



## Emotional Facial Expression Perception and Processing in Alcohol Use Disorder Subgroups: A Behavioral and Electroencephalographic Investigation of Polysubstance Use

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### Abstract

Deficits in emotion processing among individuals with Alcohol Use Disorder (AUD) are well accepted, however the potential impact of polysubstance use in this population remains uninvestigated. The current work begins to fill this gap by analyzing affective perception and processing in community controls (CCs) and two AUD subgroups differentiated by presence (Alc-Drug) or absence (Alc-Only) of polysubstance use. Behavioral task performance and electroencephalographic (EEG) indices (N170, P3) were measured for an emotion judgement task where participants classified emotional facial expressions (EFEs) morphed to 65 or 95 percent intensity. Mixed model analyses detected deficits in emotion classification accuracy among Alc-Drug relative to other groups. Although there was a main effect of emotion (greater accuracy for positive vs. negative emotions), there was no group by emotion interaction. N170 amplitude analyses found only a main effect for emotion (greater amplitude for negative vs. positive emotions). P3 amplitude analyses detected differences between controls and individuals with AUD, but no difference between AUD subgroups. No correlation was found between accuracy and event-related potential (ERP) amplitudes. These findings contribute to the developing literature on emotional processing deficits in AUD, including highlighting the importance of considering polysubstance use in characterizing these deficits.

**Keywords:** Alcohol Use Disorder, polysubstance use, emotional processing, affect, emotional facial expression

### Introduction

Alcohol Use Disorder (AUD) is a dynamic public health concern affecting over 15 million Americans (National Institute of Alcohol Abuse and Alcoholism, 2018). About 10% of those diagnosed with AUD are also diagnosed with another Substance Use Disorder (Substance Abuse and Mental Health Services Administration, 2018), not including those undiagnosed or using substances at a subclinical level. Although substantive literature has explored the manifestations of AUD, there is a lack of investigation of the large portion of this population using additional psychoactive substances. In the context of AUD, one factor that has captured the literature's

attention is affective perception, as it has a substantial impact on social health as well as rehabilitation (Foisy et al., 2007). Though measures such as vocal prosody, tone, and body language have been used, most studies focus on emotional facial expression (EFE) perception given its saliency and everyday relevance. The affective perception deficits currently being characterized in AUD studies typically do not consider groups using additional substances. The current study looks to address this gap by utilizing AUD samples with (Alc-Drug) and without (Alc-Only) polysubstance use in EFE classification tasks.

### **Behavioral Indices**

Previous EFE perception studies with AUD samples have largely been conducted excluding other Substance Use Disorders (SUDs) and ignore significant subclinical use of other substances. Some AUD studies find EFE deficits that seem to be specific to emotion, with statistic similarity between AUD and control samples when expressions are neutral (e.g. Fein, Key, & Szymanski, 2010). Individuals with AUD tend to have decreased accuracy and increased reaction time when classifying EFEs, and tend to overestimate emotional intensity (e.g. Foisy et al., 2005). Such deficits appear associated with increased risk for interpersonal problems (Hoffman, Lewis, & Nixon, 2019). The current study seeks to clarify the effect of polysubstance use on the deficits found in AUD populations.

### **Electroencephalographic (EEG) Indices**

The current study utilizes N170 and P3 amplitudes as outcome measures. N170, a negative peak found around 170ms after stimulus presentation, is a measure of early visual perception and is specifically sensitive to face processing (Luck, 2014). The P3 component, a large positive deflection beginning around 300ms, reflects higher order processing and is linked to stimulus categorization and allocation of neural resources (Luck, 2014). Previous literature demonstrates equivocal N170 amplitude deficits in AUD groups in emotional tasks. The presence of an amplitude by emotion interaction is also ambiguous throughout the literature. Some studies have found decreased amplitudes in AUD vs control participants for angry stimuli (e.g. Maurage et al., 2008b) while others have found no amplitude difference between AUD and control participants regardless of stimuli emotion (e.g. Maurage et al., 2008a). Further, AUD groups have decreased P3 amplitudes in a wide array of tasks (Mumtaz, Vuong, Malik, & Rashid, 2018), and this remains consistent in investigations using emotional stimuli. However, some EFE literature has described a group by stimulus emotion interaction for P3 amplitudes, such as amplitude deficits

in AUD vs control samples exaggerated for sad stimuli (e.g. Maurage, 2008a). Contrarily, more recent studies (e.g. Hoffman, 2019) find no interaction with stimuli emotion in the characteristic decreased P3 amplitude in samples with AUD. The current study seeks to clarify AUD effects on ERP amplitudes in EFE tasks while expanding investigation to include the potential impact of polysubstance use on these effects.

