May 2023

Examining the Role of Executive Functions on the Intention-Behavior Gap of Alcohol Harm Reduction Strategy Use

Becky K. Gius
University of South Florida

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by

Becky K. Gius

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Psychology
College of Arts and Sciences
University of South Florida

Major Professor: Robert Schlauch, Ph.D.
Diana Rancourt, Ph.D.
Jack Darkes, Ph.D.
Eun Sook Kim, Ph.D.
Judith Bryant, Ph.D.

Date of Approval:
August 20, 2022

Keywords: Alcohol, Harm Reduction, Executive Functions

DEDICATION

I stand on the shoulders of the women who came before me. This dissertation is dedicated to Mom and Grandma, without whom none of this would be possible.

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ABSTRACT

Alcohol harm reduction strategies are health behaviors that aim to minimize the likelihood or severity of consequences associated with alcohol use. Despite the demonstrated usefulness of harm reduction strategies, there is variability in who and when the strategies are used, leading to the question "if they work, why not use them all the time?" One potential explanation is a discrepancy between the intention to drink safely and actually drinking safely, termed the intention-behavior gap. It is unclear to what extent college drinkers plan on engaging in safe drinking behaviors but fail to follow through. It is plausible some drinkers have the intention to drink safely but lack the ability to effectively initiate and execute the harm reduction behaviors. As such, executive functions (EF: cognitive abilities associated with goal-directed behavior) may be one mechanism that helps explain the gap between safe drinking intentions and behavior. Using ecological momentary assessment, the current study explored the extent to which an intention-behavior gap in harm reduction strategy use exists among college student drinkers (n=77), and investigated how potential individual differences in EF (i.e., working memory, set-shifting, and inhibition) were associated with translating intentions of drinking safely into action. Daily monitoring assessments contained brief measures of intention to use harm reduction strategies, actual strategy use, and alcohol-related behaviors, and were assessed daily for twenty-one days. Multilevel model analyses revealed that although intention to use strategies predicted actual strategy use, measures of EF did not significantly moderate the relationship. Efforts to

increase intentions to use alcohol harm reduction strategies should be included in alcohol use prevention and intervention programs for all drinkers, regardless of differences in EF ability.

CHAPTER ONE: INTRODUCTION

Alcohol consumption is prevalent among college students, with recent studies estimating 60% of college students report having consumed alcohol in the past month (Schulenberg et al., 2019). Many of these students report experiencing adverse consequences due to their alcohol use ranging in severity from hangovers, academic struggles, and interpersonal conflict to physical injury, unplanned sexual activity, and accidental overdose (Patrick et al., 2020). However, not every drinking episode is accompanied by negative consequences, even at higher drinking intensity (i.e., binge episodes). In fact, quantity of drinks has been found to be only modestly correlated with negative consequences (Nixon, 2013; Park & Grant, 2005; Sadava, 1985), suggesting that at least some students are able to avoid or lower the risk of experiencing consequences while still drinking and enjoying the rewarding aspects of alcohol use. One method to lower the risk of alcohol-related consequences is to deliberately drink in a safer manner by using alcohol harm reduction strategies (Pearson, 2013; Prince et al., 2013). Despite the demonstrated usefulness of harm reduction strategies, there is variability in who and when the strategies are used (Dekker et al., 2020). One potential explanation for the variability is a discrepancy between the *intention* to drink safely and *actually* drinking safely, termed the intention-behavior gap. It is unclear to what extent college drinkers plan on engaging in safe drinking behaviors but fail to follow through. The current study sought to examine the intention-behavior gap of harm reduction strategy use and investigated potential individual difference factors in cognitive abilities underlying goal-directed behavior (i.e., executive functions) that may be associated with translating intentions of drinking safely into action.

Drinking Safely

College students continue to drink at high rates despite potential negative consequences in part due to the rewarding aspects of drinking, especially since positive consequences of alcohol use tend to occur *more* frequently and consistently than negative consequences (e.g., improved self-esteem, heightened sociability, feeling relaxed, forgetting school problems; Park, 2004; Park & Grant, 2005). As such, many university alcohol prevention and treatment intervention efforts have shifted the focus from *abstaining* from alcohol to *reducing* alcohol consumption and avoiding consequences (Larimer & Cronce, 2007; Marlatt et al., 2011). This harm reduction approach attempts to curtail rates of alcohol-related consequences by encouraging students to deliberately drink in a safer manner by adjusting their drinking behavior, thereby minimizing the likelihood of experiencing alcohol-related consequences.

Many college drinking prevention programs encourage the use of alcohol harm reduction strategies (sometimes called Protective Behavioral Strategies), which are health behaviors that aim to minimize the likelihood or severity of consequences associated with alcohol use. Harm reduction strategies are generally divided into three classes based on the desired outcome of the strategy; 1) *limiting/stopping drinking* (e.g., leaving the bar/party at a predetermined time, going out with a limited amount of cash to be spent on alcohol, consuming food and non-alcoholic beverages while drinking), 2) *manner of drinking* (e.g., pacing the number of drinks consumed throughout the night, avoiding shots or drinking games, avoiding mixing different types of alcohol such as beer and liquor), and 3) *serious harm reduction* (e.g., using a designated driver, using a "buddy system" by choosing a friend or friend group to stay with during the outing, not leaving the drink unattended) (Pearson, 2013; Prince et al., 2013). Deliberately drinking safer by using such strategies has shown to be associated with fewer negative consequences even after controlling for quantity of drinks consumed (Araas & Adams, 2008; Madden & Clapp, 2019; Pearson et al., 2012).

Health Behavior Change Frameworks: The Intention-Behavior Gap

The discrepancy between intention to drink safely and actually drinking safely is termed the intention-behavior gap, and several health behavior change frameworks have been developed to identify predictors of the gap for a variety of health behaviors. One of the earliest and most prominent health behavior change frameworks is the Theory of Planned Behavior (TPB: Ajzen, 1991) which focuses on the factors that influence *forming an intention.* Behavioral intentions are an individual's perceived likelihood of engaging in a given behavior and have been found to be one of the strongest proximal determinants of behavior (Conner, 2020; Rich et al., 2015). Although many health behaviors are habitual and prompted automatically by situational cues (e.g., wearing seatbelts) (Bargh, 2006; Wood & Neal, 2007), other health behaviors that are not yet automatized or that involve some level of effort (e.g., alcohol harm reduction strategies) require intentions to be formed for the behavior to occur (Baumeister & Bargh, 2014; Madden et al., 1992). According to the TPB, predictors of *forming an intention* include subjective norms (i.e., beliefs about peers' actual behavior, beliefs about the extent to which peers approve of the behavior), attitudes toward the behavior (e.g., expectancies, own beliefs about the behavior), self-efficacy, and perceived behavioral control (Ajzen, 1991).

Both theory (e.g., Theory of Planned Behavior: Ajzen, 1991; Temporal Self-Regulation Theory: Hall & Fong, 2007) and empirical evidence suggest that intentions play a critical role in obtaining long-term goals (Ajzen, 1991; Conner, 2020). For instance, a meta-analysis of meta-analyses including a total of over 400 prospective studies found a large sample weighted correlation (r=.53) between intentions and time-lagged measures of behavior for a range of health behaviors including dieting, physical exercise, medication compliance, and substance use (Sheeran, 2002). Further, intention has been found to be predictive of subsequent behavior above and beyond personality factors (Poropat, 2009) and perception of risk (McEachan et al., 2011; Sheeran et al., 2014). Especially in terms of changing health risk behaviors, forming an intention to change an existing habitual behavior or initiate a new healthier behavior is thought to be necessary for the health behavior to occur (Ajzen, 1991). Together, this research provides evidence that intentions meaningfully predict follow through.

Despite the robust support for intentions predicting behavior, the strength of the association between intention and behavior across a range of health behaviors is moderate at best, resulting in considerable unexplained variance (Fife-Schaw et al., 2007). For instance, a meta-analysis examining studies that experimentally manipulated intention found that change in intentions resulted in only a small-to-medium effect size for change in behavior ($d = .36$; Webb & Sheeran, 2006). More recent theory based on the TPB suggests that some of this variance can be accounted for by mechanisms of the intention-behavior gap (i.e., mediators) and factors that influence the likelihood of translating intention into action (i.e., moderators).

Moderators of the Intention-Behavior Gap. The Temporal Self-Regulation Theory (TST; Hall & Fong, 2007, 2013, 2015) expanded on the TPB to include executive functioning and behavioral propensity as moderators on the intention-behavior gap. The addition of executive functioning in the model was based on growing evidence that individual differences in executive control processes act as moderators on the intention-behavior gap for a wide range of health behaviors such as dieting (Allan et al., 2011; Hall et al., 2008), smoking (Berkman et al., 2011; Brega et al., 2008; Nestor et al., 2011), physical exercise (McAuley et al., 2011; Pfeffer & Strobach, 2017), and medication adherence (Panos et al., 2014; Stilley et al., 2010). The TST posits that an individual's ability to translate intention to engage in the health behavior to enacting the health behavior is in part related to their executive control ability. Specifically, the intention-behavior gap of health behavior is hypothesized to be smaller among those with stronger working memory, mental flexibility, and inhibition abilities because of the role the cognitive processes play in supporting goal formation and attainment (Hall & Fong, 2015).

The second moderator identified by the TST is behavioral propensity, which reflects a state-based motivational inclination that encompasses influences from affective state, drive state (i.e., appetitive and avoidant motivation; for review see Elliot, 2008), and social and environmental contingencies. The strongest evidence for the impact of the behavioral propensity moderators on the intention-behavior gap comes from evidence that integrates affect and drive state. For example, consistent with Urgency Theory (Cyders & Smith, 2008), evidence suggests that negative urgency (i.e., a tendency for impulsive behavior in response to negative affect) is associated with greater alcohol consumption and more alcohol-related consequences (Smith & Cyders, 2016), and likely reflects an interaction between momentary affect and drive state. Applying this to the intention-behavior gap, it is hypothesized that individuals with negative urgency would be less likely to follow through with intentions, especially when the behavior is inconsistent with social and environmental contingencies to engage in the behavior.

Mediators of the Intention-Behavior Gap. Other work based on the TPB has yielded support for two mediators that help explain the intention-behavior gap: habit strength and planning. In one study examining binge drinking habits and alcohol use among college students, habit strength (as assessed with a self-report questionnaire in which individuals rate statements such as "Binge drinking is something: I do frequently… that's typically 'me'… I do automatically") was found to significantly predict binge drinking at 1 month follow up (Norman, 2011). However, habit strength only explained an additional 6% variance above and beyond intentions to drink, and the interaction between intention to drink and habit strength was nonsignificant. These findings suggest that habit strength for drinking may play a less influential role on the intention-behavior gap of alcohol use among non-alcohol dependent college students relative to other factors. Namely, planning holds greater support as a mediator of the intention-behavior gap. Having a specific plan of enacting a behavior significantly increases the likelihood of actually enacting the behavior (Hall et al., 2008). Support for planning comes from a meta-analysis on TPB studies reporting a medium to strong effect size for forming an "implementation intention" (i.e., plan) on future behavior (Sheeran, 2002). This is consistent with the Health Action Process Approach model which posits that planning completely mediates the effect of intention on behavior and that the more specific the plan, the smaller the intention-behavior gap (Sutton, 2008). For example, if a college student intends to use a designated driver before going out to a party, their plan may include calling friends until someone agrees to drive, not driving themselves to the party, and downloading a ride share app (e.g., Uber). By planning these steps, they are less likely to drink and drive since they have arranged multiple alternatives to driving under the influence. Notably, executive functioning (proposed moderator) supports the activity of planning (proposed mediator) such that planning inherently relies on executive functions for the mental manipulation of information and execution of goal-directed behavior, suggesting executive functions may be particularly important in explaining the intention-behavior gap. Simply put, individual differences in EF may facilitate or impede planning.

Alcohol Use and the Intention-Behavior Gap

A significant relationship between intention to drink and subsequent drinking has been extensively and consistently demonstrated, indicating that those who plan to drink usually do

(Armitage et al., 2002; Elliott & Ainsworth, 2012; Grazioli et al., 2015; Norman, 2011; Norman et al., 2007). In this circumstance, given the opportunity to drink, there would be no intention-behavior gap. Rather, the intention-behavior gap occurs when the goal is to regulate drinking or abstain from drinking altogether. In fact, much of the literature on alcohol use and dependence is linked to theory and evidence on the well-established finding that drinking is difficult to regulate for many people despite motivation or intention to do so (e.g., Bechara, 2005; Koob, 2011; Ludwig, 1987; Marlatt, 1978).

Although no studies to date have examined intention to use alcohol harm reduction strategies and actual use of the strategies, one study has examined the interaction of *intention to drink* and use of harm reduction strategies in the prediction of alcohol consumption. Grazioli, Dillworth, et al. (2015) found that among US and Swedish high school adolescents, drinking intentions moderated the negative relationship between harm reduction strategy use and number of drinks per week such that the association was stronger among those with *high* drinking intentions. The authors hypothesized that this may be because individuals with strong intentions to drink are afforded the opportunity to plan to drink safely since they plan on drinking. Hence, a reason to initiate preparatory behavior must be perceived for the preparatory behavior to occur. For example, people do not tend to plan to use a designated driver if they do not plan on drinking. Similarly, with regard to other health risk behaviors, one study found that intentions to engage in safer sex behaviors (i.e., condom use) and actual safer sex behavior was mediated by preparatory behaviors such as purchasing condoms and talking with their partner about condom use (Bryan et al., 2002), highlighting the importance of intention and planning in engaging in health behaviors more broadly.

The role of preparatory behavior is further described by the Model of Unplanned Drinking Behavior (Pearson & Henson, 2013) which posits that unplanned drinking (i.e., drinking episodes preceded by reports of intention to abstain) is expected to be associated with increased likelihood of experiencing alcohol-related consequences because of the lack of "forethought" or opportunity for safety planning prior to the drinking event. This is consistent with evidence on other health behaviors that require a certain level of preplanning and impulse control such as condom use (Bryan et al., 2002), adherence to treatment for chronic illness (Rich et al., 2015), eating breakfast (Wong & Mullan, 2009), and physical exercise (Hall & Fong, 2015). Although cross-sectional (Pearson & Henson, 2013) and event-level (Fairlie et al., 2019) evidence support the hypothesis that unplanned drinking days may be associated with greater consequences, a recent 28-day ecological momentary assessment (EMA) study found that compared to planned drinking events, unplanned drinking events were associated with *lower* quantity of drinks consumed, *fewer* alcohol-related consequences, and *lower* subjective evaluation of the drinking event (i.e., how "worth it" the drinking event was) (Lauher et al., 2020). One potential explanation for the discrepant findings is that although an individual's plan to drink may change, some safe drinking strategies may be utilized even when the decision to drink occurs soon before onset of alcohol consumption, thereby still minimizing consequences. While many safe drinking strategies require planning and "forethought" prior to onset of drinking (e.g., eating before alcohol consumption), others may be implemented immediately before or during the drinking episode (e.g., alternating water and alcoholic beverages, avoiding shots or drinking games). It may be that those who successfully regulate their alcohol use and minimize their risk of consequences during unplanned drinking events are better able to flexibly adapt to new situations and changing demands.

Translating Intention into Action

Preparatory behavior, including harm reduction strategy use, requires planning, self-monitoring, cognitive flexibility, and inhibitory control among other cognitive functions that aid in translating intention into action in complex social settings (Luria, 1973; Miyake et al., 2000; Nigg, 2017). It is plausible some drinkers have the intention to drink safely but lack the ability to effectively initiate and execute the harm reduction behaviors. As such, executive functions (i.e., cognitive abilities associated with goal-directed behavior) may be one mechanism that helps explain the gap between safe drinking intentions and behavior. Executive function (EF) is an umbrella term for higher-order cognitive processes involved in orchestrating complex goal-directed behavior (Funahashi, 2001; Lezak et al., 2004). Although the construct of "executive functions" lacks a single agreed upon operationalized definition, three processes have consistently demonstrated particular relevance to planning and executing goal-directed behavior; working memory, set-shifting, and inhibition (for reviews see Miyake & Friedman, 2012; Miyake et al., 2000).

