Cognitive Ability and Ambivalence toward Alcohol: An Examination of Working Memory Capacity’s Influence on Drinking Behavior

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Cognitive Ability and Ambivalence toward Alcohol:
An Examination of Working Memory Capacity’s Influence on Drinking Behavior

by

Emily T. Noyes

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Psychology
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ABSTRACT

Research stemming from dual-processing theories suggest that working memory capacity may have an important role in the ability to inhibit automatic tendencies when there is the motivation to do so (Barrett, Tugade, & Engle, 2004). Ambivalence, the simultaneous desire to engage in (approach motivation) and inhibit (avoidance motivation), often occurs with problematic behaviors like alcohol abuse. The current study sought to determine whether individual differences in working memory capacity moderate the relationship between approach, avoidance and subsequent drinking behavior in a clinical sample. A total of 66 individuals with alcohol use disorder (AUD) participated in a baseline assessment of working memory capacity followed by a daily assessment of approach, avoidance, drinking behavior and situational factors (stress and self-efficacy) over a two-week monitoring period. We also explored an alternative cognitive construct (response inhibition), to determine whether it interacts with motivational states in a similar way to predict drinking behavior. Results of multilevel modeling indicated a significant interaction between approach, avoidance and working memory capacity in the prediction of drinking day, but not drinking quantity. Specifically, those with lower working memory capacity were at increased odds of a drinking episode when experiencing ambivalence, while odds of drinking did not increase for those with higher working memory capacity. Exploratory analyses demonstrated the opposite pattern of results when examining response inhibition’s interaction with approach and avoidance. The current study suggests that working memory capacity is an important cognitive ability that supports deliberative decision making...
when experiencing ambivalence toward alcohol, while also highlighting important theoretical and methodological considerations when examining cognitive and motivational processes.
INTRODUCTION

The paradoxical nature of alcohol abuse has long been a focus of addictions research. Individuals continue to use alcohol despite its negative consequences and even when expressing the desire to avoid using. These competing motivational states may partially reflect differing underlying forms of cognitive processing that contribute to the maintenance of addictive behavior. Specifically, dual-process theories posit that controlled processing allows for the ability to inhibit automatic, approach-oriented tendencies (Wiers et al., 2007). Insomuch as avoidance inclinations need to be strengthened and maintained to outweigh approach-oriented tendencies to result in adaptive decision making (Breiner, Stritzke, & Lang, 1999), the successful maintenance reflects controlled, effortful processing. Given that those in highly ambivalent states ultimately may end up deciding to drink despite their desires to avoid doing so, it is important to understand why some individuals are better at inhibiting approach-oriented tendencies more successfully than others. Extensive research in cognitive psychology and in the field of addiction demonstrate that individual differences in working memory capacity limits the ability for individuals to engage in controlled, effortful processing. More specifically, it reflects a cognitive resource that is key in determining the ability to reliably inhibit automatic processing in the face of competing sensory information and conflicting goals (Barrett, Tugade, & Engle, 2004). Consequently, working memory capacity may be a key factor especially important in the case of ambivalence, influencing whether an individual is able to ultimately inhibit automatic approach tendencies in favor of avoiding alcohol. As such, the current study was designed to examine
individual differences in working memory capacity and the potential moderating effect on approach and avoidance as it relates to drinking behavior.

**Dual-Processing Theories and their Application to Addictive Behavior**

There has been a long appreciation for the separation between a fast, intuitive way of thinking and a deliberative, rationale way of thinking. In psychology, this appreciation was formally conceptualized with dual-processing theories as cognitive psychology increased in popularity in the 1970’s (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Wason & Evans, 1974), but have maintained their influence on the field of psychology as a whole and continue to have widespread applications. While they differ in their specifics, the main premise underlying dual-process theories holds that there are two levels of processing information. These levels are often described as automatic and controlled processing, but have also been referred to as intuitive/rationale, associative/rule-based, impulsive/reflective, among others. According to Evans and Stanovich (2013), there is considerable overlap as to the defining and correlative features of these processes regardless of how they are referred to and their specific application. Defining features of automatic processing suggest that it is autonomous and does not require working memory. Automatic processing also tends to be fast, nonconscious, contextualized, associative, and reflects experience-based decision making. Conversely, controlled processing is defined by its link to higher level cognitive functions and requires working memory. Controlled processing tends to be slow, capacity limited, abstract, rule-based, and reflects consequential decision making.

Though commonalities exist across theorists, there are two major areas of disagreement. First, the specifics surrounding the nature of the two levels of processing differ. Some research takes the perspective that automatic processing reflects implicit, unconscious cognitions, while
controlled processing reflects explicit, conscious cognitions. However, the nature of this distinction and the extent at which levels of consciousness leak into one another is debated, considering that interactions at multiple stage of processing likely occur (Strack & Deutsch, 2004). Nevertheless, the current research points to one consistent underlying principle: some level of processing is more automatic and reflexive in nature while some is more effortful and deliberative. Further, the current research contends that conscious experience in itself should not be the distinction between automatic and controlled processing. Consistent with the notion that individuals are rather poor at determining the causes of his/her behavior, what individuals pinpoint in his/her conscious awareness cannot always be taken to infer causal processes (Nisbett & Wilson, 1977). Given this issue, conscious experience is not a useful marker for determining the level of processing in application. The second area of disagreement surrounds how these systems exert their control. Some propose a parallel-competitive structure where these systems operate in parallel, but one ends up dominating when conflict between responses arises between systems (Sloman, 1996). Conversely, a default-interventionist structure proposes that while automatic processing is always operating as the default, controlled processing may or may not intervene (Evans, 2007).

Regardless of perspective on these areas of debate, one key factor in determining which system ultimately exerts control is the amount of cognitive resources available. In other words, cognitive resources are needed in order to successfully inhibit a response generated using automatic processing. Further, consideration of the cognitive resources involved also circumvents the debate about conscious involvement. A promising cognitive resource that has received widespread attention across different research areas is working memory capacity. Generally, working memory capacity reflects an index of attentional control and is a key
cognitive resource that is required for controlled processing to inhibit automatic responses (Barrett et al., 2004; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008), and provides a useful perspective on dual-system processes. The importance of working memory capacity fits with both a parallel-competitive structure and a default-interventionist structure. Specifically, high working memory capacity may allow for the controlled processing to “win” if these systems operate in parallel, or it allows for the use of controlled processing to intervene on automatic processing when necessary. Further, controlled processing necessitates the use of higher level cognitive functions including working memory capacity. As such, despite the differences in approach and definitions, it is more helpful to consider the difference between automatic and controlled process by the extent by which cognitive resources are involved rather than considering levels of consciousness involved.

The Importance of Conflicting Motivational States

The role of dual-processing theories can be seen throughout the addiction literature (e.g., Deutsch & Strack, 2006; Evans & Coventry, 2006; Heather & Segal, 2016; Moss & Albery, 2009; Stacy & Wiers, 2010; Wiers et al., 2007). For example, Wiers et al. (2007) describe a comprehensive model to account for the development of addictive behaviors in adolescents with an emphasis in the importance of controlled processing in the regulation of appetitive motivation. Specifically, control of appetitive impulses is dependent on “the ability to inhibit (or to redirect addition or goals) and the motivation to do so” (Wiers et al., 2007, p. 271). In this regard, conflicting motivational states pertaining to alcohol use are important to consider in the context of automatic tendencies in response to alcohol and attempts to inhibit these tendencies.

Problematic drinking behavior is often associated with ambivalence (Miller & Rollnick, 2002); thus, studying drinking behavior from the perspective of motivational conflict helps better
understand the paradoxical nature of addictive behavior. Ambivalence can best be described as a state of conflict where an individual simultaneously wants to drink and wants to avoid drinking. The Ambivalence Model of Craving (AMC; Breiner et al., 1999) has become a useful framework that allows for simultaneously considering competing motivational states. Specifically, it considers both the desire to use (approach inclinations) and the desire to avoid using (avoidance inclinations) alcohol. These inclinations represent two motivational pathways that influence an individual’s decision to engage in alcohol use (Stritzke, McEvoy, Wheat, Dyer, & French, 2007). As such, an individual can have both strong approach and avoidance inclinations, which reflects an ambivalent state.

The ambivalence model of craving offers a useful integration of factors that influence the decision to engage in alcohol use in considering how approach and avoidance inclinations develop. Specifically, biological predispositions, personality factors, access to alternative activities, expectancies, and previous experiences with alcohol underlie the expression of approach and avoidance. In terms of experiences with alcohol, positive, rewarding outcomes associated with use result in the development of approach inclinations, while negative consequences result in avoidance inclinations (Breiner et al., 1999). Further, temporal discrepancies between immediate rewards and delayed consequences contribute to the tendency to approach rather than avoid alcohol. Indeed, research with delay discounting focuses on temporal discrepancies as the main reason for why ambivalent individuals continue to use alcohol (MacKillop et al., 2011). Consider the immediate rewarding effect that alcohol offers (e.g., euphoria, tension reduction, social lubrication). When faced with the opportunity to drink, these rewarding effects are more proximal and as a result negative consequences are less salient. As such, even with someone who reports both ongoing approach and avoidance, triggers of their
use can result an increase in their desire to use relative to their desire to avoid since these
rewards become more salient. Considering the automatic nature of this response hinders the use
of more controlled processing (Tiffany, 1990, 1999), it makes sense why the motivation to avoid
using is not always sustained.

However, it is also clear that individuals with the desire to use alcohol can inhibit this
response. Research with the Ambivalence Model of Craving has demonstrated that those high on
avoidance inclinations drink less alcohol regardless of their level of approach inclinations,
suggesting that avoidance does attenuate the effect of approach on drinking behavior (Noyes &
Schlauch, 2018; Schlauch et al., 2013; Schlauch, Rice, Connors, & Lang, 2015). Approach and
avoidance inclinations offer important insight into treatment for alcohol dependence. Schlauch et
al. (2012) demonstrated that avoidance inclinations were uniquely related to taking steps to make
a change at baseline and positively associated with number of treatment sessions attended.
Further, while baseline rates of avoidance were relatively high, decreases in approach across the
course of treatment were positively related to drinking outcomes, a finding consistent with that
of Klein, Stasiewicz, Koutsky, Bradizza, and Coffey (2007) and Klein and Anker (2013). These
findings may indicate that along with having the motivation, individuals’ ability to inhibit strong
desires to drink was successful. Subsequently, this suggests these strong desires habituated and
decreased over time, weakening the automatic nature of approach inclinations.