### Aims and Hypotheses

There is a current gap in AUD literature concerning the consideration of polysubstance use within participant groups. The current study aims to address this gap in the context of emotion perception and processing, utilizing both behavioral and ERP outcomes in groups with AUD as well as AUD with polysubstance use. With the novel consideration of differentiation between groups with AUD who did and did not demonstrate recent polysubstance use, we hypothesize a general pattern where polysubstance using individuals with AUD demonstrate greater behavioral deficits and EEG differences from controls than their non-polysubstance using AUD counterparts. In our specific measures, based on current literature, it is expected that individuals with AUD will A) be less accurate than controls in classifying emotional faces; B) demonstrate decreased N170 amplitude, with more pronounced differences for negative stimulus emotions C) demonstrate decreased P3 amplitudes relative to controls, without contingency on stimulus emotion.

### Methods

#### Participants

All procedures were approved by the University of Florida Medical IRB. Participants (N=93) included 49 community controls (CCs) and 44 treatment-seeking individuals with AUD, composed of two subgroups (Alc-Only (n=22), Alc-Drug (n=22)). Treatment-seekers were recruited from residential treatment facilities and were at least 21 days abstinent (excluding nicotine) at the time of participating in the study. AUD status of treatment-seeking individuals was consistent with DSM 5 criteria. Controls were recruited via flyers and word of mouth from the community. All participants completed self-report questionnaires documenting demographics, personal and family substance use history, depression measures through Beck Depression Inventory-II (Beck et al., 1996), anxiety measures through Spielberger State Anxiety Index (Spielberger, 1983), and brief medical history. Inclusion required age between 25-59 years, education between 10-16 years, and absence of exclusionary conditions as determined by

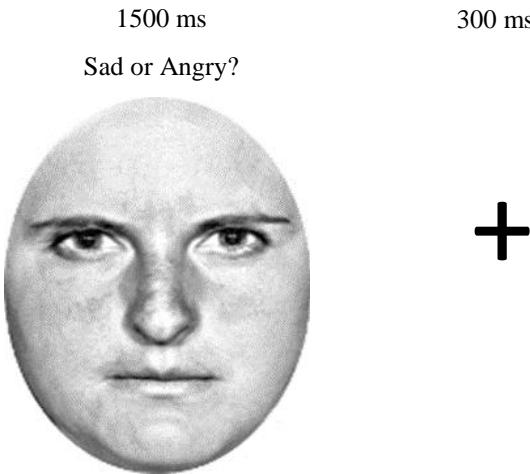
self-report and computerized Diagnostic Interview Schedule, Version IV (cDIS-IV; Robins, Cottler, Bucholz, Compton, North, & Rourke, 2000). General exclusionary conditions included neurologic disorder/injury, current conditions or medications that could compromise neurobehavioral interpretation, and report of any psychotic or bipolar disorders in medical history. CCs were excluded if they reported substance abuse history or alcohol use patterns exceeding “low risk” (Department of Health and Human Services, 2015). Sobriety at time of participation was verified for both CCs and treatment-seekers via urine and breath samples.

Participants with AUD were drawn from a larger group of treatment-seeking individuals based on their fit into pre-determined subgroups. Alc-Only participants endorsed use of no additional substances, with the exception of nicotine and up to weekly marijuana use, in the six months prior to treatment. This exception of nicotine and less-than-weekly marijuana use applied to the CCs as well. Low levels of marijuana use were not included, as they have been shown to not significantly effect cognitive efficiency (Nixon, Paul, & Phillips, 1998). Alc-Drug participants endorsed weekly or greater use of at least one substance in addition to any nicotine or marijuana use (e.g. opioids, stimulants) in the six months prior to treatment. If a subject with AUD reported greater than weekly marijuana use but not weekly or greater use of additional substances, they did not fit the criteria of either AUD group and were excluded from the study.

