

Abstract

Exposure to alcohol cues reduces the breadth of attentional scope, called “virtual myopia”. Past research has suggested approach motivation as a possible mechanism that underlies this myopia in response to alcohol cues. The current study expanded on these findings by identifying the neural underpinnings of the relationship between attentional narrowing, approach motivation, and exposure to alcohol cues. Participants completed 32 trials that consisted of neutral or alcohol related stimuli followed by a measure of attentional narrowing (i.e., Navons letter task). Electroencephalography (EEG) was recorded during the experiment to assess greater left-frontal hemispheric asymmetry, a measure of approach motivation. Results revealed alcohol cues caused greater “virtual myopia” as measured by narrowed attentional scope. Greater left-frontal activation to alcohol cues related to greater myopia, suggesting that approach motivation is associated with virtual myopia. Left-frontal activation appears to be a neural correlate of cognitive narrowing related to approach motivation.

Keywords: Alcohol Myopia, Narrowed Attention, Left-frontal Activation, Behavioral Approach System

Neural Correlates of Virtual Alcohol Myopia

Over 50 years of research has demonstrated that alcohol consumption causes a narrowed cognitive scope, called alcohol myopia (Washburne, 1956; Steele, Critchlow, & Liu, 1985; Steele & Josephs, 1990; T. MacDonald, et al., 2000; Field & Cox, 2008). Recent research has demonstrated that exposure to alcohol cues (e.g., pictures of alcohol) – even in the absence of alcohol consumption - results in narrowed attentional scope, or virtual alcohol myopia (Hicks, Friedman, Gable, & Davis, 2012). However, in the absence of a pharmacological influence, what is the mechanism which drives virtual myopia?

One potential mechanism underlying virtual myopia may be approach motivation. Approach motivation is essential to acquiring biologically important outcomes related to reproduction, social attachment, and the ingestion of food and water. Approach motivation is also integrally involved in addiction processes (Kalivas & Volkow, 2005). States high in approach motivation can occur in response to appetitive cues (e.g., addictive substances) present in the environment (Gable & Harmon-Jones, 2008; Hicks et al., 2012; Fleming & Bartholow, 2014). These approach-motivated states cause a narrowed attentional scope (Gable & Harmon-Jones, 2008; see Gable, Poole, & Harmon-Jones, 2015 for review of the Motivational Dimensional Model). Narrowing of attention towards desired objects may facilitate acquisition of the desired object by reducing distraction and enhancing focus on the desired object.

Another potential mechanism relating to virtual myopia is impulsivity. Impulsivity is thought to stem from the supervisory control system. This system is presumed to regulate impulses produced by the approach and withdrawal systems (Aron, Robbins, & Poldrack, 2014, Carver & Connor-Smith, 2010; Hester & Garavan, 2009). Impulsive individuals are prone to attentional capture evoked by alcohol cues (Fields et al, 2007). Hicks and colleagues (2015)

found that impulsivity related to greater attentional narrowing to alcohol cues in heavy drinkers. This evidence suggests that impulsivity may underlie attentional narrowing, in heavy drinkers, but not light drinkers. The current study examined the novel question of whether neural activations involved in approach motivation and impulsivity also underlie virtual myopia.

One of the most prominent neurophysiological measures of approach motivation is frontal cortical asymmetry. Seventy-five years of research suggests that the left and right frontal cortical regions are asymmetrically involved in approach and withdrawal motivational processes, respectively (Goldstein, 1939; Rossi & Rosadini, 1967; see Spielberg et al., 2008; Harmon-Jones, Gable, & Peterson, 2010 for reviews). Asymmetric activity in right- vs left-frontal cortical areas as measured by suppression of the alpha frequency band reveal that greater relative left frontal activation is associated with approach motivation and greater relative right frontal activation is associated with withdrawal motivation (Amodio, Master, Yee, & Taylor, 2008; Balconi, 2011; Davidson, 1995; Harmon-Jones, Gable, & Peterson, 2010).

Cognitive measures of hemispheric asymmetry suggest that the left and right hemisphere are asymmetrically related to attentional processing (Volberg, Kliegl, Hanslmayr, & Greenlee, 2009). The right hemisphere is associated with global processing, and the left hemisphere is associated with local processing (Boksem, Kostermans, Tops, & De Cremer, 2015; Volberg & Hübner, 2004). Enhancing left-hemisphere activation narrows attentional scope (Gable, Poole, & Cook, 2013; Harmon-Jones & Gable, 2009; Romei, Thut, Mok, Schyns, & Driver, 2012).

