Alcohol and Error Related Negativity: A test of the Response Conflict Resolution theory

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Abstract

Numerous theories highlight the role of cognitive deficits in explaining dysregulated behavior when intoxicated. Synthesis of theory and data in the alcohol literature with basic research on cognitive control led to the development of the Response Conflict Resolution (RCR) theory. To test this theory, alcohol's effect on task performance when an incorrect, dominant response is concurrently activated was examined. ERPs indexed task-related cognitive processing. Error Related Negativity (ERN), an electrophysiological index of a neural system central to the RCR theory, was a focus.

Intoxicated and non-intoxicated participants performed a modified version of the Flanker task. Each trial consisted of a string of 5 letters (H's and S's). Participants made forced choice responses to indicate the center target letter while ignoring surrounding flanker letters. Flankers were congruent (e.g., HHHHH) or incongruent (e.g., SSHSS), with congruent/incongruent trials equi-probable. A dominant response was established by manipulating target letter probability with one response more probable (p=.80) than the other (p=.20).

Intoxicated participants' behavioral impairment on infrequent target trials increased over time. This suggests that the deficit resulted from conflict with the frequent target response, which became increasingly potent through repeated execution across trials. Alcohol reduced ERN, indicating that impaired execution of the weaker stimulus-response mapping resulted from alcohol-induced deficits in the cognitive system responsible for initiating controlled, attentional processing required in this context.

Response Conflict Resolution Theory

- Alcohol intoxication will produce dysregulated behavior in contexts that elicit response conflict.
  - Experimental stimuli such as Stroop stimuli, go/stop signals, approach avoidance conflict
  - Real life stimuli such as cigarette, attractive potential mate at party
- When response conflict exists, alcohol intoxication will impair execution of the initially weaker stimulus-response complex.
  - Strength of association is a result of prior execution of the SR complex (automatic processes)
  - Can result from local training (perseveration)
  - Can result from weakly encoded stimulus (i.e., peripheral stimulus)?
  - Some stimuli may have biologically supported (hard-wired) strong associations
  - Role of emotion/motivation in S-R strength?
- The behavioral dysregulation when intoxicated results from a relatively specific deficit in anterior attentional system components of cognitive control.
  - It does not result from a deficit in earlier stimulus orienting/switching and encoding
  - Some evidence that the cognitive control deficit may be specific to evaluative control/action monitoring

Methodology

Participants

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

- Alcohol (peak blood alcohol level of 0.080%)
- No-Alcohol

Description of Modified Flanker Task

- Stimuli are: HHHHH SSHSS SSSSS HHSHH
- Stimuli presented for 500ms with 1500-2500ms ISI
- 400 trials (4 blocks of 100) with break after two blocks
- Participants were instructed to:
  - ✓ Press button (left or right) to indicate *Target* (center) letter
  - ✓ Ignore surrounding *Flanker* letters

Independent Variables

- Flanker compatibility: Flanker letters were either congruent (HHHHH or SSSSS) or incongruent (HHSHH or SSHSS) with target letter. Congruent and incongruent flankers were equi-probable.
- Target frequency: The relative frequency of the two target letters was varied to establish a pre-potent response tendency. One target was frequent (80% of trials). The other was infrequent (20% of trials).
- Block: Participants completed 4 blocks of trials. A break was provided after the second block. It was expected that the pre-potent response tendency would increase over blocks

Dependent Variables

- Response time (RT): Behavioral impairment was examined by recording response time on correct trials.
- Error related negativity (ERN): ERN is a negative-going component of the response locked ERP waveform that is observed approximately 60 ms post response. ERN was quantified as the minimum deflection in the ERP waveform in a window from 0-125 ms post response. Recent research suggests that the neural generator of ERN is Anterior cingulate cortex (ACC) and activity in this system represents the neural signal for the need for regulative controlled processing.

Behavioral Effects

Response time (RT) was analyzed within a repeated measures ANOVA with Beverage as a between subject factor and Flanker Compatibility, Target Frequency, and Block as within subject factors.