### **Emotional Judgement Task**

The Emotional Judgement Task (EJT) was adapted from a task used by Maurage and colleagues (2008a) in similar studies. The EFE stimuli, derived from the Ekman stimulus set (Ekman, 1976), depicted one of three emotions (happy, angry, sad). The emotional faces were morphed with neutral faces to create emotional intensities of 95% and 65%. This was completed for each of the three emotions and each of eight models.

In this task, participants viewed an EFE on a computer monitor and were asked to discriminate which of two emotions the face was depicting (e.g. sad vs. angry) via button press. Participants completed 15 blocks of 48 trials, with each of the 3 emotion discrimination pairs completed 5 times. Stimuli were presented for 1500ms with a 300ms interstimulus interval. Directions emphasized responding as quickly and accurately as possible. A visual representation of the task is depicted in Figure 1.



**Figure 1.** Trial Example of the Emotional Judgement Task

### **EEG Processing**

EEG was recorded on each participant using a 64-electrode array in an expanded 10-20 System configuration (Electro-Cap International, Eaton, OH). Linked ear lobe electrodes were used for reference, with the ground placed mid-forehead. Supra- and infra-orbital electrodes monitored blinks. Impedances were maintained below 10 kOhms. Data collection was conducted in a sound-attenuated, electrically-shielded booth. EEG signals were amplified and digitized at 1000Hz and band-pass filtered between 0.1-100 Hz. Data cleaning and analyses were conducted with EEGLAB toolbox and ERPLAB plugin within MATLAB. Epochs began 200ms prior to EFE stimulus onset and ended 1500ms after. To maintain consistency with behavioral measures, epochs were only utilized for trials where the participant answered correctly. Artifacts (e.g. blinks) were removed offline. N170 ERPs were analyzed via the O2 electrode in a 130-200ms window. P3 ERPs were analyzed via the Pz electrode in a 300-850ms window.

### **Data Analysis**

Potential group differences in demographic, affective, and alcohol use variables were analyzed using t-tests. Planned accuracy and ERP analyses were completed using mixed models in which emotion and morph level were repeated factors and group (CC, Alc-Only, Alc-Drug) was a fixed factor. Models included group by repeated factor interaction terms. Where main effects were detected, differences were clarified with t-tests. In ERP analyses, outliers more than 3 standard deviations from the mean were dropped. Possible confounding variables (age, education, depression, anxiety) were correlated with accuracy and amplitude outcomes and those

reaching significance were included in the above mixed models. Assumptions of homogeneity of regression were tested and confirmed. To add clarity and facilitate interpretation of results, relationships between task accuracy and ERP amplitudes were compared using Pearson correlations.

## Results

### Participants

All descriptive statistics and t-test results are presented in Table 1.

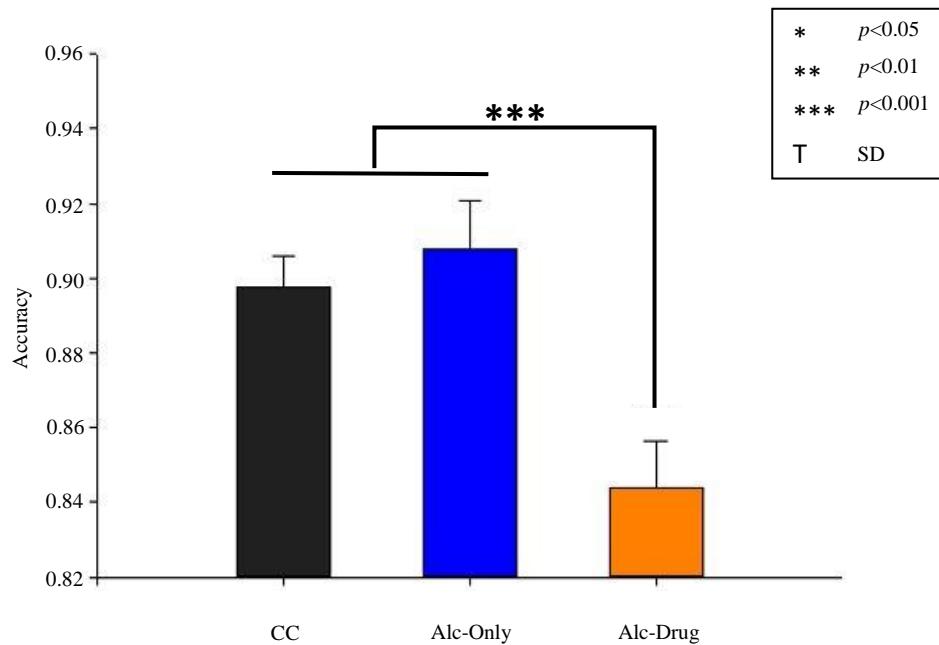
**Table 1.** Demographic, Affective, and Alcohol Use Variables of Groups

