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The Impact of Alcohol and Social Context on the Startle Eyeblink Reflex

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1 Abstract

2 **Background:** Researchers have long sought to understand how individuals respond to alcohol in
3 social settings with the aim of elucidating pathways of risk for alcohol use disorder (AUD). But
4 studies that incorporate a social context are still outnumbered by those that examine alcohol's
5 subjective effects among participants drinking alcohol in isolation. Further, perhaps due to the
6 challenges of capturing automatic affective processes in these settings, prior studies of alcohol
7 response in social context have relied mainly on self-report measures, and so relatively little is
8 known about alcohol's psychophysiological effects in social settings.

9 **Methods:** Using a novel paradigm that integrated alcohol-administration procedures, startle
10 methodology, and social context, the current study examined the impact of alcohol and social
11 context on startle eyeblink reflex among 40 social drinkers.

12 **Results:** Results indicated that there was a significant effect of group presence, indicating that
13 startle magnitude was larger when people were alone than with others. There was a significant
14 group presence by alcoholic beverage interaction, with the effect of alcohol being significantly
15 larger when people were alone versus with others. These effects were found both for the startle
16 habituation data and during the picture viewing task.

17 **Conclusions:** Results of this study highlight the importance of considering the presence of other
18 individuals for understanding alcohol response and mechanisms of AUD risk. Findings are
19 discussed in light of both emotional and also cognitive correlates of startle reflex magnitude.
20 Future research should examine these effects within larger samples of participants and further
21 explore mechanisms that might underlie these effects.

22 *Keywords:* alcohol, social context, startle, emotion, cognition

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Introduction

Researchers have long been interested in understanding individuals' responses to alcohol in social settings (Harford, 1983; Pliner & Cappell, 1974; Lindman, 1982; Aan Het Rot et al., 2008). Importantly, the vast majority of alcohol consumption in everyday life takes place in social context (Bourgault and Demers, 1997; Senchak et al., 1998; Single and Wortley, 1993). Further, Studies have found that people drink more and report greater mood enhancement from alcohol when they drink in group settings versus when they drink alone (Doty and de Wit, 1995; Pliner and Cappell, 1974). The belief that alcohol enhances social situations represents a robust correlate of heavy drinking and predictor of later transition into problematic drinking patterns (Jones et al., 2002; see also Fairbairn and Sayette, 2014; Fairbairn et al., in press). Thus, understanding alcohol's effects in social context may be critical to understanding factors that drive alcohol consumption and, ultimately, to helping trace the roots of alcohol use disorder.

Although outside the laboratory, most alcohol consumption takes place in social context, within laboratory investigations of alcohol's effects, most paradigms have examined individuals drinking in isolation (see Fairbairn and Sayette, 2014 for a review). Furthermore, among the minority of laboratory studies that have examined alcohol response in social context, the measurement of alcohol's effects on subjective experience has been limited, relying overwhelmingly on self-reports (Fairbairn and Sayette, 2014). The current study seeks to fill this gap by expanding the range of measures used to gauge alcohol's effects on subjective experience in social context. More specifically, the current study represents the first to employ startle methodology—a method with powerful advantages for capturing individuals' automatic responses—to examine the impact of social context on responses to alcohol.

Startle Responses, Emotion, and Cognition

1 Prior studies examining alcohol response in group settings have mainly relied on self-
2 reports to capture emotional responses. An understanding of acute emotional response to
3 alcohol—including the extent to which alcohol has the ability to relieve negative affective
4 states—has been thought to be key to understanding factors that reinforce drinking and thus
5 make individuals vulnerable to developing alcohol use disorder (Conger, 1956; Sher, 1987).
6 Self-reports of emotion have several well-known advantages, particularly when consciously
7 accessible emotional states are the subject of interest, as they offer a relatively low-cost,
8 straightforward means of measuring internal subjective responses (Mauss & Robinson, 2009).
9 Nonetheless, self-reports may not offer a complete picture of emotions experienced in social
10 contexts, since emotional experiences in social contexts may shift frequently from one moment
11 to the next and, further, emotions may often be beyond awareness such that they may not easily
12 be captured via explicit self-reports (Kirsch & Lynn, 1999; Locke, 2005).

13 In an effort to build on the information provided by self-reports of emotion, researchers
14 have sought measures that are capable of assessing more automatic, instantaneous emotional
15 experiences. Among these methods, startle methodology has emerged as one powerful tool for
16 capturing emotional responses. The majority of studies employing startle methodology have
17 examined the influence of foreground images on the magnitude of muscle responses to sudden
18 noise probes. Vrana, Spence, and Lang, (1988) were among the first to demonstrate that the
19 magnitude of human startle reflex is influenced by the valence and arousal of the foreground
20 images. Lang's subsequent studies consistently supported this theory by replicating the finding
21 that human startle reflex is potentiated during emotionally unpleasant and highly arousing slides
22 and attenuated during emotionally pleasant and highly arousing slides (Bradley et al., 1990; Lang
23 et al., 1990; although see Kaye et al., 2016 for psychometric issues with the paradigm).

1 Researchers have argued that startle magnitude in the context of foreground stimuli can often tap
2 into participants' automatic and instantaneous emotional dispositions and thus represent a
3 powerful method for assessing internal affective experience. In fact, startle methods have been
4 used in alcohol research to understand situational factors that affect stress dampening (Curtin, et
5 al., 1998); however, to our knowledge these methods have not been used to study the social
6 aspects of alcohol.