Working memory captures the process of temporarily holding goal relevant information in mind for the purpose of monitoring, evaluating, and updating goal-relevant information (Miyake et al., 2000). Working memory may support the implementation of health behavior strategy use by suppressing interference from goal-inconsistent distractors within the environment, which then serves to direct attention to planning and execution of desirable health behavior (Nigg, 2000; Palfai, 2004). Previous work has found that the intention-behavior gap for a range of health behaviors (e.g., sexual, exercise, and dieting behavior) is smaller among individuals with greater working memory capacity, suggesting these individuals may be better equipped to translate health behavior intentions into action (e.g., Allom & Mullan, 2014; Hall & Fong, 2015;

Hall et al., 2008; Pfeffer & Strobach, 2017; Tahaney et al., 2019). For example, one study examining risky sex harm reduction strategies found that working memory moderated the association between condom use intention and behavior (Tahaney et al., 2019). With regard to alcohol use, reduced working memory capacity has been theorized to be associated with risky drinking behavior via attention deficits specific to information related to drinking consequences (Lauher et al., 2020; Tahaney & Palfai, 2018). Together, the evidence suggests that stronger working memory may serve as a protective factor and may predict follow through with effortful health behaviors. Although not yet tested using alcohol harm reduction strategies, individuals with higher working memory capacity may be more successful in translating intention to drink safely into action through the ability to direct attention and keep alcohol-related goals in mind during planning and decision-making.

Set-shifting, a process important for planning, reflects cognitive flexibility required for purposefully allocating attention to goal-relevant information and manipulating that information to facilitate goal-directed behavior (Miyake et al., 2000). Previous ecological momentary assessment research has found that college drinkers with higher set-shifting abilities demonstrated lower likelihood of drinking on a given night than those with poorer set-shifting abilities, suggesting set-shifting may serve as a protective factor against frequency of alcohol use (Dvorak & Simons, 2014). Although the authors of the study did not hypothesize any specific mechanism driving this relationship, it may be that individuals who have stronger set-shifting abilities may be better able to flexibly alter their behavior in response to changing environmental contingencies so that their drinking behavior aligns with their safe drinking goals. For example, individuals with stronger set-shifting abilities may be better able to 1) plan ahead to facilitate harm reduction strategy use, 2) plan ahead to avoid temptation to engage in risky drinking behavior, and/or 3) effectively alter their behavior in response to increasing or unexpected demands to engage in risky drinking behavior. This hypothesis is consistent with evidence supporting greater engagement in various health behaviors among individuals with higher set-shifting abilities (snacking and eating healthier food options: Allan et al., 2011; disordered eating behaviors: Roberts et al., 2007; breakfast consumption: Wong & Mullan, 2009).

Lastly, *inhibition* of prepotent responses is required for suppressing and altering dominant or habitual responses (Allan et al., 2016; Miyake et al., 2000) and has been found to moderate the intention-behavior gap among numerous health behaviors (abstaining from smoking: Berkman et al., 2011; dieting: Hofmann et al., 2014; medication adherence: Panos et al., 2014; physical activity: Rhodes & Yao, 2015). The Temporal Self-Regulation Theory (TST; Hall & Fong, 2007, 2013, 2015) posits that although other EF abilities are involved in enacting health behaviors, inhibition in particular is strongly related to the intention-behavior gap due to the importance of altering impulsive responses to situational cues. Consistent with this, reduced inhibitory control has been identified as a vulnerability factor for adolescents and young adults for development of problematic alcohol use and later alcohol dependence (López-Caneda et al., 2014; Norman et al., 2011; Wetherill et al., 2013). Among college students, inhibition has been linked to binge drinking such that those with weaker inhibitory control are at greater risk of drinking at higher intensity (i.e., more drinks per occasion) (Henges & Marczinski, 2012; Lannoy et al., 2019). Individual differences in inhibitory control has also been found to moderate the association between binge drinking intentions and behavior among college students (Mullan et al., 2011). Given that safe drinking behaviors often require resisting desirable urges by inhibiting a behavior (e.g., not engaging in a drinking game), stronger inhibitory control should theoretically be associated with greater use of harm reduction strategies. Although untested, it may be that those who are better able to inhibit goal-inconsistent behavior (e.g., risky drinking) may demonstrate greater propensity of selecting and implementing responses that are more consistent with their safe drinking intentions (e.g., safer drinking strategies).

In sum, the initiation and maintenance of effortful health behaviors, including safe drinking behavior, rely on EF especially when the behavior is undesirable or costly in the short-term but beneficial in the long-term (Allan et al., 2016; Williams et al., 2017). Specific components of EF may be differentially associated with harm reduction strategy use; working memory and set-shifting may be especially important in planning and following through with alcohol harm reduction strategies, and individuals with greater working memory capacity and set-shifting abilities may be more successful in implementing strategies that require preplanning and have a focus on altering typical the manner of drinking (e.g., not mixing types of alcohol). Inhibition may be important for resisting temptations that are inconsistent with safe drinking goals, and those with stronger inhibitory control may be more likely to follow through with strategies that require withholding responses despite desire to engage in the behavior, such as stopping or limiting drinking (e.g., not exceeding a predetermined number of drinks). A better understanding of cognitive processes related to successful harm reduction use would help elucidate what, if any, individual difference characteristics are linked to difficulty or inability to implement harm reduction strategies despite intention to do so.

Assessing Ability to Execute Harm Reduction Strategies

Other constructs related to EF have been examined regarding the prediction of alcohol harm reduction strategy use. Specifically, one study assessing “good self-control” (as assessed by self-reported trait-based planfulness) and “poor regulation” (as assessed by self-reported trait-based impulsivity) as orthogonal constructs found that those low on trait planfulness were more likely to underutilize harm reduction strategies and report experiencing more alcohol-related consequences (Pearson, Kite, et al., 2013), while trait impulsivity was unrelated to harm reduction strategy use. In other words, those who rated themselves as more impulsive did not report using fewer harm reduction strategies as would be expected. Trait impulsivity was however significantly associated with greater alcohol consumption and negative consequences. The study was limited by the use of self-report measures of trait-based planfulness and impulsivity, and use of behavioral measures (i.e., computerized performance tasks) of these factors may help clarify the role of self-control mechanisms in the relationship between harm reduction strategy use and the experience of alcohol-related consequences. Specifically, self-report measures of self-control are designed to assess typical, trait-like self-regulatory tendencies, while behavioral measures are designed to assess maximum performance ability (Saunders et al., 2018) thus representing related yet different underlying processes. As such, it is unsurprising that poor convergent validity has been demonstrated between self-report and behavioral measures of self-control. For example, one meta-analysis found small statistically significant correlations between self-report and behavioral measures of self-control, but noted the effect size was small in magnitude ($r = .10$) (Duckworth & Kern, 2011). Another more recent Bayesian meta-analytic study found similar results (Saunders et al., 2018), and together findings indicate that conclusions drawn from studies using one type of measure (e.g., self-report) cannot be generalized to the findings of studies using the other (e.g., behavioral measures).

Since college alcohol use interventions are designed to change drinking behavior, it would important to consider an individual's *ability* to implement changes. This is especially relevant when encouraging the use of harm reduction strategies which requires effortful and motivated goal-directed behavior in specific situations, an ability not readily captured by trait-based self-report measures that capture typical behavior more broadly. As expected, trait-based self-report measures of self-control have shown to be associated with greater harm reduction strategy use (Pearson, Kite, et al., 2013), but what remains unknown is whether individual differences in self-control related cognitive abilities (i.e., EF) meaningfully predict which individuals intend to use strategies but fail, and if these individuals are particularly susceptible to alcohol-related consequences. For example, deliberately drinking safely while maximizing rewards (e.g., social connectedness) and minimizing consequences may prove challenging especially when alcohol consumption is closely tied to desirable experiences such as positive peer interactions. As such, college drinkers who use alcohol to facilitate social connectedness may struggle to follow through with harm reduction strategies that impose on peer interactions in drinking settings, such as avoiding drinking games or leaving the party at a predetermined time. It is under these circumstances, when the rewarding aspects of alcohol are pronounced, that following through with safe drinking strategies may be particularly reliant on cognitive processes responsible for flexibly adapting behavior to experience rewards while minimizing consequences.

Influence of Intoxication on Executive Functions

Although the current study seeks to examine how individual differences in EF influence the intention-behavior gap of alcohol harm reduction strategy use, it is important to note that there are additional factors that influence follow through with goal-directed behavior while drinking. Alcohol is an intoxicant that impacts cognitive functions critical for implementing harm reduction strategies, including working memory, set-shifting, and inhibition (Spinola et al., 2017). Accordingly, following through with harm reduction strategies likely becomes more challenging as more drinks are consumed throughout the drinking event and judgement becomes increasingly impaired. Consistent with this, alcohol administration research to date suggests that there is a dose-response relationship between alcohol intoxication and performance on a range of EF tasks indicating that most higher-order cognitive processes become impaired at higher levels of intoxication (Abroms et al., 2003; Chmielewski et al., 2020; Curtin & Fairchild, 2003; Weafer & Fillmore, 2012). However, no clear pattern of findings have emerged regarding which and when specific EF constructs become impaired especially at lower levels of intoxication (Corbin et al., 2020; Dry et al., 2012; Spinola et al., 2017; Volkow et al., 2006). Considering these findings in context of the aims of the current study, following through with harm reduction strategies likely becomes more difficult as intoxication increases due to the global effects of alcohol on cognitive functions critical for goal-directed behavior. As such, it may be especially important to enact harm reduction strategies before judgement is significantly impaired, which would allow the drinker to maintain a level of intoxication that allows for goal-consistent decision making, thus minimizing alcohol-related consequences.

Summary

Taken together, it is evident that college students continue to drink at high rates despite potential negative consequences. However, not every drinking event is accompanied by negative consequences, indicating that at least some students are able to avoid or at least lower the risk of experiencing consequences while still drinking and enjoying the rewarding aspects of alcohol use. Although using alcohol harm reduction strategies mitigates the experience of alcohol-related consequences, there is variability in who and when the strategies are used (Dekker et al., 2020). One potential explanation is that drinkers may plan on using harm reduction strategies but fail to follow through (i.e., intention-behavior gap). Failure to translate intention to drink safely and actually drinking safely may be further explained by individual differences in cognitive processes associated with the ability to effectively initiate and execute goal-directed behavior. Examining the potential intention-behavior gap of harm reduction strategy use and investigating potential individual difference factors associated with translating intention to drinking safely into action is important to identify who is most likely to benefit the most from harm reduction strategy use, which has important implications for prevention and treatment interventions.

Harm Reduction Strategies in College Prevention and Intervention Programs

Findings from several college drinking intervention studies indicate that simply giving college students a list of harm reduction strategies is not very efficacious by itself, but is helpful when added to an intervention such as personalized normative feedback (Barnett et al., 2007; Larimer et al., 2007; Martens et al., 2013; Murphy et al., 2012). This may be because such interventions try to change the drinker's *intention* to regulate drinking by comparing their own drinking behavior to that of their peers, and the added component of harm reduction strategy use serves to provide suggestions on how to modify typical drinking behavior. Developing an intention to use harm reduction strategies may be especially important when drinkers are asked to initiate a new behavior or alter typical drinking behavior. As such, it is necessary to first examine whether an intention-behavior gap exists and how it might relate to alcohol-related outcomes. Second, it is important to identify the mechanisms driving the gap as doing so will be critical in understanding how the translation of *intention* to drink safely to *actually* drinking safely can be improved.

Understanding these relationships may inform prevention and intervention programs so that they are optimally effective in promoting safe drinking behavior. From a public health standpoint, strategies that work for the *majority* of students could be incorporated in existing college harm reduction prevention programs. Additionally, from a targeted intervention standpoint, students who are required to undergo remediation due to drinking-related school infractions may benefit from harm reduction strategies better fit for negating inhibition deficits or other cognitive weaknesses that place them at greater vulnerability for risky drinking. As such, characterizing individual differences associated with harm reduction strategy implementation is necessary for the identification of risk factors that could be relevant when developing interventions targeting escalation of troublesome drinking patterns (e.g., remediation and similar interventions), as well as the identification of modifiable factors that could serve as targets of intervention efforts. For example, inhibitory control training has been found to decrease alcohol consumption (Bowley et al., 2013; Di Lemma & Field, 2017) as well as alter other health behavior such as decreasing snacking (Forman et al., 2016) and improving avoidance of consuming high calorie sweets (Houben & Jansen, 2011). For those with poorer set-shifting and working memory abilities, harm reduction strategies that place less of an emphasis on in-the-moment decisions between goal consistent and goal inconsistent choices may be more beneficial than those that require mental flexibility and switching between multiple goals (e.g., alternating alcoholic and nonalcoholic beverages). Ultimately, understanding potential factors influencing the intention-behavior gap of safe drinking in the real-world context will inform both prevention and remediation interventions; identification of strategies that are most protective for most students can be emphasized in class-wide or other group-based alcohol use prevention programs, and identification of strategies that work best for individuals cognitive vulnerabilities that can be implemented in remediation and other individualized drinking interventions.

Current Study

Using ecological momentary assessment (EMA; Shiffman, 2009; Shiffman et al., 2008), the current study explored the extent to which an intention-behavior gap in harm reduction strategy use exists among college students, and investigated potential individual difference factors associated with translating intentions of drinking safely into action.

Aim 1: Demonstrate the potential intention-behavior gap by investigating intention to use harm reduction strategies in the prediction of actual strategy use.

Hypothesis 1: Intention to use harm reduction strategies, as assessed by the total number of strategies planned to be used earlier in the day, would significantly and positively predict strategy use later in the day. However, consistent with previous research finding an intention-behavior gap across a range of health behaviors, the strength of the association was expected to be modest.

Aim 2: Examine the moderating role of executive functioning abilities on the relationship between intention to use harm reduction strategies and actual strategy use.

Hypothesis 2a: Based on the Temporal Self-Regulation Theory (TST; Hall and Fong, 2007, 2013, 2015), the positive association between the number of harm reduction strategies intended to be used and the number of actual strategies used was expected to be attenuated among those with poorer working memory capacity, set-shifting abilities, and inhibitory control compared to those with greater working memory capacity, set-shifting abilities, and inhibitory control.

Hypothesis 2b: Specific components of EF would be differentially associated with groupings of harm reduction strategy use; greater working memory capacity and set-shifting abilities were expected to be associated with greater use of strategies that require or rely more heavily on *preplanning* prior to the drinking event, while inhibitory control was expected to be associated with greater use of strategies that rely more heavily on *modifying* a behavior during the drinking event.

Aim 3 (Exploratory): Examine the relationship between intention to use harm reduction strategies and drinking behavior.

Hypothesis 3: Intention to use harm reduction strategies, as assessed by the total number of strategies planned to be used earlier in the day, would significantly and negatively predict number of drinks consumed during a drinking event.

CHAPTER TWO: METHOD

Participants

Undergraduate students (n =102) enrolled in psychology courses at the University of South Florida were recruited from a psychology research pool (SONA Systems) to participate in an online EMA survey study. Inclusion criteria were: a) report experiencing at least one alcohol-related consequence in the past 90 days as assessed by the BYAAQ (described below) (Read et al., 2006), b) report consuming at least one alcoholic beverage per week, c) have a personal smartphone with text messaging capabilities and access to the internet, d) have access to a desktop or laptop computer with real keyboard and access to the internet to complete baseline assessment, e) be English speaking, f) be an undergraduate student, and g) be at least 18 years of age. A total of 138 students completed the brief inclusion/exclusion screening survey, however, 2 participants were excluded for failing to meet the age inclusion criteria, 2 participants were excluded for failing to meet the alcohol consumption inclusion criteria, 14 participants were excluded for failing to meet the harm reduction strategy use inclusion criteria, 8 participants were excluded for failing to meet both the alcohol consumption and harm reduction strategy use criteria, and 3 participants were excluded for failing to meet the undergraduate student status criteria. Finally, 3 participants did not consent and 4 participants did not complete the baseline survey. Of the 102 participants who completed the baseline survey, 6 participants were excluded from analyses for failing to meet validity check requirements (i.e., inappropriately responding to an embedded attention check item in the baseline assessment). Additionally, 11 participants did not complete the computer tasks. Of the 85 participants who completed the computer tasks, 1 participant was excluded from analyses for having no EMA data, and 7 participants were excluded for having no outcome data (i.e., no harm reduction strategy use data due to no reported drinking days), bringing the final analyzed sample size to 77 participants. See Figure 1 for flow diagram of participant inclusion/exclusion.

