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I'm Tired and Feel Like Drinking: Viewing Alcohol Cues After Exerting Self-Control Increases Approach Motivation Among Individuals Lower in Alcohol Sensitivity

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Abstract

Exerting self-control depletes capacity for future self-control, which can promote greater alcohol use. However, certain populations may be more susceptible to these effects of depleted self-control capacity. For example, individuals with lower alcohol sensitivity (i.e., requiring more drinks to experience the effects of alcohol) are a high-risk group who are likely to engage in hazardous alcohol use and develop an alcohol use disorder. Those lower in alcohol sensitivity also exhibit heightened motivational reactivity in response to alcohol-related cues, which may be enhanced following exertion of self-control. However, whether drinkers lower in alcohol sensitivity are at higher risk for exhibiting greater motivations toward alcohol-related cues after exerting self-control is unclear. The current research examined the role of alcohol sensitivity in predicting approach motivation following exertion of self-control. It was expected drinkers exerting self-control would exhibit greater orientation toward rewarding cues, particularly after viewing alcohol-related cues. However, we predicted this pattern would be most prominent among drinkers lower in alcohol sensitivity. Experiment 1 supported these hypotheses, with lower alcohol sensitivity predicting greater approach motivation among drinkers required to exert self-control prior to viewing alcohol-related compared to neutral cues. Experiment 2 aimed to replicate these findings by assessing asymmetrical frontal cortical activation, an index of approach motivation. Drinkers with lower alcohol sensitivity exhibited greater relative left frontal cortical activation, consistent with approach motivation, while viewing alcohol-related cues following exertion of self-control. Results have implications for interventions aimed at identifying those at risk for greater alcohol motivations during states of mental exhaustion.

Keywords: alcohol sensitivity, self-control, approach motivation, frontal asymmetry, individual differences

I'm Tired and Feel Like Drinking: Viewing Alcohol Cues After Exerting Self-Control Increases Approach Motivation Among Individuals Lower in Alcohol Sensitivity

Self-control facilitates inhibition of excess alcohol consumption and reduces levels of alcohol-related risks (e.g., binge drinking, driving under the influence of alcohol; Costello, Anderson, & Stein, 2014; Gibson, Schreck, & Miller, 2004). However, the ability to engage in self-control is limited in capacity. Several studies have established that previous exertion of self-control reduces the success of subsequent self-control (Hagger, Wood, Stiff, & Chatzisarantis, 2010). For example, exerting self-control leads to greater acute alcohol consumption compared to when individuals do not exert self-control (Muraven, Collins, & Neinhaus; 2002; Otten et al., 2014). While there is recent debate concerning the robustness of self-control exertion effects (Friese, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2018), research suggests the likelihood of these effects may be related to individual differences (Job, Dweck, & Walton, 2010; Salmon et al., 2014). Among drinkers, alcohol sensitivity (e.g., the amount needed to experience the pharmacological effects of alcohol) is a predictor of risky alcohol use and the likelihood of developing an alcohol use disorder (AUD; Hu et al., 2005). Drinkers lower in alcohol sensitivity also exhibit greater motivational reactivity toward alcohol-related cues (Bartholow, Lust, & Tragesser, 2010). More generally, exerting self-control may enhance motivational reactivity toward any cues that an individual perceives as rewarding (Inzlicht & Schmeichel, 2012). This suggests the motivational reactivity to alcohol-related cues observed among low-sensitivity drinkers may be intensified after the exertion of self-control. Thus, the present research examines the interaction between exerting self-control and alcohol sensitivity in predicting levels of approach motivation in response to alcohol-related cues.

Self-Control

Self-control is the capacity to change one's own behavior and is used daily (e.g., delayed gratification, aligning with social norms) but is limited in capacity, so that excessive exertion of self-control is followed by reduced ability to regulate subsequent behavior across a range of domains (Baumeister, Heatherton, & Tice, 1994; Inzlicht, Schmeichel, & Macrae, 2014). In experiments where participants are presented with tasks or situations requiring either high or low levels of self-control (e.g., suppressing emotions, inhibiting automatic tendencies), those randomly assigned to exert more self-control show temporary deficits in working memory (Schmeichel & Zell, 2007), academic performance (Price & Yates, 2010), executive functioning (Gailliot & Baumeister, 2007), control of racial bias (Govorun & Payne, 2006), and inhibition of alcohol use (Muraven et al., 2002). The process model of self-control suggests that after engaging in prolonged self-control, motivation may be directed away from cues related to self-control and shifted toward rewarding cues (Inzlicht & Schmeichel, 2012; Inzlicht et al., 2014). In other words, motivation is shifted from "have-to" tasks toward "want-to" tasks, especially those that are immediately satisfying (Inzlicht et al., 2014). From this perspective, exerting self-control increases sensitivity toward rewarding cues and behaviors (i.e., approach motivation) and experimental evidence has been consistent with this hypothesized motivational shift toward reward following high versus low self-control exertion (Schmeichel, Harmon-Jones, & Harmon-Jones, 2010; Schmeichel, Crowell, & Harmon-Jones, 2015).

In studies of high-risk drinking, self-control capacity is a consistent protective factor against excess consumption and risky behavior associated with drinking such as driving under the influence of alcohol (Costello, Anderson, & Stein, 2014; Gibson, Schreck, & Miller, 2004). But in line with the broader self-control literature, experimental studies have shown greater acute consumption of alcohol for participants randomly assigned to tasks requiring more versus less exertion of control (Muraven et al., 2002; Otten et al., 2014). Similarly, individuals who experience greater demands on self-control over the course of a day also are more likely to exceed self-imposed expected drinking limits (Muraven, Collins, Shiffman, & Paty, 2005), suggesting acute self-control exertion in the lab may mimic daily exertion of self-control. According to the process model, greater alcohol consumption might be the result of shifts in motivation away from cues for controlling behavior and toward cues for rewarding behavior (e.g., alcohol-related cues; Inzlicht & Schmeichel, 2012). Alcohol is a motivational incentive that is personally relevant among drinkers, indicated by enhanced neurophysiological indices of motivation while viewing alcohol, compared to neutral, cues (Bartholow et al., 2010).