7 In addition to measuring startle magnitude during the presentation of foreground images,
8 some studies have examined the habituation of the startle response without the presentation of
9 foreground stimuli (Lane et al., 2013; LaRowe et al., 2006; Verona and Curtin, 2006). Similar to
10 startle research using foreground stimuli, prior research has shown that the rate of habituation is
11 correlated with individual differences in emotional responding (e.g., Blanch et al., 2014; LaRowe
12 et al., 2006) and can be affected by state manipulations related to emotional responding (e.g.,
13 stress; (Schicatano, 1998; Verona & Curtin, 2006). Habituation of the startle response, however,
14 has been less well studied than responses to foreground stimuli, and so, for this and other
15 reasons, the precise mechanisms underlying individual differences in overall startle response
16 during habituation are less well understood.

17 Although startle methods have emerged as a key tool for understanding affective
18 experience, it has become clear that the magnitude of startle responses may reflect elements of
19 experience beyond *emotion*. More specifically, researchers have argued that startle methods may
20 often capture elements of *cognition* or, more specifically, the allocation of attention (Anthony &
21 Graham, 1985; Hackley & Graham, 1983; Silverstein et al., 1981). In Graham's studies, findings
22 indicated that when attention was directed away from the startle-eliciting stimulus and towards a
23 distraction, the amplitude of the startle reflex was diminished. In other words, in these studies, as

1 more attention was drawn to the distraction, startle reflexes were smaller, whereas reflexes were
2 larger when the distraction was not present (Anthony & Graham, 1985; Hackley & Graham,
3 1983; Silverstein et al., 1981). Research on the habituation of the startle response suggest that it
4 may also tap into aspects of cognitive processing (e.g., Braff et al., 1992). These results suggest
5 an interaction between emotion and attention. Questions surrounding the allocation of attention
6 have historically been an area of great interest to alcohol researchers, since theories of alcohol's
7 effects have postulated that a core element of alcohol's effects is its tendency to decrease
8 individuals' ability to divide attention between tasks (Steele & Josephs, 1990). In the current
9 study, we aim to take a first step towards understanding alcohol's impact on startle in a social
10 context—an ecologically valid drinking setting with known effects on emotion and cognition—
11 in order to further explore alcohol's effects on psychological processes.

12 **Understanding Startle Responses in a Social Context**

13 Prior studies have examined the effect of social context using a variety of methods and
14 measures, including studies examining whether the presence of others influences facial
15 expressions during the viewing of photographic slides (Flores & Berenbaum, 2014) and neural
16 responses during fMRI scanning or EEG recording (Coan et al., 2006). To our knowledge,
17 however, no prior study has incorporated a “real” social context into a startle paradigm (for an
18 example of virtual social situations see Cornwell et al., 2006). Social contexts are not only a
19 setting with relatively high ecological validity for understanding alcohol's effects, but they
20 represent an area with decades of psychological research. Social contexts can exert potent
21 influences on both emotion and cognition, effects that may vary depending on the nature of the
22 social context in question. The presence of other individuals might either increase anxiety (e.g.,
23 intergroup interactions; Plant & Devine, 2003) or decrease anxiety (e.g., interactions with a

1 trusted friend/partner; Clark and Lemay, 2010). Similarly, while all social contexts tend to draw
2 attentional resources, some tend to be more cognitively demanding than others (e.g., interracial
3 interactions; Mendes et al., 2008; Richeson and Shelton, 2007). Further, even in the absence of
4 direct social interaction or engagement in shared activity, the mere presence of other individuals
5 in the same physical space can have key effects on psychological processes (e.g., Zajonc, 1965).
6 The goal of the current study was to examine the interaction of alcohol (known to both narrow
7 attention and decrease anxiety) and social context on the magnitude of startle responses.
8 Specifically, in an effort to promote precise mechanistic understanding and isolate potential
9 mechanisms that might underlie social contextual effects on startle response, we have designed a
10 paradigm that isolates the effect of the “mere presence” of other individuals on alcohol’s effects
11 on startle.

12 The primary goal of the current study was to take an initial step towards understanding
13 alcohol’s effects on startle responses within a social context. As the current study is, to our
14 knowledge, the first study to incorporate a social context into a startle paradigm, we tested two
15 competing hypotheses. To the extent to which startle represented a pure index of emotion in this
16 study, we anticipated we might find an increased effect of alcohol on startle response in groups
17 of unfamiliar individuals vs alone (e.g., Pliner & Cappell, 1974). In contrast, to the extent to
18 which startle responses capture distraction, or the allocation of attention away from the startle
19 stimulus and towards other individuals present in the room, we might anticipate a different
20 pattern of findings (Anthony & Graham, 1985; Hackley & Graham, 1983). In order to gain a
21 deeper understanding of the relative influence of emotion and attention allocation on startle
22 responses in our study, we conducted analyses examining the magnitude of effects within
23 interracial groups—contexts known to increase anxiety and also draw attention. Our secondary

1 goal of this study was to further characterize the habituation of startle magnitude. Given the
2 smaller body of research on startle habituation, we thought identifying the effects of alcohol and
3 social context would represent an addition to the literature. Taken together, these examinations
4 are aimed at gaining a deeper understanding of the effects of alcohol on automatic cognitive and
5 emotional processes across contexts and to move towards expanding our repertoire of
6 experimental paradigms capable of addressing such questions.