Main Effects

- A main effect of Flanker Compatibility was observed ($p < .001$), with slower RT on incongruent trials.
- A main effect of Target Frequency was observed ($p < .001$), with slower RT on trials involving the infrequent target
- A main effect of Block was observed ($p = .035$). Follow-up polynomial contrasts revealed a significant cubic contrast ($p = .012$), which reflects a fatigue effect. Participants' RT increased from B1 to B2, reduced in B3 after the break, and increased again in B4.
- No significant main effect of alcohol was observed on RT ($p = .571$)

Interactions involving Beverage

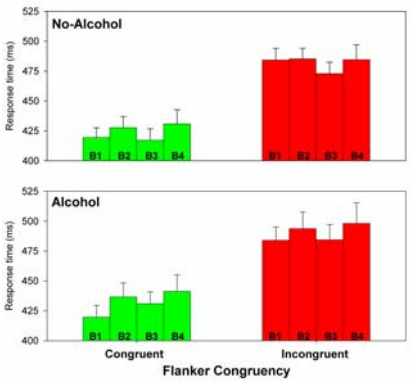
Flanker Compatibility

- Neither the Beverage X Flanker Compatibility ($p = .992$) nor the Beverage X Flanker Compatibility X Block ($p = .955$) interactions were significant.
- This indicates that alcohol did not exacerbate the behavioral impairment produced by incompatible flankers.

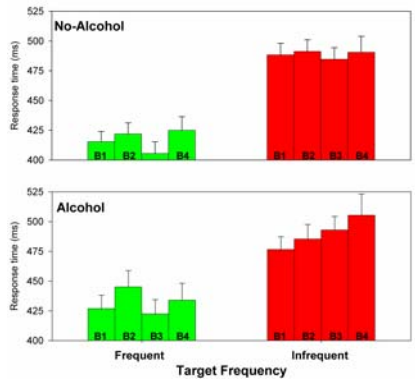
Target Frequency

- A significant Beverage X Target Frequency X Block interaction was observed ($p=.013$).
- Within beverage group follow-up analysis revealed only significant Target Frequency ($p< .001$) and trend level cubic Block ($p=.066$) effects for the no alcohol group.
- In contrast, a significant Target Frequency X Block interaction ($p=.002$) was observed for the alcohol group.
  - Further decomposition demonstrated only the significant cubic Block effect ($p< .001$) for hi frequency stimuli.
  - However, for low frequency stimuli, a significant linear Block effect ($p=.037$) was observed.
- There results suggest that intoxicated participants displayed increasing difficulty over time executing the infrequent response as the strength of the competing frequent response became increasingly stronger due to repeated execution.

Flanker Compatibility Effects

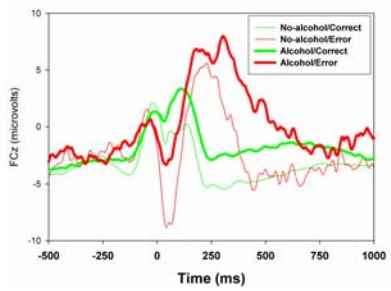


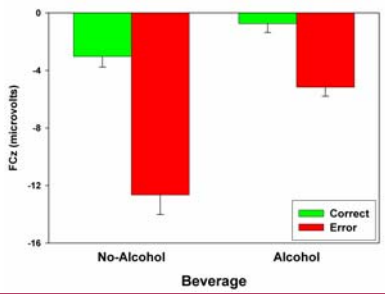
Target Frequency Effects



Error Related Negativity (ERN)

Error related negativity was analyzed within a repeated measures ANOVA with Beverage as a between subject variable and Accuracy (correct vs. error trials) as within subject variable. A significant Beverage X Accuracy interaction was observed ($p=.003$). This indicates that the magnitude of the ERN difference (error vs. correct trials) was reduced among intoxicated participants relative to non-intoxicated participants.





Conclusions

- Alcohol did not produce overall impaired performance. Instead, it selectively interfered with one aspect of task performance. Specifically, it interfered with the ability to execute the relatively weaker response option. As the discrepancy in the response strength of the two response options grew over the course of the experiment due to repeated execution of primarily one response, intoxicated participants displayed increasingly slower response on trials involving the other, more infrequent target stimulus. No such increase in impairment was observed among sober participants.
- In contrast to the target frequency interaction, alcohol did not impair (or enhance) individuals ability to selectively attend to target letters and ignore flankers. This suggests the need to examine the unitary nature of the attention construct as it is utilized in current theories about intoxicated behavior and to begin to entertain recent cognitive neuroscience theory which highlights the existence of multiple attentional systems.
- Alcohol significantly reduced ERN, a eletrophysiological index of the neural signal for the need for cognitive control. This effect suggests that intoxicated participants may fail to bring online the controlled processing resources necessary to inhibit prepotent response tendencies in favor of more adaptive, contextually appropriate response. Instead, intoxicated participants appear to be stimulus driven, relying more extensively on strength of stimulus-response association to guide behavior.