Alcohol's Impact on Cognitive Control of Behavioral Inhibition

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Abstract

There is a widespread acceptance of the potential for alcohol intoxication to impair cognitive processes (Holloway, 1994). Yet, much remains to be specified and this is a particularly critical time because theorizing about the role of cognitive deficits in understanding intoxicated emotion (e.g., SRD effects) and behavior (e.g., aggressivity, impulsivity, sexual risk-taking) is gaining increasing visibility (Lang et al., 1999). In particular, inebriates have difficulty executing cognitive control required to inhibit dominant responses that are contextually inappropriate. The purpose of the experiment described here was to examine the effects of alcohol on ability to produce contextually adaptive behavioral response when pre-potent, but incorrect, responding must be inhibited.

Participants received either alcohol (target BAL = 0.08g/100ml) or no-alcohol. They performed 432 trials of the Stroop procedure. Stroop stimuli consisted of color words (red, blue or green) presented in colored script on a computer monitor. Participants' task was to attend and respond to only one dimension of the stimulus (either word or script color). Trials were blocked on task (name script color vs. read word), with task order counterbalanced across participants. Within each task type, trials were congruent (match between script color and word), neutral, or incongruent (mismatch between script color and word). Verbal response time and accuracy were measured to examine behavioral effects of alcohol during response competition and comparison conditions. Event related potentials (ERPs) were utilized to index beverage and task/condition effects on underlying cognitive mechanisms.

Behavioral data were consistent with predictions. Specifically, alcohol intoxication resulted in impaired performance only when the task required execution of the non-dominant response (i.e., script color naming) in the context of competing, incompatible word information (i.e., non-matching color word). Examination of ERPs provided information about potential cognitive processes and systems responsible for this failure in behavioral control. Results are interpreted with reference to recent models of cognitive control which highlight the vital roles of interactive executive and conflict monitoring systems when performing tasks which require inhibition of dominant response sets in favor of contextually more adaptive but weaker competing responses. Alcohol intoxication did not affect initial stimulus evaluation, but instead impaired inhibitory processes responsible for the suppression of contextually inappropriate, pre-potent information during response selection.

Methodology

Participants

48 social drinkers (24 male/24 female) assigned to 2 beverage groups

- Alcohol (peak blood alcohol level of 0.080 g/100 ml)
- No-Alcohol

Description of Paradigm

- Participants performed an individual trial Stroop Color-Word Interference Task
- Stimuli were words presented in colored script (red, blue, or green)

- Participants performed each of two tasks in separate blocks:
  - Color naming: Participants named the script color of the stimulus
  - Word reading: Participants read the stimulus word

- Within task, trials were presented in 3 conditions:
  - Congruent: Word and script color matched (e.g., RED, GREEN)
  - Neutral: Only word or script color presented dependent on task (e.g., for color naming: TOE, WRIST; for word reading BLUE GREEN)
  - Incongruent: Word and script color did not match (e.g., RED, BLUE)

Method Details

- Stimuli were presented for 500 ms with a 2000 ms response window
- Participants completed 4 blocks each (54 trials/block) of color naming and word reading (order counterbalanced)
- Congruent, Neutral and Incongruent trials were randomly ordered and equi-probable within all blocks
- Verbal response time was recorded online with a digital VOX
- Three script colors (red, blue, green) were used in color naming blocks
- Non-color word control was used in Neutral color naming condition (toe, hand, wrist)
- Three words (red, blue, green) were used in word reading blocks
- White script (on black background) were used in Neutral word reading condition

Dependent Measures

Behavioral Response

Stroop task performance was indexed with two separate behavioral measures, Reaction time on correct trials and overall Error rate.

Event Related Potential (ERP) Indices of Cognitive Processing

ERP response was sampled at 1000hz during a 2000ms window initiating 500ms prior to stimulus onset. The ERP signal was bandpass filtered (0.05 – 30hz), eyeblink and baseline corrected, and signals that exceeded ± 75 µV were rejected as artifact. Average ERP waveforms were computed for each Condition (Congruent, Neutral, Incongruent) within the two Tasks (Color naming, Word reading).

- P3 is a parietal component of the ERP waveform the indexes stimulus evaluation. Moreover, previous research has indicated that P3 is independent of response selection related processing in Stroop. P3 was quantified as the maximum response between 200 and 500ms post-stimulus onset at the Pz scalp site.

- N400 is a frontal component of the ERP waveform that indexes a conceptual level inhibitory process that supports the suppression of word information in Stroop. N400 is observed as a negative bias (i.e., reduction) in the frontal positivity associated with the relatively automatic word identification. N400 was quantified as the maximum response between 400 and 800ms post-stimulus onset at the Fz scalp site, with smaller response indicating larger N400 inhibition.

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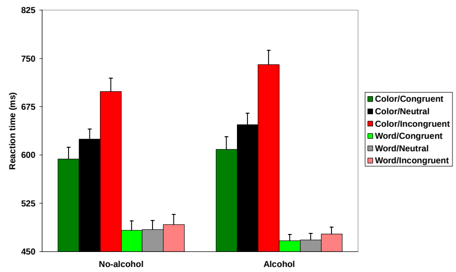
Behavioral Effects

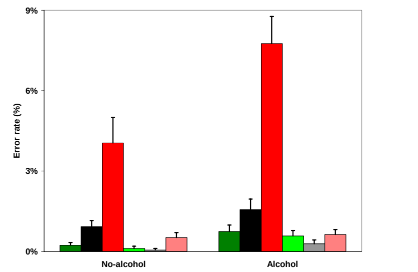
Reaction time:
Consistent with the overall Stroop literature, significant Task, Condition, and Task X Condition effects were observed for reaction time.