Participants were 65.9% female with a mean age of 20.44 years (SD = 2.19), 43.5% were white (non-Hispanic), 29.4% were Hispanic, and 5.9% were African American. The majority of participants were of junior or senior college standing (58.9%). Most participants were employed full- (10.6%) or part-time (45.9%), although 77.6% reported an average annual income of <$10,000. Most participants were single (77.6%) and either living in campus dorms (29.4%), off campus with roommates (40.0%), or off campus with family (10.6%) (see Table 1 for summary).

Baseline Measures: Self-Report

Demographics. Demographic information including gender, age, race, ethnicity, employment status, income, education/year in school, and residential status was collected using a self-report questionnaire.

Drinking History Questionnaire (DHQ). The DHQ is a 10-item self-report measure that assesses an individual's quantity and frequency of current and past alcohol use and their subjective experiences and beliefs related to their own use. This questionnaire was used to categorize general drinking behavior of participants based on quantity and frequency.

Protective Behavioral Strategies Scale-20 (*PBSS-20).* Typical harm reduction strategy use was assessed at baseline using the PBSS-20 (Martens et al., 2005, revised by Trelor et al., 2015). Each item is rated on a 6-point Likert scale from 0 (never) to 5 (always) indicating the frequency the responded engaged in each behavior over the past 3 months. The PBSS-20 was used to characterize typical safe drinking behaviors and was used to conduct post-hoc exploratory analyses. Reliability analyses in the current study yielded good internal consistency for the total scale (α = 0.86). See Table 2 for details.

Effects of COVID-19 on Drinking Behavior. To characterize the influence of the COVID-19 pandemic on student drinking behavior, *changes* in typical drinking behavior since the start of the pandemic were assessed. Items included assessment of *changes* in drinking quantity, drinking frequency, and location of alcohol consumption since the start of the COVID-19 pandemic (see Table 4).

UPPS-P Impulsive Behavior Scale. The UPPS-P (Cyders et al., 2007; Lynam, Smith, Whiteside, & Cyders, 2006), a revision to the original UPPS (Whiteside & Lynam, 2001), is a 59-item measure assessing impulsivity across 5 subscales: Positive Urgency, Negative Urgency, Premeditation (lack of), Perseverance (lack of) and Sensation Seeking. Each item is rated on a 4-point Likert scale from 1 (strongly disagree) to 4 (strongly agree) indicating the extent to which the respondent agrees with each statement. Reliability analyses in the current study yielded excellent internal consistency for the total score (α = 0.92). The UPPS-P was used to conduct post-hoc exploratory analyses. See Table 5 for correlations between computerized tasks and self-report measures of impulsivity.

Baseline Measures: Executive Functioning Performance Tasks

N-Back (Working Memory). The N-Back (Conway et al., 2005; Kirchner, 1958) is a computerized task that assesses working memory abilities by requiring participants to maintain and continuously update of pieces of information in their mind (see Figure 2). Consistent with previous studies (Bliss & Hämäläinen, 2005; Hammers & Suhr, 2010), a serial presentation of stimuli (i.e., one of 15 possible letters) was displayed for 500 milliseconds (ms) at a fixed time interval of 2500ms. For each stimulus, participants were required to decide whether the letter presented on the screen matched the previously presented letter 2 items before ("2-back"). Participants were directed to press a designated keyboard button if the current letter matched the letter presented two items before, and withhold a response if the letter did not match the letter presented two items before. Corrective feedback was provided for correct and incorrect responses denoted by green (correct) and red (incorrect) bars appearing above the trail item immediately after the response. A training block with 25 trials was completed, followed by three test blocks with 25 test trials each (30% targets). Each block lasts approximately 1 minute 18 seconds. Total task time including instructions and practice block was approximately 6.5 minutes. Total number of errors (omission and commission) was the primary index for working memory with higher number of errors representing poorer working memory abilities. See Table 3 for descriptives of computerized tasks and Table 5 for correlations between computerized tasks and self-report measures of impulsivity.

Task Switching (Set-Shifting). The Task Switching task is a computerized task that assesses set-shifting abilities (Monsell et al., 2003; Rogers & Monsell, 1995). A serial presentation of stimuli (single letter and single number combinations; e.g., "G6") were presented in one of four quadrants of a grid (see Figure 3). Participants responded by pressing a designated keyboard button according to the following rules: 1) if the stimulus appears in either top quadrant, respond to the letter (i.e., disregard the number) by pressing "B" if the letter is a consonant or "N" if the letter is a vowel; 2) if the stimulus appears in either bottom quadrant, respond to the number (i.e., disregard the letter) by pressing "B" if the number is odd or "N" if the number is even. In other words, participants needed to keep the two rules in mind and switch between them based on the position of the stimulus on each trial. Prior to completing the task, participants were administered two training blocks. The first training block taught the participant how to complete the letter task (i.e., responding to items in the top row of the grid) and the second training block taught the participant how to complete the number task (i.e., responding to items in the bottom row of the grid). Each training block consisted of 30 items. Following the training blocks, a test block consisting of 75 trials was completed. Immediate corrective feedback was provided on incorrect responses. Total task time including instructions and practice blocks was approximately 6.5 minutes. The number of errors (incorrect responses and timed-out responses) was the primary score for set-shifting with higher number of errors representing poorer set-shifting abilities.

Go/No-Go (Inhibition). The Go/No-Go is a computerized task that assesses response inhibition (i.e., withholding a prepotent behavioral response). A serial presentation of stimuli was displayed in which the participant was to respond to all "Go" target stimuli (the letter "X") by pressing a designated keyboard button and to inhibit response to all "No-Go" distractor stimuli (the letter "K"). Each item appeared in succession in white text for 1000ms in the center of a darkened display screen. Inter-trial interval was 1200ms or when a response was provided. Consistent with previous studies (e.g., Fillmore et al., 2006; Weywadt et al., 2017), the task contained 300 trails: 240 Go trials and 60 No-Go trials, reflecting an 80/20 split between target and distractor stimuli. The total task time including instructions was approximately 7 minutes. Participants were instructed to respond as quickly and accurately as possible. As an index of inhibitory control, the number of commission errors (false alarms) on No-Go trials was the primary score for response inhibition with greater errors indicating poorer inhibitory control.

Measures - EMA

Morning EMA Survey. Substance use and harm reduction strategy use from the *previous* day were assessed each morning. Additionally, *same day* intention to drink and intention to use harm reduction strategies were also assessed. The morning assessment included the following questions;

1. How many STANDARD DRINKS of alcohol did you consume yesterday?
    a. If ≥1 standard drink consumed yesterday;
        i. What time did you have your first drink?
        ii. What time did you have your last drink?
        iii. Did you use any of the strategies listed below? (*Check all that apply of the PBSS-20 items, measure described below*)
        iv. Did you experience any alcohol-related consequences? (*Yes/No list of nine common alcohol-related consequences*).
        v. What was the location of the drinking event? (*response options included home, friend's house, bar/restaurant, club, and a fill-in-the-blank option*)
        vi. Approximate number of people (not counting yourself) at drinking venue (*response options included 0, 1, 2-3, 4-8, 9-15, more than 15*).
    b. NOTE: When participants reported 0 drinks consumed yesterday, they completed filler questions.
2. Do you plan on consuming alcohol between now and the end of today?
    a. If Yes:
        i. How much?

ii. Do you plan to use any of the following strategies? (*PBSS-20 items*)

b. If No:

i. *Participants completed filler questions*.

3. Thinking about yesterday, how difficult would it have been to get alcohol if you wanted to drink?

a. *Response options included not difficult at all, somewhat difficult, and very difficult*.

4. Which of these substances did you use yesterday?

a. *Check all that apply, response options included tobacco and cannabis*.

5. Indicate to what extent you've felt this way yesterday;

a. *Previous day affect was assessed using the PANAS (described below). Items included embarrassed, disappointed, anxious, sad, enthusiastic, happy, satisfied, and excited*.

Afternoon EMA Survey. Each afternoon, *current* intention to drink and intention to use harm reduction strategies were assessed. Substance use prior to the afternoon survey was also assessed and if any alcohol use was indicated, harm reduction strategy use was assessed. The afternoon assessment included the following questions;

1. How many STANDARD DRINKS of alcohol have you consumed today?

a. If $\geq$1 standard drink consumed today;

i. What time did you have your first drink?

ii. What time did you have your last drink?

iii. Did you use any of the strategies listed below? (*Check all that apply of the PBSS-20 items*)

iv. Did you experience any alcohol-related consequences? (*Yes/No list of nine common alcohol-related consequences*).

v. What was the location of the drinking event? (*response options included home, friend's house, bar/restaurant, club, and a fill-in-the-blank option*)

vi. Approximate number of people (not counting yourself) at drinking venue: (*response options included 0, 1, 2-3, 4-8, 9-15, more than 15*).

b. NOTE: When participants reported 0 drinks consumed today, they completed filler questions.

2. Do you plan on consuming alcohol between now and the end of today?

a. If Yes:

i. How much?

ii. Do you plan to use any of the following strategies? (*PBSS-20 items*)

b. If No:

i. Participants completed filler questions.

3. Thinking about the rest of today, how difficult would it be to get alcohol if you wanted to drink?

a. *Response options included not difficult at all, somewhat difficult, and very difficult*.

4. Which of these substances have you used today?

a. *Check all that apply, response options included tobacco and cannabis*.

5. Indicate to what extent you've felt this way today;
    a. *Current day affect was assessed using the PANAS (described below). Items included embarrassed, disappointed, anxious, sad, enthusiastic, happy, satisfied, and excited.*

PBSS-20 (Harm Reduction Strategy Use at the Daily Level). The PBSS-20 (Martens et al., 2005; Treloar et al., 2015) is a 20-item measure used to assess a range of alcohol harm reduction strategies across three broad domains; Manner of Drinking (e.g., "Avoid drinking games"), Stopping/Limiting Drinking (e.g., "Alternate alcoholic and nonalcoholic drinks"), and Serious Harm Reduction (e.g., "Know where your drink has been at all times"). Given the goal of the current study of examining behaviors that rely on the three EFs of interest (i.e., working memory, set-shifting, and inhibition), each item was grouped into one of two categories: strategies that require or rely heavily on planning prior to the drinking event (e.g., only go out with people you know and trust, determine not to exceed a set number of drinks), and strategies that rely heavily on modifying behavior during the drinking event (e.g., alternate alcoholic and nonalcoholic drinks, avoid drinking games). Some strategies require both pre-planning before drinking and modifying behavior while drinking (e.g., stop drinking at a predetermined time) and were sorted into categories based on timing of the initiation of the behavior. For example, although stopping drinking at a predetermined time requires modifying drinking behavior during the drinking event (i.e., stopping drinking), the wording of the item implies that the individual must have first specified a time that they plan on stopping drinking. The strategy would first require pre-planning (determining a time to stop drinking), thus falling into the pre-planning grouping. See Table 6 below for grouping of items.

Each item on the PBSS-20 is rated on a 6-point Likert scale from 0 (never) to 5 (always) indicating the frequency the respondent engaged in each behavior over the past 3 months. However, for the purpose of the current study, the instructions were modified to assess strategy use during the previous drinking event and intention to use strategies on planned drinking days using binary yes/no response options. Item responses for each grouping (i.e., Pre-planning and Modifying, see Table 6) were summed with higher scores representing greater strategy use. Reliability analyses in the current study yielded good internal consistency for the PBSS-20 use total scale ($\alpha = 0.85$), acceptable internal consistency for the PBSS-20 use Pre-planning subscale ($\alpha = 0.77$), and acceptable for the PBSS-20 use Modifying subscale ($\alpha = 0.73$). For items assessing intent to use PBS, reliability analyses yielded good internal consistency for the PBSS-20 intent total scale ($\alpha = 0.86$), acceptable internal consistency for the PBSS-20 intent Pre-planning subscale ($\alpha = 0.74$), and acceptable for the PBSS-20 intent Modifying subscale ($\alpha = 0.79$). See Table 6 for descriptives of daily survey variables.

Alcohol-Related Consequences. Alcohol-related consequences were assessed after each drinking event. Participants responded to nine yes/no items assessing whether they had any of the following experiences associated with the drinking event: Did you drive a car when you knew you had too much to drink? Did you have a headache (hangover) the morning after you had been drinking? Did you feel very sick to your stomach or throw up after drinking? Did you show up late for work or school because of drinking, a hangover, or an illness caused by drinking? Did you skip an evening meal because you were drinking? Did you become rude, obnoxious, or insulting after drinking? Did your drinking get you into sexual situations which you later regretted? Did you wake up the morning after a good bit of drinking and find that you could not remember a part of the evening before? Did you pass out or faint suddenly?

Positive and Negative Affect Schedule (State-Based Affect). Positive and negative affect were assessed using the brief 8-item version of the PANAS (PANAS; Watson et al., 1988). Negative affect was assessed using the following items; embarrassed, disappointed, anxious, and sad. An additional item was included in the negative affect scale to assess for self-control depletion (i.e., "emotionally or psychologically drained"). Positive affect was assessed using the following items; enthusiastic, happy, satisfied, and excited. Each item is rated on a 5-point Likert scale ranging from 1 (very slightly or not at all) to 5 (extremely) indicating the extent to which the respondent had experienced different feelings and emotions. The morning survey assessed affect from the previous day and the afternoon survey assessed affect for the current day. Reliability analyses in the current study yielded good internal consistency for the Negative Affect subscale ($\alpha = 0.83$) and yielded excellent internal consistency for the Positive Affect ($\alpha = 0.91$) subscale. The PANAS was used to statistically control for the potential influence of affect in the relationship between intent to use harm reduction strategies and study outcomes.

Procedure

Eligible participants were recruited for the study through SONA and through flyers posted around the university campus. Participants were provided a brief description of the study (i.e., "Participate in a three-week brief daily survey study on drinking") and interested participants viewed a full description of the study by accessing a SONA or Qualtrics webpage. The full description included information on the estimated time of participation, compensation (i.e., points/class credit for SONA participants, eGiftcards for flyer participants), and eligibility requirements. Participants accessed a short eligibility screening survey via Qualtrics. Interested and eligible participants provided informed consent and was given the opportunity to contact the researcher with questions. During consent procedures, participants were informed that their study information would be kept private and confidential, and that identifying information would be removed from future publication. Participants were informed that their participation was voluntary and that they may end their participation at any time without penalty.

Initial Assessment. Participants completed baseline self-report surveys assessing demographics, alcohol-related behaviors, and personality via the Qualtrics website. Instructions for completing the daily surveys via Qualtrics were provided. The instructions included a review of the EMA sampling protocol (i.e., time frame of assessments) and education on a “standard” drink using the NIAAA standard drink guideline. After completion of baseline self-report questionnaires, participants were informed that a research assistant would be in contact with them in the next 1-3 days to schedule a video conference during which they would complete a battery of behavioral measures of EF (i.e., set-shifting, working memory, and inhibition) on desktop or laptop computer with real keyboard and access to the internet. The EF measures were administered online using the open-sourced software package PsyToolkit (Stoet, 2010, 2017). Participants were encouraged to give their best effort and were given the following prompt to discourage random responding; “A certain number of incorrect responses is detectable so it is important that you try your best and take breaks in-between tasks if needed.” Given that participants completed the EF tasks remotely, it is possible that alcohol could have been consumed before or during task completion. For this reason, a single item question about most recent alcohol use was administered orally by research staff prior to completing the EF tasks and those who endorsed same-day alcohol use were asked to complete the EF measures on a later date ($n = 0$). Baseline questionnaires, the EF battery, and education on the EMA protocol took an estimated 80 mins to complete.

Three-week EMA Monitoring Period. Harm reduction strategy use and alcohol-related behavior were assessed twice daily; once in the morning and once in the afternoon. Participants received a text message prompt with a hyperlink directing them to the Qualtrics website where the surveys were completed every day for the next twenty-one days. The hyperlink for the morning survey was sent at 9a and participants had until 12p before the window to complete the survey closed. The hyperlink for the afternoon survey was sent at 3p and participants had until 6p before the window to complete the survey closed. Survey completion was timestamped. The EMA survey took an estimated 3 minutes to complete. The procedures for the daily monitoring portion were similar to those used in other college drinking studies (e.g., Hepp et al., 2017; Shiffman, 2009; Trull et al., 2008).