Theories of addiction that focus on learning processes also support the idea that approach
inclinations arise out of a process more automatic in nature. The reinforcing effects of drugs of
abuse increase the likelihood of continued use, reflecting instrumental conditioning. Secondly,
the repeated pairing of alcohol with environmental cues further increases the incentive salience
of the drug which reflects classical conditioning. Learning models of addiction posit that the
transition from initial use and liking of drug to compulsive, habitual use results from the interaction between these types of learning that lead to changes at the neural level (Everitt & Robbins, 2005). This has even been referred to as a “hijacking” of neural systems involved in reward processing (i.e., dopaminergic pathways) which narrows goal-directed behavior (Hyman, 2005). Subsequently, behavior that is consistent with acquiring and using the drug becomes highly engrained and appropriate learning in response to consequences of use is unable to occur. In this regard, appetitive reactions to both the drug and associated cues is automatic in nature as would be captured with assessment of approach inclinations. Indeed, attentional bias (i.e., the tendency of problematic alcohol users to show a preference in their attention toward alcohol-related stimuli) has been consistently shown to be one feature of addictive behaviors and associated with craving (i.e., approach inclinations; (Carter & Tiffany, 1999; Field & Cox, 2008; Sayette et al., 2000). This is important as attentional bias is thought to result from classical conditioning (e.g., Siegel & Ramos, 2002) and motivational-based processes (Kavanagh, Andrade, & May, 2005; Robinson & Berridge, 1993), tapping into implicit processes that occur without deliberation and reflection.

In contrast, while evidence suggests that avoidance can be activated in response to cues (Schlauch et al., 2015) and can be more automatic in nature (i.e., aversions; Stritzke et al., 2007), the ability to sustain this motivation and successfully inhibit automatic tendencies likely varies when faced with temptations to drink and recovery status. For example, while the immediate rewarding effects of alcohol become more salient when tempted to drink, avoidance likely remain constant or even decreases due to its association with delayed punishments (Breiner et al., 1999). Further, considering evidence from learning models demonstrating the underlying brain changes involved with the compulsive motivation to approach, motivation to avoid inherently
must be more deliberate and require effort. Inhibition of these learned appetitive responses is needed, as well as the cognitive capacity to redirect attention to distal, less salient reasons for avoiding. Given that decreases in drinking across the course of treatment is associated with decreases in approach rather than avoidance (e.g., Schlauch et al., 2012), it is clear that inhibiting approach inclinations and subsequent dishabituation of these automatic tendencies is key for those making behavior change.

This likely explains why ambivalence associated with problematic use may lead to drinking, as it takes effort and time for the unlearning of appetitive responses and learning a new response (i.e., avoidance). Consistent with this notion is research demonstrating that formally problematic drinkers show an attentional bias away from alcohol-related stimuli (Christensen, 2009; Townshend & Duka, 2007), suggesting that automatic processing changes as a function of decreases in problematic drinking. However, changes likely occur at the controlled processing level as well. One study involving recently abstinent alcohol-dependent participants demonstrated that while there was an initial attention toward alcohol cues, reflecting an automatic approach bias, subsequent attentional disengagement from these cues occurred when presented in longer time intervals (Noël et al., 2006). This intentional disengagement suggests that effortful avoidance may take over and inhibit automatic response to alcohol stimuli. Stritzke et al. (2007) suggests that this reflects a conflict between automatic approach and controlled avoidance, while also positing that conflict can occur at multiple levels (automatic/automatic, automatic/controlled, controlled/controlled). Indeed, other research has demonstrated that ambivalence, reflected in conflicting automatic associations about alcohol, was associated with more variability in attentional bias using a visual probe task (Gladwin & Vink, 2018). These authors conclude that variability in attentional bias reflects conflicts between processes.
competing with one another over cognition. Importantly, Stritzke (2007) points out that even while a conflict may occur at the automatic level, the resolution of this ambivalence may depend on the balance of approach and avoidance at the controlled level of processing. Given that successful treatment of problematic drinking focuses on resolving ambivalence in favor of avoidance and decreasing approach, considering factors that allow for the successful inhibition of approach tendencies is essential to furthering our understanding of the difficulties associated with treating ambivalence.

**Working Memory Capacity’s Role in Information Processing and Drinking Behavior**

In the field of cognitive psychology, a significant amount of experimental work has been conducted to better understand working memory capacity and elucidate its role in how we process information and ultimately make decisions. Working memory capacity is thought to reliably reflect an executive aspect of attention (attentional control), and is defined as “an ability to effectively maintain stimulus, goal, or context information in an active, easily accessible state in the face of interference, to effectively inhibit goal irrelevant stimuli or responses, or both” (Kane et al., 2001, p. 180). Historically, working memory capacity stems from the idea of the “central executive” component of Baddeley’s proposed structure of working memory, which reflected an attention-controlling system (Baddeley, 1992; Baddeley & Hitch, 1974). Since then, working memory capacity has been regarded in the literature as an index of executive attention and control (Barrett et al., 2004). Working memory is recognized as essential in the coordination of processing when multiple goals are active as well as guiding behavior with information that is not in the immediate environment (D'Esposito & Postle, 2015). Needless to say, successful inhibition of our automatic preferences often requires consideration of information not in our immediate environment (e.g., potential consequences, long term goals).
Consequently, working memory capacity has pervaded research that stems from dual processing perspectives. Experimental studies in cognitive psychology have consistency demonstrated that individual differences in working memory capacity relates to differences in decision making (Fletcher, Marks, & Hine, 2011; Newstead, Handley, Harley, Wright, & Farrelly, 2004; Neys, 2006), susceptibility to interference (Kane & Engle, 2003), and self-regulation (Hofmann et al., 2008). Results consistently highlight working memory capacity’s important role in successful controlled, effortful processing. Further, manipulating load on working memory capacity has been shown to lead to more discounting of delayed monetary rewards (Hinson, Jameson, & Whitney, 2003). In other words, following increased cognitive load individuals showed a preference for immediate monetary rewards over larger, delayed rewards. Thus, more impulsive decision making may occur due to limits of working memory capacity as a resource.

For example, Hofmann and colleagues (2008) examined the importance of working memory in determining behavior in response to conflict between automatic, appetitive desires and goals to self-regulate. Specifically, automatic, appetitive responses were examined (i.e., automatic, implicit attitudes toward candy) along with self-reported motivation to forego sweets. Results demonstrated among those with low working memory capacity, automatic, appetitive responses were predictive of behavior (i.e., more candy consumption), whereas those with higher working memory behaved in line with their stated motivation to avoid sweets. Further, the latter group of individuals was better able to self-regulate (e.g., eat less sweets in line with their stated goals) even if they held automatic, appetitive responses to sweets. The same pattern of results was observed for sexual interest behavior and aggression. The authors make an important conclusion: “…self-regulatory outcomes may often be the result of a complex interplay between
automatic forces (such as automatic attitudes), controlled dispositions (such as self-regulatory goals) and key moderators (such as WMC)” (Hofmann et al., 2008, p. 974). In sum, working memory capacity is one important factor that explains individual differences in the ability to regulate behavior. Given the clear relationship between working memory capacity, decision making and self-regulation, the study of working memory has naturally been translated to the study of drinking behavior. For example, the Cognitive-Motivational Theory (CMT) of personality vulnerability to alcoholism focuses on key personality risk factors including impulsivity, harm avoidance and excitement, while also suggesting working memory may moderate the relationship between these factors and risk for alcohol dependence (Finn, 2002). Specifically, higher working memory capacity allows for less salient information to maintain relevance and influence on behavior, permits greater mental manipulation allowing for more reflection during decision making, and allows for representations to be maintained for longer periods of time leading sustained deliberative processes. In sum, working memory capacity has a direct impact on decision-making abilities, which suggests that deficits may inherently impact decisions in favor of use despite negative consequences associated with such use. Indeed, empirical work has demonstrated that working memory capacity moderates the relationship between measures of impulsivity and alcohol use (Ellingson, Fleming, Verges, Bartholow, & Sher, 2014; Finn & Hall, 2004), such that relationship between alcohol use behavior and impulsivity (i.e., trait sensation seeking and trait lack of planning) was strongest for individuals with low working memory capacity. As such, high working memory capacity may buffer the effects of approach driven behaviors and serves as a protective factor.

The role of working memory capacity is further highlighted in research suggesting it relates to both the initiation and maintenance of problematic drinking. For example, in a sample
of adolescents, weaknesses in working memory ability has been shown to predict increased
frequency of alcohol use over the course of four years (Khurana et al., 2013). Further, this effect
was mediated by measures of delay discounting and one facet of impulsivity (acting without
thinking). This supports that weaknesses in working memory may be a risk factor for early
alcohol use and is consistent with other longitudinal research with adolescents (Khurana, Romer,
Betancourt, & Hurt, 2017; Peeters et al., 2015) as well research establishing executive
functioning weaknesses more generally as a risk factor for subsequent substance abuse (e.g.,
Nigg et al., 2006). However, alcohol misuse has also been shown to negatively impact working
memory, which has been supported with longitudinal research (Peeters, Monshouwer, Janssen,
Wiers, & Vollebergh, 2014). As such, in addition to premorbid weaknesses in working memory,
risk of problematic drinking into adulthood may be inflated when considering further deleterious
effects of drinking on working memory abilities. Indeed, adults with substance dependence
evidence deficits in the executive aspect working memory and this relates to poor performance
on decision making tasks (Bechara & Martin, 2004). As a result, while working memory
capacity deficits may be both a risk factor and maintaining factor for problematic drinking, it has
an important role in predicting drinking behavior.

Some research has examined the relationship of working memory capacity and drinking
behavior with dual-process theories directly in mind. This research assesses learned associations
about alcohol at the implicit level to reflect automatic processes. For example, Thush et al.
(2008) demonstrated that implicit cognitions about alcohol (as measured by the Implicit
Association Test) was more predictive of drinking behavior for adolescents with low working
memory capacity. Conversely, for those with high working memory capacity, explicit cognitions
were more predictive of drinking behavior. This result has been replicated in another sample of
at-risk adolescents (Grenard et al., 2008). These findings highlight that strong influence that automatic associations have on drinking behavior for those with low working memory. More specifically, these differential findings suggest that positive associations with drinking tend to be highly salient when triggered, whereas long term negative associations are weakly activated in comparison. This requires working memory to allow for attention to shift away from a highly salient goal (e.g., feel intoxicated) toward goals that are less salient (e.g., avoid a hangover). Therefore, automatic associations are more predictive of drinking behavior for those who are unable to shift their attention away and inhibit this automatic tendency due to low working memory capacity.