	CC n=49 M (SD)	Alc-Only n=22 M (SD)	Alc-Drug n=22 M (SD)	T-Test Results
Age (Yrs)	42.2 (12.5)	46.5 (8.6)	37.7 (7.7)	** Alc-Only > Alc-Drug, $p < .01$
Sex				
% Female	55.1%	36.4%	18.2%	
% Male	44.9%	63.6%	81.8%	
Education (Yrs)	14.8 (1.4)	13.3 (1.6)	12.9 (1.6)	*** CC > Alc-Only, Alc-Drug, $p < .001$
Race •				
% White/Caucasian	73.5%	68.2%	72.7%	
% Black/African American	14.3%	18.2%	22.7%	
% American Indian	2.2%	0.0%	0.0%	
% Pacific Islander	0.0%	0.0%	0.0%	
% Other	2.2%	4.8%	9.1%	
% Hispanic Ethnicity	4.4%	9.5%	13.6%	
Depression Symptoms †	4.9 (5.1)	15.3 (9.9)	15.0 (9.4)	***CC < Alc-Only, Alc-Drug, $p < .001$
Anxiety Symptoms ‡	43.0 (7.2)	56.1 (19.6)	56.3 (13.3)	***CC < Alc-Only, Alc-Drug, $p < .001$
Average Standard Drinks per Day	0.3 (0.5)	34.3 (20.5)	20.8 (14.5)	***CC < Alc-Drug < Alc-Only, $p < .001$
Maximum Standard Drinks per Day	3.5 (2.3)	57.2 (58.2)	36.0 (20.5)	***CC < Alc-Only, Alc-Drug, $p < .001$ *Alc-Drug < Alc-Only, $p < .034$

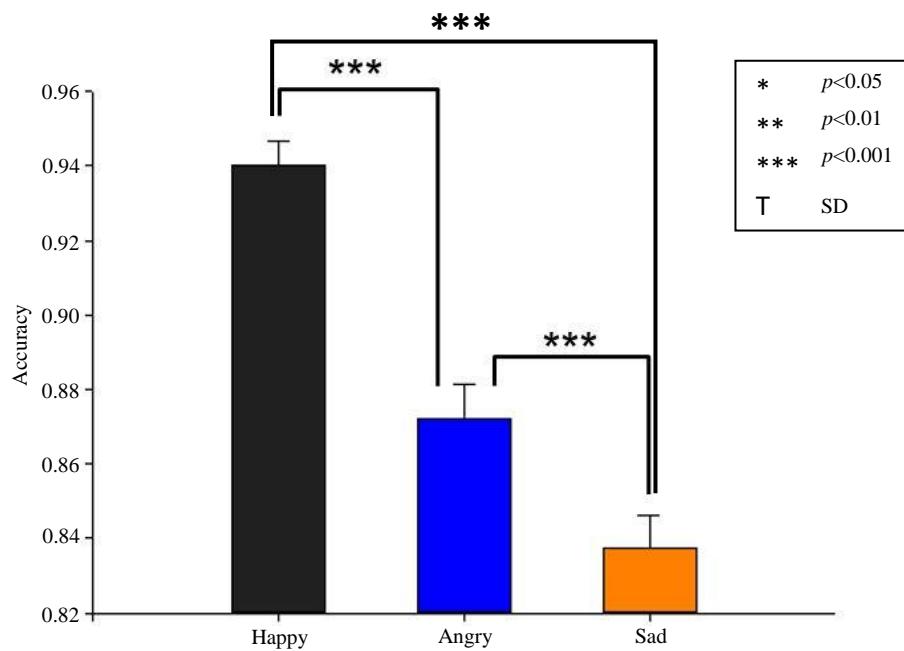
Note. • Participants could choose more than one race. † Scores from Beck Depression Inventory II (Beck, 1996). ‡ Scores from Spielberger State Anxiety Index with age-adjustment (Spielberger, 1983).