7 **Materials and Methods**

8 **Participants**

9 Participants consisted of 60 healthy social drinkers, aged 21 to 28, recruited via
10 advertisements and posted notices in the local community. In order to meet the eligibility criteria
11 for the current study, participants were required to report consuming at least 2 drinks on at least 2
12 occasions per month, or at least 4 drinks on at least 1 occasion per month, over the past 12
13 months. Individuals who successfully completed an initial phone screening interview were
14 invited to the Alcohol Research Laboratory for further screening. Exclusion criteria included
15 medical conditions that contraindicated alcohol consumption, a diagnosis of alcohol use disorder
16 as indexed by the Diagnostic and Statistical Manual of Mental Disorders (5th ed.), pregnancy in
17 women and being uncomfortable with study drinking requirements. Participants with a body
18 mass index (BMI) less than 19 or greater than 27 were also excluded, due to alcohol dosing
19 requirements. Participants who met the eligibility criteria were invited to participate in the
20 experiment. Of these participants, 30 were male and 30 were female. 57% were European
21 American, 12% were African American, 5% were Hispanic, and 20% were Asian. Participants
22 reported drinking on average two to three times per week and consuming 4.07 (SD = 1.94) drinks
23 per occasion. Of the 60 participants, all engaged in alcohol-administration procedures and were

1 involved in the “group” startle condition, and 40 (50% MALE, average age=22.73) served as
2 primary startle participants (see Table 1 for descriptive characteristics; see also below for
3 description of startle procedures).

4 **Procedures**

5 All participants attended two beverage administration visits – one alcohol beverage
6 administration session and one control beverage administration session – in same-gender groups
7 of three, a drinking configuration chosen to reflect a reasonably common real-world social
8 drinking setting (Sayette et al., 2012). Participants attended all visits with the same group of
9 individuals to ensure that all conditions were held constant across the experimental beverage-
10 administrations sessions as much as possible, aside from beverage content. Measures were taken
11 to ensure that all participants were unacquainted prior to study participation (see procedures in
12 (Fairbairn & Sayette, 2013).

13 The two beverage-administration sessions started at approximately 3 pm. The second
14 laboratory session was held 3 days after the first session. During one of these experimental
15 sessions, groups were administered an alcoholic beverage and, during the other session, they
16 were administered a control beverage. The order of sessions was counterbalanced across groups.
17 A placebo condition, in which participants are given a non-alcoholic beverage but informed that
18 they would be receiving alcohol, was not used in this study (Balodis et al., 2011) because
19 placebo manipulations can lead to unanticipated compensatory effects (Testa et al., 2006); in
20 addition, a within-subject design makes placebo manipulations challenging, as it would have
21 been difficult to deceive participants regarding the content of their beverages on the second
22 beverage-administration session.

1 Upon arrival, participants were brought into separate rooms and asked to provide a breath
2 sample to assess blood alcohol concentration (BAC). They also completed a variety of self-report
3 questionnaires. The three participants then moved to the beverage administration room to
4 consume drinks. On the alcohol beverage administration session, participants were informed that
5 they would be receiving alcohol and that the dose would be about the legal driving limit. The
6 alcoholic beverage was 100-proof vodka and 3.5 parts cranberry juice cocktail. The difference
7 between men and women in rates of alcohol metabolism was accounted by adjusting the dose of
8 alcohol according to gender. Men were administered a 0.82-g/kg dose of alcohol, while women
9 were administered a 0.74-g/kg dose. On the control beverage administration session, participants
10 were given the same volume of cranberry juice. Participants remained seated for a total of 36
11 min while beverages were administered in three equal parts at 0 min, 12 min, and 24 min. They
12 were instructed to drink their beverages evenly during the 12-min intervals. Immediately after
13 the drinking period, we recorded participants' BACs and had them complete a set of
14 questionnaires that are unrelated to the current research questions.

15 *Startle.* Startle procedure (a picture viewing task) began approximately 20 minutes after
16 the completion of beverage administration. Among the three participants in each group, one
17 participant was assigned to the Alone condition in which the individual completed the startle task
18 alone on both alcohol and control sessions. Another participant was assigned to the Group
19 condition, in which the individual completed the startle task in the presence of the other two
20 participants on both alcohol and control sessions.¹ In the Group condition, the startle participant

¹ The third group member was not a participant in the startle task (i.e., no startle data were collected from them). This was done because the number of group members and conditions did not lead to a balanced design. This group member, however, did participate in the group condition

1 was facing the computer screen, while the other two group members were seated on either side
2 of this participant, facing the other direction (i.e., they could not see the images). The room was
3 7 feet by 7 feet and participants were approximately 12 inches from each other. This measure
4 was taken to ensure that only the presence or absence of others—and not also the knowledge of
5 shared viewing—varied across Alone and Group conditions. Participants in the Group condition
6 were told not to talk during the task. Group/Alone condition assignment was held constant for
7 each participant across sessions because there are large individual differences in startle
8 magnitude and this allowed us to make our key comparison (the effect of alcohol vs. control for
9 Group and Alone) within-subjects, which made individual differences irrelevant as each person
10 served as their own control. The roles were randomly assigned for each group. The order of two
11 startle sessions (Alone, Group) was counterbalanced across groups. For one group, there was no
12 startle data for the alcohol session due to a computer error.

13 After the startle procedure, participants completed other tasks unrelated to the current
14 research questions. Individuals were paid \$160 for participation. In the alcohol condition,
15 participants were dismissed only after their BACs were reduced to .03% or below.