Recent critical examinations of the collected evidence for acute self-control depletion debates the genuineness of self-control exertion effects (see Friese et al., 2018). However, research suggests these effects, such as shifts in motivation toward rewarding cues, may be influenced by individual differences (Job et al., 2010; Salmon et al., 2014; Schmeichel et al., 2015). Relatedly, neurophysiological indices of motivation while viewing alcohol-related cues have been studied as a function of individual difference factors including AUDs and alcohol sensitivity (Bartholow et al., 2010; Namkoong, Lee, Lee, Lee, & An, 2004). However, research has yet to examine how acute factors (e.g., exerting self-control) may interact with individual differences (e.g., alcohol sensitivity) to impact motivation toward alcohol-related cues.

Alcohol Sensitivity

Individuals differ in their experiences of acute alcohol consumption (Sher, Wood, Richardson, & Jackson, 2005) and this variability is known as alcohol sensitivity, or the intensity of response to alcohol consumption (Schuckit, 1994). Low sensitivity to alcohol (i.e., requiring more drinks to experience the pharmacological effects of alcohol) is a risk factor for greater alcohol use and the development of an AUD (Hu et al., 2005; Schuckit, Smith, Anderson, & Brown, 2004). Alcohol sensitivity is a validated moderator of motivational responses to alcohol-related cues. Individuals lower in alcohol sensitivity exhibit greater motivational salience toward alcohol-related cues, as indicated by heightened amplitudes of the P3 event-related potential, compared to those higher in alcohol sensitivity (Bartholow, Henry, & Lust, 2007; Bartholow et al., 2010). These findings also parallel individuals with an AUD demonstrating greater motivational salience toward alcohol-related cues compared to social drinkers (Namkoong et al., 2004). However, whether exerting self-control exaggerates these already heightened motivational responses toward alcohol-related cues is unknown. Further, individuals lower in alcohol sensitivity show deficits in regulating automatic responses to alcohol-related stimuli, demonstrating difficulty inhibiting behavior related to alcohol-related cues (Fleming & Bartholow, 2014), suggesting alcohol sensitivity may identify those at-risk of impaired control of alcohol-related behavior. While alcohol sensitivity is a moderator of motivational reactivity to alcohol cues (i.e., P3; Bartholow et al., 2007; Bartholow et al., 2010), research has not examined alcohol sensitivity's role in predicting motivational reactivity toward alcohol-related cues after exerting self-control.

Present Research

The current research examines alcohol sensitivity as a moderator of motivational responses (i.e., approach motivation) to alcohol-related cues after exerting self-control across 2 experiments. Consistent with prior work, we predicted (H1) approach motivation would be greater among individuals required to exert excessive self-control compared to those not required to exert excessive self-control (Schmeichel et al., 2010). It was also expected that (H2) approach motivation would be greater after viewing alcohol, compared to non-alcohol, cues, consistent with previous research (Bartholow et al., 2010). However, it was expected that these factors would interact such that (H3) approach motivation would be greater after viewing alcohol-related cues among drinkers exerting excessive self-control compared to those not required to exert self-control. Finally, it was hypothesized that (H4) alcohol sensitivity would interact with exertion of self-control in predicting approach motivation toward alcohol-related cues. Specifically, we expected lower alcohol sensitivity would predict greater approach toward alcohol-related cues following exertion of self-control. Experiment 1 tested these hypotheses using self-report methods, assessing general approach motivation using the behavioral activation system (BAS) scale developed by Carver and White (1994), whereas Experiment 2 utilized established neurophysiological measures of approach motivation (i.e., asymmetrical frontal cortical activation; Schmeichel et al., 2015).

Experiment 1

We aimed to extend past research examining motivational reactivity among drinkers with varying levels of alcohol sensitivity. Whereas past research has found individuals lower in alcohol sensitivity exhibit exaggerated motivational responses after exposure to alcohol-related cues (Bartholow et al., 2007; Bartholow et al. 2010), whether these responses generalize to other measures of motivation (e.g., approach motivation) and are affected by exertion of self-control have not been tested. While exerting self-control has been well-established to increase alcohol consumption (Muraven et al., 2002; Otten et al., 2014), self-control's impact on alcohol-related motivation is unclear. Thus, Experiment 1 sought to establish whether viewing alcohol-related cues promotes approach motivation among drinkers lower in alcohol sensitivity required to exert self-control.

Method

Participants. One-hundred and thirty undergraduate students reporting active alcohol use (i.e., at least 1 alcoholic drink in the past 30 days) were recruited from a Midwestern university to take part in a study described as opinions of advertisements and social issues. Participants were compensated with research credit for participating in the experiment. Five participants were excluded from analyses for failure to follow instructions ($n = 3$) and computer error ($n = 2$), resulting in a total sample of 125 participants (71.2% female) ranging from 18 to 37 years of age ($M_{age} = 23.93$, $SD_{age} = 7.42$). Participants self-reported their race/ethnicity as Caucasian/White (52%), African American/Black (26.4%), Multiracial (8%), Latino(a) (4%), Asian/Pacific Islander (3.2%), and less than 7% identified as another race. All participants were compensated with course credit. Sample size was determined a priori and analyses were conducted after data collection.

Materials and procedure. Upon arrival to the lab, participants were seated, provided informed consent, and were then directed to complete online self-report measures of alcohol and caffeine habits using Qualtrics (Provo, UT). Participants completed the alcohol use and experiences questionnaire (AUEQ) adapted from Bartholow et al. (2010) which defines a standard drink (e.g., 12-ounce can or bottle of beer) and includes items about recent alcohol consumption (e.g., the past 2 weeks, 30 days, etc.). Only participants indicating drinking at least 1 alcohol drink in the past 30 days were eligible to complete the study. Participants then completed a measure of alcohol sensitivity adapted from Fleming et al. (2016). Participants were presented with 15 items describing the effects of alcohol ($\alpha = .92$) and were asked to report whether they experienced each effect. If participants reported experiencing an effect of alcohol, they were then asked to estimate the minimum (for lighter drinking effects; e.g., "Do you ever feel more relaxed after drinking alcohol?") or maximum (for heavier drinking effects; e.g., "Do you ever pass out after drinking alcohol?") amount of drinks needed to feel the effect (using standard drink estimates adapted from the AUEQ). Amount of drinks needed to experience the effects were averaged across all items such that higher values indicated lower sensitivity to the effects of alcohol.

