# Alcohol Effects on ERP Correlates of Cognitive Control

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## Abstract

Behavioral deficits associated with alcohol intoxication are often most severe when inappropriate prepotent responses conflict with incompatible but more adaptive responses. These same situations engage cognitive control processes, suggesting alcohol may impair normal cognitive control function. Current cognitive control models include an evaluative component that detects response conflict and a regulative component that executes control processes. This project used electrophysiological (ERP) measures to link alcohol effects on each component with associated behavioral consequences.

Participants were assigned to a no-alcohol control group, a placebo group, or an alcohol group (target blood alcohol level = 0.08%). They performed a modified Stroop color-naming task in which the frequency of congruent, neutral, and incongruent conditions was manipulated to create mostly congruent (MC) and mostly incongruent (MI) contexts. Theoretical and empirical work indicates that evaluative and regulative control contribute differentially to performance in each context.

Alcohol expectancy (control-placebo contrast) and pharmacology (placebo-alcohol contrast) produced distinct effects on error rate and ERP correlates of regulative control function in the MC context. Expectancy led to improved performance mediated by regulative control, while pharmacology impaired both performance and regulative function. These results further delineate the cognitive mechanisms underlying intoxicated behavioral deficits and have implications for understanding the development 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)

## Methods

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, receive 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 of behavior included error rate and response time (correct trials only). ERPs were sampled at 1000Hz in a 2000ms window initiating 500ms prior to stimulus onset. ERPs were filtered (0-15Hz) and eyeblink, artifact (signals > +/-75uV rejected), and baseline corrected. Average ERP waveforms were calculated for the congruent and incongruent conditions in each context and beverage group. Analysis focused on two specific components:

- ***N2*** is a phasic frontal negativity suggested by previous research to index evaluative control. Its topography, suggested source (ACC), latency, and sensitivity to condition effects support this assertion. N2 was calculated as the average response from 375-475ms post-stimulus onset at the Cz scalp site.
- ***Negative slow wave (NSW)*** is a negative frontal slow wave suggested by previous research to index regulative control. Its topography, suggested source (PFC), latency, and sensitivity to condition effects support this assertion. NSW was calculated as the average response in the last 400ms of the sampling window at the Fz scalp site.

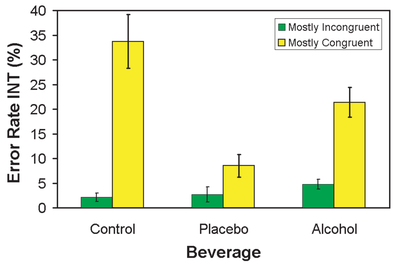
Interference conrasts (INT) were calculated for all dependent measures as the difference between the congruent and incongruent conditions.

## Behavior Results

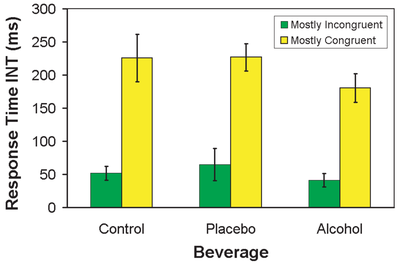
**Error Rate:**
A significant Beverage x Condition interaction (p=.001) was observed, indicating that beverage only had an effect in the mostly congruent context (p=.001)

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

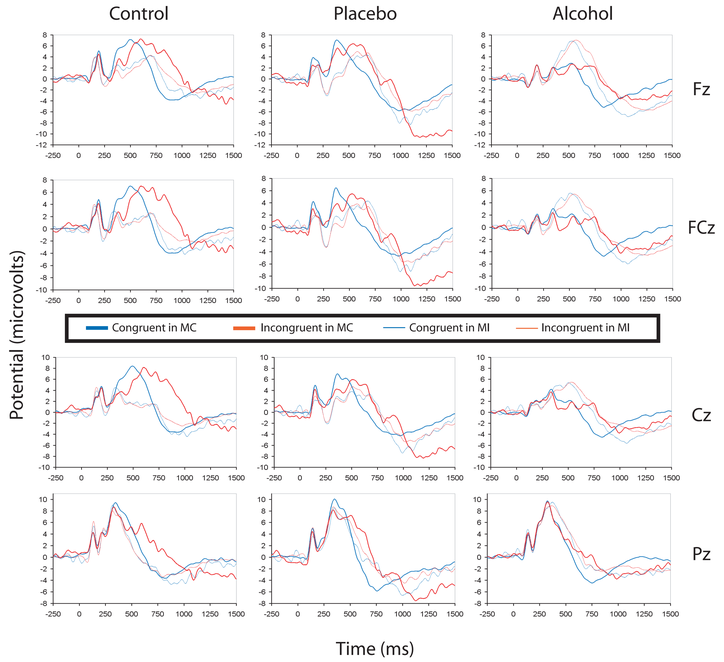
-> a significant *pharmacology* effect (p=.019) indicated more interference in the alcohol group than the placebo group




**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)




## Average ERP Waveforms by Site and Beverage Group

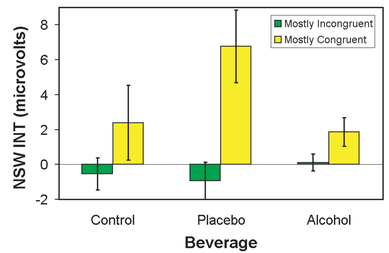



## ERP Results

**NSW:**
A significant Beverage x Context interaction (p=.041) was observed, indicating that beverage only had an effect in the mostly congruent context (p=.012)

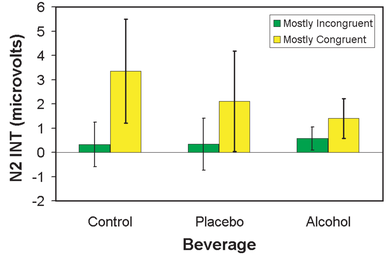
-> a significant expectancy effect (p=.028) indicated more interference in the placebo group than the control group. This means the placebo group exhibited a larger NSW in the incongruent condition, indicating more regulative activity. This regulative activation could be the basis of the improved error 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 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 for the incongruent condition was larger in the mostly congruent context, a pattern of activity confirming that the context manipulation successfully changed the demand placed on evaluative control

However, there was no Beverage x Context interaction (p=.386). Combined with the results for NSW, these data suggest 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 are specific to conflict resolution processes like cognitive control

-> Alcohol expectancy and pharmacology produced distinct effects on performance, with expectancy enhancing performance and pharmacology impairing it. The pharmacology effect is likely due to alcohol's action 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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