Relatedly, research has examined how individual differences in working memory capacity may moderate the relationship between attentional bias and drinking behavior. The ability to control attention logically may be an important factor that influences the saliency of alcohol-related cues and disengage from stimuli and therefore resulting in attentional bias. Indeed, Friese and colleagues (2010) examined working memory capacity and attentional-bias using eye tracking methodology in a sample of social drinkers. Results demonstrated that individuals with low working memory capacity had shorter time to initial orientation and spent longer dwelling on alcohol cues compared to those with high working memory. More importantly, this difference compared to those with high working memory was seen irrespective of implicit cognitions about alcohol. That is, even if they had positive implicit cognitions about alcohol, those with high working memory capacity were able to self-regulate successfully with more controlled, top down processing (Friese, Bargas-Avila, Hofmann, & Wiers, 2010). Another study with adolescents demonstrated that executive control (indexed using an attention task) moderated the relationship between attentional bias and drinking outcomes such that attentional
bias was only predictive of drinking among those with weak executive control (van Hemel-Ruiter, de Jong, Ostafin, & Wiers, 2015). This suggests that higher working memory capacity makes it easier to counter the effect of an attentional bias toward alcohol. Overall, there is support that that those with low working memory capacity have more difficulty controlling their attention and disengaging from alcohol-related stimuli. Additionally, there is evidence that higher working memory aids in inhibiting automatic tendencies.

In sum, working memory capacity has offered important insight into our understanding of what is required for inhibition of automatic responses. While dual-processing theories offer a useful framework to explore inhibition as a controlled process requiring cognitive resources, the current research is not attempting to disentangle automatic and controlled processing. Rather, the focus of the current research is to explore differences in the ability to inhibit automatic tendencies in the context of conflicting motivational states, and proposes that a key individual difference variable that explains this difference is working memory capacity.

**Present Study**

Multiple areas of research have established that problematic alcohol use is characterized by an automatic appetitive response to alcohol and that successful inhibition of this prepotent response requires the motivation to avoid as well as the cognitive ability to do so. Provided that many individuals do hold the motive to do so in the case of ambivalence, the current study seeks to better understand how differences in cognitive abilities may explain differences in how ambivalence influences drinking outcomes. Specifically, the current study was designed to examine the extent to which working memory capacity moderates the relationship between approach and avoidance and subsequent drinking. There is a significant amount of evidence that individuals with high working memory capacity tend to be more successful in inhibiting
automatic tendencies. We suggest this will be pertinent to ambivalence about drinking such that those with high working memory capacity will inhibit automatic responses to approach alcohol in favor of avoidance. Given the natural fluctuation of motivational states, ecological momentary assessment was used to capture fluctuations in approach and avoidance as it relates to drinking behavior. Given potential for overlap with other cognitive constructs, we also considered response inhibition’s relationship with working memory capacity and potential interaction with motivational states. Following baseline assessment of working memory capacity and response inhibition, daily reports of approach and avoidance inclinations and drinking behavior were collected for a period of two weeks. Based on the review of the literature, the proposed study had the following aim:

To examine the interaction between working memory capacity and daily reports of approach and avoidance and subsequent drinking behavior.

Hypothesis 1: We predicted that when experiencing ambivalence, those low on working memory capacity would have higher rates of drinking when compared to those with lower working memory capacity.

Hypothesis 2: We predicted that when not experiencing motivational conflict, differences in working memory capacity would not be related to drinking behavior. Specifically, when only experiencing approach-oriented motivation, individuals would engage in drinking regardless of working memory capacity. Likewise, when only experiencing avoidance-oriented motivation, both high and low working memory individuals would avoid drinking alcohol.

Exploratory Aim 1: The study explored potential situational factors influencing the relationship between working memory capacity, approach and avoidance and drinking behavior. Known situational factors linked to decision making and alcohol use that may additionally
influence the ability to inhibit include self-efficacy to abstain from drinking (Cooney et al., 2007), and stress level (Armeli, Carney, Tennen, Affleck, & O'Neil, 2000). For example, stress may further influence the amount of cognitive resources available to inhibit approach inclinations.

Exploratory Aim 2: The study explored the extent to which response inhibition is related to working memory capacity, as it may be an important, distinct cognitive construct to consider simultaneously when predicting drinking outcomes. Specifically, we examined relationships between working memory capacity and response inhibition. We then examined the interaction between response inhibition and daily reports of approach and avoidance and subsequent drinking behavior.
METHODS

Participants

A sample of non-treatment seeking individuals (n = 66) between the ages of 18 and 65 were recruited using advertisements through Craigslist and with flyers posted in the community. Inclusion criteria included (a) meeting criteria for a current diagnosis of an alcohol use disorder (initial screening with the AUDIT ≥ 8, confirmed with the M.I.N.I during the intake interview), (b) have access to a telephone for the study period, (c) live within commuting distance to the study site, and (d) provide informed consent. Exclusion criteria included (a) meeting criteria for acute psychosis or severe cognitive impairment (assessed via Psychotic Module of the M.I.N.I and Mini-Mental State Exam ≥ 23), (b) meeting criteria for a current drug use other than nicotine or marijuana, and c) currently seeking treatment for AUD.

The mean score obtained on the Mini-Mental State Exam was 28.82 (SD = 1.20), suggesting little to no cognitive impairment. The mean age of the sample was 32.50 (SD = 14.04). The sample consisted of 62.9% males and was predominately Caucasian (69.4%; 22.6% African American, 1.6% Asian, 3.2% Multiracial, 3.2% Other). Approximately one third of participants were students (33.9%; 22.6% employed part-time; 17.7% job seeking, employed 9.7% full-time, 9.4% retired; 3.2% temporary, 3.2% not working/not seeking work). A majority of participants were single (69.4%; 12.9% divorced; 8.1% married; 9.7% partnered). See Table 1 for a summary of demographic information for the final sample.
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<tr>
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<tr>
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<tr>
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<tr>
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<td>3.2</td>
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<tr>
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<td>4.8</td>
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<td>50,001 or higher</td>
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</table>

**Procedure**

Participants were recruited from the community using local Craigslist advertisements and flyers. The advertisement sought individuals concerned about their drinking for a study on drinking related behavior and decision making, and informed individuals that it requires
participation for two weeks via brief phone surveys and an in-person assessment. Those who responded to the advertisement were contacted by study research assistants to complete a telephone screening to determine initial eligibility. The research assistant provided more detailed information regarding the study and the individual provided verbal consent to participate in the phone screening. The telephone screening consisted of brief questions of demographics, questions regarding current treatment status, and administration of the AUDIT. Research assistants also confirmed their telephone number and ensured participants had telephone access for the study period. If participants met criteria for participation, they were invited for an on-site intake assessment scheduled within one week of the phone screening. Research assistants informed individuals that they will be answering questionnaires and completing computer tasks, and that the entire appointment would take approximately 90 minutes. Participants were also informed that alcohol breath test would be conducted to ensure they have a zero blood alcohol level at intake assessment, and as a result they were told they cannot drink alcohol in the 24 hours prior the appointment.

**Baseline Assessment Procedures.** Participants were verbally consented to the in-person screening upon arrival. A breath alcohol test was administered to ensure a zero blood alcohol level. The MMSE was administered to test for cognitive impairment (score of < 23). The MINI was administered to assess other substance use disorders well as discern whether the participants meets criteria for alcohol use disorder. Informed consent was obtained for participants who were eligible for the study. 

First, the participant completed study measures either on paper or an iPad. Next, the computerized tasks were administered in a standardized order. A research assistant was present throughout in order to provide instructions and ensure understanding of the tasks. Reading Span
was administered first. Following completion of Reading Span, participants were administered a timeline followback interview. Participants then completed Symmetry Span followed by the Flanker task. The research assistant then provided information and instructions for completing the daily phone calls. Participants were paid $10 dollars for the initial baseline assessment.

Research assistants scheduled a follow up appointment after the two-week monitoring period for participants to come in and receive payment for the completion of the study.

Two-week monitoring period. Current approach and avoidance inclinations and drinking behavior of the preceding day were assessed daily for two weeks beginning the day following the baseline assessment. Participants called into an interactive voice response (IVR) system and provide responses to the daily questions. Participants were instructed to call in prior to 12pm. Participants who did not call into the system by 12pm were contacted by research assistants to complete the daily assessment. Further, if participants had missing data on a previous day, they were contacted by research assistants to provide an oral report of their drinking behavior.

Participants received up to $1 per day with a $13 bonus for 7 consecutive days of survey completion, or a bonus of $10 if only 2 non-consecutive days were missed over a 7-day period. This allowed for a maximum of $40 dollars over the course of the two weeks.

Study Completion. Participants were reminded of their appointment with a phone call the day before. Participants filled out one follow up study measure before receiving payment for their completion of the surveys based on the payment schedule described above. This concluded their participation in the study.

Measures – IVR

AAAQ-6. The Brief Approach and Avoidance of Alcohol Questionnaire (AAAQ; Levine et al., 2018) was used to assess approach and avoidance inclinations specific to alcohol use. This
brief measure of the AAAQ was designed from the original AAAQ (McEvoy, Stritzke, French, Lang, & Kettermann, 2004) for use in clinical samples and for repeated assessments. Participants were asked to rate how much they agree with each item on a scale of 0 (Not at All) to 8 (Very Strongly) right now. This measure was also included at the baseline assessment.

Before answering the AAAQ-6, participants were asked if they have had anything to drink since 6am. If they reported drinking, they were not asked about their motivations to drink/avoid drinking and answered filler questions instead.

*Alcohol and Drug Use.* Alcohol use will be assessed each day using the following questions: “Have you had anything to drink since this time yesterday?”

If they answered no they were asked alternative filler questions about their desire to drink in response to different situations. If they answered yes, they were asked the following questions about their use:

- How many standard drinks have you had since this time yesterday?
- What time did you have your first drink?
- What time did you have your last drink?
- Describe the most intoxicated you have been since this time yesterday using a scale from 1 to 4 with 1 being ‘not at all’ and 4 being ‘extremely’ intoxicated.

Participants were also asked the following questions about other drug use:

- Have you smoked cigarettes since this time yesterday?
- Have you used marijuana since this time yesterday?
- Have you used any drugs other than marijuana since this time yesterday?”

*Alcohol Abstinence Self Efficacy.* Self-efficacy to abstain from drinking was assessed with the following question: “How confident are you in your ability to abstain from drinking?”
Participants rated this item on a 5-point Likert scale ranging from 1 (not at all confident) to 5 (completely confident).

**Stress.** An index of the amount of stress the participant was experiencing was assessed with the following item: “Please rate your stress level since the last prompt on a scale of 1 (not at all stressed) to 10 (extremely stressed).”

**Measures – Other**

**Demographics.** Standard questions were used to collect information including gender, age, education, and race.

**Alcohol Use Disorders Identification Test.** The Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, De La Fuente, & Grant, 1993) was administered to determine severity of alcohol problems. The AUDIT is a widely used screening tool that assesses alcohol consumption, drinking behaviors, and alcohol-related consequences across diverse populations. The AUDIT has demonstrated strong psychometric properties, including identification of an optimal cutoff of 8 points or more in identifying problematic drinking levels. The current study used the AUDIT during the telephone screen to assess drinking severity and determine initial eligibility.

**MINI Mental State Exam.** The MINI Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) is a 19-item instrument that assesses current overall cognitive functioning. A score of less than 23 out of 30 is indicative of severe cognitive impairment. The MMSE was used to screen potential participants for study eligibility during the baseline assessment.