## Accuracy

Main effects of group ( $F(2,87)=8.17, p=.0006$ ), emotion ( $F(2,174)=108.53, p<.0001$ ), and morph level ( $F(1,87)=7.04, p=.0095$ ) were detected. The Alc-Drug group was less accurate than the CC ( $t(87)=3.58, p=.0006$ ) and Alc-Only ( $t(87)=3.60, p=.0005$ ) groups, which did not differ significantly (see Figure 2). Accuracy pertaining to stimuli emotion showed a step-wise pattern where angry stimuli were classified more accurately than sad ( $t(174)=3.74, p=.0002$ ), and happy stimuli were classified more accurately than both angry ( $t(174)=7.36, p<.0001$ ) and sad ( $t(174)=7.36, p<.001$ ) (see Figure 3). Higher morph intensities (95%) were classified more accurately than lower morph intensities (65%) ( $t(87)=2.65, p=.009$ ). There were no group by emotion or group by morph level interaction effects. In accordance with preliminary analyses, age and years of education were included as covariates. Only education was found to have a main effect ( $F(1,84)=5.70, p=.0192$ ), but it did not change the presence of the previously stated main effects (group  $F(2,84)=5.64, p=.005$ , emotion ( $F(2,170)=100.19, p<.0001$ ).

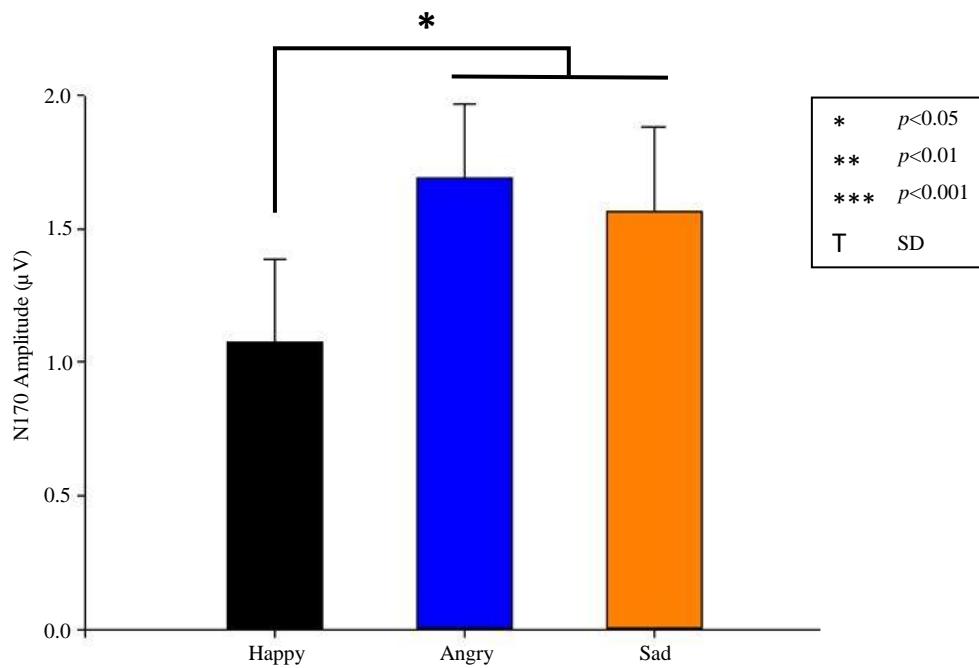
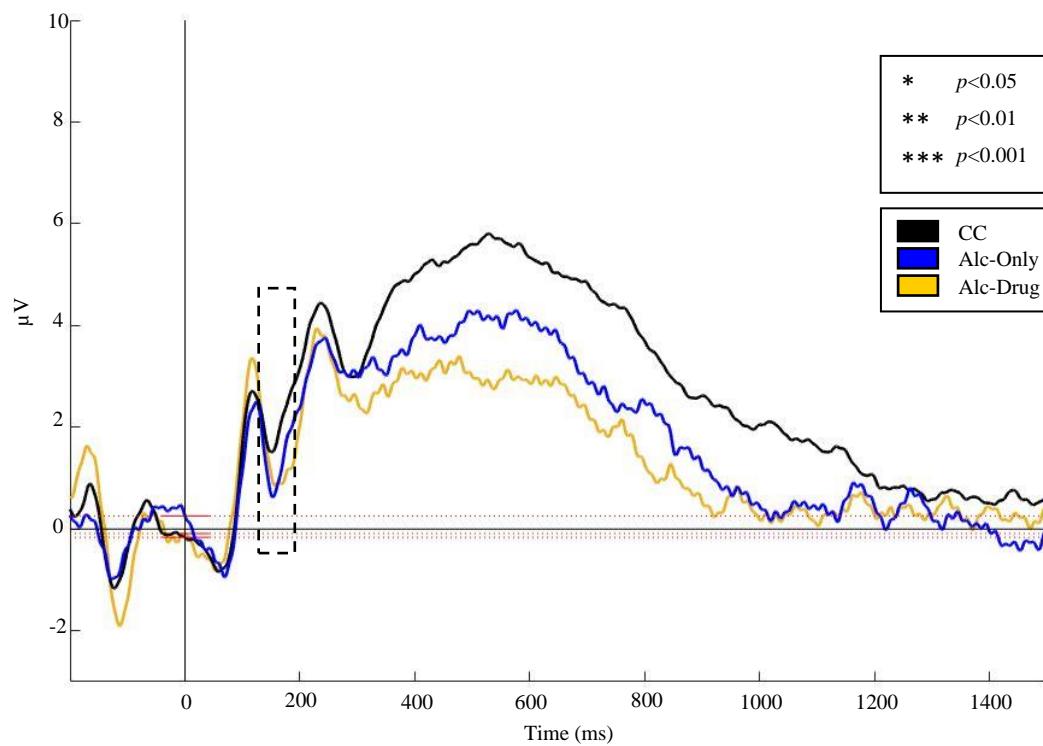