16 **Measures**

17 *Startle.* Participants completed a computer task in which they viewed neutral and
18 unpleasant IAPS images (e.g., Bradley et al., 2007; Sadeh & Verona, 2013).² Prior to the picture-
19 viewing task, 11 habituation probes were presented to reduce the effect of abnormally large
20 blinks (Lane et al., 2013). These trials were later used in the habituation analyses. A total of 60

² As an exploratory factor, the images also varied in complexity (i.e., figure-ground [low complexity] or scenes [high complexity]; Bradley et al., 2007). Within valence, these images were matched on valence and arousal, so concerns about collapsing across complexity level are minimized. Moreover, there were not any significant effects of interactions involving complexity.

1 images, split into two sets of 30, were used in the current study. In each session, 28 images (14
2 from each category) were presented along with a probe and 2 were presented without a probe to
3 decrease predictability of the startle probe.³ Prior research suggests that 7 blinks are sufficient
4 for a reliable startle response (Lieberman et al., 2017). In any given session, both participants
5 saw the same set of images. Presentation order was counterbalanced across participants. Images
6 were presented between 4.25 and 5.25 seconds, with an intertrial interval of 2 seconds. The
7 probes were played at 2.5, 3.0, or 3.5 seconds after picture onset. Acoustic startle probes (each a
8 105-dB, 50-ms burst of white noise with an instantaneous rise time) were administered
9 binaurally over earphones to elicit a blink response. Due to concerns about participant burden
10 and the timing of the peak of the BAC curve, participants did not rate the images on valence and
11 arousal, as is common in these paradigms (Bradley et al., 2007).

12 Two 4-mm Ag-AgCl electrodes were placed on the orbicularis oculi muscle under the left
13 eye, in order to record the eyeblink component of the startle reflex. Electrode impedance was
14 kept below 10k Ω . The signal was amplified using a Neuroscan Synamps and digitized online at
15 2000Hz using a 24-bit A/D converter. Data were processed using the Physbox add-on toolbox to
16 EEGLab in Matlab (Curtin, 2011; Delome & Makeig, 2004). The data were first high-pass
17 filtered (28 Hz butterworth filter), then rectified and low-pass filtered (30 Hz butterworth filter).
18 Startle magnitude, the peak response between 20-100 ms post-probe relative to the mean of the
19 50 ms baseline, was calculated by an automated procedure. Negative values were set to zero.

20 We took several steps to ensure the integrity of our data. First, trials where the magnitude
21 did not exceed the maximum value of the baseline period, including trials set to zero (13% of

³ IAPS numbers for the images: 7150, 2210, 7190, 7175, 2810, 7211, 7705, 7224, 6150, 2271, 7100, 2221, 7110, 2230, 2383, 7550, 9210, 7234, 3210, 6000, 2752, 2480, 7495, 7700, 2749, 2870, 2518, 7590.

1 trials), and trials with peak baseline values that exceeded the absolute value of $10\mu\text{V}$ (3% of
2 trials) were excluded from all analyses. Second, we examined the number of usable trials for
3 each participant for the smallest cell of interest. In the habituation portion of the data,
4 participants had on average 8.88 (out of 11) usable trials ($SD = 2.93$). Six participants had fewer
5 than seven useable trails for one cell. In the task portion of the data, participants had on average
6 11.72 (out of 14) usable trials ($SD = 2.49$). Four participants had fewer than seven trials for one
7 cell. Our results were largely the same when we excluded the cells from participants that had
8 fewer than seven trials as when we included all usable trials. Based on this and the fact that
9 multi-level modeling is robust to missing data (Judd, Westfall, & Kelly, 2012; Quené, & van den
10 Berg, 2004), we report results with all usable trials included. Finally, we examined the presence
11 of outliers. Outliers (2% of trials) were defined as values greater than $\pm 2.5 SD$ from the
12 participants mean across trials for that portion of the task (i.e., habituation trials or task trials).
13 Outlier values were replaced with the corresponding $\pm 2.5 SD$ value.

14 **Data Analysis**

15 Because of the nested nature of our data (i.e., people nested within groups and trials
16 nested within people), we used multi-level modeling to analyze our data. Multi-level modeling
17 has three major advantages over repeated measures ANOVA (see. Judd et al., 2012; Quené, &
18 van den Berg, 2004 for reviews). First, it allows for the explicit modeling of different sources of
19 variation, which allows for more statistical power. Second, it allows for more flexible modeling
20 of the variance/covariance matrix than repeated measures ANOVA, which requires sphericity.
21 This flexibility has been shown to protect against Type-I errors. Finally, multi-level modeling is
22 robust to unbalanced data (i.e., participants having different numbers of trials). This allowed us
23 to use all possible data. An additional advantage of multi-level modeling for startle magnitude

1 data, is that it allows for the research to include linear and quadratic effects to adjust for
2 habituation of the startle response to the noise probe during the task, further strengthening the
3 statistical power. Although most startle research has used repeated measures ANOVA and mixed
4 model ANOVAs, there are examples of uses of multi-level modeling (e.g., Bresin & Verona,
5 2016; Verona et al., 2013).

6 *Habituation analysis.* To examine the effect of group presence (Alone, Group) and
7 alcoholic beverage (control, alcohol) on habituation startle, we used a three-level multi-level
8 model to understand variation in the first 11 habituation probes. Because startle magnitude
9 generally decreases during the habituation period, it is important to consider time in this analysis
10 (Lane et al., 2013). Therefore, we first started by modeling startle magnitude as a function of
11 trial number to understand the normative habituation of startle magnitude across trials. Based on
12 previous research (Lane et al., 2013), we also included a quadratic effect of trial. The Level 1
13 (within-person, within-group) modeled startle magnitude as a function of trial number and trial
14 number squared. Trial was centered on the average trial number so that the intercept represented
15 the average startle magnitude during the habituation period and the slopes represent changes
16 from that average. The Level 2 (between-person, within-group) and Level 3 (between-groups)
17 models only contained a random effect for variation in the intercept. After establishing the
18 normative trend, we added group presence, and alcoholic beverage along with relevant
19 interactions (e.g., group presence x alcoholic beverage, trial number x group presence, trial
20 number x group presence x alcoholic beverage) to see how those factors moderated the
21 normative change.