**MINI International Neuropsychiatric Interview for DSM-5.** The MINI (MINI; Sheehan et al., 1998) is a semi-structured diagnostic interview designed to assess psychopathology in line with DSM-V standards. Participants were administered the modules for alcohol use disorder,
other substance use disorders and active psychosis during baseline assessment to screen participants for study eligibility.

*Working Memory Capacity.* The assessment of working memory capacity has received an extensive amount of research attention. Complex span tasks have become a common method to assess working memory capacity, and are superior to simple span tasks (e.g., digit span tasks), as they call for both the storage and processing of information in the face of interference (Redick et al., 2012). These tasks are readily available in automated, easy-to-administer versions using E-Prime 2.0 Software (Psychology Software Tools, Pittsburgh, PA). The current study used validated, shortened versions of two complex span tasks: reading span and symmetry span (Foster et al., 2015), which is consistent with recommendations to use multiple tasks and take the average of scores (Conway et al., 2005; Shipstead, Redick, & Engle, 2012). Further, reading span involves more verbally mediated processes and symmetry span is a visuospatial task. Both tasks include a processing task and a recall task. In reading span, participants were given a sequence of letters they are asked to remember while simultaneously completing a distractor task of determining whether short sentences they read make sense. In symmetry span, participants were asked to remember the locations of squares in a 4x4 grid of potential locations while completing a distractor task of determining whether a shape is symmetrical along its vertical axis.

In addition, an individualized time limit to complete the processing task is imposed to ensure they properly attended to the processing task instead of rehearsing items from the recall task. This time limit was calculated from a participant’s average time to complete the processing practice trials (plus 2.5 SDs). For the current study, the first practice trial was excluded from
calculation of this time since the first presentation likely results in an upper bound outlier as participants adjust to the newness of the task.

These tasks resulted in two different classes of scores, namely a processing task score and a recall score. Given that participants are encouraged to complete the processing task with 100% accuracy and ceiling effects are typically observed, these scores are typically not included as a main outcome of the task. Further, researchers have typically discarded cases that have less than 85% accuracy on the processing task, as this suggests the participant was not properly attending to the task (Conway et al., 2005). In terms of the recall score, research supports that the partial scoring method is superior over an absolute score (Conway et al., 2005; Redick et al., 2012). With the partial scoring method, credit is given to partially correct items where some items are recalled in the correct sequence. With the absolute scoring, points are only given if all items are recalled in the correct sequence. As such, the current study utilized the partial scoring method when calculating the recall score. The average of the two partial scores from each task was used in the main analyses.

*Response Inhibition.* The flanker task (Eriksen, 1995) is a computerized task that will be used to assess response inhibition. The current study used a version programmed with E-Prime 2.0. In this task, participants were asked to choose the correct direction of an arrow presented to them while ignoring distractor symbols surrounding that arrow. Participants were provided instructions for where to place their index fingers on the keyboard, and they were instructed to respond to stimuli as quickly and as accurately as possible. Participants completed 10 practice trials before beginning the task to ensure understanding of the task. Stimuli were shown until the participant provided a response. The flanker task for the current study utilized 200 presentations of stimuli with randomized presentation of both congruent and incongruent trials. Correct
responses were utilized to calculate average response time to congruent and incongruent trials. The interference score (i.e., an index of inhibition) was calculated by subtracting mean response time on correct congruent trials from mean response time on correct incongruent trials. Response times to the task demonstrate the influence of response competition, with faster times indicative of better ability to inhibit a prepotent response. This was used to address the study’s exploratory aim simultaneously examining response inhibition and working memory capacity.

*Drinking History Questionnaire.* Alcohol use was assessed using the 10-item Drinking History Questionnaire (DHQ). Based on the work of (Cahalan, Cisin, & Crossley, 1969), this instrument assessed both quantity and frequency of drinking. Frequency was assessed using a 10-point scale ranging from once a month or less to 21 or more times a week. The number of standard drinks they typically consumed per drinking occasion indicated quantity. This questionnaire was administered at the baseline assessment to characterize the drinking behavior and history of the sample.

*Timeline Followback.* Recent patterns of alcohol use will be estimated using the Timeline Followback method (TLFB; Sobell & Sobell, 1992) for the past 3 months. The TLFB is a calendar-based retrospective recall interview of daily alcohol use. This was administered to better understand the drinking patterns and problem severity of the sample.

*Short Index of Problems.* The Short Index of Problems (SIP), an abbreviated version of the Drinker Inventory of Consequences (DrInC; Miller, Tonigan, & Longabaugh, 1995), is a self-report measure of drinking-related negative consequences. The SIP was used to assess drinking-related negative consequences during the baseline assessment.

*UPPS-P Impulsive Behavior Scale.* The UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007; Lynam, Smith, Whiteside, & Cyders, 2006), a revision to the original UPPS
(Whiteside & Lynam, 2001) is a 59-item measure assessing impulsivity across 5 domains: Positive Urgency, Negative Urgency, Premeditation (lack of), Perseverance (lack of) and Sensation Seeking. The UPPSP provides two composite scores of these domains including Emotion-Based Rash Action and Lack of Conscientiousness, as well as a total score across all domains. The UPPSP was included to explore the association of trail-level impulsivity with working memory capacity and behavioral inhibition.

*Readiness to Change Scale.* The Readiness to Change Questionnaire is a 12-item instrument that assesses the stage of change an individual has reached in regard to changing their drinking behavior. This scale is based on the work of Prochaska and DiClemente (1984) that describes how individuals transition through the following stages of changes: precontemplation, contemplation, and action. This was administered at baseline and at the follow up in order to conduct post-hoc exploratory analyses.

**Date Analytic Strategy**

Prior to all analyses, outliers (median + or – 2 interquartile ranges) and normality of variables were examined. Outliers for computerized cognitive tasks were identified in accordance with prior research recommendations. Descriptive statistics were computed for variables of interest to characterize the sample. Correlations among variables of interest and between secondary variables (i.e., working memory capacity, drinking behavior) were examined.

Multilevel time-lagged regression models were conducted to address the main hypotheses. Multilevel regression is well suited for within person data as it simultaneously estimates both within person and between person data. Our main outcomes included drinking day (yes/no) and heavy drinking day (yes/no). For the main analyses, the within person predictors (level 1) included time-lagged daily approach and avoidance inclinations, and their interaction.
Approach and avoidance inclinations were person-mean centered in order to examine how variability around one’s own mean predicts drinking outcomes. Between person predictors (level 2) included working memory capacity (grand mean centered), age (grand mean centered), and participants’ overall average scores on approach and avoidance inclinations (i.e., averaged over all 14 days to get between person estimates; also grand mean centered).

To test our primary hypotheses examining whether working memory capacity moderates the relationship between approach, avoidance and subsequent drinking behavior, the cross-level interaction (i.e., approach X avoidance X working memory capacity) was entered between working memory capacity (level 2) and time-lagged indices of approach and avoidance, and their interaction at level 1. Further, age and between person effects of approach and avoidance were controlled for on the intercept\(^1\). Outcome variables to be examined included both the occurrence of drinking (yes or no) and the occurrence of a heavy drinking day (yes or no). Heavy drinking was defined as 5 or more drinks for men and 4 or more drinks for women. Bernoulli sampling distribution and logit link function with restricted PQL was used. Unit-specific results with robust standard errors were interpreted.

\(^1\) We also considered the need to control for drinking history (i.e., drinking variables reported at baseline). Controlling for these variables (e.g., drinks per week, TLFB daily drinking average) did not change model results and was subsequently removed. The parsimonious model is reported below.
RESULTS

Descriptive Statistics of Baseline Data

Outliers and Normality. All variables were first examined for normality. Initial examination of baseline WMC tasks demonstrated that both tasks resulted in a normal distribution of partial scores for both Symmetry and Reading Span. A participant’s mean partial score was computed and used in main analyses. However, given recommendations to drop data from participants who did not obtain at least 85% accuracy in the processing portion of tasks, these scores were also examined. All subjects completed the processing portion of Reading Span with at least 75% accuracy. Given the higher variability expected in performance on these tasks as a function of the diverse sample, this threshold was determined to be acceptable and all subjects were retained based on their Reading Span Scores. However, the processing accuracy scores for Symmetry Span were slightly more variable. A majority of subjects (n = 64) completed this task with an accuracy of at least 70% and these subjects were retained. However, two subjects completed the processing task with near chance level (50% and 51%), suggesting they were not adequately engaged in the task. The same two participants were identified as significant outliers on the Flanker task, and subsequently these participants were removed from main analyses due to larger concerns with their task engagement and following of instructions.

Due to interest in extracting an index of behavioral inhibition from the flanker task, only correct trials were analyzed (94.8% of total trials). Within person outliers were also identified and removed from current analyses (accounting for 2.2% percent of the data). Outliers were defined as reaction times that deviated more than 2.5 standard deviations from an individual’s mean
reaction time, a method consistent with prior research (Lopez-Garcia, Sobrado, Penalver, Górriz, & Ruz, 2020). Resulting interference scores greatly improved normality.

**Drinking Characteristics and Bivariate Correlations.** A majority of the sample met criteria for severe AUD (75%; 7.8% mild, 17.2% moderate). The current sample reported typically drinking an average of 4.34 occasions (SD = 4.46) per week and an average of 5.82 drinks (SD = 2.60) per occasion. Additionally, in the past 90 days the sample reported drinking an average of 3.25 drinks (SD = 2.02) drinks per day. On average, participants endorsed low readiness to change drinking as assessed with the RCQ (Means below zero across the precontemplation, contemplation and action subscales).

