Alcohol & Stroop task: Examining the role of cognitive control

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Abstract

Alcohol intoxication often leads to dysregulated behavior (e.g., aggression, impulsivity, sexual risk-taking) in contexts characterized by conflict between pre-potent, but inappropriate, response tendencies and incompatible alternative responses that are more adaptive. Recent theory about cognitive control processes and underlying neurobiological substrates responsible for adaptive behavior suggest mechanisms for intoxicated behavior. This project examined intoxicated behavior in a classic laboratory analogue conflict paradigm and utilized ERPs to tie behavioral deficits to impairment in candidate cognitive control systems.

Intoxicated and non-intoxicated participants performed the Stroop task. Stimuli consisted of color words presented in colored script and trials were congruent, neutral or incongruent. Participants' task was to name either the word or script color. Response time and accuracy were measured to examine behavioral effects of alcohol during response conflict. ERPs indexed beverage and task/condition effects on underlying cognitive/attentional systems.

Alcohol impaired performance only when the task required the non-dominant response (script color-naming) in the context of competing, incongruent word information. Alcohol did not affect parietal P3 magnitude/latency, indicating that timing and integrity of stimulus evaluation remained intact. In contrast, alcohol reduced frontal components of the ERP (N450 & negative slow wave) that result from activity in systems which bias processing in favor of contextually appropriate, but relatively weaker, stimulus-response mappings to produce flexible, adaptive behavior.

Cognitive Neuroscience of Attention

- Multiple functions of attention include (Posner, 1995):
  - Maintenance of alert state
  - Sensory orienting (attentional "spotlight")
  - Executive function
- Different neural sub-systems responsible for these functions
  - NE pathways from locus coeruleus
  - Posterior system* for attentional engagement/disengagement and moving (parietal lobe, pulvinar, superior colliculus)
  - Anterior executive attention/cognitive control system (PFC, ACC, SMA)
    - Evaluative control: Responsible for monitoring the need for control ("action monitoring") and signaling when adjustments are necessary
    - Regulative control: Responsible for activation and implementation of control related processes

Methodology

Participants

- 48 social drinkers (24 male/24 female) assigned to two beverage groups
  - Alcohol (peak blood alcohol level of 0.080%)
  - No-alcohol

Description of Paradigm

- Participants performed an individual trial Stroop Color-Word Task
- Stimuli were words presented in colored script (red, blue, or green)
- Participants performed each of two *TASKS* in separate blocks:
  - Color naming task (CNT): Participants named the script color of the stimulus
  - Word reading task (WRT): Participants read the stimulus word
- Within task, trials were presented in thee *CONDITIONS*:
  - Congruent Condition (CC): Word and script color matched (e.g., RED, GREEN)
  - Neutral Condition (NC): Only word or script color presented according to task (e.g., for CNT: TOE, WRIST; for WRT: BLUE GREEN)
  - Incongruent Condition (IC): 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 color words (red, blue, green) were used in word reading blocks
- White script (on black background) were used in Neutral word reading condition

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Dependent Measures

Behavioral Measures

Stroop task performance was indexed with two separate behavioral measures: verbal Response time on correct trials and overall Error rate.

Event Related Potential (ERP) Indices

- ERPs were sampled at 1000Hz in a 2000ms window initiating 500ms prior to stimulus onset. ERPs were filtered (0.05 – 10Hz), and eyeblink, artifact (signals > ±75 µV rejected) and baseline corrected. Average ERP waveforms were computed for each *Condition* within the color-naming task.
- P3 is a posterior/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 average response between 250 and 450ms post-stimulus onset at the Pz scalp site.
- N450 is an anterior/frontal component of the ERP waveform that previous research has suggested indexes evaluative cognitive control in Stroop. Specifically, its topography and suggested source (ACC), latency, phasic nature, and sensitivity to condition effects support this assertion. N450 was quantified as the average response between 400 and 500ms post-stimulus onset at the Fz and Fcz scalp sites.
- Negative Slow Wave (NSW) is an anterior/frontal slow wave that previous research has suggests indexes regulative cognitive control. Specifically, its topography and suggested source (PFC), latency, relatively tonic nature and sensitivity to condition effects support this assertion. NSW was indexed as the average level in the last 500ms of the sampling window after the phasic components of the ERP had resolved.

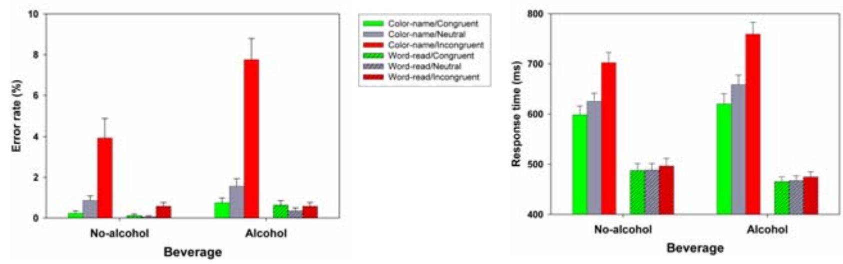
Behavioral Measures

Error rate:
As expected, significant *Task* (p< .001), *Condition* (p< .001), and *Task X Condition* effects (p< .001) were observed for error rate, with the interaction indicating that the *Condition* effect was greater during CNT than WRT.