Compensation. Participants who were recruited through SONA earned class credit for participating in the study, awarded to them through SONA. Participants who were recruited through flyers earned up to $35 in the form of an Amazon eGiftcard. Additionally, all participants had the opportunity to earn a $5 bonus for each week of 100% survey compliance, for a maximum of a $15 bonus in the form of an eGift Card.

Compliance. To maximize EMA survey compliance, participants who did not complete the survey one hour prior to the window closing received a text message reminder to complete the survey. Participants who did not complete the survey by the end of the survey window were contacted by research assistants via telephone and reminded to complete the survey. Participants were given the option to have the survey administered to them over the phone.

Data Analytic Strategy

Preliminary Analyses. All variables were examined for outliers and violations of normality prior to analyses. Outliers with values outside of the median ± two interquartile ranges (IQRs) were replaced with the value of the median ± two IQRs. Effects were estimated using robust standard errors and other appropriate techniques if distributions are non-normal. Descriptive and EMA compliance statistics were computed to characterize the sample (see Tables 7 and 8). Visual inspection of response times on the EF tasks revealed no occurrences of excessive or inappropriate rapid responding or timed out responses which may have been suggestive of random responding or inattention. Additionally, error rates on the EF tasks that were greater than 80% of total responses were deemed to fail to meet performance validity criteria and were excluded from analyses (n = 0).

Analytic Strategy Overview. To test study hypotheses, time-lagged multilevel regression models (Kenny, Kashy, & Bolger, 1998; Schwartz & Stone, 1998) were estimated using Hierarchical Linear Modeling (HLM 7.0; Raudenbush et al., 2011). Multilevel regression accommodates the two levels of nesting in the current study; time points (level-1) nested within-person (level-2) and allow for estimation of both within-person (variability in strategy use intention around person-centered means) and between-person (individual differences in EF) data simultaneously. Due to our interest in safe drinking behaviors during drinking events, oppose to complete drinking restraint or abstinence, only days in which at least one drink was consumed were included in analyses. All effects were estimated using restricted maximum-likelihood estimation for count variables, which yield less biased variance estimates than other estimation methods for count data (e.g., Hox, 2010). To examine between-person effects, participant's overall average scores on strategy use intention (i.e., strategy use intention total score averaged over all EMA datapoints to get between-person estimates; also grand mean centered) was modeled on the intercept. The level-1 predictors (e.g., strategy use intention) were initially entered as random effects. However, level-1 predictors were entered as fixed effects when the random slope for the model was nonsignificant to reflect the more parsimonious model. Level-1 predictors were person-mean centered. Control variables (affect, number of drinks) were entered at fixed effects and person-mean centered where appropriate.

Aim 1: Intention Predicting Strategy Use. First, to examine the potential intention-behavior gap, a time-lagged index of strategy use intention (total number of strategies intended to be used as reported in the afternoon survey) was entered as a level-1 predictor of actual strategy use (reported in the morning survey the following day) controlling for affect and number of drinks.

Aim 2. The extent to which individual differences in working memory, set-shifting, and inhibition moderate the relationship between intention and actual harm reduction strategy use later on the same day were examined.

Hypothesis 2a: Intention x EF Predicting Total Strategy Use. Each EF variable (working memory, set-shifting, inhibition) was individually entered into the first model as a level-2 moderator on strategy use intention (total number of strategies intended to be used as reported in the afternoon survey) predicting actual strategy use. The level-1 predictors (e.g., strategy use intention) were initially entered as random effects. However, level-1 predictors were entered as fixed effects when the random slope for the model was nonsignificant to reflect the more parsimonious model. The level-2 predictors (working memory, set-shifting, inhibition) were entered at fixed effects and grand-mean centered. All effects were estimated using restricted maximum-likelihood estimation for count variables.

Hypothesis 2b: Intention x EF Predicting Strategy Use Subgroups. Again, each EF variable (working memory, set-shifting, inhibition) was individually entered into the first model as a level-2 moderator on strategy use intention (as reported in the afternoon survey), however the Pre-planning and Modifying subgrouping of strategy use items was used for both strategy use intentions (predictor) and actual strategy use (outcome). Consistent with the previously described model, the level-2 predictors (working memory, set-shifting, inhibition) were entered at fixed effects and grand-mean centered, and all effects were estimated using restricted maximum-likelihood estimation for count variables.

Aim 3: Intention Predicting Drinking Behavior. To examine the relationship between strategy use intention and drinking behavior, a time-lagged index of strategy use intention (total number of strategies intended to be used as reported in the afternoon survey) was entered as a level-1 predictor of drinking quantity (i.e., number of drinks consumed during a drinking event), controlling for affect and day of the week. The level-1 predictor (strategy use intention) was entered as random effects and person-mean centered. The control variable (affect) was entered at fixed effects and person-mean centered. All effects were estimated using restricted maximum-likelihood estimation for count variables.

Power Analysis. Estimating power to detect cross-level interactions in MLM requires consideration of both level-1 and level-2 sample sizes such that as the number of observations increases, the size of the level-2 sample necessary to detect an effect decreases (Hox, 2010). The current study has total of 21 level-2 assessment opportunities, and according to simulation studies a level-1 sample size of 18 surpasses power of 80% with level-2 sample sizes of 35 (Mathieu et al., 2012). However, we expected that not every day would be a drinking day, thus a larger sample size was necessary to avoid being underpowered. According to previous estimates of drinking frequency among college students in a SONA participant pool at the same Southeast university where data were collected, approximately one to two drinking episodes per week per participant were expected with the current inclusion/exclusion criteria. Using these estimates, a sample size of 100 was expected to yield a total of 600 time points (i.e., drinking days). Additionally, based on the best available guidelines utilizing simulation studies, a sample size of 100 would meet MLM power recommendations and would accommodate fewer drinking occasions reported per participant (Mathieu et al., 2012). A sample size of 100 is consistent with previous literature examining factors similar to those in the current study (Dvorak & Simons, 2014; Pearson, D'Lima, et al., 2013; Sell et al., 2018).

Table 1. Summary of Participant Demographics (n=85)

Variable	Frequency (Percent)
Sex	
Female	56 (65.9%)
Male	29 (34.1%)
Age, Mean (SD)	20.44 (2.19)
Race/Ethnicity	
White (non-Hispanic)	37 (43.5%)
Hispanic	25 (29.4%)
Black/African American	5 (5.9%)
Asian or Asian/American	6 (7.1%)
Multiracial	11 (12.9%)
Other or Unknown	1 (1.2%)
Sexual Orientation	
Straight	58 (68.2%)
Gay or Lesbian	2 (2.4%)
Bisexual	23 (27.1%)
Other	2 (2.4%)
College Standing	
Freshman	17 (20.0%)
Sophomore	18 (21.2%)
Junior	27 (31.8%)
Senior	23 (27.1%)
Member of Fraternity or Sorority	10 (11.8%)
Employment Status	
Employed Full Time	9 (10.6%)
Employed Part Time	39 (45.9%)
Unemployed, Looking for work	17 (20.0%)
Unemployed, Not looking for work/ Disabled	20 (23.5%)
Residence	

Table 1. (Continued)

Variable	Frequency (Percent)
Campus Residence Hall/Dorm	25 (29.4%)
Off-Campus, Student Housing	10 (11.8%)
Off-Campus, with roommates	34 (40.0%)
Off-Campus, with significant other	4 (4.7%)
Off-Campus, with family	9 (10.6)
Off-Campus, alone	3 (3.5%)
Relationship Status	
Single/Never Married	66 (77.6%)
Partnered, not living with partner	14 (16.5%)
Partnered, living with partner / Married	5 (5.9%)
Income	
0 to $10,000	66 (77.6%)
$10,101 to $20,000	10 (11.8%)
$20,001 to $40,000	7 (8.2%)
Over $40,000	2 (2.4%)

Table 2. Descriptive Statistics for Baseline Survey Variables

Variable	Mean (SD)	Minimum-Maximum	Skewness	Kurtosis
PBSS-20 Total	56.75 (16.52)	17-100	-.019	.034
Pre-planning subscale	29.20 (9.02)	5-50	-.225	-.062
Modifying subscale	27.44 (9.19)	10-50	.106	-.594
YAACQ	16.04 (9.17)	3-41	.552	-.465
UPPSP Total Score	133.01 (22.07)	79-185	-.096	-.473

Table 3. Descriptive Statistics for Computer Task Variables

Variable	Mean (SD)	Minimum-Maximum
Go/No-Go		
Total Errors	11.0 (7.96)	0-47
Commission Errors	10.05 (7.27)	0-46
Omission Errors	.95 (2.29)	0-16
N-Back Total Errors	9.72 (7.66)	0-50
Task Switching Total Errors	4.67 (5.18)	0-36

Table 4. Descriptive Statistics for COVID-19 Drinking Behavior Questionnaire* (n=85)

Variable	Frequency (Percent)
How much I drink:	
Drinking much less	4 (4.7%)
Drinking somewhat less	12 (14.1%)
Drinking about the same amount	29 (34.1%)
Drinking somewhat more	23 (27.1%)
Drinking much more	17 (20.0%)
How often I drink:	
Drinking much less often	3 (3.5%)
Drinking somewhat less often	11 (12.9%)
Drinking as often as before	25 (29.4%)
Drinking somewhat more often	34 (40.0%)

Table 4. (Continued)

Variable	Frequency (Percent)
Drinking much more often	12 (14.1%)
Drinking Location: Home	
Less often	14 (16.5%)
As often as before	22 (25.9%)
More often	36 (42.4%)
Not applicable	13 (15.3%)
Drinking Location: Friend's house	
Less often	14 (16.5%)
As often as before	34 (40.0%)
More often	34 (40.0%)
Not applicable	3 (3.5%)
Drinking Location: Family's house	
Less often	27 (31.8%)
As often as before	26 (30.6%)
More often	13 (15.3%)
Not applicable	19 (22.4%)
Drinking Location: Restaurant	
Less often	18 (21.2%)
As often as before	25 (29.4%)
More often	26 (30.6%)
Not applicable	16 (18.8%)
Drinking Location: Bar/club	
Less often	19 (22.4%)
As often as before	15 (17.6%)
More often	42 (49.4%)
Not applicable	9 (10.6%)
Drinking alone	
Drinking alone much less often	43 (50.6%)
Drinking alone somewhat less often	7 (8.2%)
Drinking alone as often as before	31 (36.5%)
Drinking alone somewhat more often	2 (2.4%)
Drinking alone much more often	2 (2.4%)

* Changes in drinking since the start of the pandemic (approximately April 2020).

Table 5. Summary of means, standard deviations, and correlations for executive function and impulsivity related measures/subscales

	M	*SD*	1.	2.	3.	4.	5.	6.
1. N-Back Total Errors	9.72	7.66	-					
2. Task Switching Total Errors	4.67	5.18	.503**	-				
3. Go/No-Go Total Errors	11.0	7.96	.125**	.090**	-			
4. UPPSP Total Score	133.01	22.07	.090**	.162**	.084**	-		
5. UPPSP Emotion-Based Rash Action	57.89	14.47	.108**	.228**	.151**	.900**	-	
6. UPPSP Deficits in Conscientiousness	40.83	8.67	.042*	.180**	.162**	.670**	.429**	-

Note: * $p < .05$; ** $p < .001$.

Table 6. PBSS-20 Item Groupings

Strategies that rely heavily on planning prior to drinking event	**Strategies that rely heavily on modifying behavior during drinking event**
Use a designated driver	Know where your drink has been at all times
Make sure that you go home with a friend	Refuse to ride in a car with someone who has been drinking
Only go out with people you know and trust	Avoid combining alcohol with marijuana
Make sure you drink with people who can take care of you if you drink too much	Drink water while drinking alcohol
Eat before or during drinking	Alternate alcoholic and nonalcoholic drinks
Have a friend let you know when you've had enough to drink	Put extra ice in your drink
Determine not to exceed a set number of drinks	Avoid drinking games
Avoid "pre-gaming" (i.e., drinking before going out)	Avoid mixing different types of alcohol
Leave the bar/party at a predetermined time*	Drink slowly, rather than gulp or chug
Stop drinking at a predetermined time*	Avoid trying to keep up or out-drink others

*Items hypothesized to rely on both Pre-planning and Modifying.

Table 7. Descriptive Statistics for Daily Survey Variables

Variable	Mean (SD)	Minimum-Maximum	Skewness	Kurtosis
PBSS-20 Intent Total	12.76 (4.56)	0-20	-.154	-.505
Pre-planning subscale	6.61 (2.31)	0-10	-.229	-.323
Modifying subscale	6.16 (2.62)	0-10	-.202	-.999
PBSS-20 Use Total	11.77 (4.64)	0-20	-.039	-.516
Pre-planning subscale	5.75 (2.56)	0-10	-.027	-.670
Modifying subscale	6.02 (2.54)	0-10	-.214	-.702
Alcohol-Related Consequences	.53 (1.06)	0-6, median = 0	--	--
PANAS				
Negative Affect*	10.50 (4.56)	5-25	.910	.503
Positive Affect	10.90 (4.11)	4-20	.197	-.666
Number Drinking Days	4.39 (3.62)	0-19, median = 3	--	--
Number of Drinks per Drinking Day	3.75 (2.87)	1-20	--	--

*PANAS Negative Affect Subscale included an additional item.

Table 8. Compliance by Prompt Number and Day of the Week (n=84); % (raw survey count/total possible surveys)

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total by prompt number
AM Prompt	79.76% (201/252)	83.73% (211/252)	80.16% (202/252)	82.14% (207/252)	82.54% (208/252)	81.35% (205/252)	80.95% (204/252)	81.52% (1438/1764)
PM Prompt	77.78% (196/252)	79.37% (200/252)	80.95% (204/252)	81.35% (205/252)	79.37% (200/252)	79.37% (200/252)	79.37% (200/252)	79.65% (1405/1764)
Total by day of the week	78.77% (397/504)	81.55% (411/504)	80.56% (406/504)	81.75% (412/504)	80.95% (408/504)	80.36% (405/504)	80.16% (404/504)	Total: 80.58% (2843/3528)

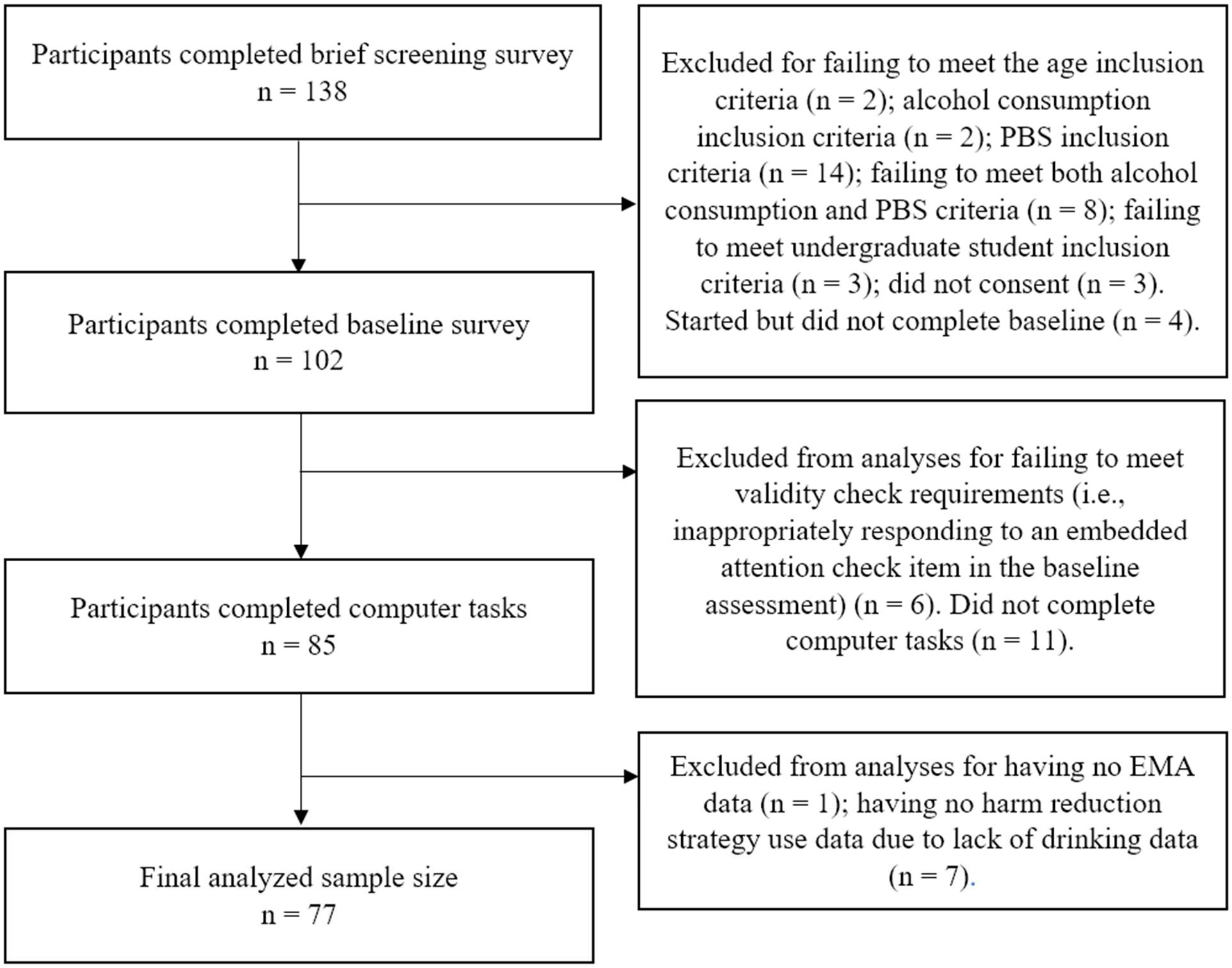

Figure 1. Flow Diagram of Participant Inclusion/Exclusion.

