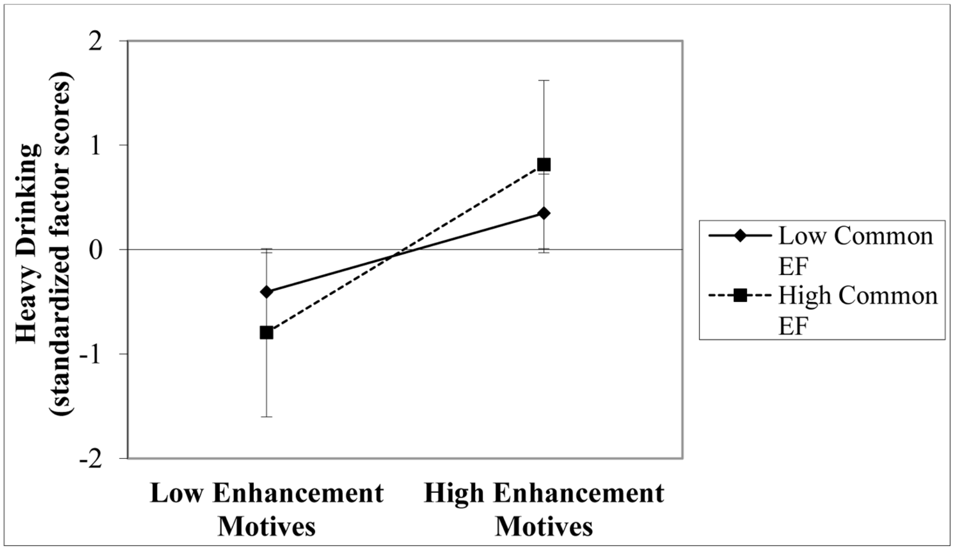

Figure 7.
Enhancement motives × Common EF factor interaction on heavy drinking (standardized factor scores). Conditional effects were estimated at the 20th percentile and 80th percentile values on the distribution of factor scores of the moderating variable.

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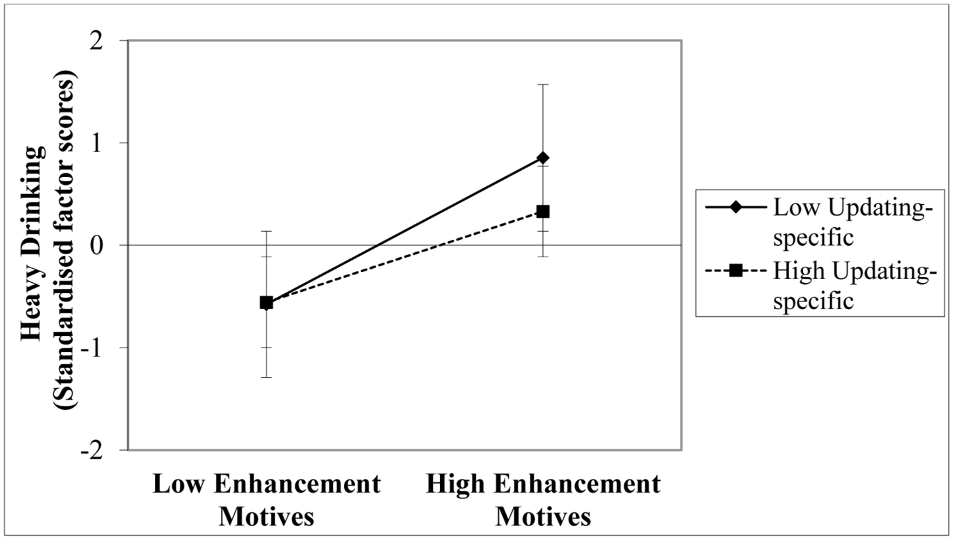

Figure 8.

Enhancement motives × Updating-specific factor interaction on heavy drinking (standardized factor scores). Conditional effects were estimated at the 20th percentile and 80th percentile values on the distribution of factor scores of the moderating variable.

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Table 1

Sample Characteristics (N = 764)

	n	Range	Mean (*SD*)	%
Demographic characteristics				
Gender (Female %)	764			49.2
Age (in years)	763	21–35	23.1 (2.60)	
Race				
American Indian or Alaska Native	4			0.5
Asian	10			1.3
Black or African American	38			5.0
White	680			89.0
No information	32			4.2
Alcohol variables				
Enhancement motives	757	1–4	2.72 (0.56)	
Coping motives	751	1–4	1.79 (0.67)	
Quantity alcohol use 3 months	753	1–13	4.10 (2.14)	
Frequency alcohol use 3 months	761	0.08–15	2.31 (1.48)	
Alcohol-related consequences	696			91.1
0 consequences	288			41.4
1–2 consequences	246			35.3
3–4 consequences	100			14.4
5+ consequences	62			8.9

Note. SD = standard deviation.

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Table 2

Summary of Fit Indices of Measurement and Baseline Structural Models Used in the Analyses

Model	*N*	*df*	χ^2	SRMR	RMSEA [90% CI]	CFI	TLI	AIC	BIC
Measurement models									
Correlated factors EF model	764	24	47.81**	.029	.036 [0.021–0.051]	.97	.95	46889.62	47028.78
"Nested" factors EF model	764	21	38.62*	.029	.033 [0.016–0.049]	.97	.96	46886.71	47039.78
Two-factor motives model	764	18	52.13***	.027	.050 [0.034–0.066]	.98	.97	12194.93	12315.54
Heavy drinking	763	1	2.83	.007	.049[0.000–0.120]	1.00	.99	7380.25	7440.54
Baseline SEM models									
Alcohol use and Problems									
Baseline structural model	764							42728.06	43178.00
Heavy drinking									
Baseline structural model	764	200	450.65***	.039	.041[0.036–0.045]	.95	.94	43011.43	43470.65

Note. SRMR = Standardized root mean square residual; RMSEA = Root mean square error of approximation; CFI = Comparative fit index; TLI = Tucker-Lewis index.

* $p < .05$

** $p < .01$

*** $p < .001$