Individual differences in core personality systems also relate to frontal asymmetry. The Behavioral Activation Scale (BAS; Carver & White, 1994) assesses individual differences in the tendency to approach rewarding goals and activities. Greater behavioral approach system sensitivity relates to greater relative left frontal activation (Coan & Allen, 2003; Amodio et al.,

2008; Gable & Poole, 2014; Harmon-Jones & Gable, 2009; Balconi, Brambilla, & Falbo, 2009). The UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007) assesses individual differences in the tendency towards rash action and is inversely related to the strength of the supervisory control system. Trait impulsivity is associated with greater relative left frontal activity (Gable, Mechin, Hicks, & Adams, 2015; Santesso et al., 2008).

Approach motivation and impulsivity both predict alcohol cue reactivity (Zisseron & Palfai, 2007; Perry & Carroll, 2008; Papachristou, et al., 2012). Alcohol cue reactivity appears to be related to greater left-frontal activation (Myrick et al., 2004). Because the approach system and supervisory control system are related to greater left frontal activation, it seems likely that these systems should relate to left-frontal activation to alcohol cues.

The current study tested whether trait behavioral approach, trait impulsivity, and greater relative left frontal activation to alcohol cues relate to virtual alcohol myopia. Importantly, we sought to investigate the neural correlates of non-pharmacological mechanisms relating to virtual alcohol myopia. Based on past evidence, greater left frontal activation when viewing alcohol cues should be associated with greater narrowing of attention triggered by alcohol cues. We predicted that greater BAS sensitivity, and trait impulsivity (UPPS-P) would relate to greater left frontal activation during alcohol cues. However, because the influence of impulsivity on virtual myopia may depend on individual differences in drinking experience (Hicks et al., 2015), we predict that trait approach motivation, but not impulsivity, should relate to alcohol cue induced narrowing. Because recent drinking behavior may not accurately measure motivation towards alcohol cues or relate to neural responses to alcohol cues (Baer, 2002; Bartholow, Lust, & Tragesser, 2010), predictions were not made for drinking behavior.

Methods

Participants

Forty-one right-handed participants (29 female, 3 declined to respond) participated for course credit. Participants were college students with an average age of 19.20 ($SD = 4.60$) and ranged in drinking habits from lifetime abstainers ($n = 5$) to participants reporting binge drinking in the past month ($n = 22$). The current sample included abstainers and light drinkers in order to assess alcohol cue reactivity in young adults with a broad range of drinking experience. Reaction time data on the attentional scope task was excluded for one participant because they did not follow instructions. EEG data from 6 participants was not analyzed due to recording problems. Participants were included in analyses for which they had usable data.

Measures

Trait approach motivation was measured using the behavioral inhibition/behavioral activation system (BIS/BAS) questionnaire (Carver & White, 1994). BIS measures reactions to the expectation of punishment. BAS sub-scales measure persistent pursuit of desired goals (BAS drive), positive responses to the occurrence or anticipation of reward (BAS reward responsiveness), and a desire for and willingness to approach new rewards (BAS fun seeking). BAS Total combines the sub-scales to assess overall behavioral approach. Trait impulsivity was measured using the UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007). The combined UPPS-P scale (UPPS-P Total) assesses negative urgency, positive urgency, lack of premeditation, lack of perseverance, and sensation seeking.

Participants reported the frequency of drinking episodes in the past month (“During the past month, how many times did you have at least one drink of alcohol”) and the average amount of alcohol consumed in an episode (“During the past month, how many times did you have at least one drink of alcohol” and “During the past month, on the days you drank, on average, how

many drinks did you have"; NIAAA, n.d.b). Binge drinking was measured using the 5/4 definition: more than five drinks per episode for men and more than four drinks per episode for women (NIAAA, n.d.b). A single variable assessing alcohol use was created by calculating the product of monthly frequency and monthly quantity (Hicks et al., 2015). See Table 1 for descriptive statistics of personality and neurophysiological measures.