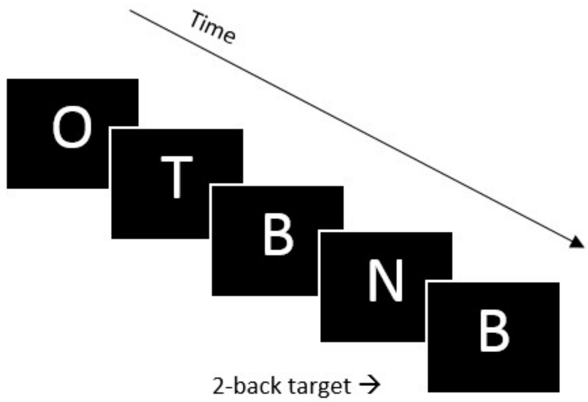

Figure 2. Experimental Design for the 2-back Version of the N-back Measure.

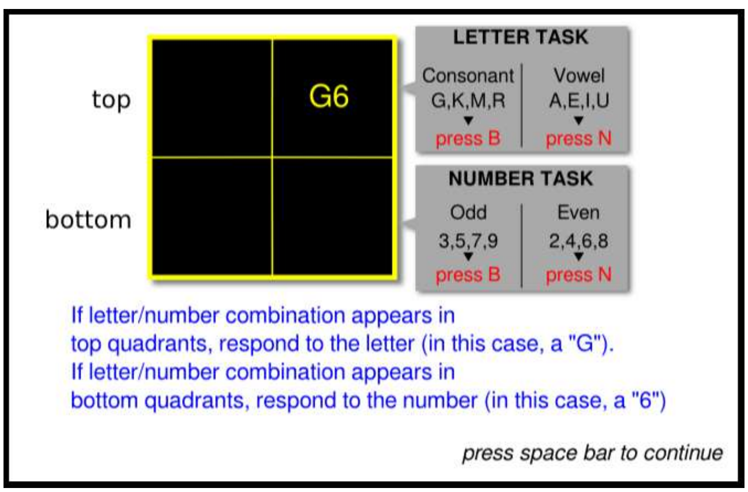

Figure 3. Experimental Design for the Task Switching Task.

CHAPTER THREE: RESULTS

Descriptive and Compliance Statistics

A total of 102 participants consented to the study and a total of 85 completed the computer tasks. The final analyzed sample size was 77 participants (see Figure 1 for details). A total of 2843 (80.58%) EMA assessments were completed (out of 3528 total possible surveys). Compliance was consistent with those reported in previous studies using similar methods (Jones et al., 2019). Compliance rates were quite consistent for AM and PM prompts (range: 79-81%) and day of the week (range: 78-81%) (see Table 8 details). During the 21-day monitoring period, participants reported a total 365 drinking days (20.69% of reported days). The mean number of drinking days during the three-week monitoring period was 4.39 (*SD* = 3.62, median = 3). On those drinking days, participants consumed an average of 3.75 drinks (*SD* = 2.87, range 1-20). Compared to before the COVID-19 pandemic (approximately April 2020), about half the sample (54.1%) reported drinking at least somewhat more often than before the pandemic, and reported drinking at least somewhat more in terms of quantity (47.1%; see Table 7). To examine the proportion of variance accounted for due to clustering, unconditional models for strategy use intent, actual strategy use, and drink quantity were conducted, yielding interclass correlations of .7125 for strategy intent, .5485 for strategy use, and .1626 for drink quantity.

Aim 1: Intention Predicting Strategy Use

Between-Person Effects. To examine the between-person effects of strategy use intention, the overall means for strategy use intention was modeled on the intercept (level-2 variable).

Results indicated that the strategy use intention between-person effect was significant (*b* = .695, *SE* = .080, *p* < .001) (see Table 9 for final model results), suggesting that higher levels of strategy use intention between individuals was associated with greater use of strategies even after controlling for drink quantity and positive and negative affect.

Within-Person Effects. Consistent with our hypothesis that higher strategy use intention would be associated with greater strategy use, a significant within-person effect was found (*b* = .551, *SE* = .062, *p* < .001), suggesting that when participants planned on using harm reduction strategies, they were likely to follow through with using them. Exploratory analyses of the model without covariates revealed similar results (see Supplemental Table A.1 for details).

Effect Size. The proportional reduction in prediction error at the individual level was computed using the formula provided by Snijders and Bosker (2012). The proportion of variance in strategy use explained by the predictors and covariates was 46.30%. The measure of effect size was computed using the formula provided by Cohen (1992). Relative to the unexplained variance in strategy use, 86.23% of the variance in strategy use was explained by the predictors and covariates.

Aim 2 Hypothesis 2a: Intention x EF Predicting Total Strategy Use

The extent to which individual differences in working memory, set-shifting, and inhibition moderated the relationship between intention and actual harm reduction strategy use later on the same day were examined (Table 10). Results indicated nonsignificant between-person effects for working memory (*b* = -.007, *SE* = .060, *p* = .904), set-shifting (*b* = -.103, *SE* = .101, *p* = .313), and inhibition (*b* = -.061, *SE* = .037, *p* = .109). Results further indicated nonsignificant within-person effects for cross-level interactions between strategy use intent and working memory (*b* = -.001, *SE* = .019, *p* = .950), set-shifting (*b* = -.003, *SE* = .016, *p* = .857), and inhibition (*b* = .012, *SE* = .012, *p* = .296) predicting actual strategy use. Exploratory analyses of the models without covariates revealed similar results (see Supplemental Table A.2 for details). Additional analyses examining the between-person interaction between intent and the EF variables were conducted. Specifically, the level-2 interaction between intent (grand mean centered) and each EF variable (grand mean centered) was modeled on the intercept of the full models (see Supplemental Table A.3 for details). Results indicated significant between-person interaction for set-shifting (*b* = -.061, *SE* = .024, *p* = .015). Inspection of the plotted estimated means for high (85^{th} percentile) and low values (15^{th} percentile) suggested that greater set-shifting errors was predictive of relatively fewer strategies used compared to fewer set-shifting errors, especially when intent was high (see Figure 4 for visual representation of interaction). A significant simple slope for intent was observed at high (*b* = .340, *SE* = .164, *p* = .042) and low (*b* = .825, *SE* = .094, *p* < .001) levels of set-shifting errors. The between-person interactions for working memory (*b* = .002, *SE* = .010, *p* = .822) and inhibition were nonsignificant (*b* = .006, *SE* = .008, *p* = .446).

Aim 2 Hypothesis 2b: Intention x EF Predicting Strategy Use Subgroups

Pre-Planning Harm Reduction Strategies. Results indicated that the between-person effect for intention to use Pre-Planning strategies predicting actual Pre-Planning strategy use was significant (*b* = .332, *SE* = .048, *p* < .001), suggesting that differing levels of Pre-Planning strategy use intention between individuals was associated with actual strategy use behaviors even after controlling for drink quantity and positive and negative affect. Further, a significant positive within-person effect (*b* = .477, *SE* = .058, *p* < .001) was found, suggesting that when participants planned on using Pre-Planning harm reduction strategies, they were likely to follow through with the behavior (Table 11). Exploratory analyses of the models without covariates revealed similar results (see Supplemental Table A.4 for details).

The extent to which individual differences in working memory, set-shifting, and inhibition moderated the relationship between intention to use Pre-Planning harm reduction strategies and actual Pre-Planning harm reduction strategy use later on the same day were examined. Results indicated nonsignificant between-person effects for working memory (b = .002, SE = .034, p = .957), set-shifting (b = -.040, SE = .056, p = .475), and inhibition (b = -.038, SE = .022, p = .090). Results further indicated nonsignificant within-person effects for cross-level interactions between intention to use Pre-Planning strategies and working memory (b = .003, SE = .011, p = .784), set-shifting (b = -.021, SE = .019, p = .271), and inhibition (b = -.004, SE = .005, p = .435) predicting actual Pre-Planning strategy use (Table 12). Exploratory analyses of the models without covariates revealed similar results (see Supplemental Table A.5 for details). Additional analyses examining the between-person interaction between intent and the EF variables predicting pre-planning strategy use were conducted (see Supplemental Table A.6 for details). Specifically, the level-2 interaction between intent (grand mean centered) and each EF variable (grand mean centered) was modeled on the intercept of the full models. Results indicated nonsignificant between-person interactions for set-shifting (b = -.020, SE = .014, p = .18), working memory (b = .002, SE = .006, p = .701) and inhibition (b = .002, SE = .004, p = .712).

Modifying Harm Reduction Strategies. Results indicated that the between-person effect for intention to use Modifying strategies predicting actual Modifying strategy use was significant (b = .354, SE = .041, $p < .001$), suggesting that differing levels of Modifying strategy use intention between individuals was associated with actual strategy use behaviors even after controlling for drink quantity and positive and negative affect (Table 13). Further, a significant within-person effect ($b = .430$, $SE = .098$, $p < .001$) was found, suggesting that when participants planned on using Modifying harm reduction strategies, they were likely to follow through with the behavior. Exploratory analyses of the models without covariates revealed similar results (see Supplemental Table A.3 for details).

The extent to which individual differences in working memory, set-shifting, and inhibition moderated the relationship between intention to use Modifying harm reduction strategies and actual Modifying harm reduction strategy use later on the same day were examined (Table 13). Results indicated nonsignificant between-person effects for working memory ($b = -.009$, $SE = .033$, $p = .788$), set-shifting ($b = -.064$, $SE = .057$, $p = .270$), and inhibition ($b = -.022$, $SE = .021$, $p = .285$). Results further indicated nonsignificant within-person effects for cross-level interactions between Modifying strategy use intent and working memory ($b = -.013$, $SE = .022$, $p = .569$) and inhibition ($b = .017$, $SE = .025$, $p = .493$) predicting actual Modifying strategy use. The within-person effect for the cross-level interaction between Modifying strategy use intention and set-shifting was significant ($b = -.090$, $SE = .030$, $p = .007$). Exploratory analyses of the models without covariates revealed similar results (see Supplemental Table A.7 for details). Additional analyses examining the between-person interaction between intent and the EF variables predicting modifying strategies were conducted (see Supplemental Table A.8 for details). Specifically, the level-2 interaction between intent (grand mean centered) and each EF variable (grand mean centered) was modeled on the intercept of the full models. Results indicated significant between-person interaction for set-shifting ($b = -.038$, $SE = .014$, $p = .009$). Inspection of the plotted estimated means for high (85^{th} percentile) and low values (15^{th} percentile) suggested that greater set-shifting errors was predictive of relatively fewer strategies used compared to fewer set-shifting errors, especially when intent was high (see Figure 5 for visual representation of interaction). A significant simple slope for intent was observed at low ($b = .432$, $SE = .051$, $p < .001$) but not high ($b = .124$, $SE = .093$, $p = .186$) levels of set-shifting errors. The between-person interactions for working memory ($b = .0001$, $SE = .006$, $p = .990$) and inhibition were nonsignificant ($b = .004$, $SE = .005$, $p = .481$).

Aim 3: Intention Predicting Drinking Behavior

The relationship between strategy use intention and drinking quantity was examined (Table 14). Results indicated that the between-person effect for strategy use intention predicting drink quantity was significant ($b = -.132$, $SE = .061$, $p = .035$), suggesting that higher levels of strategy use intention between individuals was associated with fewer number of drinks consumed during a drinking event even after controlling for day of the week and affect. Results further indicated a nonsignificant within-person effect for strategy use intention predicting drink quantity ($b = -.059$, $SE = .047$, $p = .211$). Exploratory analyses examining the extent to which individual differences in working memory ($b = .008$, $SE = .010$, $p = .394$), set-shifting ($b = .009$, $SE = .018$, $p = .628$), and inhibition ($b = -.003$, $SE = .012$, $p = .819$) moderated the relationship between strategy use intention and number of drinks were nonsignificant (Table 15).

Exploratory Analyses: Strategy Use Intention, Actual Strategy Use, and Drink Quantity Predicting Alcohol-Related Consequences

Associations between total strategy use intention, total strategy use, and drink quantity predicting number of alcohol-related consequences for the same drinking episode were examined (Table 16). Results indicated that higher drink quantity significantly predicted greater consequences ($b = .125$, $SE = .026$, $p < .001$). After controlling for number of drinks, strategy use intention (*b* = -.009, *SE* = .019, *p* = .656) and actual strategy use (*b* = -.014, *SE* = .017, *p* = .415) predicting consequences were nonsignificant.

Exploratory Analyses: Intention to Use Individual Strategies Predicting Actual Use

Descriptives and ICCs for the PBSS-20 items were computed to get a more nuanced picture of how frequently each individual strategy was used on the daily-level (ICC range = .198-.510) (see Supplemental Table A.9). Exploratory analyses were conducted to examine associations between intention predicting behavior of each individual strategy (i.e., PBSS-20 items) (see Supplemental Table A.10). Intentions significantly predicted behavior of each individual strategy for all items except "Refused to ride in a car with someone who had been drinking" (*b* = 2.219, *SE* = 1.153, *p* = .061; OR = 9.198, CI = .896,94.413). The strategies that had the greatest likelihood of follow-through included "Alternated alcoholic and nonalcoholic drinks" (*b* = 4.087, *SE* = .840, *p* < .001; OR = 59.579, CI = 11.079,320.383), "Had a friend let you know when you've had enough to drink" (*b* = 3.967, *SE* = 1.082, *p* < .001; OR = 52.838, CI = 6.046,461.754), and "Knew where your drink had been at all times" (*b* = 3.819, *SE* = .675, *p* < .001; OR = 45.537, CI = 11.791,175.861). The strategies that had relatively lower likelihood of follow-through included "Made sure that you went home with a friend" (*b* = 1.474, *SE* = .688, *p* = .036; OR = 4.367, CI = 1.100,17.333), "Avoided trying to keep up or out-drink others" (*b* = 1.890, *SE* = .664, *p* = .006; OR = 6.621, CI = 1.750,25.054), "Put extra ice in your drink" (*b* = 2.088, *SE* = .578, *p* < .001; OR = 8.069, CI = 2.535,25.682), "Avoided "pre-gaming" (i.e., drinking before going out)" (*b* = 2.116, *SE* = .591, *p* < .001; OR = 8.299, CI = 2.515,27.385), "Used a designated driver" (*b* = 2.143, *SE* = .552, *p* < .001; OR = 8.528, CI = 2.821,25.777), and "Determined not to exceed a set number of drinks" (*b* = 2.166, *SE* = .623, *p* < .001; OR = 8.720, CI = 2.502,30.398).