Eligible participants then completed a vowel search task on a computer using 2 scanned pages from an advanced graduate statistics textbook (adapted from Baumeister, Bratslavsky, Muraven, & Tice, 1998). For the first page, participants were instructed to click on every instance of the vowel *e* that appeared. Following completion of the first page, participants who were randomly assigned to not exert excessive self-control completed the same task again using the second scanned page. However, participants assigned to exert excessive self-control were given additional instructions prior to the second page, being instructed to only click an *e* when it is not adjacent to another vowel or one letter away from a vowel (e.g., the participant could not click the *e* in the word *vowel*; Baumeister et al., 1998). These additional instructions required participants to inhibit automatic responses learned from the first page (i.e., click on every instance of the letter *e*), engaging additional self-control. In addition, for those exerting excessive self-control, the scanned image of the second page was lightened to make it more difficult for the participant to read (see Baumeister et al., 1998). After the vowel search task, participants completed a 4-item (α = .84) manipulation check assessing task difficulty, rating items from 1 (*Strongly disagree*) to 6 (*Strongly agree*). Example items included, "The previous task was challenging," and, "The previous task was difficult." Items were averaged, such that higher values represented greater task difficulty.

Participants were then instructed to rate advertisements using stimuli adapted from Stepanova et al. (2012). Participants were randomly presented 6 alcoholic or non-alcoholic drink advertisements. Non-alcoholic drink advertisements were included as comparison stimuli since both are similarly consumed beverages (i.e., drinking), but only alcoholic beverages are associated with pharmacological effects of intoxication. Further, no advertisements contained people (Weinberg & Hajack, 2010). For each advertisement, participants were asked to rate the images using 7-items (α = .943) from 1 (*Strongly disagree*) to 6 (*Strongly agree*). Example items included, "This ad was pleasing," and "It is likely that I would purchase this product." Items were averaged within each advertisement and means were then averaged across all advertisements to create a single index of advertisement appeal. Finally, participants then completed a measure of approach motivation adapted from the BAS scale (Carver & White, 1994). Thirteen items (α = .90) were rated on a 4-point scale, from 1 (*Very false for me*) to 4 (*Very true for me*). Participants were told to answer the questions regarding how they feel in the current moment, reflecting prior research (Schmeichel et al., 2010). Example items included, "I go out of my way to get things I want," and "I crave excitement and new sensations." Items were averaged such that higher values indicated greater approach motivation or greater sensitivity to rewarding cues. Procedures were approved by the university's institutional review board.

Results

Manipulation and stimuli checks. Table 1 shows descriptive statistics regarding sex, alcohol sensitivity, and drinking history. An independent samples *t*-test indicated participants required to exert excessive self-control reported greater task difficulty ($n = 63$; $M = 3.04$, $SD = 1.07$) compared to those not required to exert excessive self-control ($n = 62$; $M = 2.02$, $SD = 1.26$), $t(123) = 4.87$, $p < .001$, $d = 0.87$, suggesting the self-control manipulation was effective.

To examine whether advertisements were equally appealing across conditions, advertisement ratings were analyzed using a 2 (self-control: no exertion, exertion) X 2 (advertisement: non-alcohol, alcohol) factorial analysis of variance (ANOVA). Results indicated no main effect of self-control, $F(1,121) = 1.01$, $p = .317$, or advertisement conditions, $F(1,121) = 1.07$, $p = .304$, on advertisement ratings. Further, no significant interaction emerged between factors, $F(1,121) = 2.04$, $p = .156$, suggesting advertisements were equally appealing regardless of condition.

INSERT TABLE 1 HERE

Approach motivation. State approach motivation was analyzed using a 2 (self-control: no exertion, exertion) X 2 (advertisement: non-alcohol, alcohol) factorial ANOVA. There was no main effect for self-control, $F(1,121) = 1.04$, $p = .311$, inconsistent with hypothesis 1. Supporting hypothesis 2, there was a main effect of advertisement on approach motivation, $F(1,121) = 23.26$, $p < .001$, $\eta_p^2 = .161$, suggesting alcohol advertisements ($M = 2.91$, $SD = 0.58$) elicited more orientation toward rewarding behaviors compared to non-alcohol advertisements ($M = 2.42$, $SD = 0.57$). The self-control condition X advertisement type interaction was also significant, $F(1,121) = 5.65$, $p = .019$, $\eta_p^2 = .045$. No significant differences emerged between participants who exerted ($n = 29$; $M = 2.34$, $SD = 0.56$) or did not exert ($n = 31$; $M = 2.48$, $SD = 0.59$) self-control before viewing non-alcohol advertisements, $F(1,121) = 0.89$, $p = .347$. However, those who viewed alcohol advertisements who exerted self-control reported greater approach motivation ($n = 34$; $M = 3.08$, $SD = 0.45$) compared to those who did not exert self-control ($n = 31$; $M = 2.73$, $SD = 0.66$), $F(1,121) = 6.00$, $p = .016$, $\eta_p^2 = .047$, consistent with hypothesis 3 (see Figure 1).

INSERT FIGURE 1 HERE

Alcohol sensitivity. The PROCESS macro for SPSS 25 (Hayes, 2012) was used to examine the interaction among conditions and alcohol sensitivity on approach motivation. Consistent with hypothesis 4, a significant self-control condition X advertisement type X alcohol sensitivity interaction emerged, $F(1,117) = 4.77$, $p = .031$, $\Delta R^2 = .028$, 95% CI [0.0531, 1.0841]. Conditional effects revealed the interaction between self-control conditions and alcohol sensitivity was significant among participants who viewed alcohol advertisements. $F(1,117) = 10.98$, $p = .001$, $b = 0.55$. Lower alcohol sensitivity predicted greater approach motivation approach among those assigned to exert self-control, $t(117) = 4.56$, $p < .001$, $b = 0.58$, 95% CI [0.3282, 0.8322]. No relation was present between alcohol sensitivity and approach motivation among those not required to exert self-control, $t(117) = 0.26$, $p = .793$, $b = 0.03$, 95% CI [-0.1844, 0.2409] (see Figure 2). No interaction between self-control conditions and alcohol sensitivity was present among those who viewed non-alcohol advertisements, $F(1,117) = 0.01$, $p = .934$, $b = -0.02$.