Picture viewing and attentional scope task. After completing individual difference measures the experimenter administered electroencephalography (EEG) electrodes. Then, participants completed a picture viewing and an attentional scope task (Navon, 1977). In the Navon (1977) letters task, participants identify local and global elements of hierarchical stimuli. Faster responses to local elements demonstrates more narrowed attention, while faster responses to global elements demonstrates more broadened attention. This task has been used as a measure of attentional breadth in previous research using appetitive stimuli, including alcohol cues (Gable & Harmon-Jones, 2008; Hicks et al., 2012; Hicks, Fields, David, & Gable, 2015). Participants viewed 64 color photographs. Half were images of alcoholic beverages, including beer, wine, and liquor to capture attentional bias to alcohol (Miller & Fillmore, 2010). The other half were neutral objects also consisting of one category (i.e., rocks; Vollstädt-Klein et al., 2011; Nikolaou, Field, Critchley, & Duka, 2013; Townshend & Duka, 2001). Alcohol and neutral pictures were matched for size, color, complexity, and object size to control for perceptual features influencing attention. On each trial, a picture was displayed for 6 s following a 500 ms fixation cross. After each picture, another fixation cross (500 ms) appeared and a composite Navon letter (Navon, 1977) was presented until the participant responded. If a response did not occur within 5 s, the next trial began. Intertrial interval was 3 s. Of the 64 Navon letter trials, 32 presented global targets and 32 presented local targets.

Neurophysiological assessment. Electroencephalography was recorded using 64 tin electrodes mounted in a stretch lycra cap (Electro-Caps, Eaton, OH). EEG activity was referenced to the left earlobe with a ground electrode located between FPz and Fz. Electrode impedances were kept under 5 k Ω and within 1k Ω for all homologous sites. EEG signals were amplified using Neuroscan SynAmps RT amplifier units (El Paso, TX). All data was low-pass filtered at 100 Hz, notch filtered at 60 Hz, high-pass filtered at 0.05 Hz, and digitized at 2,000 Hz. Eye movements and artifacts in the data were removed by hand. Blinks were removed using a regression-based eye movement correction followed by an additional visual inspection of the data to ensure proper modification. All epochs 1.02 s in duration were extracted through a Hamming window and re-referenced using a common average reference. Consecutive epochs were overlapped by 50%. A fast Fourier transform was used to calculate power spectra in the low alpha band (8 – 10.25 Hz) during picture presentation (Harmon-Jones & Gable, 2009). Asymmetry indexes were then calculated (log right minus log left) for frontal (F1-F4), central (C1-C4) and parietal (P1-P4) sites, excluding midline sites (FZ, CZ, and PZ). Alpha power is inversely related to cortical activity (Laufs et al., 2003) therefore higher asymmetry scores indicate greater relative left-hemisphere activity. Because predictions were directional, derived from theory, and specified a priori; they were evaluated using a one-tailed criterion of significance (Rosenthal, Rosnow, & Rubin, 2000).

Results

Reaction times to attentional scope task

Alcohol pictures narrowed attentional scope, as revealed in a 2 (alcohol or neutral picture) X 2 (local or global target) within-subjects analysis of variance using log-transformed RTs, $F(1, 36) = 9.03, p = .01, \eta_p^2 = 0.99$. Log-transformed means and untransformed means

(M_{Raw}) are reported. Following alcohol pictures, participants responded faster to local ($M = 6.63[0.27]$; $M_{Raw} = 821.42[230.86]$) than to global targets ($M = 6.66[0.26]$; $M_{Raw} = 864.87[269.39]$), $t(38) = -1.97$, $p = .05$, $d = 0.64$. Following neutral pictures, participants responded similarly to local ($M = 6.65[0.26]$; $M_{Raw} = 828.40[230.25]$) and global targets ($M = 6.63[0.26]$; $M_{Raw} = 808.82[225.88]$), $t(37) = 1.24$, $p = .22$, $d = .41$.

In order to test the relationship between trait measures and local-global reaction times, we computed difference scores between picture type. Following past procedure (Gable & Harmon-Jones, 2008; Hicks et al., 2012), we computed a difference score between the global-alcohol and the global-neutral RTs (Global RT Difference). Second, we computed a difference score between the local-alcohol and the local-neutral RTs (Local RT Difference). For both dependent variables, smaller scores indicate more global or local scope following alcohol pictures. BAS reward responsiveness related to more narrowed attention after alcohol pictures, but not broadened attention (see Table 2). Other BIS/BAS subscales, UPPS-P Total, and alcohol use did not relate to global or local reaction times following alcohol pictures. To further examine whether approach motivation was a stronger predictor of virtual alcohol myopia than impulsivity, we conducted a Steiger's Z analysis comparing these correlations. Results revealed that the relationship between BAS reward responsiveness and narrowed attention after alcohol pictures was marginally stronger than the relationship between UPPS-P Total and narrowed attention after alcohol pictures, $z = -1.57$, $p = 0.058$.