Additional exploratory analyses examined the cross-level interaction between intent and EF for the three strategies that had the greatest within-person variability (i.e., lowest ICC of items assessing actual strategies used), which included "Used a designated driver," "Only went out with people you knew and trusted," and "Ate before or during drinking." Working memory, set-shifting, and inhibition significantly moderated the relationship between intention and actual strategy use for "Used a designated driver" (working memory task errors: b = .886, SE = .354, p = .015; OR = 2.425, CI = 1.192,4.931; set-shifting task errors: b = 2.131, SE = .789, p = .009; OR = 8.422, CI = 1.733,40.941; inhibition task errors: b = .767, SE = .145, p <.001; OR = 2.089, CI = 1.562,2.793). Inspection of the plotted estimated means for high (85^{th} percentile) and low values (15^{th} percentile) suggested that greater errors on the EF tasks was predictive of lower likelihood of using a designated driver when intention was low, whereas fewer errors were associated with a greater likelihood of using a designated driver regardless of level of intention (see Figures 6-8 for visual representation of interactions). However, the simple slopes for intention to use a designated driver were nonsignificant at high and low levels of errors in tasks of working memory (high: b = -.105, SE = .069, p = .138; low: b = .153, SE = .137, p = .269), set-shifting (high: b = -.223, SE = .119, p = .068; low: b = .559, SE = .328, p = .096), and inhibition (high: b = -.136, SE = .076, p = .083; low: b = .139, SE = .156, p = .376). The cross-level interactions for "Only went out with people you knew and trusted" and "Ate before or during drinking" were nonsignificant for all three EF variables. Given the exploratory nature of the analyses, results must be interpreted with caution.

Table 9. Aim 1. Summary of Results for Intention Predicting Total Strategy Use (full model)

	b	*SE*	*p*
Intercept	12.716	.510	<.001
Intent (between-person effect)	.695	.080	<.001
Drink quantity	-.092	.074	.216
PA	.051	.059	.388
NA	.086	.099	.386
Intent (within-person effect)	.551	.062	<.001
Random Effects Variances	*Var*	χ^2	*p*
Intercept	6.248	303.163	<.001
Level-1, *e*	4.858	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 10. Aim 2a. Summary of Results for Intent X EF Tasks Predicting Total Strategy Use (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	12.712	.512	<.001	12.663	.508	<.001	12.732	.492	<.001
Intent (between-person effect)	.700	.081	<.001	.691	.077	<.001	.707	.079	<.001
EF Variable	-.007	.060	.904	-.103	.101	.313	-.061	.037	.109
Drink quantity	-.092	.074	.216	-.088	.077	.255	-.100	.072	.172
PA	.051	.059	.391	.050	.059	.392	.052	.060	.382
NA	.085	.093	.361	.087	.100	.386	.087	.101	.392
Intent (within-person effect)	.550	.066	<.001	.548	.055	<.001	.594	.080	<.001
Intent X EF Variable (cross-level interaction)	-.001	.019	.950	-.003	.016	.857	.012	.012	.296
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	6.376	301.08	<.001	6.300	306.55	<.001	6.202	301.568	<.001
Level-1, *e*	4.897	--	--	4.88	--	--	4.850	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 11. Aim 2b. Summary of Results for Intent Predicting Strategy Use Subgroups (full models)

	Pre-Planning			*Modifying**		
	b	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.198	.293	<.001	6.529	.284	<.001
Intent (between-person effect)	.332	.048	<.001	.354	.041	<.001
Drink quantity	-.005	.043	.908	-.091	.045	.047
PA	.061	.044	.163	.005	.046	.922
NA	-.004	.041	.921	.0700	.079	.0380
Intent (within-person effect)	.477	.058	<.001	.430	.098	<.001
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	2.202	315.787	<.001	1.500	151.899	<.001
Intent	--	--	--	.067	1.946	.008
Level-1, *e*	1.760	--	--	1.946	--	--

*Random effects model. Note: *b* = unstandardized estimates; *SE* = standard error; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 12. Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Pre-Planning (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.197	.293	<.001	6.175	.297	<.001	6.192	.284	<.001
Intent (between-person effect)	.332	.049	<.001	.330	.047	<.001	.340	.022	<.001
EF Variable	.002	.034	.957	-.040	.056	.475	-.038	.048	.090
Drink quantity	-.005	.042	.915	-.003	.045	.955	-.005	.044	.906
PA	.062	.044	.164	.062	.042	.147	.061	.044	.163
NA	-.003	.043	.943	-.0008	.040	.984	-.004	.041	.921
Intent (within-person effect)	.482	.057	<.001	.447	.052	<.001	.461	.062	<.001
Intent X EF Variable (cross-level interaction)	.003	.012	.784	-.021	.019	.271	-.004	.005	.435
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	2.247	312.803	<.001	2.245	318.95	<.001	2.193	318.668	<.001
Level-1, *e*	1.774	--	--	1.763	--	--	1.764	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 13. Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Modifying (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.513	.288	<.001	6.461	.286	<.001	6.53	.275	<.001
Intent (between-person effect)	.356	.042	<.001	.345	.040	<.001	.360	.040	<.001
EF Variable	-.009	.033	.788	-.064	.057	.270	-.022	.021	.285
Drink quantity	-.088	.046	.060	-.081	.051	.115	-.093	.045	.041
PA	.002	.047	.959	.009	.040	.814	.008	.045	.867
NA	.064	.075	.396	.054	.072	.459	.064	.075	.393
Intent (within-person effect)	.414	.104	<.001	.348	.117	.004	.477	.145	.002
Intent X EF Variable (cross-level interaction)	-.013	.022	.569	-.090	.033	.007	.017	.025	.493
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	1.527	148.509	<.001	1.534	167.455	<.001	1.545	158.925	<.001
Intent	.052	56.659	.009	.147	65.818	.001	.168	62.340	.002
Level-1, *e*	1.974	--	--	1.837	--	--	1.839	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 14. Aim 3: Summary of Results for Intention Predicting Drinking Behavior (full model)

	b	*SE*	*p*
Intercept	2.860	.321	<.001
Intent (between-person effect)	-.132	.061	.035
Day of Week (weekend)	-.614	.305	.045
PA	.039	.047	.405
NA	-.157	.060	.010
Intent (within-person effect)	-.059	.047	.211
Random Effects Variances	*Var*	χ^2	*p*
Intercept	4.002	281.007	<.001
Level-1, *e*	5.990	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 15. Exploratory Analyses. Summary of Results for Intention X EF Tasks Predicting Drinking Behavior (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	2.766	.311	<.001	2.788	.329	<.001	2.777	.315	<.001
EF Variable	-.035	.041	.392	.035	.118	.767	.004	.025	.870
Day of week (weekend)	-.554	.306	.071	-.579	.299	.053	-.570	.305	.063
Intent (within-person effect)	-.043	.049	.379	-.045	.053	.402	-.061	.059	.302
Intent X EF Variable (cross-level interaction)	.008	.010	.394	.009	.018	.628	-.003	.012	.819
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	4.106	284.387	<.001	4.191	293.013	<.001	4.203	289.702	<.001
Level-1, *e*	6.177	--	--	6.141	--	--	6.175	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table 16. Exploratory Analyses. Summary of Results for Strategy Use Intention, Actual Strategy Use, and Drink Quantity Predicting Alcohol-Related Consequences (full models)

	Strategy Use Intention			Actual Strategy Use			Drink Quantity		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	.582	.117	<.001	.572	.091	<.001	.568	.092	<.001
Predictor	-.009	.019	.656	-.014	.017	.415	.125	.026	<.001
Drink Quantity as covariate	.166	.032	<.001	.159	.030	<.001	--	--	--
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	.657	331.554	<.001	.491	411.484	<.001	.507	507.192	<.001
Predictor	--	--	--	.004	101.018	.002	.019	169.572	<.001
Level-1, *e*	.374	--	--	.461	--	--	.394	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

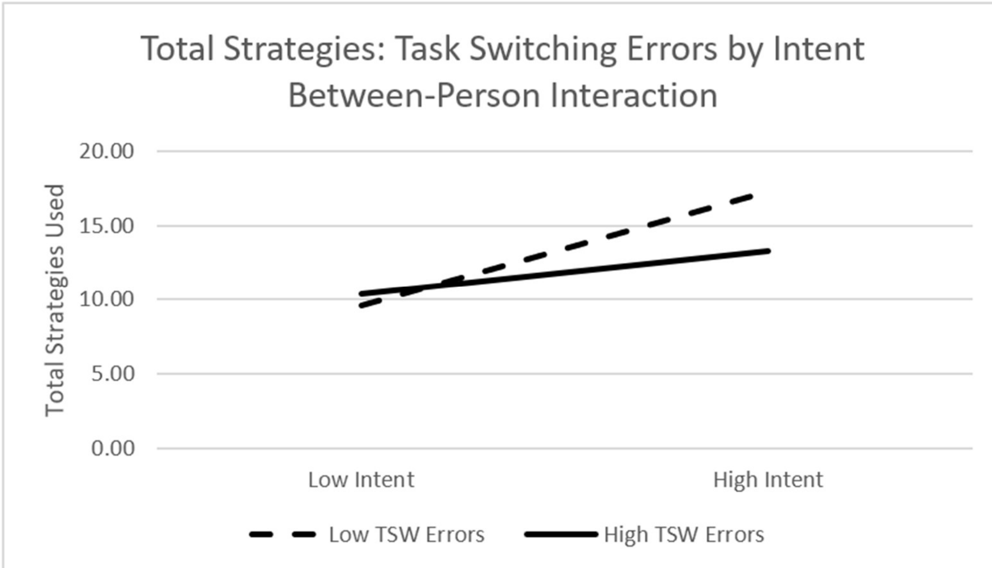

Figure 4. Graph of 2-way Task Switching x Intent Interaction Predicting Total Strategy Use. Note: TSW = Task Switching.

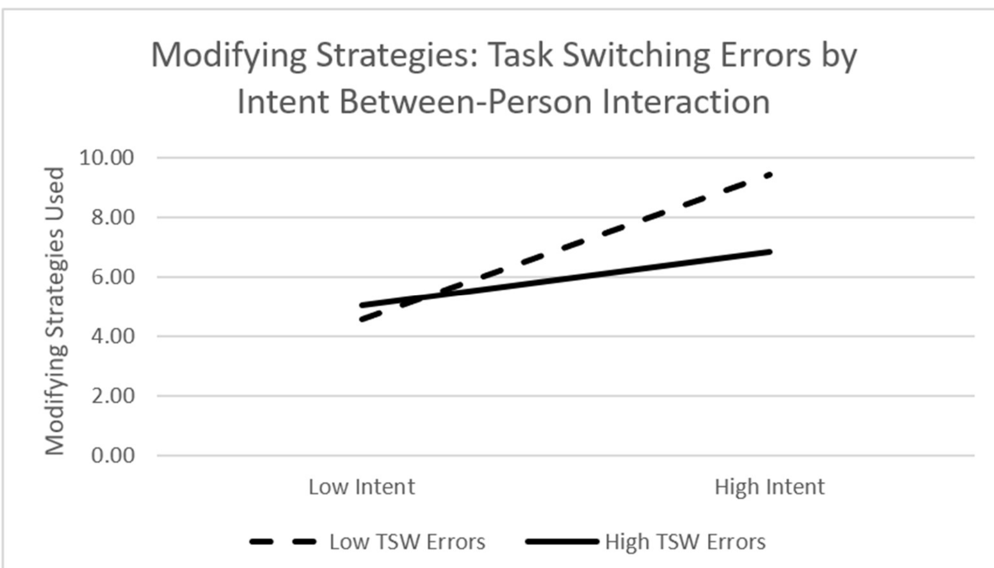

Figure 5. Graph of 2-way Task Switching x Intent Interaction Predicting Modifying Strategy Use. Note: TSW = Task Switching.

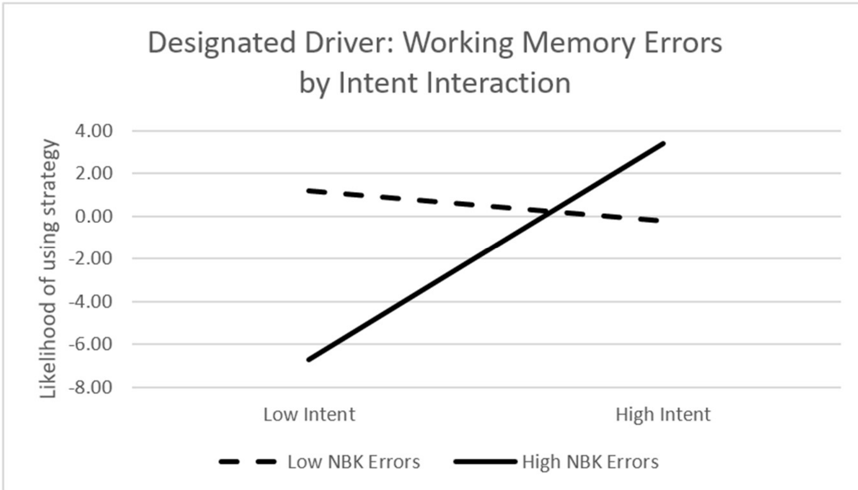

Figure 6. Graph of 2-way Working Memory x Designated Driver Intent Interaction Predicting Designated Driver Use. Note: NBK = N-Back.

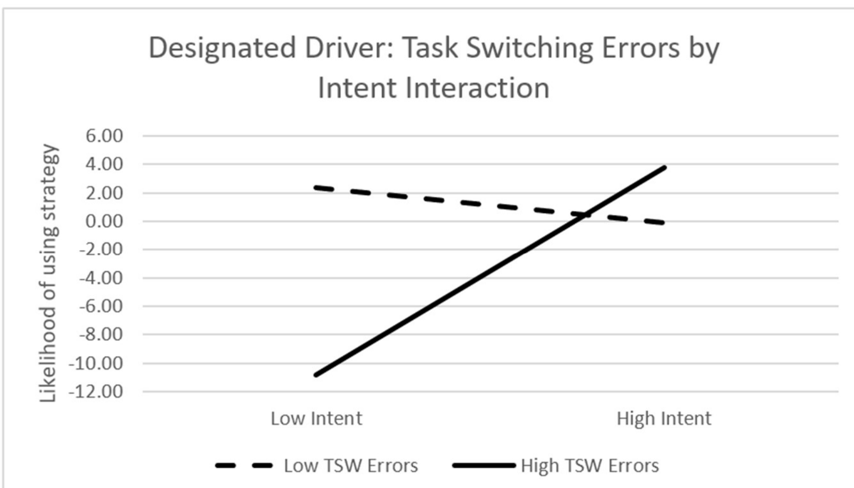

Figure 7. Graph of 2-way Task Switching x Designated Driver Intent Interaction Predicting Designated Driver Use. Note: TSW = Task Switching.

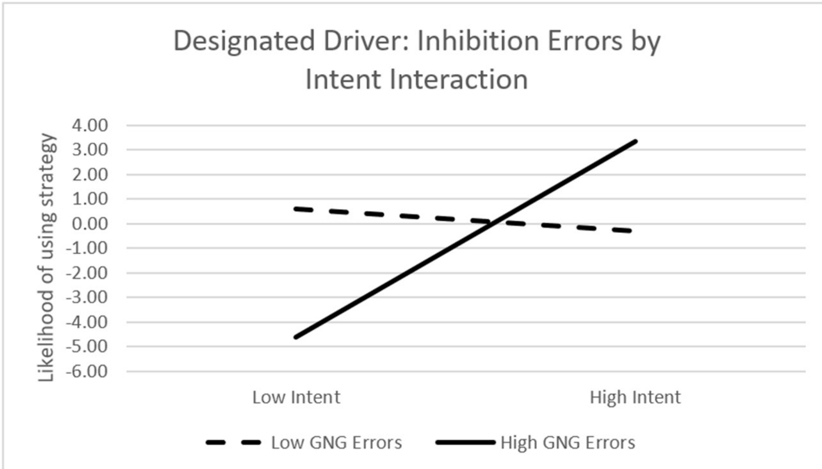

Figure 8. Graph of 2-way Inhibition x Designated Driver Intent Interaction Predicting Designated Driver Use. Note: GNG = Go/No-Go.

CHAPTER FOUR: DISCUSSION

The current study prospectively examined the association between intention to use alcohol harm reduction strategies and actual strategy use among college students. The role of executive functions associated with translating intentions of drinking safely into action was also examined. Based on the Temporal Self-Regulation Theory (TST; Hall and Fong, 2007, 2013, 2015), the association between intent and actual strategy use was hypothesized to be attenuated among those with poorer working memory capacity, set-shifting abilities, and inhibitory control compared to those with greater working memory capacity, set-shifting abilities, and inhibitory control. Results indicated that those who intended to use harm reduction strategies typically followed through, and this relationship was not moderated by individual differences in EF.

