Alcohol Expectancy and Pharmacology: Cognitive Mechanisms Underlying Behavior Regulation Effects

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Abstract

The behavioral deficits associated with alcohol intoxication often occur in situations involving conflict between a strong inappropriate response tendency and weaker but more appropriate responses. These same situations have been shown to engage cognitive control processes necessary for goal-directed behavior, suggesting alcohol may interfere with normal cognitive control function to produce these behavioral deficits. Current models of cognitive control include both an evaluative component that detects response conflict and a regulative component responsible for executing control processes. Altered function in these systems could result from either pharmacological effects of alcohol, or psychological expectancy of alcohol impairment. This study utilized both behavioral and event-related brain potential (ERP) measures to examine alcohol pharmacology and expectancy effects on evaluative and regulative cognitive control function and subsequent behavioral consequences.

Participants were assigned to one of three beverage groups: a no-alcohol control group, an alcohol placebo group, or a true alcohol group (target BAL = 0.08%). They then performed a modified Stroop task in which they were presented with color words written in colored script. Participants were asked to identify the script color in congruent, neutral, and incongruent conditions, and the relative frequency of each condition was manipulated between subjects to create "mostly incongruent" (MI; 80% incongruent) and "mostly congruent" (MC; 80% congruent) experimental contexts. Cognitive control theory and recent empirical research indicate that the relative contribution of evaluative vs. regulative cognitive control to task performance is manipulated across MC vs. MI contexts.

Alcohol expectancy led to decreased error rate in the MC context, while alcohol pharmacology led to an increased error rate. ERP analyses indicated these behavioral consequences were mediated by changes in regulative control function. These results further delineate the cognitive mechanism underlying behavioral regulation when intoxicated and may have important implications for understanding the developmental trajectory of alcohol use disorders.

Alcohol & Cognitive Control

Alcohol intoxication is associated with certain stereotypical patterns of inappropriate behavior, including aggression, risk-taking, and "loss of control" drinking. All these behaviors are characterized by inappropriate resolution of conflict between incompatible response tendencies, suggesting alcohol may impair cognitive processes necessary for appropriate resolution of response conflict.

Cognitive control is an emerging construct in the field of cognitive neuroscience that refers to the effortful activation and allocation of cognitive resources for the purpose of guiding behavior. It is critical for performance on tasks that are complex, difficult, or novel, as well as those that involve response conflict. This profile corresponds to the deficits observed during intoxication and suggests alcohol may interfere with normal cognitive control function.

Recent research on cognitive control has identified two distinct components, either of which may be affected by alcohol:

-> **Evaluative control**: responsible for monitoring the need for control by detecting conflict and signalling when adjustments are necessary; likely instantiated in anterior cingulative cortex (ACC)

-> **Regulative control**: responsible for implementation of control-related processes; likely instantiated in prefrontal cortex (PFC)

Methodology

To test the effects of alcohol on cognitive control we utilized the Stroop task, an experimental paradigm known to activate the cognitive control system. Sixty-four participants were presented with color words written in colored script, and asked to identify the script color. Different combinations of word and script color led to three **Conditions**:

-> **Congruent**: word and script color match (e.g., RED, GREEN)
-> **Incongruent**: word and script color differ (e.g., RED, BLUE)
-> **Neutral**: non-color word (e.g., TOE, HAND)

In addition, the frequency of each condition was manipulated between subjects to create two experimental **Contexts**:

-> **Mostly Incongruent** (MI): 80% incongruent, 10% congruent, 10% neutral
-> **Mostly Congruent** (MC): 80% congruent, 10% incongruent, 10% neutral

Cognitive control theory suggests that the context manipulation should produce more conflict on the incongruent condition in the MC context than in the MI context, placing a differential demand on evaluative control. Indeed, Carter et al. (*PNAS*, 2000) used fMRI to demonstrate increased activation of ACC on the incongruent condition in the MC context.