A significant *Beverage X Task X Condition* effect (p= .007) was also observed. Follow-up *Beverage* simple effect tests revealed a significant increase in error rate among intoxicated participants for incongruent color-naming trials (p= .009). No other *Beverage* simple effects were significant.

Response time:
As expected, significant *Task* (p< .001), *Condition* (p< .001), and *Task X Condition* (p< .001) effects were observed for response time on correct trials.

Consistent with results for error rate, a significant *Beverage X Task X Condition* effect (p= .044) was observed. Follow-up *Beverage* simple effect tests revealed a trend toward slower response times for intoxicated participants on incongruent color-naming trials (p= .073). No other Beverage simple effects approached significance.



Event Related Potential Indices during Color-Naming

Posterior P3 (Stimulus Evaluation)

A significant main effect of *Condition* was observed (p< .001) for P3 magnitude. To decompose the condition effect, follow-up *Interference* (IC vs. NC) and *Facilitation* (CC vs. NC) contrasts were conducted. Both simple contrasts were significant indicating that P3 magnitude was reduced for IC and CC trials relative to NC trials. Importantly, no main effect or interactions involving *Beverage* were observed for P3 magnitude. No significant effects involving P3 latency were observed. Grand average P3 latency was 354 ms post stimulus onset.

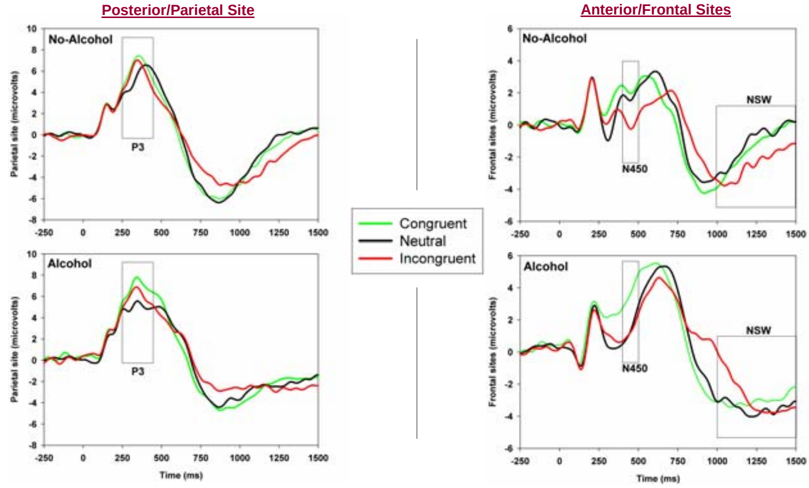
Anterior N450 (Evaluative Control)

A significant main effect of *Condition* was observed (p< .001) for N450. Follow-up significant *Interference* (p= .023) and *Facilitation* effects (p< .001) indicated that N450 was increased during IC trials and decreased during CC trials relative to NC trials. Importantly, the Beverage X Condition effect was significant (p= .042). Follow-up contrasts indicated that the *Interference* effect was reduced in intoxicated participants relative to their sober counterparts (p= .046). Similarly, the *Facilitation* effect was also reduced in intoxicated participants (p= .020).

Anterior Negative Slow Wave (NSW; Regulative Control)

A significant *Beverage X Condition* effect was observed for NSW (p= .032). Follow-up contrasts indicated that the expected *interference* effect was significantly reduced in intoxicated relative to sober participants (p= .009).

Posterior/Parietal Site — Anterior/Frontal Sites



Conclusions

- Alcohol significantly impaired context appropriate adaptive behavioral response when that response had to compete with an conflicting, pre-potent response. Specifically, alcohol did not produce overall impairment in execution of weakly established stimulus-response mappings (i.e., color naming). Moreover, it did not produce overall impairment when response conflict existed (i.e., all incongruent trials regardless of task). Alcohol intoxication produced selective impairment that was limited to trials involving both response conflict and the execution of relatively weaker stimulus-response mapping. These are the trials for which cognitive control was most essential for adaptive behavior.
- This behavioral impairment associated with intoxication did not appear to result from deficits in early posterior attentional function related 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.
- Consistent with the thesis that behavioral impairment when intoxicated results for deficits in anterior executive attention cognitive control, alcohol reduced electrophysiological indices of both evaluative and regulative cognitive control (i.e., N450 and NSW). Among sober individuals, both of these components increased on incongruent color-naming trials, indicating the contribution of cognitive control to adaptive task performance when response conflict exists and adaptive behavior requires execution of relatively weaker mapped response. The deficits observed among intoxicated individuals suggests that b/c of failure in evaluative control, the regulative system is not recruited to support flexible, contextually appropriate behavior. Therefore, intoxicated participants' behavior appears to be more stimulus driven.