**Figure 2.** Accuracy by Group

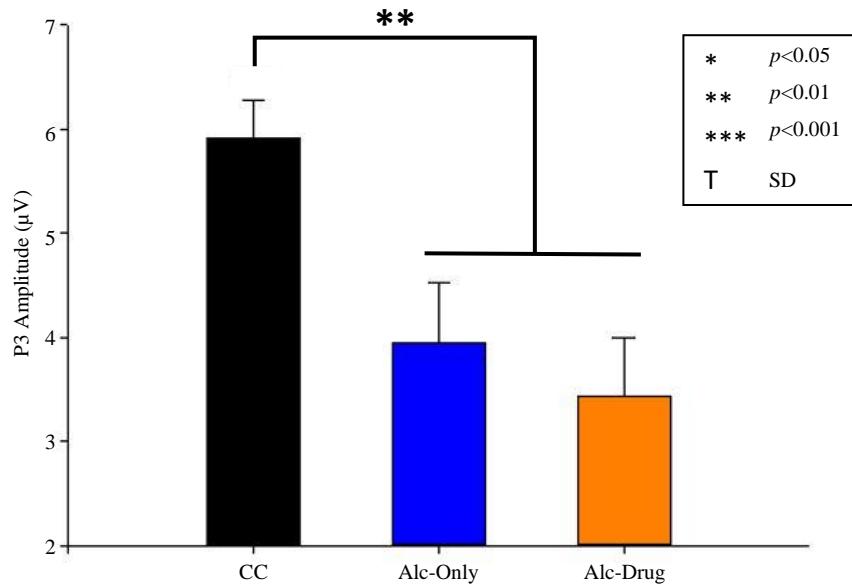
**Figure 3.** Accuracy by Face Emotion

### ERP Amplitudes

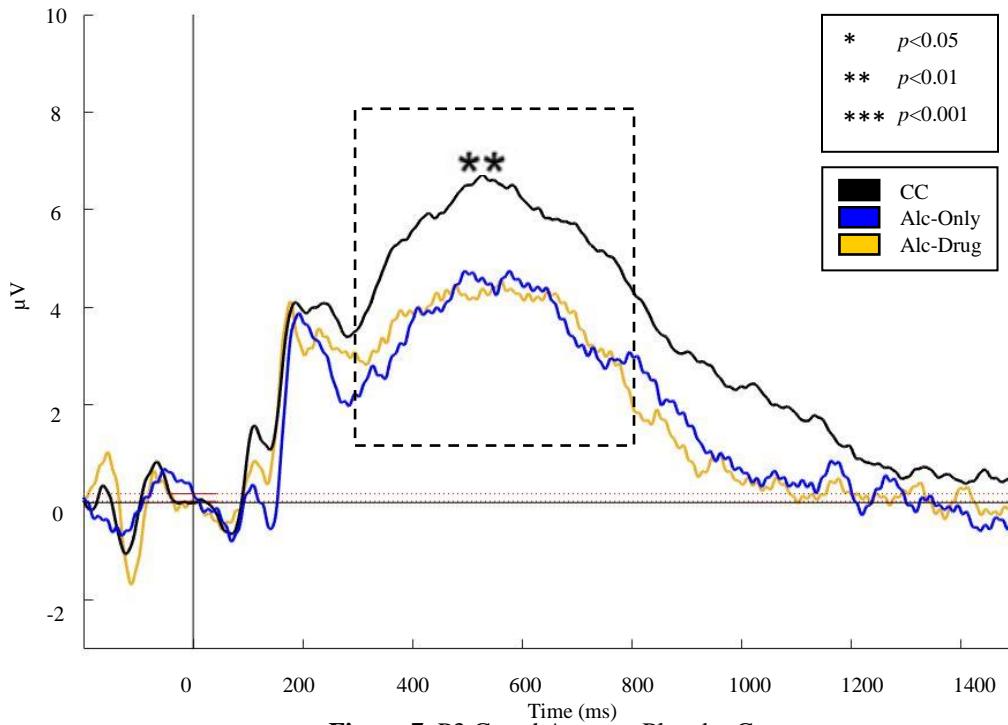
Mixed models for N170 amplitude revealed a main effect for face emotion ( $F(2,122)=5.62$ ,  $p=.0046$ ), but not for group or morph effects. Trials with happy EFE stimuli resulted in significantly lower amplitudes than both angry ( $t(122)=3.02$ ,  $p=.0031$ ) and sad ( $t(122)=2.42$ ,  $p=.0169$ ) trials, which did not differ (see Figures 4 and 5). There were no significant interaction effects for group by face emotion and group by morph level. According to preliminary analyses, no covariates warranted inclusion in this model. Three subjects were dropped from N170 analyses due to their amplitudes being greater than three standard deviations from the mean.

**Figure 4.** N170 Amplitudes by Face Emotion**Figure 5.** N170 Grand Average Plots by Group  
Dashed box superimposed demonstrates the N170 window used in analyses

Analyses of P3 amplitude detected a main effect for group ( $F(2,63)=8.38, p=.0006$ ). The CC group showed significantly larger P3 amplitudes than both Alc-Only ( $t(63)=2.85, p=.006$ ) and Alc-Drug ( $t(63)=3.67, p=.0005$ ) groups, which did not differ (see Figures 6 and 7). No group by face emotion or group by morph level interaction effects were found. Depression and years of education were included as covariates in models due to preliminary analyses, but neither altered the presence of a significant group effect (with education  $F(2,62)=4.97, p=.01$ ) (with depression  $F(2,60)=3.42, p=.039$ ). Two subjects were dropped from P3 analyses due to their amplitudes being greater than three standard deviations from the mean.