INSERT FIGURE 2 HERE

Discussion

Results suggest approach motivation is greater after viewing alcohol-related cues compared to non-alcohol cues, which is consistent with research demonstrating alcohol-related cues elicit greater indices related to approach motivation compared to neutral cues (Bartholow et al., 2010). However, this study found no differences in levels of approach motivation between those exerting and not exerting excessive self-control, which is inconsistent with prior findings (Schmeichel et al., 2010). Although, Schmeichel et al. (2015) suggest shifts toward approach motivation may depend on other situational and individual-difference factors. Consistent with this, exerting self-control did elicit greater approach motivation, but only after viewing alcohol advertisements. Moreover, alcohol sensitivity was related to greater approach motivation following exposure to alcohol cues, but not non-alcohol cues, demonstrating individual differences may interact with situational factors to drive approach motivation. (Schmeichel et al., 2015). Further, the three-way interaction indicated that this relation was strongest among individuals required to exert excessive self-control, such that those lower in alcohol sensitivity were more likely to orient motivation toward rewarding cues when mentally exhausted.

Limitations. Although these results provide novel contributions and suggest important implications to the literatures on self-control, alcohol-related cues, and alcohol sensitivity, there are limitations in the current experiment. Research suggests exerting self-control may orient motivation and attention toward personally relevant or rewarding cues, promoting approach motivation (Inzlicht & Schmeichel, 2012). While the sample consisted of active drinkers, the extent to which alcohol advertisements were perceived as more rewarding than non-alcohol advertisements is unclear. There was also not a non-drinker comparison group in the present experiment and the advertisements used likely did not reflect the wide variety of preferences drinkers may find personally relevant. Further, advertisements were rated equally appealing across conditions, suggesting alcohol images may not have been perceived as more rewarding compared to neutral images. However, we did not assess personal or motivational relevance of the advertisements.

The ecological validity is also limited due to the manipulation of self-control (vowel search task) and exposure to advertisements (structured rating task). While participants are likely to experience impaired inhibition after exceeding daily self-control capacity limits (Muraven et al., 2005), the manipulation may not generalize to typical states of impaired self-control. Further, time spent on the self-control manipulation may have been a confounding variable. Since the vowel task was not time restricted, participants given additional instructions to promote excessive self-control exertion likely spent more time completing the task compared to controls. Thus, whether results are solely due to self-control exertion is unclear. Exposure to alcohol-related cues in the advertisement rating task also may not generalize to typical viewing of advertisements (e.g., a billboard on the highway or television commercial). The use of a self-reported measure of approach motivation may also limit the generalizability of the study due to social desirability concerns (Greenwald, Poehlman, Uhlmann, & Banaji, 2009). Further, the measure of approach motivation assessed general motivations toward rewarding behaviors not directly related to alcohol and was not assessed during exposure to alcohol-related cues. Thus, while our findings suggest greater motivations to engage in rewarding behaviors may occur following exposure to alcohol advertisements after exerting self-control, whether this approach motivation is alcohol-specific remains unclear.

Experiment 2

Experiment 2 utilized neurophysiological measures of approach motivation to assess motivational reactivity toward alcohol-related cues among drinkers lower in alcohol sensitivity required to exert self-control. Functional differences in left versus right hemispheres of the prefrontal cortex (PFC) are well established as indicators of motivation (see Harmon-Jones, Gable, & Peterson, 2010). Research using electroencephalography (EEG) has utilized the alpha frequency band, a measure of cortical inactivation, to examine asymmetrical activation of the PFC (Tomarken, Davidson, Wheeler, & Doss, 1992). Greater left over right activation of the PFC is associated with greater approach motivation, as assessed by the BAS used in Experiment 1 (Harmon-Jones & Allen, 1997), whereas greater right over left activation is associated with lower approach motivation or greater avoidance motivation (Sutton & Davidson, 1997; Amodio, Master, Yee, & Taylor, 2008). In line with self-report findings using the BAS, increased left over right activation of the PFC, consistent with approach motivation, has been observed following exertion of self-control. (Schmeichel et al., 2015). However, these shifts toward approach motivation as assessed by cortical asymmetries may depend on individual differences, such as alcohol sensitivity (Schmeichel et al., 2015). Thus, Experiment 2 aimed to replicate findings from Experiment 1 through assessing neurophysiological measures of approach motivation (i.e., asymmetrical PFC activation) while participants viewed advertisements opposed to after cue exposure as in Experiment 1. Experiment 2 also utilized an alternative, time restricted task to manipulate exertion of self-control to reflect the variety of self-control manipulations commonly reported in the literature (Hagger et al., 2016), examine the generalizability of results from Experiment 1, and to remove time to task completion as a potential confound.

Method

Participants. Seventy-two participants were recruited to take part in a study described as opinions of advertisements and social issues. Participants were recruited through a Midwestern university and from ResearchMatch.org and were compensated with $20 or research credit for participating in the experiment. Similar to Experiment 1, participants were active alcohol drinkers (i.e., at least 1 alcoholic drink in the past 30 days). Participants were also right-handed, had no history of a traumatic brain injury, were not currently taking any psychotropic medications, and had normal or corrected vision. One participant was excluded from analyses due to computer error, resulting in a total sample of 71 participants (71.8% female) ranging from 18 to 29 years of age (M_{age} = 22.66, SD_{age} = 2.94). Participants self-reported their race/ethnicity as Caucasian/White (67.6%), African American/Black (11.3%), Asian/Pacific Islander (8.5%), Latino(a) (7.0%), and Multiracial (5.6%). Sample size was determined a priori and analyses were conducted after data collection.

Materials and procedure. Participants first completed an online prescreening questionnaire prior to the lab session to determine eligibility (e.g., handedness, normal or corrected vision, etc.). Eligible participants then completed an online questionnaire using Qualtrics (Provo, UT) measuring alcohol sensitivity and demographics. Sensitivity to the effects of alcohol consumption was assessed using the alcohol sensitivity questionnaire developed by Fleming and colleagues (2016), identical to Experiment 1 (α = .91). Participants then made an appointment for the lab portion of the study via an online calendar (i.e., Doodle). Upon arrival to the lab, participants had an EEG cap attached to their scalp for continuous measure of EEG data during the study. Following setup, participants completed a 4-minute baseline period with eyes open in a sitting position and then were randomly assigned to self-control condition (not exerted, exerted). Participants completed a free writing task where they were instructed to write a short story describing a recent trip they had taken (adapted from Schmeichel, 2007). Participants required to exert excessive self-control were instructed to not use the letters *a* or *n* during the task, previously established to increase task difficulty (Schmeichel, 2007). This restriction on writing requires participants to exert self-control by inhibiting the use of two frequent letters. Participants not required to exert self-control completed the writing task with no restriction of letters. Participants were instructed to write continuously until the researcher instructed them to stop after 6 minutes of writing. Those required to exert self-control were given the following instructions prior to the task (adapted from Lewandowski, Ciarocco, & Pettanato, 2012):

> "Please write a story about a recent trip you have taken. It may be a trip to the store, to another state, or to another country – wherever! Please write until the researcher asks you

to stop. Very important! Please do not use the letters A or N anywhere in your story (For example, use 'plus' instead of 'and')."