22 *Image analysis.* To examine whether valence (unpleasant, neutral) affected startle
23 magnitude in the main task, we used a similar model to that above. First, we included trial and

1 trial² as covariates to account for continued habituation to the noise probe throughout the task
2 (e.g., Bresin & Verona, 2016). The Level 1 (within-person, within-group) modeled startle
3 magnitude as a function of valence, alcoholic beverage, and all interactions. The Level 2
4 (between-person, within-group) model contained group presence and the Level 3 (between-
5 groups) model only contained a random effect for variation in the intercept. All models were run
6 in SAS using full information maximum likelihood with degrees of freedom estimated with the
7 between function.

8 **Results**

9 **Manipulation Check**

10 All participants in both conditions had zero BAC upon arrival to the lab. BAC peaked
11 just after the startle task ($M = .07\%$, $SD = .001$). During the control session, all participants had
12 a zero BAC after the drink period.

13 **Habituation**

14 Consistent with previous research (e.g., Lane et al., 2013), we found a significant linear
15 decrease in startle across the habituation period, $\gamma = -.98$, $t(672) = -4.72$, $p < .001$ and a quadratic
16 increase, $\gamma = .16$, $t(673) = 2.36$, $p = .018$. Taken together, this suggests that in general there is an
17 initial steep linear decrease that levels out in later trials. When group presence, alcoholic
18 beverage, and interactions were added to the model, there were several significant effects. There
19 was a significant effect of alcohol, such that startle magnitude was lower overall in the alcohol
20 condition, $\gamma = -6.32$, $t(675) = -2.51$, $p = .012$. There was a marginal effect of group presence,
21 indicating that startle magnitude was larger when people were alone versus with others, $\gamma =$
22 12.87 , $t(51.5) = 1.94$, $p = .058$. These effects were qualified by a significant group presence x
23 alcoholic beverage interaction, $\gamma = -7.70$, $t(675) = -2.12$, $p = .034$. To decompose this

1 interaction, we looked at the effect of alcohol within group presence (see Figure 1 top panel).
2 The effect of alcohol was significant when people were alone, $F(1, 680) = 100.14, p < .001, d =$
3 $.38$, and with others, $F(1, 677) = 15.88, p < .001, d = .15$; however, the interaction indicated that
4 the effect of alcohol was significantly bigger when people were alone than when they were with
5 others. Because time is centered on the average trial number, the effect sizes only apply to the
6 average startle magnitude during the habituation period.

7 Although alcoholic beverage did not interact with trial, group presence interacted with
8 the linear, $\gamma = -1.94, t(672) = -3.68, p < .001$, and quadratic $\gamma = .43, t(672) = 2.29, p = .025$
9 components. These significant interactions indicate that the change in startle magnitude overtime
10 is influenced by the presence (versus absence) of group members. Figure 2 shows the estimated
11 growth curves for each condition. Two things are worth noting. First, when people were in the
12 presence of others there was a significant linear decrease, $\gamma = -.35, t(336) = -2.90, p = .004$, but
13 not a significant quadratic effect, $\gamma = .04, t(337) = .92, p = .360$. When people were alone,
14 however, both effects were significant, linear: $\gamma = -1.65, t(337) = -4.56, p < .001$; quadratic: $\gamma =$
15 $.32, t(336) = 2.43, p = .016$. Moreover, the linear decrease in the Alone condition was 5 times
16 larger than the Group condition. Second, it appears that part of the reduced decrease in the
17 Group condition was possibly influenced by the fact that they began with relatively lower startle
18 magnitude.

19 **Image Task**

20 Similar to the results from the habituation trials, there was a significant quadratic effect
21 for trial number during the picture viewing task, $\gamma = -.01, t(1767) = 2.41, p = .016$. There was
22 also a trend for a linear effect, $\gamma = -.06, t(1776) = -1.50, p = .134$. Thus, we included both as
23 covariates. The results from this analysis did not show any effect of valence or interactions

1 involving valence (p 's range from .617 - .941). There was a main effect of alcohol, such that
2 startle magnitude was lower in the alcoholic beverage condition than the control beverage
3 condition, $F(1, 1735) = 295.22, p < .001$. There was also a significant interaction between
4 alcoholic beverage and group presence, $F(1,1735) = 58.60, p < .001$. As above, we looked at the
5 effect of alcohol according to group presence condition. When people were alone, there was a
6 significant effect of alcohol, $F(1, 1736) = 304.25, p < .001, d = .42$, with smaller blinks while
7 intoxicated ($M = 4.58$) compared to sober ($M = 17.11$). There was a similar effect in the Group
8 condition (Alcohol: $M = 3.40$; Control: $M = 8.21$); however this effect was significantly smaller,
9 $F(1, 1733) = 46.00, p < .001, d = .16$.