Significant between- and within-person effects were found when examining the intention-behavior gap of harm reduction strategy use, suggesting that those *who* planned to use harm reduction strategies tended to follow through, and *when* participants planned on using harm reduction strategies they tended to follow through. The size of the effect was large, indicating that much of the explained variance in actual strategy use could be attributed to strategy use intention and the covariates (i.e., affect, drink quantity). In other words, the intention-behavior gap of alcohol harm reduction strategy use was relatively small. These findings are consistent with a recent EMA study that similarly found significant within- and between-person associations between harm reduction strategy plans and use (Fairlie, et al., 2021) and provides additional evidence that intentions of enacting a behavior significantly increases the likelihood of actually enacting the behavior (Hall et al., 2008). The Health Action Process Approach model underscores the influential role of intention in enacting health behaviors and posits that the more specific the plan, the smaller the intention-behavior gap (Sutton, 2008). Developing a plan to use a harm reduction strategy may be as easy as deciding to use the strategy in some circumstances (i.e., forming an intention) given that many strategies already contain the specificity sufficient to constitute a plan (e.g., alternate alcoholic and nonalcoholic drinks, avoid drinking games). The current study adds to the growing literature that intentions meaningfully predict follow through by demonstrating that intentions to use alcohol harm reduction strategies were significantly and positively associated with actual strategy use.

Intentions x EF Predicting Alcohol Harm Reduction Strategy Use

Given results from the first model revealing a relatively small intention-behavior gap, the largely nonsignificant findings for EF as a moderator on the gap were unsurprising. Specifically, results from multilevel models examining the role of executive functioning abilities as a moderator on the relationship between intention to use harm reduction strategies and actual strategy use indicated nonsignificant between- and within-person effects for cross-level interactions between total strategy use intent and working memory, set-shifting, and inhibition predicting actual strategy use. Results from the current study failed to yield support for predictions based on the Temporal Self-Regulation Theory (TST; Hall and Fong, 2007, 2013, 2015) and was inconsistent with previous literature implicating poorer working memory abilities, set-shifting, and inhibition in risky alcohol use behaviors (e.g., Dvorak & Simons, 2014; Lannoy et al., 2019; Lauher et al., 2020). Most surprising was the nonsignificant results for inhibition given that disinhibition/impulsivity has been well established as a risk factor for risky and problematic alcohol use (López-Caneda et al., 2014; Norman et al., 2011; Wetherill et al., 2013).

According to the TST, inhibition in particular is strongly related to the intention-behavior gap due to the importance of altering impulsive responses to situational cues. Results from the current study suggest that generally people follow through with using harm reduction strategies when they intend to and individual differences in inhibition have minimal impact on follow through.

Additional analyses were conducted to explore whether the specific components of EF (i.e., working memory, set-shifting, inhibition) would be differentially associated with groupings of harm reduction strategy use (i.e., Pre-Planning and Modifying subgroups of strategies). Again, results largely indicated nonsignificant between- and within-person effects for cross-level interactions between groupings of strategy use intent (i.e., Pre-Planning, Modifying) and working memory, set-shifting, and inhibition predicting actual strategy use groupings. Specifically, the hypothesis that greater working memory capacity would moderate the intention-behavior association between strategies that require or rely more heavily on *preplanning* prior to the drinking event was not supported. Similarly, the hypothesis that inhibitory control would moderate the intention-behavior association between strategies that rely more heavily on *modifying* a behavior during the drinking event was not supported. Although it was hypothesized that set-shifting would be associated with Pre-Planning strategies, the within-person effect for the cross-level interaction between Modifying strategy use intention and set-shifting was significant, indicating that compared to those with fewer errors on a set-switching task, those with greater errors were less likely to follow through with Modifying strategies when they intended to use the strategies. Additionally, the between-person effect for the level-2 interaction between strategy use intention and set-shifting predicting total strategy use and modifying strategy use was significant. Previous research examining the relationship between set-shifting and alcohol use behaviors has shown that college student drinkers with higher set-shifting abilities demonstrated lower likelihood of drinking on a given night than those with poorer set-shifting abilities, suggesting set-shifting may serve as a protective factor against frequency of alcohol use (Dvorak & Simons, 2014). Set-shifting may similarly be a protective factor against *risky* alcohol use behaviors such that those who are better able to evaluate and manipulate goal-relevant information in context of their drinking goals may be more equipped to negotiate changing demands in the drinking environment. This may be one potential explanation for the association between set-shifting and modifying strategies but not pre-planning strategies and is consistent with previous evidence supporting greater engagement in various health behaviors among individuals with higher set-shifting abilities (snacking and eating healthier food options: Allan et al., 2011; disordered eating behaviors: Roberts et al., 2007; breakfast consumption: Wong & Mullan, 2009). Given the exploratory nature of the analyses, replication is necessary before conclusions may be drawn.

There are several potential explanations for the nonsignificant findings for EF as a moderator on the intention-behavior gap. First, strategy use may be over-learned and reflect established habits. Consistent with this, the within-person variability of intent and actual strategy use was diminished as indicated by high ICCs, which reflects variability due to grouping of the data. Perhaps those who regularly use a specific set of strategies continue to use them regularly when they drink. This is consistent with the Theory of Planned Behavior (Ajzen, 1991), which emphasizes the role of habit strength in the Intention-Behavior Gap. Over-learned behaviors rely less on EF, and many strategies could reasonably become part of an individual's typical drinking behavior repertoire, such as "drink slowly rather than gulp or chug" or "avoid mixing different types of alcohol." As such, it is possible that EF is more important in certain drinking contexts, such as those that require underused or new strategies. The sample in the current study were people who reported alcohol use at least once weekly, and 51.8% reported drinking at the current rate for approximately one year or longer. Additional research is needed to explore the role of EF on strategy use among people who have less experience with alcohol use and harm reduction strategy use as they learn to balance the rewarding aspects of drinking and negative consequences. Similarly, EF may play a larger role in following through with safe drinking behaviors in higher risk drinking situations, such as binge drinking in novel or dangerous environments (e.g., fraternity parties, music festivals). Drinkers may only intend on using certain strategies when in higher risk situations (Pearson, 2013). For example, if individuals do not plan on drinking enough to become intoxicated, they are unlikely to plan on using strategies such as "make sure you drink with people who can take care of you if you drink too much" or "have a friend let you know when you've had enough to drink."

Item-Level Analyses for Harm Reduction Strategies

When considering intention-behavior associations of each individual item of the PBSS-20 on the daily level, intentions significantly predicted behavior of each individual strategy for all items except "Refused to ride in a car with someone who had been drinking." Endorsement rate for *intention* of using this strategy was very high (91%) indicating that drinkers usually planned on *not* riding in a car with someone who had been drinking. The relatively lower endorsement rate of actual use of the strategy (70%) and nonsignificant model results may reflect a diminished need to use the strategy when there are multiple alternatives easily available (e.g., sober friend, ride share services). Given the high endorsement rate of using this strategy in previous literature (Treloar et al., 2015), it is likely that during at least some drinking episodes participants may not have needed to *refuse* to ride in a car with someone who had been drinking because the people they were drinking with were similarly using alternatives to driving under the influence. This would reflect a lack of opportunity, as opposed to failure to follow through with the harm reduction strategy.

The strategies that had the greatest likelihood of follow-through included “Alternated alcoholic and nonalcoholic drinks,” “Had a friend let you know when you’ve had enough to drink,” and “Knew where your drink had been at all times.” Closely monitoring drinks and having a friend look out for oneself while drinking are strategies that decrease the likelihood of serious harm such as drug drink spiking and sexual assault. High endorsement rates of strategies that aim to avoid serious harm in the current study are consistent with previous literature showing that these strategies are among those that are most commonly reported, especially among female college drinkers (e.g., Treloar et al., 2015). Given the strong likelihood of following through with these behaviors, increasing intentions to engage in these strategies would be important especially for genders that are at risk for sexual assault while drinking.

In contrast, the strategies that had relatively lower likelihood of follow-through included “Made sure that you went home with a friend,” “Avoided trying to keep up or out-drink others,” “Put extra ice in your drink,” “Avoided “pre-gaming” (i.e., drinking before going out),” “Used a designated driver,” and “Determined not to exceed a set number of drinks.” Four of the six strategies with the relatively lowest likelihood of follow-through were those in the Pre-planning grouping of strategies. One potential explanation may be related to changes in plans. For example, a drinker may plan on drinking mixed drinks and putting extra ice in their drink but change plans to consuming beverages that do not require ice (e.g., beer). Future research is warranted to examine the extent to which lack of opportunity as opposed to barriers explains lack of follow through with strategy use. That being said, the likelihood of following through with strategy use across nearly all individual strategies was relatively high so focusing intervention efforts on increasing intentions to use any and all strategies might be most worthwhile in decreasing alcohol related consequences. Findings from exploratory analyses further suggest that intervention efforts to encourage use of harm reduction strategies should be directed toward all college drinkers regardless of individual differences in EF given the largely nonsignificant interactions for the items with the greatest within-person variability.

Strategy Use Intention Predicting Alcohol Use

Consistent with hypotheses, those who intended to use more strategies tended to drink less. This finding was unsurprising given that several strategies aim to limit the number of drinks consumed (e.g., “determine not to exceed a set number of drinks”, “alternate alcoholic and nonalcoholic drinks”) and was consistent with the literature showing a negative relationship between harm reduction strategy use and alcohol use quantity (Pearson, D'Lima, et al., 2013; Treloar et al., 2015). Exploratory analyses examining EF as a moderator between intent and drink quantity were nonsignificant, further suggesting that individual differences in EF play less of a role in using strategies to limit the number of drinks consumed. Although drink quantity significantly predicted alcohol-related consequences in exploratory analyses, neither strategy use intent or actual strategy use were significantly associated with alcohol-related consequences reported during the same drinking event. This was inconsistent with previous cross-sectional studies finding associations between strategy use and consequences at the aggregate level (Araas & Adams, 2008; Martens et al., 2004). It must be noted that alcohol-related consequences at the event level were endorsed at low rates in the current study which may have limited the power to detect an effect if there was one, and future research examining event-level consequences over a longer period of time is warranted.

Changes in Drinking During the COVID-19 Pandemic

Consideration of how typical harm reduction strategy use may have been altered as a result of changes in typical drinking behavior during the COVID-19 pandemic is warranted. Data collection for the present study occurred after social distancing restrictions were lifted in the southeastern state where the study was conducted. Although many businesses including restaurants, bars, and clubs reopened during the time of data collection, many university classes remained online. Online classes likely reduced the frequency of in-person interactions among the college student sample. Although fewer in-person interactions could reasonably impact opportunities to consume alcohol in social settings, especially among those who were under the legal drinking age, 46% of participants in the current study reported drinking at least somewhat *more* in terms of quantity and 54% reported drinking at least somewhat *more* often. Although this is consistent with recent literature showing increased rates of drinking during the COVID-19 pandemic among adults (Patrick et al., 2022), other research suggests that in the early stages of the pandemic college students reported *decreased* rates of drinking (Jackson et al., 2021; Jaffe et al., 2021). This may be due to changes in drinking context early in the pandemic (i.e., less opportunity to drink in clubs or with friends during quarantine), but it appears this was less of a trend in the current study due to the timeframe of data collection which occurred later in the pandemic after quarantine restrictions lifted. Considering drinking contexts, 41% of the sample reported drinking at home *more* often than before the pandemic, but 40% of the sample reported drinking at friends' homes more often than before the pandemic, and 49% reported drinking at bars/clubs more often than before the pandemic. Additionally, the majority of the sample (58%) reported drinking *alone* at least somewhat *less* often than before which suggests that the sample actually decreased, rather than increased, their solitary alcohol use during the pandemic. Given that many harm reduction strategies are most applicable in social drinking contexts (e.g., make sure that you go home with a friend, know where your drink has been at all times), it seems unlikely that there were significant decreases in post-pandemic strategy use given the reported increases in drinking in social contexts.

Clinical Implications

Although the hypothesis of a significant yet modest association was not supported, it is promising that those who intend to drink safely usually do. Increasing intentions to drink safely can be easily incorporated into drinking prevention and intervention efforts. Many prevention and intervention programs increase awareness of harm reduction strategies by providing a list of strategies, but this may be insufficient for increasing strategy use among those who are not motivated to drink in a safer manner. Perhaps those who are not motivated or invested in purposely drinking safer do not see the value or usefulness of using harm reduction strategies. Providing psychoeducation on the purpose and value of using harm reduction strategies may increase intention to use the strategies, thereby increasing actual strategy use and decreasing alcohol related consequences. When providing psychoeducation, it may be useful to emphasize that the strategies are intended to reduce alcohol related consequences, oppose to encouraging abstinence, since some individuals have the goal of drinking heavily. Previous literature has found that strategies aiming to limit alcohol use are endorsed at lower rates than those that aim to change the manner of drinking (e.g., “Avoid drinking games”) or avoid serious consequences (e.g., “Know where your drink has been at all times”) (Fairlie et al., 2021), which highlights the importance of considering alternative outcomes when encouraging college students to drink safely (e.g., harm reduction vs abstinence).

Considering other perceived barriers to harm reduction strategy use is equally important. Evidence from a qualitative study examining college students perceived "pros" and "cons" of using harm reduction strategies found that reasons for choosing not to use strategies were related to goal conflict (e.g., planning on drinking heavily), perceived ineffectiveness, difficulty of implementation, and negative peer/social repercussions of using strategies (Bravo et al., 2018). This suggests that some strategies may not be used because they conflict with social goals, such as avoiding drinking games and leaving the bar/party at a predetermined time. However, the likelihood of following through with such strategies in the current study was relatively high (ORs: 11-21). Given the influence of social pressures on behavior, especially among young adults, it is both promising and surprising that strategies that may conflict with social goals are still typically used when planned. There are several potential explanations. Perhaps safe drinking goals are prioritized above social goals. More likely, however, perhaps social goals are met in other ways during the drinking event. For example, instead of playing drinking games, social connectedness may occur through other facilitators that take commonly take place at drinking venues such as dancing. Additionally, findings from interventions providing personalized normative feedback for harm reduction strategy use suggests that those who think their peers use strategies are more likely to use them too (Leavens et al., 2020). Moreover, personalized normative feedback interventions have shown to be effective in changing the college student drinker's *intention* to regulate drinking by comparing their own drinking behavior to that of their peers (Barnett et al., 2007; Larimer et al., 2007; Martens et al., 2013; Murphy et al., 2012). Considering the results of the current study along with these findings, prevention and intervention programs may increase intentions to use harm reduction strategies by 1) providing personalized normative feedback on both harm reduction strategy use and alcohol use behavior, and 2) addressing reasons for not wanting to use the strategies while framing the strategies as a way to drink safer oppose to abstinence or drinking less.

Limitations

The EMA study design allows for a better understanding of temporal relationships between intention to use harm reduction strategies and actual strategy use. However, the nonexperimental design prevents any causal inferences from being drawn. The data were based on self-report, and actual alcohol consumption was not independently verified by objective measures such as blood alcohol concentration obtained by transdermal alcohol sensors. Additionally, strategy use was not verified by collateral information or observation. There was somewhat limited within-person variability in intent and actual strategy use which calls for examination of these relationships in samples with differing level of experience with alcohol use and strategy use. Relatedly, examination of strategy use among those with and without alcohol use disorder who are actively trying to change their drinking is warranted. Consistent with previous literature, the current study assessed harm reduction strategy use using the PBSS-20, which is a list of commonly used harm reduction behaviors that has been well validated in college student samples. However, some individuals may use strategies not listed in the measure. Future research on harm reduction strategies in daily life would benefit from a fill-in-the-blank option to capture other strategies used to avoid alcohol related consequences. Working memory, set-shifting, and inhibition were assessed using computerized tasks that serve as proxy indicators for complex cognitive abilities that are not easily captured by laboratory performance measures. Although performance measures provide stronger indicators than self-report measures of EF, the measures reflect performance under ideal circumstances (one-on-one with test administrator in a quiet environment) and are administered in a "low-stakes" context without salient drinking-related rewards. The role of EF in safe drinking behaviors while pursuing rewarding aspects of alcohol use in the drinking environment may differ compared to circumstances where rewards are less salient (i.e., laboratory).