In order to evaluate the effects of alcohol, **Beverage** was manipulated between subjects:

-> **Control:** expect no alcohol, receive no alcohol
-> **Placebo**: expect alcohol, recieve no alcohol
-> **Alcohol**: expect alcohol, receive alcohol (dose designed to produce peak BAL of 0.08%)

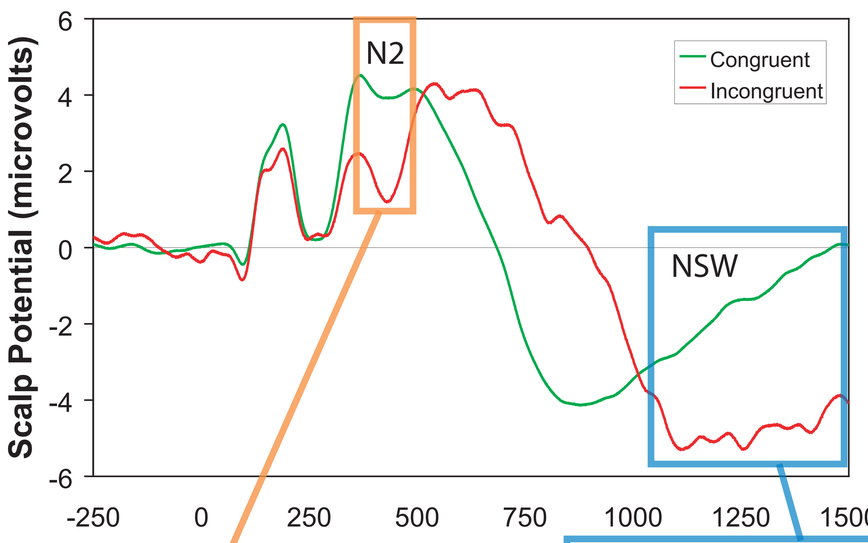
This design permits assessment of alcohol *expectancy* (control vs. placebo) as well as alcohol *pharmacology* (placebo vs alcohol)

Dependent Measures

Interference contrasts (INT) for all measures were calculated as the difference between the congruent and incongruent conditions

Behavioral indices
-> Error rate
-> Response time (correct trials only)

Electrophysiological indices: record brain activity using event-related brain potentials (ERPs)
-> Measurements of electrical activity on the scalp generated by specific neural processes
-> ERP waveform (shown below) represents fluctuations in scalp potential over time
-> Stroop stimulus is presented at time zero
-> Specific components measure **evaluative** and **regulative** control activity



N2
Phasic frontal negativity occuring 375-475ms after stimulus presentation. Previous research suggests N2 may be generated in ACC, and thus index **evaluative** control activity. Measured at the Cz scalp site.

Negative slow wave (NSW)
Tonic frontal negativity occuring 1100-1500ms after stimulus presentation. Previous research suggests NSW may be generated in PFC, and thus index **regulative** control activity. It may be a response to evaluative activity seen in the N2. Measured at the Fz scalp site.

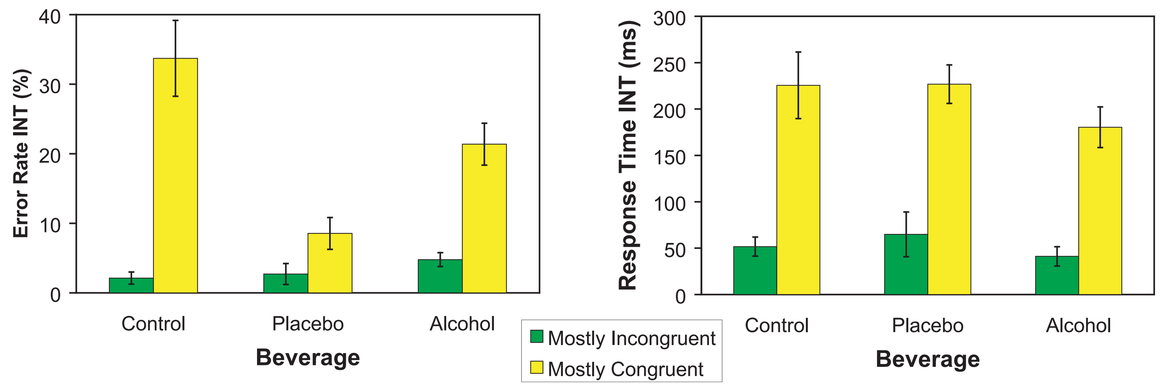
Behavioral Measures

Error Rate:
A significant Beverage x Condition interaction (p=.001) was observed, indicating that beverage only had an effect in the mostly congruent context (p=.001)

-> a significant *expectancy* effect (p<.001) indicated less interference in the placebo group than the control group

-> a significant *pharmacology* effect (p=.019) indicated more interference in the alcohol group than the placebo group

Response Time:
A significant effect of context was observed (p<.001), indicating more interference in the mostly congruent context. However, unlike the error rate data, no Beverage x Context interaction was observed (p=.245)