10 **Exploratory Follow-up Analysis**

11 Given that our results were somewhat ambiguous as to whether they reflected emotion or
12 attention, we conducted further exploratory analyses. Because our results showed that the effect
13 of alcohol on startle magnitude was smaller in the Group condition, we wanted to explore
14 whether a factor that varied within groups showed a similar effect. The number of out-group
15 members (as compared to the participant) was one factor that varied within groups. Therefore,
16 we looked at whether the number of out-group members (as compared to the participant)
17 influenced the effect of alcohol on the startle magnitude. Prior research has shown that
18 intergroup interactions tend to increase anxiety, an effect that extends across divergent group
19 racial compositions and varying attitudes towards outgroup members (e.g., Richeson and
20 Shelton, 2007; Stephan and Stephan, 1989, 1985). Thus, if the effects are on emotion, you might
21 expect diminished effects of alcohol when more out-group members were present. If the effect
22 was larger when more out-group members were present, however, it would be more consistent
23 with an attentional allocation effect (i.e., out-group members are distracting attention away from

1 the startle probe). Note that, as these follow-up analyses were not the main focus of our research,
2 this particular study was not well powered for these models, and so our analysis of outgroup
3 members should be considered preliminary.

4 For this analysis, we only considered participants in the Group condition. The number of
5 out-group members was calculated by comparing the self-reported race of the participant
6 viewing the images to that of the other participants in the room. Group composition was
7 analyzed as a continuous variable ranging from 0 (neither of the other 2 individuals in the room
8 with the image-viewing participant were racial out-group members) to 2 (both of the other 2
9 individuals in the room were racial out-group members). Of the 20 groups used in the analysis, 3
10 contained no out-group members, 5 contained one out-group member, and 12 had 2 out-group
11 members. Although a comparison of racial subcategories (i.e., beyond in-group and out-group)
12 is not within the scope of this paper, our sample did include representation from a variety of
13 racial categories racial configurations—the participants who were viewing images were 30%
14 White, 20% African American, 25% Asian, 5% Hispanic, 5% Pacific Islander, and 15% Other;
15 individuals sitting in the same room with them were 67.5% White, 7.5% African American,
16 17.5% Asian, 5% Hispanic, and 2.5% Other.

17 As with the main results, separate analyses were run for the habituation period and the
18 picture viewing period. The models were similar to those above, with the major difference being
19 that instead of group presence, the number of out-group members was included as a predictor of
20 startle magnitude. Because zero out-group members had different meanings for the Alone
21 condition as compared to the all in-group members condition, we only look at participants in the
22 Group condition. Therefore, the key parameter of interest was the alcoholic beverage x number
23 of out-group members' interaction.

1 In the analysis for the habituation period, there was an effect of alcohol, $F(1, 303) =$
2 84.65, $p < .001$, which was clarified by a significant alcoholic beverage x number of out-group
3 members interaction, $F(2, 303) = 6.91$, $p = .001$. The effect of alcohol was larger when there
4 were no out-group members $\gamma = -11.70$, $t(59) = -4.71$, $p < .001$, $d = .61$, and one out-group
5 member, $\gamma = -8.97$, $t(76) = -5.26$, $p < .001$, $d = .60$, than when there were two out-group
6 members, $\gamma = -4.23$, $t(173) = -4.69$, $p < .001$, $d = .35$. Given that there were so few participants
7 per cell, we also looked at the relation between the number of out-group members and startle
8 magnitude within each session. In the alcohol session, the number of out-group members was
9 not significantly related to startle magnitude, $\gamma = -.42$, $t(16.7) = -.44$, $p = .662$, and for the control
10 session, there was a marginal negative relation between the number of out-group members and
11 startle magnitude, $\gamma = -4.45$, $t(17.2) = -1.76$, $p = .095$.

12 Very similar results were found during the task. Among those in the Group condition,
13 there was a significant interaction between alcohol and number of out-group members, $F(2, 791)$
14 $= 53.75$, $p < .001$. The effect of alcohol was bigger when there were no out-group members, $\gamma =$
15 -11.59 , $t(156) = -8.59$, $p < .001$, $d = .68$, or one out-group member, $\gamma = -7.90$, $t(183) = -8.27$, $p <$
16 $.001$, $d = .6$, than two out-group members, $\gamma = -1.65$, $t(456) = -4.28$, $p < .001$, $d = .20$. In the
17 alcohol session, the number of out-group members was not significantly related to startle
18 magnitude, $\gamma = .61$, $t(19) = .72$, $p = .479$, but was significantly negatively related in the control
19 session, $\gamma = -4.35$, $t(18.4) = -2.27$, $p = .035$. Together these results are more consistent with out-
20 group members distracting participants from attending to the startle probes, which combined
21 with our other results might suggest that the effects of group are more about cognitive resources
22 than affect per se.

23

Discussion

1 The current study offers a novel paradigm for understanding alcohol’s reinforcing effects,
2 for the first time examining how social context and alcohol interact to predict startle responses.
3 This paradigm made it possible to capture effects of alcohol on automatic psychological
4 processes and to examine how these processes vary according to social setting—a setting with
5 relatively high ecological validity for understanding alcohol’s effects. Our results indicate that
6 there was a significant effect of group presence, indicating that startle magnitude was larger
7 when people were alone versus with others. In addition, there was a significant group presence
8 by alcoholic beverage interaction, with the effect of alcohol being significantly larger when
9 people were alone than when they were with others. These effects were found both for the startle
10 habituation data and during the picture viewing task.