Conclusion

The current study adds to the existing literature by demonstrating the importance of considering the influential role of intention in the prediction of alcohol harm reduction strategy use and draw attention to the need for further investigation into the specific drinking contexts that impact follow through with strategy use in daily life. Findings from the current study suggest that those who plan to use strategies typically follow through regardless of individual differences in EF. Efforts to increase intention to drink safely can be incorporated into existing alcohol prevention and intervention programs, which would likely lead to increased use of harm reduction strategies and decreased alcohol-related consequences.

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APPENDIX A: SUPPLEMENTAL TABLES

Table A.1: Aim 1. Summary of Results for Intention Predicting Total Strategy Use without Covariates (full model)

	b	*SE*	*p*
Intercept	12.332	.376	<.001
Intent (between-person effect)	.708	.080	<.001
Intent (within-person effect)	.552	.067	<.001
Random Effects Variances	*Var*	χ^2	*p*
Intercept	6.438	314.715	<.001
Level-1, *e*	4.821	--	--

Note: *b* = unstandardized estimates; *SE* = standard error.

Table A.2: Aim 2a. Summary of Results for Intent X EF Tasks Predicting Total Strategy Use without Covariates (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	12.331	.378	<.001	12.293	.375	<.001	12.322	.369	<.001
Intent (between-person effect)	.709	.081	<.001	.702	.077	<.001	.721	.079	<.001
EF Variable	-.003	.061	.961	-.113	.010	.261	-.062	.038	.113
Intent (within-person effect)	.547	.072	<.001	.547	.058	<.001	.590	.089	<.001
Intent X EF Variable (interaction)	-.005	.021	.810	-.004	.017	.810	.011	.012	.369
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	6.571	312.674	<.001	6.466	318.397	<.001	6.390	312.711	<.001
Level-1, *e*	4.855	--	--	4.843	--	--	4.819	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function.

Table A.3: Aim 2a. Summary of Results for Intent X EF Tasks Predicting Total Strategy Use (full models with level-2 interaction)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	12.700	.531	<.001	12.593	.512	<.001	12.701	.497	<.001
Intent (between-person effect)	.699	.083	<.001	.604	.087	<.001	.710	.080	<.001
EF Variable	-.009	.059	.881	-.190	.092	.045	-.070	.046	.097
Intent X EF Variable (level-2 interaction)	.002	.010	.822	-.061	.024	.015	.006	.008	.446
Drink quantity	-.091	.075	.232	-.100	.073	.193	-.098	.072	.177
PA	.051	.059	.392	.051	.059	.384	.052	.060	.383
NA	.085	.093	.361	.086	.099	.388	.087	.101	.391
Intent (within-person effect)	.550	.066	<.001	.548	.055	<.001	.594	.080	<.001
Intent X EF Variable (cross-level interaction)	-.001	.019	.949	-.003	.016	.861	.012	.012	.296
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	6.511	299.818	<.001	5.952	291.132	<.001	6.293	297.496	<.001
Level-1, *e*	4.901	--	--	4.867	--	--	4.856	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table A.4: Aim 2b. Summary of Results for Intent Predicting Strategy Use Subgroups without Covariates (full models)

	Pre-Planning			*Modifying**		
	b	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.167	.220	<.001	6.159	.198	<.001
Intent (between-person effect)	.3330	.048	<.001	.367	.041	<.001
Intent (within-person effect)	.490	.060	<.001	.436	.119	<.001
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	2.187	315.544	<.001	1.626	173.883	<.001
Intent	--	--	--	.165	66.461	.001
Level-1, *e*	1.763	--	--	1.846	--	--

*Random effects model. Note: *b* = unstandardized estimates; *SE* = standard error.

Table A.5: Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Pre-Planning without Covariates (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.168	.220	<.001	6.153	.219	<.001	6.160	.216	<.001
Intent (between-person effect)	.332	.034	<.001	.331	.047	<.001	.341	.048	<.001
EF Variable	.003	.004	.929	-.041	.056	.464	-.040	.022	.082
Intent (within-person effect)	.495	.059	<.001	.458	.056	<.001	.471	.063	<.001
Intent X EF Variable (interaction)	.004	.012	.756	-.021	.019	.252	-.005	.005	.372
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	2.231	312.268	<.001	2.227	318.706	<.001	2.173	318.452	<.001
Level-1, *e*	1.777	--	--	1.766	--	--	1.766	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function.

Table A.6: Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Pre-Planning (full models with level-2 interaction)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.179	.303	<.001	6.152	.296	<.001	6.183	.286	<.001
Intent (between-person effect)	.334	.049	<.001	.303	.053	<.001	.341	.048	<.001
EF Variable	.0001	.033	.997	-.068	.053	.202	-.041	.048	.095
Intent X EF Variable (level-2 interaction)	.002	.006	.701	-.020	.014	.180	.002	.004	.712
Drink quantity	-.003	.043	.941	-.005	.044	.911	-.005	.044	.913
PA	.062	.044	.165	.062	.042	.145	.061	.044	.163
NA	-.003	.043	.946	-.001	.040	.979	-.004	.041	.921
Intent (within-person effect)	.482	.057	<.001	.447	.052	<.001	.461	.062	<.001
Intent X EF Variable (cross-level interaction)	.003	.012	.783	-.021	.019	.269	-.004	.005	.435
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	2.293	313.361	<.001	2.234	314.392	<.001	2.239	317.910	<.001
Level-1, *e*	1.775	--	--	1.765	--	--	1.766	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table A.7: Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Modifying without Covariates (full models)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.157	.199	<.001	6.129	.197	<.001	6.153	.196	<.001
Intent (between-person effect)	.367	.043	<.001	.357	.042	<.001	.373	.041	<.001
EF Variable	-.005	.034	.872	-.072	.054	.191	-.022	.021	.317
Intent (within-person effect)	.411	.127	.002	.342	.132	.012	.479	.156	.003
Intent X EF Variable (interaction)	-.019	.026	.480	-.106	.036	.005	.018	.025	.493
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	1.652	169.214	<.001	1.638	188.099	<.001	1.663	178.929	<.001
Intent	.129	62.873	.002	.203	74.347	<.001	.250	69.923	<.001
Level-1, *e*	1.886	--	--	1.771	--	--	1.777	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function.

Table A.8: Aim 2b. Summary of Results for Intent X EF Tasks Predicting Strategy Use Subgroups: Modifying (full models with level-2 interaction)

	N-Back Total Errors			Task Switching Total Errors			Go/No-Go Total Errors		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	6.512	.300	<.001	6.417	.291	<.001	6.509	.276	<.001
Intent (between-person effect)	.356	.044	<.001	.292	.046	<.001	.362	.040	<.001
EF Variable	-.009	.033	.792	-.120	.054	.029	-.028	.026	.275
Intent X EF Variable (level-2 interaction)	.0001	.006	.990	-.038	.014	.009	.004	.005	.481
Drink quantity	-.088	.046	.064	-.087	.058	.073	-.092	.045	.043
PA	.002	.047	.961	.007	.039	.853	.007	.045	.880
NA	.064	.075	.396	.053	.070	.453	.064	.075	.394
Intent (within-person effect)	.414	.104	<.001	.345	.124	.007	.476	.145	.002
Intent X EF Variable (cross-level interaction)	-.013	.022	.569	-.087	.035	.016	.016	.025	.513
Random Effects Variances	*Var*	χ^2	*p*	*Var*	χ^2	*p*	*Var*	χ^2	*p*
Intercept	1.567	148.284	<.001	1.392	162.943	<.001	1.553	152.891	<.001
Intent	.052	56.597	.009	.169	66.902	<.001	.164	61.984	.003
Level-1, *e*	1.976	--	--	1.794	--	--	1.846	--	--

Note: *b* = unstandardized estimates; *SE* = standard error; EF = Executive Function; PA = PANAS Positive Affect; NA = PANAS Negative Affect.

Table A.9: Descriptive Statistics for PBSS-20 EMA Items

PBSS-20 Item		Percent (Frequency)	Mean (SD)	ICC
1. Used a designated driver	Intent	74.6% (296/397)	.75 (.436)	--
	Behavior	55.4% (236/426)	.55 (.498)	.265
2. Determined not to exceed a set number of drinks	Intent	50.4% (200/397)	.50 (.501)	--
	Behavior	39.9% (170/426)	.40 (.490)	.416
3. Alternated alcoholic and nonalcoholic drinks	Intent	57.9% (230/397)	.58 (.494)	--
	Behavior	46.5% (198/426)	.46 (.499)	.357
4. Had a friend let you know when you've had enough to drink	Intent	58.4% (232/397)	.58 (.493)	--
	Behavior	34.1% (145/425)	.34 (.475)	.480
5. Avoided drinking games	Intent	40.1% (159/397)	.40 (.491)	--
	Behavior	61.3% (261/426)	.61 (.488)	.401
6. Left the bar/party at a predetermined time	Intent	36.9% (146/396)	.37 (.483)	--
	Behavior	31.0% (132/426)	.31 (.463)	.461
7. Made sure that you go home with a friend	Intent	82.1% (326/397)	.82 (.384)	--
	Behavior	67.1% (286/426)	.67 (.470)	.273
8. Knew where your drink had been at all times	Intent	93.7% (372/397)	.94 (.243)	--
	Behavior	86.4% (368/426)	.86 (.343)	.291
9. Stopped drinking at a predetermined time	Intent	40.6% (161/397)	.41 (.492)	--
	Behavior	35.0% (149/426)	.35 (.477)	.510
10. Drank water while drinking alcohol	Intent	70.5% (280/397)	.71 (.456)	--
	Behavior	58.5% (249/426)	.58 (.493)	.330
11. Put extra ice in your drink	Intent	25.9% (103/397)	.26 (.439)	--
	Behavior	28.6% (122/426)	.29 (.453)	.375
12. Avoided mixing different types of alcohol	Intent	47.9% (190/397)	.48 (.500)	--
	Behavior	50.9% (217/426)	.51 (.500)	.277
13. Drank slowly, rather than gulp or chug	Intent	59.4% (236/397)	.59 (.492)	--
	Behavior	63.1% (269/426)	.63 (.483)	.341
14. Avoided trying to keep up or out-drink others	Intent	59.9% (238/397)	.60 (.491)	--
	Behavior	66.9% (285/426)	.67 (.471)	.443
15. Refuse to ride in a car with someone who had been drinking	Intent	90.7% (360/397)	.91 (.291)	--
	Behavior	69.5% (296/426)	.69 (.461)	.343
16. Only went out with people you knew and trusted	Intent	90.9% (361/397)	.91 (.288)	--
	Behavior	81.9% (349/426)	.82 (.385)	.198
17. Avoided combining alcohol with marijuana	Intent	69.5% (276/397)	.70 (.461)	--
	Behavior	70.0% (298/426)	.70 (.459)	.500
18. Avoided "pre-gaming" (i.e., drinking before going out)	Intent	44.6% (177/397)	.45 (.498)	--
	Behavior	59.6% (254/426)	.60 (.491)	.353
19. Made sure you drank with people who could take care of you if you drank too much	Intent	89.9% (357/397)	.90 (.301)	--
	Behavior	85.9% (366/426)	.86 (.348)	.316
20. Ate before or during drinking	Intent	92.9% (369/397)	.93 (.256)	--
	Behavior	85.2% (363/426)	.85 (.355)	.216

Note: Intent items were worded to reflect future tense. ICC = Intraclass Correlations.

Table A.10: PBSS-20 Item Level Results: Intention Predicting Behavior

		Fixed Effects					Random Effects		
PBSS-20 Item	Effect	Coefficient	SE	*p*	OR	CI	Variance	χ^2	*p*
1. Used a designated driver	Intercept	-1.268	.504	.016	.281	(.102,.779)	.482	45.253	.299
	Predictor	2.143	.552	<.001	8.528	(2.821,25.777)	-	-	-
2. Determined not to exceed a set number of drinks	Intercept	-1.714	.482	<.001	.180	(.068,.477)	.696	45.398	.293
	Predictor	2.166	.623	<.001	8.720	(2.502,30.398)	-	-	-
3. Alternated alcoholic and nonalcoholic drinks	Intercept	-3.411	.772	<.001	.033	(.007,.157)	.681	36.013	>.500
	Predictor	4.087	.840	<.001	59.579	(11.079,320.383)	-	-	-
4. Had a friend let you know when you've had enough to drink	Intercept	-3.640	1.011	<.001	.026	(.003,.203)	2.354	56.965	.040
	Predictor	3.967	1.082	<.001	52.838	(6.046,461.754)	-	-	-
5. Avoided drinking games	Intercept	-.831	.398	.043	.436	(.195,.972)	.443	60.133	.027
	Predictor	2.461	.533	<.001	11.715	(4.028,34.072)	-	-	-
6. Left the bar/party at a predetermined time*	Intercept	-2.601	.453	<.001	.074	(.030,.186)	.868	10.334	.066
	Predictor	3.051	.692	<.001	21.130	(5.217,85.572)	3.563	13.474	.019
7. Made sure that you go home with a friend	Intercept	-.346	.585	.557	.707	(.217,2.306)	1.441	62.483	.017
	Predictor	1.474	.688	.036	4.367	(1.100,17.333)	-	-	-
8. Knew where your drink had been at all times	Intercept	-1.149	.565	.049	.317	(.101,.992)	1.905	38.039	>.500
	Predictor	3.819	.675	<.001	45.537	(11.791,175.861)	-	-	-
9. Stopped drinking at a predetermined time	Intercept	-1.949	.395	<.001	.142	(.064,.316)	.238	44.002	.345
	Predictor	2.635	.548	<.001	13.939	(4.654,41.745)	-	-	-
10. Drank water while drinking alcohol	Intercept	-1.551	.376	<.001	.212	(.099,.453)	.001	36.477	>.500
	Predictor	2.836	.513	<.001	17.041	(6.097,47.635)	-	-	-

Table A.10 (Continued)

PBSS-20 Item	Effect	Coefficient	SE	*p*	OR	CI	Variance	χ^2	*p*
		Fixed Effects					Random Effects		
11. Put extra ice in your drink	Intercept	-1.694	.385	<.001	.184	(.084,.400)	1.176	50.730	.142
	Predictor	2.088	.578	<.001	8.069	(2.535,25.682)	-	-	-
12. Avoided mixing different types of alcohol*	Intercept	-1.538	.516	.005	.215	(.076,0609)	2.631	26.713	.001
	Predictor	2.330	.649	<.001	10.279	(2.771,38.125)	4.654	17.793	.023
13. Drank slowly, rather than gulp or chug*	Intercept	-1.033	.356	.006	.356	(.173,.731)	.835	10.241	.036
	Predictor	2.677	.663	<.001	14.544	(3.815,55.448)	5.357	14.831	.005
14. Avoided trying to keep up or out-drink others	Intercept	-.493	.570	.393	.611	(.193,1.933)	1.607	62.338	.017
	Predictor	1.890	.664	.006	6.621	(1.750,25.054)	-	-	-
15. Refuse to ride in a car with someone who had been drinking*	Intercept	-.849	.951	.378	.428	(.063,2.925)	6.913	8.022	.090
	Predictor	2.219	1.153	.061	9.198	(.896,94.413)	16.388	9.707	.045
16. Only went out with people you knew and trusted*	Intercept	-1.140	.523	.035	.320	(.111,.920)	1.044	6.010	.259
	Predictor	3.285	.750	<.001	26.713	(5.867,121.628)	4.185	16.130	.007
17. Avoided combining alcohol with marijuana*	Intercept	-.802	.509	.123	.449	(.160,1.254)	1.624	17.824	.013
	Predictor	3.018	.723	<.001	20.448	(4.746,88.094)	3.594	15.375	.031
18. Avoided "pre-gaming" (i.e., drinking before going out)*	Intercept	-.772	.392	.056	.462	(.210,1.020)	1.528	9.978	.189
	Predictor	2.116	.591	<.001	8.299	(2.515,27.385)	3.146	14.322	.045
19. Made sure you drank with people who could take care of you if you drank too much	Intercept	-.698	.539	.203	.498	(.167,1.479)	.609	31.743	>.500
	Predictor	3.186	.607	<.001	24.198	(7.170,81.667)	-	-	-
20. Ate before or during drinking	Intercept	-.645	.498	.202	.525	(.192,1.434)	.389	32.894	>.500
	Predictor	2.178	.710	<.001	15.145	(3.657,62.722)	-	-	-

Note: *SE* = standard error; OR = odds ratio; CI = Confidence Interval. * = Random effects model. All models were run as unit-specific models with robust standard errors. Predictors are uncentered.