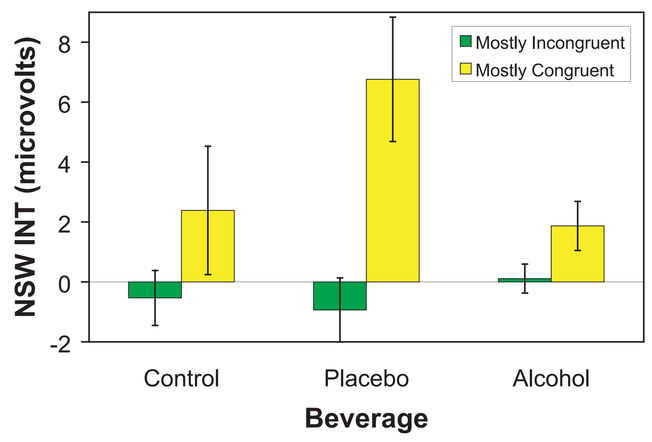


NSW

A significant Beverage x Condition interaction (p=.041) was observed, indicating that beverage only had an effect in the mostly congruent condition (p=.012)

-> a significant expectancy effect (p=.028) indicated more interference in the placebo group than the control group. This means the placebo group exhibited a larger NSW in respose to the incongruent condition, indicating more regulative activity. This regulative activation could be the basis of the improved error rate performance of the placebo group

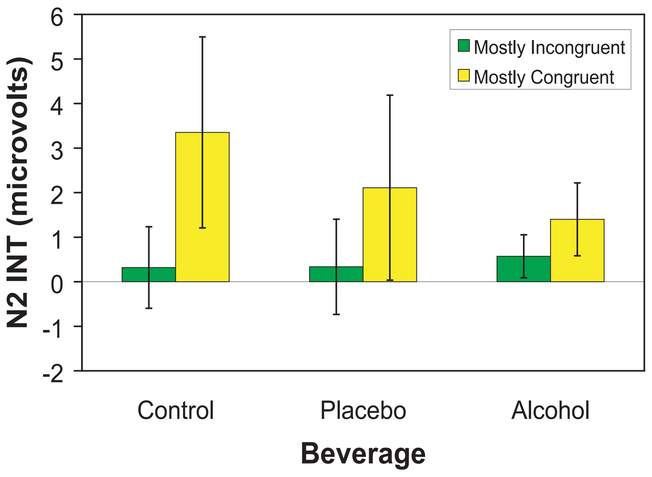
-> a significant pharmacology effect (p=.006) indicated less interference in the alcohol group than the placebo group. The alcohol group thus exhibited a smaller NSW in respose to the incongruent condition, indicating less regulative activity. This decrease in regulative activation could be the basis of the error rate performance deficit seen in the alcohol group



N2

A significant main effect of context was observed (p=.008), indicating more N2 interference in the. mostly congruent context. Thus the N2 response to the incongruent condition was larger in the mostly congruent context, a pattern of activity that verifies the context manipulation was successfully varied the demand placed on evaluative control.

However, there was no Beverage x Context interaction (p=.386). Combined with the NSW results, this suggests that alcohol may have a selective effect on either the regulative system itself or communication between the evaluative and regulative systems



Summary

-> Beverage effects on task performance and brain activity were only seen in the high-conflict mostly congruent context, providing additional evidence that the cognitive deficits associated with acute alcohol intoxication may be specific to conflict resolution processes like cognitive control

-> Alcohol expectancy and pharmacology produced distinct effects on performance, with expectancy enhancing performance and pharmacology diminishing it. The pharmacology effect is likely due to alcohol's effect on the cognitive control system, while the expectancy effect may be due to a compensatory effort by the placebo group. This group may have attributed the conflict experienced in the mostly congruent context to the expected effects of alcohol and attempted to compensate by enhancing their performance

-> The NSW data correspond well to the error rate results and suggest that compensatory efforts by the placebo group as well as the performance deficit in the alcohol group are related to regulative control. Alcohol did not appear to have any effect on the evaluative control system.

-> Future studies will investigate whether alcohol is directly affecting the regulative control system, or if it interferes with communication between the evaluative and regulative systems.

-> Research in this vein may be helpful for understanding the developmental trajectory of alcohol use disorders, which are often characterized by conflicting urges to use and to abstain from use. An inherited or acquired deficit in cognitive control function could predispose one to resolve this conflict in favor of continued use despite adverse consequences.

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