Pearson’s correlations were used to examine the relationships between working memory capacity, interference scores, approach and avoidance and drinking behaviors reported at baseline. In summary, working memory capacity was negatively associated with avoidance, frequency and quantity of drinking, drinking patterns in the past three months, alcohol consequences and age. Interference (higher scores equate to lower behavioral inhibition) was positively associated with approach, avoidance, frequency, and alcohol consequence, and was negatively associated with readiness to change (significant association with the precontemplation scale on the RCQ). Interestingly, working memory capacity was not significantly correlated with interference. Neither working memory capacity or interference were significantly associated with trait-level impulsivity (UPPS-P scores). See Table 2 for a full summary of these results.
Table 2. Summary of means, standard deviations, and correlations for baseline variables (n = 62)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
<th>12.</th>
<th>13.</th>
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<td>4.</td>
<td>Avoidance</td>
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<td>2.44</td>
<td>-.209***</td>
<td>.259***</td>
<td>.343***</td>
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<tr>
<td>5.</td>
<td>Frequency</td>
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<td>4.46</td>
<td>-.320***</td>
<td>.180***</td>
<td>.302***</td>
<td>.271***</td>
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<td>6.</td>
<td>Quantity</td>
<td>5.82</td>
<td>2.60</td>
<td>.123***</td>
<td>-.001</td>
<td>.126***</td>
<td>.070*</td>
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<td>7.</td>
<td>TFLB Average</td>
<td>3.25</td>
<td>2.02</td>
<td>-.257***</td>
<td>-.025</td>
<td>.337***</td>
<td>.212***</td>
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<td>8.</td>
<td>SIP-A Total</td>
<td>18.27</td>
<td>10.67</td>
<td>-.136***</td>
<td>.117**</td>
<td>.575***</td>
<td>.575***</td>
<td>.430***</td>
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<td>9.</td>
<td>UPPS-P Total</td>
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<td>19.03</td>
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<td>-.047</td>
<td>.386***</td>
<td>.353</td>
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<td>.267***</td>
<td>.127***</td>
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<td>-.150</td>
<td>-.166</td>
<td>-.083</td>
<td>-.302*</td>
<td>-.089</td>
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<td>RCQ-Contemplation</td>
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<td>.063</td>
<td>.012</td>
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<td>12.</td>
<td>RCQ-Action</td>
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<td>1.70</td>
<td>.072</td>
<td>.000</td>
<td>-.118</td>
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<td>-.056</td>
<td>-.042</td>
<td>-.028</td>
<td>-.015</td>
<td>-</td>
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<td>13.93</td>
<td>-.636***</td>
<td>-.020</td>
<td>.048</td>
<td>.157***</td>
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<td>.012</td>
<td>.372***</td>
<td>.257***</td>
<td>-.251***</td>
<td>.023</td>
<td>-.080</td>
<td>-.093</td>
</tr>
</tbody>
</table>

Note: WMC = working memory capacity; Frequency = number of drinking occasions per week; quantity = number of drinks per occasion; TFLB Average = average number of drinks reported per day over the past 90 days; SIP-A: Short Inventory of Problems; UPPS-P: UPPS Impulsive Behavior Scale; RCQ: Readiness to Change Questionnaire. *p < .05, **p < .01, ***p < .001.
Descriptive and Compliance Statistics of Daily Monitoring Data

Two participants were excluded from analyses for missing IVR data (i.e., missing data on the approach and avoidance measure), bringing the final sample size to 62 participants. Participants completed 829 daily assessments resulting in a compliance rate of 95.51% during the 14-day assessment period. This high compliance rate is likely due to the procedure of study staff reaching out to participants who missed a report to collect missing data. Participants reported 415 drinking days during the 14-day period (47.81% of reported days). Of those days, 200 were heavy drinking days (48.19%).

Unconditional Models and Intraclass Correlations

Prior to main analyses, unconditional models for each outcome (drinking day yes/no and heavy drinking day yes/no) were estimated in order to calculate the intraclass correlation. The intraclass correlation is the proportion of variance in our outcome accounted for due to clustering (i.e., correlation among observations within persons). Since our outcomes were binary, an alternative approach to estimating ICC with a binary outcome was followed \[ \rho = \sigma^2/(\sigma^2 + 1/\pi) \] (Hox, 2010). The ICC was .291 for drinking day and .267 for heavy drinking day, indicating that approximately 29% of the variance in drinking day and 27% of the variance in heavy drinking days lies between groups. In addition, all random intercepts were significant. This suggests that further modeling is warranted.

Working Memory Capacity X Approach X Avoidance (Primary Aim)

Our primary aim was to examine the interaction between an individual’s working memory capacity (i.e., between person effect) and daily reports of approach and avoidance on subsequent drinking behavior (i.e., within person effects). We hypothesized that when experiencing ambivalence (high approach, high avoidance), those lower on working memory capacity will have higher rates of drinking when compared to those with higher working memory
capacity. We also hypothesized that when not experiencing motivational conflict, differences in working memory capacity would not be related to drinking behavior. To examine these hypotheses, we first examined a three-way interaction between working memory capacity, approach and avoidance and how this interaction related to drinking outcomes (drinking day and heavy drinking day). Random effects of predictors (i.e., random slopes) were initially entered into the model, but were removed due to being non-significant. See Table 3 for a summary of these model results.

**Drinking Day.** Results indicated significant between person main effects of both approach (b = .267, SE = .108 , p = .017, OR = 1.306) and avoidance inclinations (b = -.302, SE = .097, p = .003, OR = .740), indicating that on average people with higher levels of approach inclinations had higher odds of drinking and people with higher levels of avoidance had lower odds of drinking. More importantly, results indicated a significant three-way interaction between Working Memory Capacity (between-effect) X Approach (within-effect) X Avoidance (within-effect) in the prediction of a drinking day (b = -.010, SE = .005 , p = .021, OR = .990). To further explore this interaction, estimated means were plotted (see Figure 1) and simple slopes were tested using high (85th percentile) and low (15th percentiles) values of approach, avoidance, and working memory capacity.

At lower levels of working memory capacity, follow-up analyses indicated a significant interaction between approach and avoidance (b = .212, SE = .086, p = .014, OR = 1.236). Simple slopes of approach were tested next at both higher and lower levels of avoidance. Results indicated that approach inclinations was trending towards significance at higher levels of avoidance (b = .414, SE = .225, p = .066, OR = 1.513), indicating that among individuals with lower working memory capacity, as approach increased relative to a person’s mean the odds of
drinking increased when also experiencing higher than average levels of avoidance. The simple slope of approach was non-significant at lower levels of avoidance (b = .045, SE = .254, p = .860, OR = 1.046). Further, the simple slope for avoidance was non-significant at both lower (b = -.142, SE = .255, p = .579, OR = 0.868) and higher levels of approach (b = .295, SE = .264, p = .265, OR = 1.115).

Among those higher on working memory capacity, follow-up analyses indicated that the interaction between approach and avoidance was non-significant (b = -.113, SE = .082, p = .171, OR = .893). Further, the simple slopes for approach was non-significant at both lower (b = .233, SE = .157, p = .138, OR = 1.263) and higher levels of avoidance (b = .078, SE = .161, p = .626, OR = 1.082), and the simple slopes for avoidance were also non-significant at both lower (b = .226, SE = .255, p = .377, OR = 1.254) and higher levels of approach (b = -.006, SE = .220, p = .978, OR = 0.994).

Heavy Drinking Day. Results indicated that the three-way interaction of Working Memory Capacity (between effect) X Approach (within effect) X Avoidance (within effect) was non-significant (b = -.002, SE = .006 , p = .760, OR = 1.00) in the prediction of heavy drinking days. Further examination of all two-way interactions (after removing the three-way interaction) revealed that the Approach X Avoidance, Approach X Working Memory Capacity, and Avoidance X Memory Capacity were also all non-significant.

After removing all interactions, both between and within person main effects were examined. Results indicated that both the between person (b = .268, SE = .117, p = .026, OR = 1.307) and within person main effect of approach (b = .179, SE = .088, p = .043, OR = 1.20) were significant, suggesting that individuals were at a greater odds of a heavy drinking day when they had on average higher levels of approach (i.e., between effect) and when their approach
inclinations increased relative to their own mean on any given day (i.e., within person effect). Both the between (b = -.180, SE = .019, p = .490, OR = 0.836) and within person main effects of avoidance (b = .048, SE = .102, p = .640, OR = 1.049) were non-significant. Further, the between person main effect of working memory capacity was non-significant (b = .013, SE = .019, p = .490, OR = 1.013).

Figure 1. Graphic Illustrations of Approach X Avoidance X Working Memory Capacity
Table 3. Summary of Results for Approach X Avoidance X WMC Predicting Drinking Outcomes (full models)

<table>
<thead>
<tr>
<th></th>
<th>Drinking Day (yes/no)</th>
<th>Heavy Drinking Day (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$b$</td>
<td>$SE$</td>
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<tr>
<td>Intercept</td>
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<td>.389</td>
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<tr>
<td>X Age</td>
<td>.020</td>
<td>.013</td>
</tr>
<tr>
<td>X Approach (between)</td>
<td>.267</td>
<td>.108</td>
</tr>
<tr>
<td>X Avoidance (between)</td>
<td>-.302</td>
<td>.097</td>
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<tr>
<td>X WMC</td>
<td>.006</td>
<td>.016</td>
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<tr>
<td>Approach (within)</td>
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<td>.262</td>
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<tr>
<td>X WMC</td>
<td>-.002</td>
<td>.010</td>
</tr>
<tr>
<td>Avoidance (within)</td>
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<td>.287</td>
</tr>
<tr>
<td>X WMC</td>
<td>.001</td>
<td>.013</td>
</tr>
<tr>
<td>Approach (within) X Avoidance (within)</td>
<td>.253</td>
<td>.101</td>
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<td>X WMC</td>
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<td>.005</td>
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Random Effects Variances

<table>
<thead>
<tr>
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<th>$\chi^2$</th>
<th>$p$</th>
<th>$Var$</th>
<th>$\chi^2$</th>
<th>$p$</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
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<td>183.78</td>
<td>&lt;.001</td>
<td>1.590</td>
<td>158.74</td>
<td>&lt;.001</td>
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</table>

Note: $b$ = unstandardized estimate; SE = standard errors; $p$ = p-value; $Var$ = random effects variance; $\chi^2$ = chi square test; OR = odds ratio.
Examination of Situational Factors (Exploratory Aim)

We also examined whether situational factors including stress and self-efficacy may further impact the relationship between approach, avoidance and working memory capacity. To address this exploratory aim, multiple multilevel models were conducted after coding for high and low levels of stress and self-efficacy. A median split of the ratings for stress and self-efficacy was done to separate high and low values, and the three-way interaction was examined within each group. The median value for stress, which was rated on a 1-10 scale, was 4. The median value for self-efficacy, which was on a 1-5 scale, was 4. Although median splits have been criticized for resulting in a loss of variation in scores as well as an increased Type I and II error (Rucker, McShane, & Preacher, 2015), we elected for this strategy to aid in interpretation in these exploratory analyses (i.e., avoid testing a four-way interaction).