Hemispheric activation

Hemispheric activation at frontal sites following alcohol pictures related to difference scores for local targets ($r = -.32$, $p = .03$; see Table 3). Greater left-frontal activation (referred to as LFA to Alcohol Pictures in Table 1) related to faster local target reaction times, or more

narrowed attention. Central and parietal activation during alcohol pictures were not related to local target reaction times ($r_s < .23, p_s > .36$). Frontal activation during alcohol pictures was unrelated to global target reaction times ($r = -.03, p = .84$).

Greater BAS reward responsiveness related to greater relative left frontal activation to alcohol pictures ($r = 0.32, p = 0.03$). Central and parietal activation were not related to BAS reward responsiveness ($r_s < 0.30, p_s > 0.10$). Although trait impulsivity did not relate to narrowing following alcohol cue exposure, it did relate to greater relative left frontal activation to alcohol pictures ($r = 0.47, p = 0.005$). Central and parietal hemisphere asymmetry scores were not related to trait impulsivity ($r_s < 0.30, p_s > 0.05$). Alcohol use was not related to any index of hemispheric asymmetry ($r_s < 0.18, p_s > 0.34$).¹

Discussion

The present results revealed that attentional narrowing induced by alcohol cues (virtual myopia) appears to be related to approach motivational traits and neural correlates of approach-motivation. Individual differences in behavioral approach sensitivity and relative left frontal activation to alcohol pictures both relate to attentional narrowing following alcohol pictures. In conjunction with past research demonstrating that trait approach motivation is predictive of addictive and high-risk behaviors (Franken, Muris, & Georgieva, 2006; Gray, 1993), the current results suggest that individuals high in trait approach motivation may be more prone to the attentional narrowing effects caused by appetitive stimuli.

The relationship of frontal asymmetry and individual differences in approach motivation on attentional narrowing to alcohol cues may be indicative of the close relationship between systems of approach motivation and goal acquisition. That is, greater BAS may enhance an organism's attentional narrowing to rewarding stimuli, and trigger neurophysiological processes

of approach and greater cognitive resources devoted towards the desired object. This would likely facilitate goal acquisition, as the organism plans approach behaviors and focuses on the desirable object or goal.

Did impulsive individuals show increased narrowing to alcohol cues? No, UPPS-P Total did not relate to virtual myopia. Greater impulsivity did relate to greater left-frontal activation to alcohol pictures. This finding is consistent with past work relating frontal-cortical activity to impulsivity and alcohol cue reactivity (Myrick et al., 2004; Gable et al., 2015; Mechin, Gable, & Hicks, in prep). Hicks et al. (2015) found that impulsivity only related to attentional narrowing when individuals were heavy drinkers. As compared to the Hicks et al. (2015) sample, the current sample may not have contained a large number of heavy drinkers. If so, then results from Hicks et al. (2015) and the current sample would suggest that only trait approach motivation is related to virtual myopia in light drinkers.

Drinking behavior may not have related to left frontal activation or attentional narrowing because the sample was comprised of light drinkers and drinkers without much past experience. However, even in a relatively young sample without much drinking experience, there is a relationship between approach motivation, alcohol cues, attentional narrowing, and neural activation. Alcohol cues seem to be a powerful environmental cue, even among non-problem drinkers.

Alcohol use was not related to attentional narrowing or greater left frontal activation to alcohol pictures. Past month alcohol use may have reflected the propensity to drink, as opposed to alcohol-related approach motivation. The propensity to drink may be largely due to social norms and not the strength of the incentive (Baer, 2002). Past drinking as measured in the current study may not accurately assess motivation towards alcohol pictures, in part because relatively

inexperienced drinkers may not have developed consistent drinking behaviors. Additionally, recent drinking behaviors may not influence neural responses to alcohol cues (Bartholow, Lust, & Tragesser, 2010).