Participants not required to exert self-control were given the following instructions:

"Please write a story about a recent trip you have taken. It may be a trip to the store, to another state, or to another country – wherever! Please write until the researcher asks you to stop."

Participants then completed the alertness subscale of the Multidimensional Mood Questionnaire (Steyer, Schwenkmezger, Notz, & Eid, 1997) to assess the effectiveness of the self-control manipulation. This measure replaced the manipulation check used in Experiment 1, to better align with prior research assessing the effectiveness of self-control manipulations (Geisler, Kleinfeldt, & Kubiak, 2016; Webb & Sheeran, 2003). Participants indicated how they felt at the current moment for 10 items (e.g., rested, tired, alert; $\alpha = .89$) from 1 (*Not at all*) to 5 (*Very much so*). Scores were averaged together, such that lower values represented more exhaustion. Participants then completed an advertisement viewing and rating task adapted from Schmeichel and colleagues (2015) in which they were presented a set of 60 images consisting of 30 alcoholic beverage advertisements and 30 non-alcoholic beverage advertisements (e.g., water). Inclusion criteria for advertisements were identical to Experiment 1. Advertisements were pretested to ensure images were equally appealing across conditions. While images used in Experiment 1 were included, additional images were added so participants did not view the same advertisement more than once. Unlike Experiment 1, participants viewed both alcohol and non-alcohol images, similar to previous methodology used while assessing neurophysiological indices of motivation during alcohol cue exposure (Bartholow et al., 2010) and after exertion of self-control (Schmeichel et al., 2015). Images were presented in randomized order. During the task, a fixation cross appeared on the screen for 2-3s (randomly determined), followed by the advertisement for 6s. After the advertisement was displayed, participants were asked to rate the advertisement (e.g., “How appealing was this advertisement?”) using a 6-point scale ranging from 1 (*Not at all*) to 6 (*Very*). The question remained on the screen until the participant responded, followed by an inter-trial interval between 8-12s (randomly determined) and another fixation cross, image, and rating. Finally, participants were debriefed, compensated, and dismissed. All procedures were approved by the university’s institutional review board.

Electrophysiological recording. EEG recordings were acquired using a 16-channel amplifier and data acquisition software (ActiveTwo System, BioSemi, Amsterdam, The Netherlands). Sixteen Ag/AgCl active electrodes were placed on the scalp according to the 10–20 International System (O1, Oz, O2, P3, Pz, P4, T7, T8, C3, Cz, C4, F3, Fz, F4, Fp1, Fp2) using a nylon electrode cap (BioSemi). Vertical electrooculogram (VEOG) and horizontal electrooculogram (HEOG) were recorded by attaching electrodes (UltraFlat Active electrodes, BioSemi) below the left eye and outside of the right eye. Two electrodes were attached to the left and right mastoids (M1/2) and an additional electrode was placed on the left side of the nose. All voltages were digitized with a sample rate of 512 Hz and recorded relative to a common mode voltage derived from the Active Two’s Common Mode Sense/Driven Right Leg feedback loop. All scalp electrodes were referenced to an averaged mastoid reference and an independent components analysis was conducted on all scalp electrode data utilizing recorded VEOG and HEOG signals to correct for ocular artifacts using BrainVision Analyzer 2 (Brain Vision LLC; Morrisville, NC). All segments were baseline-corrected by subtracting the average voltage during the 100ms before stimulus presentation. Segments were rejected based on a maximum allowed voltage gradient of 50 μV and a maximum absolute difference threshold of 70 μV. For the advertisement viewing task, data were filtered using a 1-15 Hz band-pass filter and segmented into 2s epochs after presentation of each image for the duration of the image (6s). A Fast Fourier Transformation was then applied to each remaining segment after artifact rejection to determine the power of the alpha frequency band (8-13 Hz) and was then averaged over all segments within each stimuli type during the advertisement viewing task (non-alcohol, alcohol). Values at all sites were log transformed to reduce positive skew (Harmon-Jones & Allen, 1998). Hemispheric asymmetry was computed by subtracting left alpha power from right alpha power (F4-F3) such that positive values represent greater left frontal cortical activation (i.e., greater approach motivation) and negative values indicate greater right frontal cortical activation (i.e., lower approach motivation; Harmon-Jones & Allen, 1997). Individual hemispheric asymmetry scores were also computed for each 6s image presentation to compute internal reliability (see Towers & Allen, 2009). Hemispheric asymmetry while viewing non-alcohol (Cronbach's α = .91) and alcohol (Cronbach's α = .89) images had good internal reliability across trials.

Results

Manipulation and stimuli checks. Table 2 shows descriptive statistics regarding sex, alcohol sensitivity, and drinking history. An independent samples *t*-test indicated participants required to exert excessive self-control reported feeling more exhausted ($n = 35$; $M = 2.72$, $SD = 0.92$) compared to those not required to exert self-control ($n = 36$; $M = 3.60$, $SD = 1.19$), $t(69) = 3.49$, $p = .001$, $d = 0.83$, suggesting the self-control manipulation was effective. To examine whether advertisements were equally appealing across conditions, advertisement ratings were analyzed using a 2 (self-control: no exertion, exertion) X 2 (advertisement: non-alcohol, alcohol) mixed ANOVA, with the last factor repeated. Results indicated no main effect of self-control, $F(1,69) = 1.94$, $p = .168$, or advertisement conditions, $F(1,69) = 0.41$, $p = .524$, on advertisement ratings. Further, no significant interaction emerged between factors, $F(1,69) = 0.99$, $p = .321$, suggesting advertisements were equally appealing regardless of condition.