Model results were examined to determine if differing stress or self-efficacy levels influenced relationships. The Approach X Avoidance X WMC interaction was non-significant in the prediction of heavy drinking day at varying levels of stress and self-efficacy. However, the three-way interaction continued to be significant for the prediction of a drinking day (yes/no), at high ($b = -.019$, $SE = .009$, $p = .033$, OR = .981) and low levels of stress ($b = -.020$, $SE = .008$, $p = .095$, OR = .980). Further, the three-way interaction was significant at both high ($b = -.022$, $SE = .007$, $p = .003$, OR = .978) and low levels of self-efficacy ($b = -.014$, $SE = .009$, $p = .095$, OR = .986). In sum, the nature of the three-way interaction and relationship to drinking outcomes did not differ at varying levels of stress or self-efficacy. See Table 4 for a summary of these model results at high and low levels of stress, and Table 5 for a summary of model results at high and low levels of self-efficacy.
Table 4. Summary of Results for Approach X Avoidance X WMC Predicting Drinking Day by Stress Level

<table>
<thead>
<tr>
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<th>Low Stress</th>
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<tbody>
<tr>
<td></td>
<td>b</td>
<td>SE</td>
<td>p</td>
<td>OR</td>
<td>b</td>
<td>SE</td>
<td>p</td>
</tr>
<tr>
<td>Intercept</td>
<td>-.280</td>
<td>.553</td>
<td>.616</td>
<td>.756</td>
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<td>.485</td>
<td>.718</td>
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<tr>
<td>X Age</td>
<td>.016</td>
<td>.015</td>
<td>.293</td>
<td>1.016</td>
<td>.013</td>
<td>.019</td>
<td>.478</td>
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<tr>
<td>X Approach (between)</td>
<td>.099</td>
<td>.152</td>
<td>.518</td>
<td>1.104</td>
<td>.227</td>
<td>.167</td>
<td>.177</td>
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<tr>
<td>X Avoidance (between)</td>
<td>-.189</td>
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<td>.210</td>
<td>.828</td>
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<td>.105</td>
<td>.004</td>
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<tr>
<td>X WMC</td>
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<td>.489</td>
<td>1.015</td>
<td>.001</td>
<td>.022</td>
<td>.974</td>
</tr>
<tr>
<td>Approach (within)</td>
<td>.728</td>
<td>.278</td>
<td>.010</td>
<td>2.071</td>
<td>-.105</td>
<td>.324</td>
<td>.747</td>
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<tr>
<td>X WMC</td>
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<td>.012</td>
<td>.155</td>
<td>.983</td>
<td>.015</td>
<td>.013</td>
<td>.249</td>
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<tr>
<td>Avoidance (within)</td>
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<td>.024</td>
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<td>.574</td>
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<td>.257</td>
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<td>X WMC</td>
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<td>.013</td>
<td>.048</td>
<td>1.026</td>
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<td>.023</td>
<td>.669</td>
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<tr>
<td>Approach (within) X Avoidance (within)</td>
<td>.590</td>
<td>.223</td>
<td>.009</td>
<td>1.804</td>
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<td>.176</td>
<td>.116</td>
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<td>X WMC</td>
<td>-.019</td>
<td>.009</td>
<td>.033</td>
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<td>-.020</td>
<td>.008</td>
<td>.017</td>
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<td>1.328</td>
<td>125.300</td>
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</table>

Note: $b$ = unstandardized estimate; SE = standard errors; $p$ = p-value; $Var$ = random effects variance; $\chi^2$ = chi square test; OR = odds ratio.
Table 5. Summary of Results for Approach X Avoidance X WMC Predicting Drinking Day by Self-Efficacy Level

<table>
<thead>
<tr>
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<th>Low Self-Efficacy</th>
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<td>$p$</td>
<td>$OR$</td>
<td>$b$</td>
<td>$SE$</td>
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<tr>
<td>Intercept</td>
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<td>.194</td>
<td>.408</td>
<td>.182</td>
<td>.497</td>
</tr>
<tr>
<td>X Age</td>
<td>.016</td>
<td>.023</td>
<td>.485</td>
<td>1.016</td>
<td>.008</td>
<td>.014</td>
</tr>
<tr>
<td>X Approach (between)</td>
<td>.111</td>
<td>.151</td>
<td>.465</td>
<td>1.118</td>
<td>.053</td>
<td>.168</td>
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<tr>
<td>X Avoidance (between)</td>
<td>-.308</td>
<td>.103</td>
<td>.005</td>
<td>.735</td>
<td>-.084</td>
<td>.167</td>
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<tr>
<td>X WMC</td>
<td>.009</td>
<td>.026</td>
<td>.715</td>
<td>1.009</td>
<td>.014</td>
<td>.021</td>
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<tr>
<td>Approach (within)</td>
<td>.236</td>
<td>.452</td>
<td>.602</td>
<td>1.266</td>
<td>.074</td>
<td>.321</td>
</tr>
<tr>
<td>X WMC</td>
<td>-.003</td>
<td>.017</td>
<td>.833</td>
<td>.996</td>
<td>.006</td>
<td>.014</td>
</tr>
<tr>
<td>Avoidance (within)</td>
<td>-.403</td>
<td>.350</td>
<td>.250</td>
<td>.668</td>
<td>.302</td>
<td>.343</td>
</tr>
<tr>
<td>X WMC</td>
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<td>.075</td>
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<td>.015</td>
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<tr>
<td>Approach (within) X Avoidance</td>
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<td>.218</td>
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</tr>
<tr>
<td>X WMC</td>
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<td>.003</td>
<td>.978</td>
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<td>.009</td>
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Random Effects Variances

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</thead>
<tbody>
<tr>
<td>Interception</td>
<td>1.093</td>
<td>92.586</td>
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</tr>
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</table>

Note: $b =$ unstandardized estimate; SE = standard errors; $p$ = p-value; $Var$ = random effects variance; $\chi^2$ = chi square test; $OR$ = odds ratio.
Interference X Approach X Avoidance (Exploratory Aim)

In order to compare the impact of response inhibition on drinking outcomes (another measure of executive functioning), multilevel models as above were estimated with flanker interference scores as a level-2 moderator instead of working memory capacity (Approach X Avoidance X Interference). Specifically, we conducted similar analyses in which we examined a three-way interaction between interference, approach and avoidance and how this interaction related to drinking outcomes (drinking day and heavy drinking day). Random effects of predictors were initially entered into the model, but were removed due to being non-significant. See Table 6 for a summary of these model results.

Drinking Day. Results indicated significant between person main effects of both approach ($b = .294, SE = .102, p = .006, OR = 1.342$) and avoidance inclinations ($b = -.294, SE = .092, p = .002, OR = .745$), indicating that on average people with higher levels of such approach inclinations had higher odds of drinking and people with higher levels of avoidance had lower odds of drinking. More importantly, results indicated a significant 3-way interaction between Interference (between-effect) X Approach (within-effect) X Avoidance (within-effect) in the prediction of a drinking day ($b = .003, SE = .0009, p = .016, OR = 1.002$). To further explore this interaction, estimated means were plotted (see Figure 2) and simple slopes were test using high (85th percentile) and low (15th percentiles) values of approach, avoidance, and interference.

At lower levels of interference (i.e., high levels of inhibition), follow-up analyses indicated that interaction between approach and avoidance was non-significant ($b = -.039, SE = .059, p = .504, OR = .961$). Simple slopes of approach were tested next at both higher and lower levels of avoidance. Results indicated that approach inclinations was significant at higher levels
of avoidance (b = .324, SE = .121, p = .008, OR = 1.383), indicating that among individuals with lower levels of interference (i.e., higher levels of inhibition), as approach increased relative to a person’s mean the odds of drinking increased when also experiencing higher than average levels of avoidance. The simple slope of approach was trending towards significance at lower levels of avoidance (b = .256, SE = .137, p = .063, OR = 1.291). Further, the simple slope for avoidance was non-significant at both lower (b = .068, SE = .165, p = .680, OR = 1.071) and higher levels of approach (b = -.013, SE = .131, p = .922, OR = .987)

Among those higher on interference (i.e., low inhibition), follow-up analyses indicated that the interaction between approach and avoidance was significant (b = .102, SE = .033, p = .002, OR = 1.108). Follow up analyses indicated that simple slopes for approach were non-significant at both lower (b = -.021, SE = .187, p = .893, OR = .975) and higher levels of avoidance (b = .153, SE = .201, p = .446, OR = 1.165), and the simple slopes for avoidance were also non-significant at both lower (b = .007, SE = .199, p = .972, OR = 1.007) and higher levels of approach (b = .218, SE = .181, p = .231, OR = 1.243).

Heavy Drinking Day. Results indicated that the three-way interaction of Interference (between effect) X Approach (within effect) X Avoidance (within effect) was non-significant (b = -.0002, SE = .001 , p = .893, OR = 1.00) in the prediction of heavy drinking days. Further examination of all two-way interactions (after removing the three-way interaction) revealed that the Approach X Avoidance, Approach X Interference, and Avoidance X Interference were also all non-significant.

After removing all interactions, both between and within person main effects were examined. Results indicated that the between person (b = .314, SE = .113, p = .013, OR = 1.369) was significant and the within person main effect of approach was trending significance (b =
.212, SE = .122, p = .083, OR = 1.237). This suggests that individuals were at a greater odds of heavy drinking when they had on average higher levels of approach (i.e., between effect) and when their approach inclinations increased relative to their own mean on any given day (i.e., within person effect. The between person main effect avoidance was trending significance (b = -.218, SE = .119, p = .073, OR = 0.804), suggesting that individuals were at a decreased odds of a heavy drinking day when they had on average higher levels of avoidance. The within person main effect of avoidance was non-significant (b = .053, SE = .101, p = .602, OR = 1.054). Further, the between person main effect of interference was non-significant (b = -.004, SE = .005, p = .451, OR = .996).

Figure 2. Graphic Illustration of Approach X Avoidance X Inhibition
Table 6. Summary of Results for Approach X Avoidance X Interference Predicting Drinking Outcomes (full models)

<table>
<thead>
<tr>
<th></th>
<th>Drinking Day (yes/no)</th>
<th></th>
<th>Heavy Drinking Day (yes/no)</th>
<th></th>
</tr>
</thead>
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<tr>
<td></td>
<td>b</td>
<td>SE</td>
<td>p</td>
<td>OR</td>
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<tr>
<td>Intercept</td>
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<td>.672</td>
<td>1.083</td>
</tr>
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<td>X Age</td>
<td>.016</td>
<td>.011</td>
<td>.105</td>
<td>1.019</td>
</tr>
<tr>
<td>X Approach (between)</td>
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<td>.102</td>
<td>.006</td>
<td>1.342</td>
</tr>
<tr>
<td>X Avoidance (between)</td>
<td>-.294</td>
<td>.092</td>
<td>.002</td>
<td>.745</td>
</tr>
<tr>
<td>X Interference</td>
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<td>.006</td>
<td>.131</td>
<td>.991</td>
</tr>
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<td>Approach (within)</td>
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<td>.097</td>
<td>.008</td>
<td>1.292</td>
</tr>
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<td>X Interference</td>
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<td>.004</td>
<td>.373</td>
<td>.997</td>
</tr>
<tr>
<td>Avoidance (within)</td>
<td>.041</td>
<td>.114</td>
<td>.720</td>
<td>1.042</td>
</tr>
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<td>X Interference</td>
<td>.001</td>
<td>.004</td>
<td>.750</td>
<td>1.001</td>
</tr>
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<td>Approach (within) X Avoidance (within)</td>
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<td>.052</td>
<td>.727</td>
<td>.982</td>
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<td>X Interference</td>
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<td>.016</td>
<td>1.002</td>
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Random Effects Variances

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<th>χ²</th>
<th>p</th>
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<td>1.180</td>
<td>159.99</td>
<td>&lt;.001</td>
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</table>

Note: b = unstandardized estimate; SE = standard errors; p = p-value; Var = random effects variance; χ² = chi square test; OR = odds ratio.
Figure 2. Graphic Illustration of Approach X Avoidance X Inhibition
DISCUSSION

The primary aim of this study was to examine whether working memory capacity moderates the relationship between approach and avoidance and subsequent drinking behavior. Because working memory capacity is a cognitive resource that allows individuals to shift attention in the face of conflicting goals, we posited it would be a key variable to inhibit desires to drink when experiencing the conflicting motivational state of ambivalence. Specifically, it was hypothesized that when experiencing an ambivalent motivational state (high approach, high avoidance), those low on working memory capacity would have higher rates of drinking behavior compared to those with higher working memory capacity. We also hypothesized that when not experiencing ambivalence, differences in working memory capacity would not be related to differences in drinking behavior. Our central hypothesis was partially supported. Specifically, we found a significant interaction between approach, avoidance and working memory capacity in the prediction of a drinking day. Follow up analyses of this interaction demonstrated that those with lower working memory capacity were at increased odds of drinking as approach increased when also experiencing higher than average levels of avoidance (i.e., experiencing ambivalence). In contrast, for those with higher working memory capacity, odds of a drinking episode did not increase when experiencing ambivalence. Interestingly, our hypothesis was not supported in examining this interaction in the prediction of a heavy drinking day.