A significant Beverage X Task effect, $F(1,46) = 4.51$, $p = .039$, was also observed. Specifically, a larger Task effect was observed among intoxicated participants with these individuals exhibiting generally slower color naming and faster word reading than sober participants.

Error rate:
As expected, similar significant Task, Condition, and Task X Condition effects were observed for error rates.

A significant Beverage X Task X Condition effect, $F(1,46) = 3.40$, $p = .042$, was also observed. Follow-up Boneferroni-corrected simple effect tests revealed a significant increase in error rate among intoxicated participants in the color naming interference condition, $t(46) = 2.66$, $p = .011$.

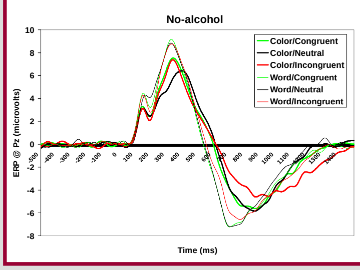


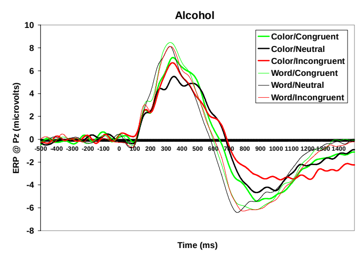


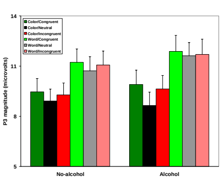
P3 index of Stimulus Evaluation

A significant main effect of Task, $F(1,46) = 35.28$, $p < .001$, was observed for P3 magnitude with greater P3 displayed during word reading than color naming, indicating superior attentional processing of word relative to color information. A significant effect of condition, $F(2, 45) = 4.94$, $p = .012$, was also observed, with increased P3 during congruent and incongruent conditions relative to the neutral condition.

No main effect or interactions involving Beverage were observed for P3 magnitude, indicating that alcohol did not affect stimulus evaluation of either word or color information. Moreover, alcohol did not affect the latency of the P3 response, indicating that the locus of the alcohol's effect on reaction time occurred at a stage of processing after stimulus evaluation.





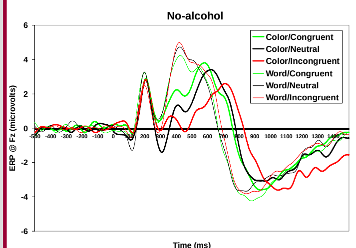


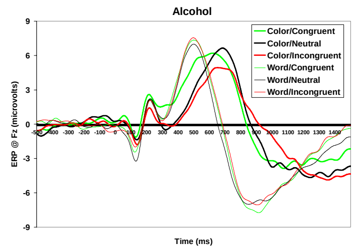
N400 index of Inhibitory Processing

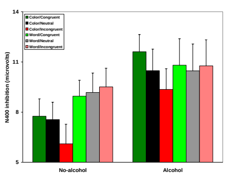
No-alcohol:
Among non-intoxicated participants, significant effects of Task, $F(1,23) = 7.98$, $p = .010$, and Task X Condition, $F(2,22) = 4.53$, $p = .024$, were observed. Specifically, sober individuals displayed greater N400 inhibition of frontal positivity during color naming than word reading. Moreover, significant linear increase in N400 inhibition across congruent to neutral to incongruent conditions was limited to the color naming task, $F(2,22) = 6.33$, $p = .007$. No condition effect on N400 was observed during word reading.

Alcohol:
Intoxicated participants did not exhibit the main effect of Task on N400 observed among sober participants. Moreover, intoxication participants displayed significantly less N400 inhibition during color naming than did their non-intoxicated counterparts, $F(1,46) = 4.91$, $p = .032$.

Intoxicated participants did display a trend toward a Task X Condition effect ($p = .067$) with significant linear increase in N400 inhibition during color naming ($p = .002$) but not word reading.







Conclusions

- Alcohol significantly impaired context appropriate adaptive behavioral response when that response had to compete with an incompatible, relatively automatic, pre-potent response. Specifically, intoxicated behavioral impairment was evidenced as increased error rates when automatic, pre-potent response was incorrect (i.e., incongruent color naming) and as an overall relative slowing of response time when more controlled-processing was required (i.e., all color naming conditions).

- These behavioral deficits associated with intoxication did not appear to result from deficits in attentional allocation to initial stimulus evaluation. Specifically, alcohol did not reduce the magnitude or delay the latency of the P3 component of the ERP, an electrophysiological index of stimulus evaluation, regardless of task or condition.

- Alcohol intoxication produced impairment in a frontal inhibitory process required to suppress or attenuate the influence of contextually inappropriate but pre-potent word information on response selection processes during color naming. Specifically, intoxicated participants exhibited significantly less N400 inhibition of frontal positivity during color naming.