One potential limitation of the current study is the predominantly female sample. However, past research indicates that this distribution did not likely affect our results. Specifically, attentional bias or cue craving to alcohol cues does not appear to be affected by gender (Hicks et al., 2012; Ramirez, Monti, & Colwill, 2015). Recent research has demonstrated that there are “no sex differences with regard to craving and attentional bias to alcohol at baseline or after cue exposure” (p. 164, Ramirez, Monti, & Colwill, 2015). The cognitive effects of alcohol cue exposure do not appear to be specific to one gender.

Another potential limitation is the absence of a positive (i.e., appetitive) control condition (Bartholow et al., 2010). Hicks et al. (2012; Study 2) investigated the influence of appetitive (i.e., dessert) vs. alcohol cues on attentional narrowing and found that alcohol cues narrowed attentional scope in comparison to the dessert cues. Attentional narrowing was related to approach motivation. These past results suggest that approach motivation influences attentional narrowing to alcohol cues as compared to neutral or appetitive stimuli.

The present study integrates research on motivation, substance use, attentional focus, and their associated neural processes. Virtual myopia engages the same neural circuitry related to approach motivation. Activation of this neural circuitry by alcohol cues relates to more narrowed attentional scope. Approach motivation appears to be one mechanism driving attentional narrowing to alcohol cues. In conclusion, the search for neurological underpinnings of substance use necessitates understanding our basic motivational systems and their interrelation with fundamental cognitive processes (Kalivas & Volkow, 2005).

Footnotes

1. To examine whether abstainers may have influenced the current results, correlation analyses were reexamined excluding abstainers ($N = 5$). Significant relationships between personality variables, attentional scope, and frontal asymmetry remained significant and were not affected by these participants (Change in r -values $< .04$).

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Table 1: *Descriptive Statistics for Personality Measures, Reaction Times, and Frontal*

Asymmetry in Women, Men, and the Combined Sample

	Women (N = 29) Mean (SD)	Men (N = 10) Mean (SD)	Combined Mean (SD)
BAS Total	2.96 (0.41)	3.03 (0.29)	2.96 (0.37)
BAS Reward Responsiveness	3.31 (0.31)	3.18 (0.29)	3.27 (0.31)
BAS Fun Seeking	2.84 (0.59)	3.04 (1.27)	2.85 (0.61)
BAS Drive	2.63 (0.61)	2.83 (0.26)	2.67 (0.53)
BIS	3.05 (0.56)	2.49 (0.72)	2.91 (0.66)
UPPS-P Total	2.91 (0.36)	2.76 (0.48)	2.88 (0.39)
Alcohol Use	20.07 (27.16)	27.67 (47.28)	22.03 (30.59)
LFA to Alcohol Pictures	0.02 (0.13)	-0.01 (0.15)	0.01 (0.13)
LFA to Neutral Pictures	0.02 (0.11)	0.04 (0.09)	0.02 (0.11)

Note. Three participants declined to report gender. Mean comparisons between men and women revealed only one significant difference. This difference occurred for the BIS variable, $t(36) = 2.56, p = 0.01$.

Table 2: *Correlations for Local and Global Reaction Time Difference Scores with BIS/BAS scales, UPPS-P scales, and Past Drinking Behavior.*

	Local RT Difference	Global RT Difference	N[†]
BAS Total	-.22	.01	39
BAS Reward Responsiveness	-.44*	-.14	39
BAS Fun Seeking	.07	-.01	39
BAS Drive	-.26	.13	39
UPPS-P Total	-.07	.16	39
Alcohol Use	.04	.07	39

* $p < .01$; All other relationships, $p > .05$. [†]Due to global error rates, one participant was excluded from the Global RT Difference score. Analyses with Global RT Difference contain 38 participants.

Table 3: *Correlations for Frontal Hemispheric Asymmetry to Alcohol and Neutral Pictures with BIS/BAS scales, UPPS-P scales, and Past Month Drinking Behavior*

	Alcohol Pictures	Neutral Pictures	N
Local RT Difference	-.32*	-.24	34
Global RT Difference	-.04	-.22	33
BAS Total	.09	.18	34
BAS Reward Responsiveness	.32*	.27	34
BAS Fun Seeking	-.15*	-.04	34
BAS Drive	.13	.25	34
UPPS-P Total	.47*	.13	34
Alcohol Use	.16	.05	33

* $p < .03$; All other relationships, $p > .05$.