This study also explored the impact of situational factors on the relationship between working memory capacity, motivational states and subsequent drinking. However, it appeared that the nature of the relationships remained similar at varying levels of stress and self-efficacy.
This suggests that self-reported self-efficacy and stress did not alter the nature of how working memory capacity interacted with motivational states to predict the occurrence of drinking.

Results of the current study suggests that working memory capacity may be an important individual difference variable that allows for inhibiting the desire to drink when having the desire to do so. Individuals with higher working memory capacity may be better able to redirect their attention in favor of avoidance-oriented goals when experiencing temptations to drink. Indeed, research has demonstrated that individuals with higher working memory capacity are better able to inhibit automatic, appetitive tendencies (e.g., temptation for unhealthy food, sexual interest, stereotype processing, affective responses/expression) when they have the desire to do so (Barrett et al., 2004; Hofmann et al., 2008). In the alcohol literature, those with lower working memory capacity demonstrate more attentional bias toward alcohol-related cues (Friese et al., 2010), may be at greater risk for increased drinking frequency and alcohol abuse (Khurana et al., 2013), demonstrate more impulsive decision making and subsequent drinking behavior (Ellingson et al., 2014; Finn & Hall, 2004). The current study extends the literature by establishing working memory capacity as an important cognitive construct that impacts how an individual resolves ambivalence towards drinking and improves our understanding of part of the decisional process that underlies drinking behavior. Results lend support to the dual-process perspective wherein those with higher working memory capacity are better able to engage in more deliberative processing when experiencing ambivalence, redirecting their attention to goals associated with abstinence. In contrast, automatic tendencies more often guide the decisions of those with lower working memory capacity.

Although unexpected, the lack of consistent effect across the prediction of a drinking day and heavy drinking day may aid in improving our understanding of decisional processes.
surrounding drinking. Working memory capacity is a cognitive resource that allows for coordination of processing when multiple goals are active and guiding behavior with information that is not in the immediate environment (D'Esposito & Postle, 2015). As such, working memory capacity has a prominent role in the initial decision to engage in a behavior when multiple goals are present and one must shift attention to deliberative goals. However, it may have a lesser role in disengagement from a behavior, and this may be especially true in regard to drinking. This is because executive functioning like working memory capacity can be compromised after even modest levels of alcohol consumption (Montgomery, Ashmore, & Jansari, 2011), with older adults being especially susceptible to these effects (Boissoneault, Sklar, Prather, & Nixon, 2014). Therefore, once drinking is initiated, working memory capacity may no longer have an appreciable influence on the amount an individual drinks. It could also be that given that this was a non-treatment seeking sample, there was an absence of actively trying to control drinking quantity (i.e., moderated drinking), especially since avoidance inclinations were not measured throughout the day. As a result, working memory capacity does not have a measurable effect in the prediction of heavy drinking.

While the current study was designed to explore working memory capacity’s impact on drinking behavior, we also examined response inhibition as an alternative executive functioning measure. We sought to explore the possible overlap and differentiation between these related cognitive constructs. Interestingly, results suggest that working memory capacity and inhibition do not overlap, as evidenced by a lack of significant association between these constructs. Further, we saw a surprising pattern of results when examining response inhibition’s interaction with approach and avoidance. That is, those with higher inhibition appeared to be at increased odds of a drinking episode as approach increased, even when experiencing higher than average
avoidance, while odds did not increase for those with lower inhibition regardless of motivational state. However, these findings must be interpreted within the context of mixed results observed in the response inhibition and alcohol literature. For example, some research has found that adolescents with poorer response inhibition were at increased risk for comorbid substance use and alcohol related problems (Nigg et al., 2006), whereas other research has failed to find a relationship between response inhibition and drinking behavior (Fernie, Cole, Goudie, & Field, 2010; Goudriaan, Grekin, & Sher, 2011). Thus, the relationship between response inhibition is unclear. This lack of consistent finding may reflect underlying theoretical considerations that require further investigation, as well as methodological issues with response inhibition.

Response inhibition literature highlights several theoretical considerations that may help explain mixed results and help put our results into context. For example, one study examining intoxication effects determined that those with higher inhibitory control are more susceptible to alcohol’s acute intoxication effects, that is, alcohol had the largest effect among these individuals (Bartholow et al., 2018), which may seem counterintuitive. However, these findings highlight the potential difficulties of assessing behavioral control at the trait level. Specifically, individuals with higher response inhibition have “more to lose” such that they may exercise self-control more frequently throughout the day. As a result, a single, baseline type assessment of response inhibition may result in very different relationships to outcome variables than when considering repeat assessment of response inhibition over time. Indeed, research has demonstrated that the relationship of inhibitory control to alcohol consumption is nuanced. One study found that only within person changes in inhibitory control predicted same day drinking such that inhibitory control that worsened across the course of the day was predictive of drinking later in the day (Jones, Tiplady, Houben, Nederkoorn, & Field, 2018). As such, the observed interaction between
inhibition and motivation as it relates to drinking may differ substantially if we were able to capture state level changes of inhibition.

Results from our study also suggest that the relationship of inhibition to drinking is nuanced. Specifically, when examining correlational results from the present study, higher interference (low inhibition) related to increased self-reported frequency of drinking at the baseline assessment. That is, inhibition related to differences in drinking behavior in the expected direction. This could demonstrate that response inhibition’s relationship to drinking outcomes may be more consistent with our expectation (i.e., higher inhibition is associated with less drinking) when examining cross-sectionally reported data. To follow up on his possibility, we conducted analyses isolating the main effect of inhibition in predicting drinking across the 14-day monitoring period. Interestingly, the effect was non-significant when examining the occurrence of a drinking day and heavy drinking day. As such, this suggests potential methodological differences underlie these variable results. That is, participant’s report on their drinking behavior across the 14-day monitoring period resulted in important differences compared to retrospective reports about typical drinking patterns at the baseline assessments. One possibility underlying this difference is assessment reactivity. There is mixed findings in the literature regarding the impact of assessments on drinking reports, with some evidence that there is little reactivity to daily IVR assessments in individuals who recently completed AUD treatment (Simpson, Kivlahan, Bush, & McFall, 2005), while other research recognizes that assessment exposure can have significant impacts on alcohol use behavior (Clifford, Maisto, & Davis, 2007), and even suggest that it can be an active treatment in itself (Schrimsher & Filtz, 2011).
Exploratory analyses in our study suggested that the likelihood of a drinking day decreased overall across the 14-day monitoring period. While some research has suggested that assessment exposure does not impact drinking outcomes, this effect may largely depend on characteristics of the sample. For example, Simpson and colleagues (2005) found no evidence for assessment reactivity in people who had recently completed AUD treatment. Presumably these individuals had already made changes to their drinking. Conversely, in individuals who have some level of motivation to change their drinking, assessment exposure may help facilitate these changes. The nature of meeting criteria for AUD inherently points to some motivation to change drinking behavior (i.e., one symptom is wanting to reduce or control alcohol use).

Further, advertisement for the current study began with asking “Are you concerned about your drinking?”, which in theory should result in all study participants have some underlying desire to change their drinking. Given this, there is evidence to suggest that assessment exposure impacted participant’s behavior and responses to the daily monitoring survey, which may explain why we saw inconsistent results in cross-sectional baseline analyses of inhibition and IVR results. However, these inconsistencies were not observed in working memory capacity results, which may suggest that inhibition interacted with motivation in surprising ways and this drove these results.

Another possibility to consider is that inhibitory control alone does not lead to decreases in drinking behavior. For example, after exploring underlying mechanisms of response inhibition training on observed reductions in drinking, one study found that reduced affective associations (reduced valuation of alcohol as measured by implicit associations), accounted for reductions in drinking rather than increased response inhibition mediating this effect (Houben, Nederkoorn, Wiers, & Jansen, 2011). That is, there was no training effect on response inhibition. The training
resulted in reduced affective associations with alcohol stimuli and this is what influenced reductions in drinking behavior. Therefore, it is possible inhibitory control alone does not impact drinking behavior. It may be that when one is able to reduce affective associations they hold related to alcohol, inhibitory control is more successful in inhibiting drinking behavior.

In addition to these important theoretical considerations, methodological challenges may explain some of the inconsistent findings with response inhibition and has important implications for our results. For example, although alcohol’s acute effects on inhibition is commonly studied in the literature, there is a large degree of variability in these findings due in part to the diversity of tasks used (Weafer & Fillmore, 2016). Among different laboratory measures of executive functions, measures of inhibition typically demonstrate the lowest reliability (Burgess, 1997; Stuss & Alexander, 2000), and appear to capture task-specific processes that may not necessarily relate to the latent construct of inhibition. This is demonstrated by weak associations observed across different tasks (Paap, Anders-Jefferson, Zimiga, Mason, & Mikulinsky, 2020; Rey-Mermet, Gade, & Oberauer, 2018). As a result, our assessment of inhibitory control may be more unreliable than the working memory capacity tasks, which have demonstrated high reliability as well as predictive utility (Conway et al., 2005; Foster et al., 2015; Shipstead et al., 2012).