INSERT TABLE 2 HERE

Approach motivation. Frontal cortical asymmetry was analyzed using a 2 (self-control: no exertion, exertion) X 2 (advertisement: non-alcohol, alcohol) mixed ANOVA, with the last factor repeated. Results indicated no main effect of self-control, $F(1, 69) = 0.51$, $p = .476$, $\eta_p^2 = .007$, or advertisement, $F(1,69) = 0.002$, $p = .962$, $\eta_p^2 < .001$, on frontal cortical asymmetry, contrary to hypotheses 1 and 2. The interaction between self-control and advertisement condition was also not significant in affecting levels of frontal cortical asymmetry, $F(1,69) = 0.07$, $p = .796$, $\eta_p^2 = .001$, contrary to hypothesis 3.

Alcohol sensitivity. The MEMORE macro for SPSS 25 (Montoya & Hayes, 2017) was used to examine the interaction between self-control conditions, alcohol sensitivity, and advertisement type on frontal cortical asymmetries while viewing advertisements, with the last factor repeated. Consistent with hypothesis 4, the self-control condition X alcohol sensitivity X advertisement type interaction was significant in predicting asymmetrical frontal cortical activation, $t(67) = 2.99$, $p = .004$, $b = 0.09$, 95% CI [0.0301, 0.1511]. Conditional effects revealed the interaction between self-control conditions and alcohol sensitivity was significant in predicting approach motivation while viewing alcohol advertisements, $F(1,67) = 5.18$, $p = .026$, $b = 0.08$, 95% CI [0.0095, 0.1451]. Tests of simple slopes indicated lower alcohol sensitivity predicted greater left over right frontal cortical activation among participants instructed to exert self-control, $t(67) = 2.02$, $p = .047$, $b = 0.05$, 95% CI [0.0007, 0.0982]. Alcohol sensitivity did not predict frontal cortical asymmetry among those who did not exert self-control, $t(67) = -1.18$, $p = .242$, $b = -0.02$, 95% CI [-0.0750, 0.0192] (see Figure 3). The interaction between self-control conditions and alcohol sensitivity was not significant in predicting approach motivation while viewing neutral advertisements, p = .738.

INSERT FIGURE 3 HERE

Discussion

Results indicated approach motivation, as assessed by frontal cortical asymmetries, were not significantly different between those who exerted self-control and those who did not exert self-control. Further, requiring participants to exert self-control (or not) did not significantly interact with advertisement type (non-alcohol vs. alcohol) for levels of frontal cortical asymmetries, inconsistent with predictions. This finding suggests that exerting self-control may not promote approach motivation for all active drinkers as seen in Experiment 1, even if participants are viewing potentially emotionally relevant stimuli such as alcohol-related cues. These findings are also inconsistent with prior research demonstrating approach motivation increases after exertion of self-control (Schmeichel et al., 2010), but consistent with prior research suggesting shifts in motivation after exerting self-control may rely on individual differences and may not be universally promoted after prior exertion of self-control (Schmeichel et al., 2015). In line with this interpretation, alcohol sensitivity interacted with self-control conditions in predicting asymmetrical cortical activation. As in Experiment 1, those reporting lower sensitivity exhibited greater approach motivation, indicated by greater relative left frontal cortical activation, while viewing alcohol advertisements after exerting self-control.

While research has established reactivity to alcohol-related cues differ due to trait factors, such as AUDs (Namkoong et al., 2004) and alcohol sensitivity (Bartholow et al., 2010), this experiment reports how these trait factors (e.g., alcohol sensitivity) may interact with acute experiences (i.e., exerting self-control) in predicting motivation toward alcohol-related cues.

While past work suggests self-control is related to greater alcohol consumption (Muraven et al., 2002), it remains unclear whether this greater consumption may be due to shifts in motivation toward alcohol-related cues after exerting self-control. The current findings are also inconsistent with broader predictions based on the process model of self-control, which holds that exerting self-control is sufficient to increase motivation toward rewarding cues (e.g., alcohol-related cues; Inzlicht & Schmeichel, 2012; Inzlicht et al., 2014). However, our findings indicate alcohol sensitivity may interact with exertion of self-control in predicting approach motivation while viewing alcohol-related cues. These findings are consistent with research suggesting shifts in motivation after exerting self-control may rely on individual differences (Schmeichel et al., 2015). This suggests only individuals at risk for hazardous alcohol use, like those reporting lower alcohol sensitivity, may exhibit greater approach toward alcohol-related cues after exerting self-control. While prior research has demonstrated the predictive validity of alcohol sensitivity on alcohol use (Schuckit, 1994; Schuckit & Smith, 2000), the present research contributes to this literature by demonstrating how this construct influences motivations toward alcohol-related cues after exerting self-control.

Limitations. Although results provide novel contributions to the literatures on self-control, alcohol sensitivity, and alcohol-related cues, there are several limitations in the design. As in Experiment 1, the ecological validity is limited due to the manipulation of self-control (restricted writing task) and exposure to advertisements (structured advertisement viewing task). While participants are likely to exhibit impaired self-control capacity by other means (e.g., long day of work; Heatherton & Baumeister, 1996; Muraven et al., 2005), the current manipulation may not generalize to typical states of mental exhaustion and exposure to advertisements in a controlled lab setting may not generalize to typical viewing of advertisements (e.g., a billboard on the highway or television commercial). Unlike Experiment 1, participants completed a writing task instead of a vowel counting task. These manipulations reflect commonly used self-control manipulations reported in the literature and are well-established in promoting exertion of self-control (Garrison, Finley, & Schmeichel, 2019; Hagger et al., 2016). However, whether the change in manipulation limited findings of Experiment 2 is unclear. For example, unlike Experiment 1, no interaction between self-control condition and advertisement type emerged on approach motivation. Whether this was related to the change in manipulation, presentation of advertisements (i.e., within-participant comparison), or assessment of approach motivation (i.e., cortical asymmetries) is unclear. Another limitation is the use of a mixed experimental design, with all participants viewing both alcohol and non-alcohol advertisements. While this design was chosen to parallel research examining neurophysiological measures of motivation (Bartholow et al., 2010, Schmeichel et al., 2015), it is unclear how only viewing non-alcohol advertisements following exertion of self-control may affect approach motivation in the current experiment. Despite these limitations, the present experiment provides several novel contributions to the literature and has implications for future research and interventions.