11 Prior research examining the effect of alcohol and social context on *emotion* has
12 produced results that would appear to diverge from the results of this study, with findings of
13 these studies indicating that alcohol’s effects on emotion are *larger* in social context (Doty and
14 de Wit, 1995; Pliner & Cappell, 1974). Of note, these prior studies have focused on neutral or
15 explicitly pleasurable social stimuli (e.g., conversing in a room with books and games,
16 composing cartoon captions), and the emotion outcomes did not explicitly target stress processes.
17 One possible explanation for the results of the current study is that, given this somewhat
18 uncomfortable and sometimes distressing experimental procedures/stimuli in our study
19 (darkened room, experimental electrodes, distressing images), people were feeling more
20 comfortable in the presence of another person (albeit a relatively unfamiliar individual) than they
21 were when they were alone. Some past studies, i.e., Flores & Berenbaum (2017), indicate that
22 even holding the hand of a stranger can be comforting when individuals are presented with a
23 stressful situation. Thus, alcohol and social context may have been performing similar functions

1 of alleviating anxiety in this paradigm. In this regard, alcohol might have less of an effect in
2 reducing anxiety in the group setting because another source of comfort – the presence of others
3 – was already available.

4 A second possible explanation for our results is that the presence of others served as a
5 *distraction*, which pulled attention away from the startle probes. The current study focused on
6 overall startle response during the habituation and task period, rather than emotion modulated
7 startle associated with the viewing of different emotionally laden slides. Overall startle response
8 is likely influenced by a variety of different psychological processes, not all of which are well
9 characterized within the literature (Kaye et al., 2016). Of note, the presence of other individuals
10 was already a cognitively demanding experience for participants, and thus they might have had
11 less attentional resources to focus on the task in the Group condition (Anthony & Graham, 1985;
12 Hackley & Graham, 1983; Silverstein et al., 1981). This was supported by the fact that startle
13 magnitude was not significantly influenced by the presence of affective foreground images.
14 Moreover, the follow-up analysis on interracial groups appear to provide some support, although
15 preliminary, for this cognitively-focused interpretation of findings. Interracial interactions serve
16 both to increase anxiety and also to usurp attentional resources. Thus, were startle magnitude in
17 the social context serving primarily as an index of emotion (i.e., anxiety), we might expect
18 enhanced startle magnitude in interracial contexts whereas, were it serving primarily as an index
19 of attention allocated away from the startle procedures, we might expect diminished startle
20 magnitude. In fact, the results indicated that the effect of alcohol on the startle reflex was larger
21 when there were no out-group members than when there was one out-group member, or two out-
22 group members. These results appear to provide support for a cognitive (i.e., attention allocation)
23 explanation of our group presence by alcoholic beverage interaction, Importantly, however,

1 power was low for these between-group analyses, and these models further examined effects of
2 intergroup contexts across a range of group racial compositions. Findings examining effects of
3 intergroup context should therefore be viewed as preliminary.⁴ Future research might examine
4 effects within specific racial pairings (e.g., Black-White interactions) and among individuals
5 higher in automatic racial bias, and could further examine attention allocation effects by
6 combining startle with event-related potentials (e.g., P300; Drislane et al., 2013).

7 We did not find evidence of the well-replicated effect of increased startle magnitude for
8 unpleasant (versus neutral) images during the task. There are several possible reasons for this.
9 First, it is possible that the manipulations and procedures of the task were such that they
10 distracted participants from fully attending to the images, even when they were alone in the
11 control condition. It is also possible that the manipulations influenced how participants
12 appraised the images. We did not have participants rate the valence and arousal of the pictures,
13 which may have provided some insights into why we did not find the common valence effects.
14 Although the lack of valence effect is difficult to interpret, this is not a problem with the
15 habituation data, which showed an identical pattern of effects as the task data. There is not a
16 consensus as to what the startle habituation means; however, many studies suggest a cognitive

⁴ Some prior research has examined the interaction between alcohol and distraction (i.e., attention allocation) in a startle context. For example, unlike the current study, Curtin and colleagues (Curtin et al., 1998) found no interaction between alcohol and attention allocation. One difference between the current study and that of Curtin is the presumed congruity of the distracting stimulus and the probe stimulus. In Curtin's study, startle probes were auditory and distractions were visual (e.g., slides). While we also used an auditory probe, in the current study, given that group mates were outside of the sight line of our participants, it is more likely that distractions would have been experienced as auditory in form. While the participants in the current study were instructed not to talk during the task, it is possible that other forms of auditory distractions (i.e., adjusting body position, shifting chairs, etc.) took place. Some research suggests that the extent to which probes and distractions match in modality can have significant effects on startle responses (e.g., Anthony & Graham, 1985). Thus, the mismatched probe-distraction modality in Curtin's work and the matched probe-distraction modality in our own work may account for our divergent findings here. However, the exact nature of potential distraction in the current study is unclear (e.g., auditory, visual, other). Future work is needed to clarify whether the match or mismatch in stimulus modality has direct effects on startle responses.

1 component (e.g., Braff et al., 1992) further supporting our interpretation that our manipulations
2 had effects on cognition.

3 The results of this study might ultimately have implications for understanding alcohol
4 response and risk for AUD. For decades, alcohol researchers have been seeking to understand
5 the emotional and also cognitive effects of alcohol with a view to better elucidating the factors
6 that make people vulnerable to developing AUD. As the majority of alcohol consumption occurs
7 in social context and people mainly drink together with other people regardless of age or
8 problem drinking status, it is important to understand how social factors and alcohol act in
9 combination in order to fully understand alcohol's rewarding effects (Fairbairn & Sayette, 2014).
10 Nevertheless, perhaps partially due to the methodological challenges regarding the adoption of
11 social context into studying the effects of alcohol, relatively little is known about alcohol's
12 rewarding effects in social settings. In this regard, the current research may have important
13 methodological implications as it investigated the reinforcing effects of alcohol in social context.
14 Specifically, the current study is the first step towards capturing the automatic emotional and
15 cognitive effects of alcohol in a social context, using a startle methodology.