Indeed, there is some evidence that suggests the Flanker task may be a problematic measure of response inhibition. For example, one study sought to examine the relationship between aspects of inhibition and working memory capacity, and utilized multiple behavioral tasks (stop signal task, go/no-go task, Simon task, Stroop color-word interference test, Flanker test, shape matching task). Consistent with prior literature (e.g., Rey-Mermet et al., 2018) correlations between these different tasks were weak overall. However, the Flanker was only correlated with one other task (Stroop performance), and stood out as the only task that failed to
demonstrate any association with working memory capacity performance (Tiego, Testa, Bellgrove, Pantelis, & Whittle, 2018). This finding is consistent with results from the current study, and may suggest that the Flanker task is more apt to capture task-specific rather processes rather than probe the latent-level response inhibition. With these considerations in mind, the current study would have benefited from utilizing more than one assessment method for response inhibition.

Beyond these potential methodological limitations, differences observed between working memory capacity and response inhibition may have important theoretical considerations. The current study’s hypotheses were formulated on the grounds that approach oriented motivation is more automatic in nature and subsequently must be inhibited by an individual in line with dual-processing theories. While we theorized that approach tendencies are more automatic in nature relative to avoidance inclinations, our self-report questionnaire assessment methods may not have allowed for fully capturing the automaticity of approach. Answering these items inherently requires a level of deliberative reflection. Consistent with this idea, a meta-analysis of the craving literature demonstrated that implicit measures of craving (i.e., attentional bias) are weakly associated with subjective craving for alcohol (Field, Munafò, & Franken, 2009). Subsequently, it is possible that the daily assessment did not capture more automatic associations an individual possessed in the moment. Therefore, one possibility for our findings with working memory capacity and inhibition is that these constructs may have differential effects at varying levels of processing as it relates to the decision to drink. It could be that working memory capacity matters more in deliberative processing that occurs prior to a drinking episode, as it reflects the ability to maintain and manipulate goal-relevant information. Conversely, inhibitory control is clearly defined as the ability to inhibit an automatic, prepotent
response. We may have seen that inhibition related to decreased likelihood of a drinking episode if we could more readily capture motivations at the automatic level.

This idea is consistent with the notion that conflict can occur at multiple levels of processing (automatic/automatic, automatic/controlled, controlled/controlled) and all levels ultimately exert influence on behavior as discussed by Stritzke et al. (2007). Working memory capacity, response inhibition, and other executive and affective processes may have differentiating roles in resolving conflicts at these various levels. The current study raises this possibility in regard to working memory capacity and response inhibition specifically. Future research would do well to delineate factors that relate to how these conflicts are resolved at different levels of processing and their subsequent impact on drinking behavior.

Lastly, underlying differences in the stability of working memory capacity and response inhibition may contribute to their respective roles in decision making. Inhibition may be more susceptible to state-dependent factors and this results in important differences between person and within person processes. Conversely, working memory capacity is more static in nature such that between person and within person processes look similar. This is consistent with research highlighting the importance of same day fluctuations in response inhibition as it relates to drinking (Jones et al., 2018). More research is needed with repeat assessment of working memory capacity. However, the high test-retest reliability of working memory capacity tasks and its association with general intelligence (Conway et al., 2005; Conway et al., 2003) provides preliminary support to the idea that we can expect it to have higher stability than inhibition.

**Implications**

This study offers preliminary evidence that working memory capacity is an important individual difference variable that allows individuals to inhibit approach-oriented tendencies
when they have the desire to so (i.e., conditions of conflicting motivational states). We saw this effect for the occurrence of drinking, but failed to demonstrate it when examining the occurrence of heavy drinking over the 14-day monitoring period. From a theoretical standpoint, this study raises the possibility that working memory capacity has an important impact on the initiation of drinking, but may not exert significant influence on the amount of drinking that occurs once drinking is initiated. Our response inhibition results suggests that these cognitive constructs may have differing influences as it relates to drinking behavior, and underscore the complex nature of how decisions may be impacted at various levels of processing in the context of conflicting motivations (i.e., automatic/automatic, automatic/controlled, controlled/controlled). Additionally, our study tentatively suggests that the effect of these cognitive constructs may differ when considering between person and within person processes. One direction for future research is to explore how intraindividual differences in working memory performance and response inhibition are related to drinking outcomes. While research suggests that working memory capacity has high stability (Conway et al., 2003; Conway et al., 2005), these studies were conducted in optimal, laboratory settings. Therefore, in daily life working memory capacity may be more susceptible to factors that deplete it. Repeat, in-vivo assessment of working memory capacity as it relates to drinking behavior could greatly further this line of research and may better explain determinants of heavy drinking (e.g., individuals may drink more after experiencing depletion of working memory capacity). Further, response inhibition is also susceptible to depletion (e.g., Jones et al., 2018). As such, studying both within person fluctuations in working memory capacity and response inhibition would greatly improve our understanding of their relationship to drinking behavior. Given that repeat mobile cognitive assessments are gaining more attention in
clinical practice and research (Moore, Swendsen, & Depp, 2017), this is an especially promising area for future studies.

This study highlights important methodological implications pertaining to the use of behavioral tasks to probe cognitive processes. Our selection of working memory capacity tasks was based off of extensive psychometric validation of these tasks and subsequent recommendations for best practices (Conway et al., 2005; Redick et al., 2012). However, the use of the Flanker task may not be the most reliable task for inhibition based on prior research (i.e., Tiego et al., 2018). Similar to the guidelines for use of working memory capacity tasks, assessment of inhibition may best be accomplished by utilizing more than one task in order to parse out task specific processes. Additionally, along with repeat assessment, future research should explore timing of assessments to best capture potential fluctuations in cognitive constructs and establish a more proximal relationship to drinking events.

From a clinical standpoint, there has been an interest in working memory training and cognitive training more broadly as an intervention method to utilize in alcohol use disorder. While these trainings demonstrate that they improve working memory functioning, their influence on drinking behavior has been met with mixed results (Khemiri, Brynte, Stunkel, Klingberg, & Jayaram-Lindström, 2019). Findings from the current study suggest that working memory capacity does have a relationship to drinking behavior, however this relationship differs as a function of motivation to use and not use alcohol. Previous studies examining the utility of working memory training may be limited in that they do not account for differences in motivational factors. The central premise of the current study purports that both the ability to inhibit as well as the motivation to do so are required to inhibition approach tendencies toward alcohol. Future studies examining working memory training may do well to incorporate
assessment of both approach and avoidance motivation as well as include a motivation component in their intervention. For example, motivational interviewing could be a feasible intervention method to integrate into these training sessions.

Limitations and Conclusion

To our knowledge, the current study was the first to examine how baseline working memory capacity interacted with within person processes (i.e., daily reports of motivational states), as previous research that includes assessment of working memory capacity relies on cross-sectional, between person analytic techniques. Further, previous research with working memory capacity and drinking outcomes has been conducted on adolescent, college and social drinker samples, and the current study extends these findings by using a heterogenous, clinical sample.

Although the focus of the study was working memory capacity, the current study was limited in that we did not utilize more than one behavioral task of response inhibition. Given the discussed assessment difficulties with response inhibition discussed above, this may limit the reliability of our findings for response inhibition. Although a strength of this study was the daily assessment of drinking and motivation, approach and avoidance may be subject to fluctuations throughout the course the day leading up to a drinking event. Therefore, our study is limited in that we cannot draw strong conclusions about the proximal effects of these processes.

Importantly, other characteristics of this sample may result in reduced generalizability. First, this study recruited a clinical sample of individuals who were not actively seeking treatment, and these relationships may differ in a nonclinical sample as well as those who are actively in treatment or have recently finished treatment. For example, individuals who have recently finished treatment likely have higher avoidance than a nonclinical sample. Importantly,
avoidance may have a stronger relationship with drinking behavior in samples of individuals actively trying to change their drinking. Further, given that approximately one-third of the sample were college students, this may reduce generalizability to older more chronic problem drinkers. We attempted to address this by controlling for age in all analyses. Lastly, this study may have been under-powered to detect some effects due to a premature end to recruitment and subsequent smaller sample than we intended.

Despite these limitations, the current study offers insight into how cognitive factors interact with motivation to influence drinking behavior. Specifically, for those with lower working memory capacity, ambivalence was associated with increased likelihood of engaging in drinking. This increased likelihood was not seen among individuals with higher working memory capacity. Surprisingly, higher response inhibition related to increase odds of drinking when experiencing ambivalence, which point to potential key differences between working memory capacity and response inhibition as cognitive processes, as well as issues with reliably assessing cognitive constructs with laboratory tasks. These findings also call for careful consideration of levels of processing and corresponding conflicts that occur within these levels, as well as consideration of important methodological differences that may impact results when attempting to better understand decisional processes.
REFERENCES


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APPENDIX A: RECRUITMENT MATERIALS

Concerned about your drinking?

If so, you may be eligible for a paid research opportunity at the University of South Florida exploring motivation and alcohol use.

Compensation of $50 for completing a single in-person session at USF and a brief phone survey for 14 days.

If interested, please call (813) 974-0839 and refer to the “motivation and alcohol” study to determine if you qualify and to schedule an appointment.

(USF IRB Pro#00040914: Principle Investigator Emily Noyes)

Figure 1A. Example Recruitment Flyer for Study
June 24, 2019

Emily Noyes
Psychology
4202 E Fowler Ave
Tampa, FL 33647

RE: Expedited Approval for Initial Review
IRB#: Pro00040914
Title: Cognition and Motivational States

Study Approval Period: 6/21/2019

Dear Ms. Noyes:

On 6/21/2019, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents contained within, including those outlined below. Please note this study is approved under the 2018 version of 45 CFR 46 and you will be asked to confirm ongoing research annually in place of a full Continuing Review. Amendments and Reportable Events must still be submitted per USF HRPP policy.

Approved Item(s):
Protocol Document(s):
  Protocol, Version #1, 5-29-19

Consent/Assent Document(s)*:
*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent documents are valid until the consent document is amended and approved. Verbal and Phone-screening forms are not stamped.

It was the determination of the IRB that your study qualified for expedited review which includes activities that: (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45 CFR 46.110. The research proposed in this study is categorized under the following expedited review category:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your study qualifies for a waiver of the requirements for the documentation of informed consent as outlined in the federal regulations at 45 CFR 46.117(c), which states that an IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects if it finds any of the following: (1) That the only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality. Each subject (or legally authorized representative) will be asked whether the subject wants documentation linking the subject with the research, and the subject's wishes will govern; (2) That the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context; or (3) if the subjects or legally authorized representatives are members of a distinct cultural group or community in which signing forms is not the norm provided that the research presents no more than minimal risk of harm to subjects and provided there is an appropriate alternative mechanism for documenting that informed consent was obtained. (Verbal and phone-screening forms).

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB via an Amendment for review and approval. Additionally, all unanticipated problems must be reported to the USF IRB within five (5) business days.
We appreciate your dedication to the ethical conduct of human subjects research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

[Signature]

Melissa Sloan, PhD, Vice Chairperson USF Institutional Review Board