General Discussion

Across 2 experiments, results demonstrate how exerting self-control may promote greater approach motivation toward alcohol-related cues, particularly among those at risk for hazardous alcohol use (i.e., lower alcohol sensitivity). While the sequence of acute, short-term exertion of self-control immediately followed by alcohol cues may have limited ecological validity, similar states of mental fatigue are commonly experienced due to extensive self-control throughout the day and alcohol may be promoted daily via prevalent cues (e.g., billboards, magazine advertisements, television commercials; Muraven et al., 2005). The present study demonstrates mere exposure to these advertisements during states of mental exhaustion (e.g., after exerting self-control) may lead to shifts toward approach motivation, which is linked to engaging in risky health behaviors (Voight et al., 2009). These findings may inform interventions to reduce negative alcohol-related outcomes associated with deficits in self-control and increased approach motivation. For example, while the effects of alcohol advertising promoting drinking behaviors are well-established (Collins, Ellickson, McCaffrey, & Hambarsoomians, 2007; Morgenstern, Isensee, Sargent, & Hanewinkel, 2011), the current research suggests viewing these advertisements during states of mental exhaustion may exacerbate these behaviors by increasing approach motivation toward alcohol among at-risk populations (e.g., those lower in alcohol sensitivity). Thus, interventions could promote this information about the negative effects of mental exhaustion, which has been shown to reduce the likelihood of excess alcohol consumption compared to those without this self-awareness (Otten et al., 2014).

Although results provide novel contributions to the literature, there are several limitations to be considered. Across both experiments, the ecological validity of self-control manipulations and exposure to advertisements are limited. The tasks used to manipulate self-control also differed between experiments. This reflects the variety of experimental paradigms reported in the literature to manipulate self-control and shows generalizability of some effects across paradigms, but whether these manipulations similarly required participants to exert self-control to the same extent is unclear. Further, while approach motivation was assessed following (in Experiment 1) and during (in Experiment 2) exposure to alcohol and non-alcohol advertisements, drinking behavior was not assessed. However, approach motivation toward alcohol and similar neurophysiological measures of motivation are predictive of previous, acute, and future alcohol use (Bartholow et al., 2010; Namkoong et al., 2004; Palfai & Ostafin, 2003). Further, while prior research related to alcohol sensitivity have focused on alternative neurophysiological indices of motivation (i.e., P3; Bartholow et al., 2007; Bartholow et al., 2010), this is the first study to our knowledge to examine alcohol sensitivity's relation to approach motivation as assessed through the BAS scale and asymmetrical PFC activation.

Within the broader context of self-control, recent debate exists regarding the effects of exerting excessive self-control (see Friese et al., 2018). While meta-analyses initially established a medium to large effect size of self-control exertion (Hagger et al., 2010), subsequent meta-analyses and registered replication studies suggest these effects to be indistinguishable from zero, attributing previous findings to publication bias and *p*-hacking (Carter & McCullough, 2014; Hagger et al., 2016). Consistent with this literature, the experiments reported in this paper did not find any main effects of self-control on expected outcomes, suggesting exerting self-control did not *universally* promote approach motivation. However, within the self-control literature, there is evidence across a variety of studies that self-control exertion effects may be moderated by individual differences, such as sensitivity to the effects of exerting self-control (Salmon et al., 2014), theories of willpower (Job, Dweck, Walton, 2010), and trait approach motivation (Schmeichel et al., 2015). Consistent with this literature, in the current experiments, the hypothesized effects of self-control exertion were only consistently present among drinkers reporting lower alcohol sensitivity, suggesting individual differences may play a role in the effectiveness of self-control manipulations. Future research should examine how individual differences may interact with manipulations of self-control and their impact on the effects of ego-depletion. Notwithstanding these limitations, the present study provides novel contributions to literatures on self-control, alcohol sensitivity, and alcohol-related cues. Across 2 experiments, results suggest exerting self-control promotes approach motivation toward alcohol specifically among drinkers lower in alcohol sensitivity, which has implications for future research and interventions.

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Table 1. Summary of descriptive statistics for alcohol use for Experiment 1

Variables	1.	2.	3.	4.	5.
1. Sex	-				
2. Alcohol sensitivity	-.246**	5.23(1.81)			
3. Drinking frequency (3 months)	-.153	.450***	3.22(1.84)		
4. Drinking quantity (3 months)	-.132	.535***	.611***	3.06(1.71)	
5. Lifetime maximum drinks	-.286**	.371***	.621***	.607***	9.13(4.59)

Note. *M*(*SD*) reported on diagonal of correlation matrix. Sex is dummy coded (0 = male, 1 = female). Higher alcohol sensitivity values indicate lower sensitivity (i.e., more drinks needed to experience effects of alcohol consumption). $^{**}p < .01$, $^{***}p < .001$

Table 2. Summary of descriptive statistics for alcohol use for Experiment 2

Variables	1.	2.	3.	4.	5.
1. Sex	-				
2. Alcohol sensitivity	-.378**	6.12(1.20)			
3. Drinking frequency (3 months)	-.194	.552***	4.01(1.58)		
4. Drinking quantity (3 months)	-.124	.515***	.433***	3.80(1.51)	
5. Lifetime maximum drinks	-.136	.454***	.458***	.525***	8.74(5.38)

Note. M(SD) reported on diagonal of correlation matrix. Sex is dummy coded (0 = male, 1 = female). Higher alcohol sensitivity values indicate lower sensitivity (i.e., more drinks needed to experience effects of alcohol consumption). **$p < .01$, ***$p < .001$