16 Another important contribution of the current study is that, to our knowledge, this is the
17 first study to incorporate a social context into a startle paradigm. As noted previously, while
18 many past studies have attempted to examine the effect of social context on psychological
19 processes using a variety of methods and psychophysiological measures (Donohue et al., 2007),
20 to our knowledge, no study has employed startle methodology in social context. Social contexts
21 are complex, impacting both emotional and cognitive processes with high relevance for physical
22 and mental wellbeing (Boyce et al., 1998). In this regard, the current study is intended to take an
23 initial step towards the integration of a social context into startle paradigms, and, in broader

1 terms, to help further develop various ecologically valid startle paradigms (Dunsmoor et al.,
2 2014; Mühlberger et al., 2008).

3 Limitations and future directions should be noted. First, in this study of the impact of
4 social context on startle response, we examined the influence of social context on responses to a
5 slide viewing task. We chose a slide paradigm as the most widely studied and well understood
6 context for examining startle, which we concluded was a useful starting place for the study of
7 social context effects. Unlike much prior startle research, however, the current study did not
8 produce a significant effect of slide valence on the startle magnitude—possibly due to the
9 salience of other manipulations employed in the current study (e.g., beverage manipulation,
10 social context, etc.). Assessing alcohol’s effects on emotional responses to more diverse stimuli,
11 i.e., audiovisual stimuli (Gerdes et al., 2014), might be a direction for future studies. Another
12 possibility is that null effects are attributable to the relatively low reliability for emotion
13 modulated startle measured via slide viewing tasks when compared with overall startle responses
14 (Kaye et al., 2016). Second, we also acknowledge that the design of the current study was highly
15 complex, and some of the positive and negative findings should further be studied in more
16 parsimonious designs to clarify their meaning. Future studies could simplify the study design by
17 investigating the effect of alcohol alone or the effect of social situation alone, on the startle
18 magnitude. Third, another limitation of note in the current study is that the follow-up analysis
19 exhibited low power to detect significant between-group differences. Although we speculate
20 about attention and affect changes that could covary with number of outgroup members, our
21 interpretations are one of many processes that could have varied across groups with different
22 numbers of outgroup members. Further, the sample size was very small for interracial groups,
23 leading to low power and a higher possibility for false positive effects. Future research would be

1 indicated to examine these effects in designs with better statistical power to detect effects for
2 these supplemental analyses. Fourth, a limitation of the alcohol administration procedure is that a
3 placebo condition was not used. As mentioned previously in this paper, placebo manipulations
4 can lead to unanticipated compensatory effects (Testa et al., 2006), which is why we chose to use
5 a control comparison in the current study. Nonetheless, future studies might consider
6 incorporating a comparison group that accounts for alcohol expectancy effects. Fifth, individuals
7 with alcohol use disorder were excluded from the current study. The National Institute on
8 Alcohol Abuse and Alcoholism indicates concerns associated with administering alcohol to
9 individuals with problematic drinking patterns (National Advisory Council on Alcohol Abuse
10 and Alcoholism, 1989). Nonetheless, future research might consider investigating whether the
11 findings can be generalized not only to social drinkers but also to individuals with alcohol use
12 disorder. Sixth, another aspect of the current research is our choice to examine social context by
13 exploring the effects of the mere presence of other individuals, rather than examining active
14 social exchange or engagement in a joint activity. We made this choice for several reasons: 1)
15 Accurate psychophysiological measurement precludes the kind of activity involved in some
16 natural social exchange; 2) Social interactions involve multiple complex psychological
17 processes, and the current design allowed us to more accurately pinpoint mechanisms underlying
18 effects of social context. Although the current paradigm mirrors aspects of some common social
19 drinking contexts (e.g., bar patrons seated in very close proximity but engaged in separate
20 conversations), future research might alter our current design to more closely mirror features of
21 everyday social drinking settings. Finally, the current study employed only one dose of
22 alcohol—a “moderate” dose. Future studies should examine whether effects generalize to higher
23 or lower doses.

1 In summary, in the present study, we integrated methods and theory from multiple fields
2 to examine the impact of alcohol in a social context. Findings provide initial evidence for an
3 interaction between alcohol and social context in predicting the magnitude of startle responses.
4 More generally, the present study might offer new directions for understanding the effects of
5 alcohol on automatic cognitive and emotional processes across contexts.

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4

5

1 Table 1

2 *Descriptive Characteristics of the 60 participants in the Study Sample. Data are expressed as*3 *mean SD or frequency (%).*

✓ The original published version of this Table included errors (Age, % White, and Number of Drinking Occasions in the past 30 days). Correct numbers are reported in this version.

Variable	All participants (n=60)	Primary Startle Participants (n=40)	Non-startle Participants (n=20)
Age	22.50 (1.88)	22.73 (2.01)	21.95 (1.47)
Sex (% Female)	50	50	50
% White	55	50	70
% Black	12	15	5
% Asian	20	22.5	15
% Hispanic	5	2.5	10
Number of Drinking Occasions in the past 30 days	10.30 (5.48)	9.93 (4.92)	11.45 (6.38)

Number of Drinks 4.07 (1.94) 3.82 (1.84) 4.55 (2.09)
per Occasion

1

2 Of the 60 participants, all engaged in alcohol-administration procedures and were involved in the

3 “group” startle condition, and 40 (50% MALE, average age=22.7) served as primary startle

4 participants (see above for description of startle procedures).