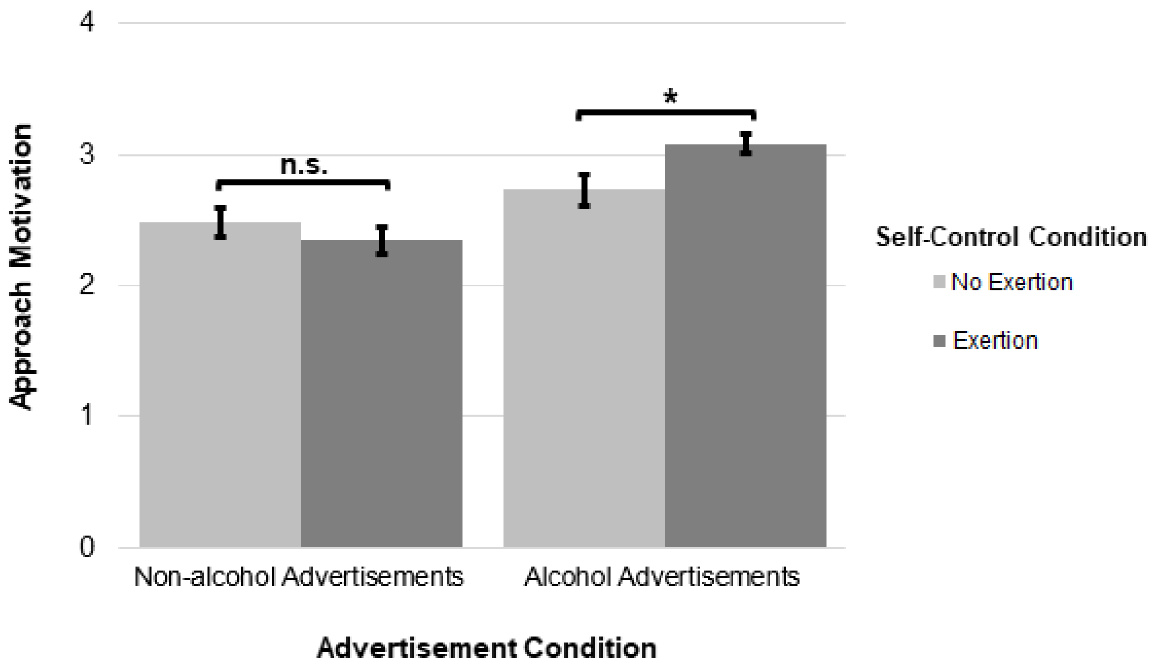

Figure 1. Approach motivation after viewing advertisements as a function of self-control condition (No exertion, Exertion) and advertisement type (non-alcohol, alcohol). Error bars represent standard error. *$p < .05$

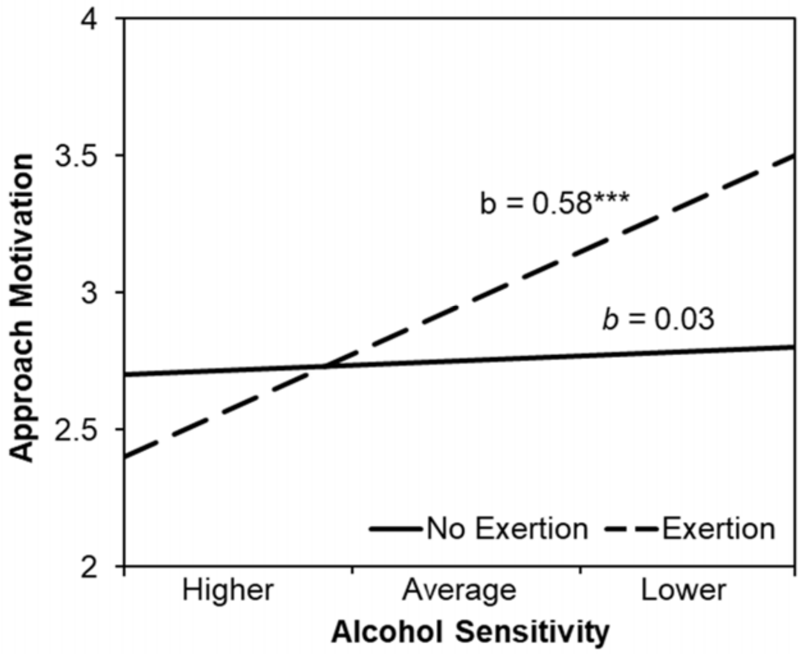

Figure 2. Interaction between alcohol sensitivity and self-control condition predicting approach motivation after viewing alcohol advertisements. Higher, positive values on the *y*-axis indicate greater approach motivation. Higher alcohol sensitivity values indicate lower sensitivity (i.e., more drinks needed to experience effects of alcohol consumption). Alcohol sensitivity is graphed at -1SD (higher), at the mean (moderate) and +1SD (lower). ***$p < .001$

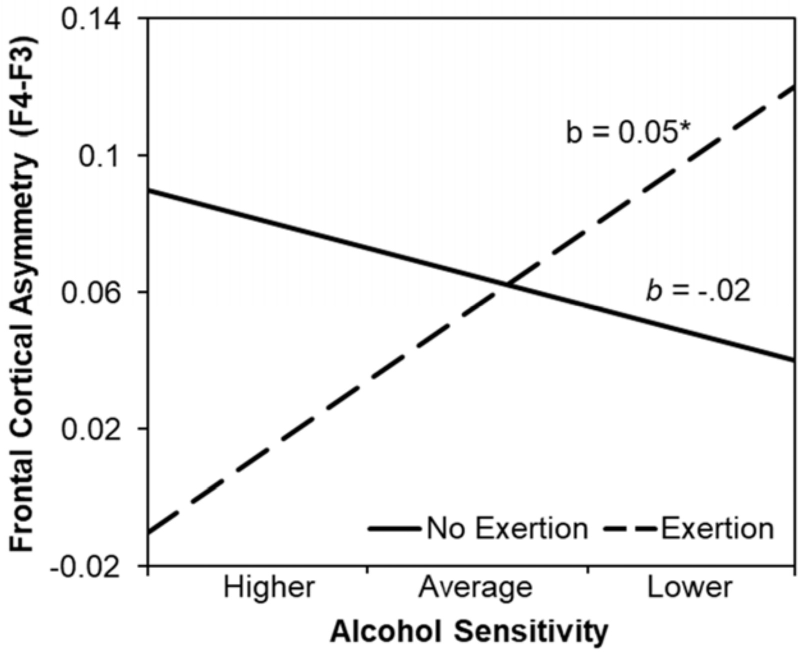

Figure 3. Interaction between alcohol sensitivity and self-control condition predicting frontal cortical asymmetry while viewing alcohol advertisements. Higher, positive values on the *y*-axis indicate greater left over right frontal cortical activation, indicating approach motivation. Higher alcohol sensitivity values indicate lower sensitivity (i.e., more drinks needed to experience effects of alcohol consumption). Alcohol sensitivity is graphed at -1SD (higher), at the mean (moderate) and +1SD (lower) *$p < .05$