**Figure 6.** P3 Amplitude by Group



**Figure 7. P3 Grand Average Plots by Group**  
Dashed box superimposed demonstrates the P3 window used in analyses

### Accuracy and Amplitude Correlations

Analyses correlating overall task accuracy and ERP amplitudes showed no significance for either N170 amplitude ( $r=.13, p=.192$ ) or P3 amplitude ( $r=.13, p=.202$ ). Similarly, emotion-specific correlations failed to reach significance for happy (P3 ( $r=.072, p=.502$ ), N170 ( $r=.09, p=.385$ )), angry (P3 ( $r=.18, p=.09$ ), N170 ( $r=.17, p=.121$ )), and sad (P3 ( $r=.10, p=.36$ ), N170 ( $r=.00, p=.98$ )).

### Discussion

This study highlights the importance of considering polysubstance use in assessments of EFE perception and processing among individuals with AUD. While the behavioral findings are provocative, the inconsistency between behavioral and electrophysiological patterns of group differences suggest complex relationships, potentially including differential patterns of compensation for neural insults associated with alcohol and polysubstance use.

With regard to behavioral findings, our data supported our hypothesis that individuals with a recent history of polysubstance use demonstrated significant deficits in classifying EFEs. However, our prediction of Alc-Only demonstrating less accuracy than CC was not substantiated. The lack of significant difference between CC and Alc-Only groups was

surprising, but not unprecedented. A recent review found over 25% of facial expression recognition studies fail to find deficits in accuracy among those seeking treatment for AUD (Donadon & Osorio, 2014). The inconsistencies in findings is often attributed to differential task difficulty. With average task accuracies above 84% for all groups, the task used in this study was relatively easy. Thus, this task may have been insensitive to relatively subtle deficits among the Alc-Only group despite sensitivity to the more severe deficits in the Alc-Drug group.

Across groups, performance was sensitive to stimulus emotion, with classification accuracy being greatest for happiness, followed by anger, then sadness. However, as predicted, there was no significant group by stimulus emotion interaction present. While these findings are consistent with other investigations using a similar task (Maurage, 2008a), the current literature remains equivocal with others finding emotion-specific classification deficits (e.g. deficits in identification of sadness; Townshend, 2003). Whether these inconsistencies are related to task difficulty, intensity of stimulus emotion, or response demands remains unclear.

N170 results failed to support our hypotheses regarding AUD effects, subgroup differences, or group by emotion interaction. N170 amplitude was only predicted by the stimulus emotion. This finding disagrees with some previous studies documenting reduced amplitudes in AUD samples (e.g. Maurage, 2008b). However, variability in our N170 amplitude data was large (Mean=1.75, SD=3.40), making it difficult to interpret any meaningful conclusion.

Our P3 amplitude data support some, but not all, of our hypotheses. P3 amplitude differences between groups agreed with our hypothesis of decreased amplitudes among our AUD samples, but not our general hypothesized pattern of greater differences among the Alc-Drug than the Alc-Only group. These findings are in line with previous observations of greater P3 amplitudes among controls (e.g. Maurage et al., 2007). Our hypothesis of the absence of a group by emotion interaction was also supported. In contrast with behavioral performance, stimulus emotion did not have a main effect in the context of P3 amplitude. The marked difference between behavioral and electrophysiological results with respect to stimulus emotion effects may suggest that the observed P3 differences reflect processes utilized in general, but not emotion-specific, stimulus discrimination. The lack of significant difference between the AUD groups' P3s suggests a more broad consequence of substance abuse instead of being pharmacologically-specific, given the large variability in AUD participants' use patterns.

Finally, task accuracy did not correlate with amplitudes of either ERP component. Due to pre-existing dataset and investigation constraints, these analyses were conducted using data from trials where participants classified stimuli correctly. There is a possibility that analyses including EEG data from incorrect trials could find different results. Correlating behavioral and ERP outcomes is uncommon in the existing literature. Of the few recent studies investigating this relationship, some document strong relationships between accuracy and P3 (Maurage, 2008a) while others find insignificance (e.g. Recio, Wilhelm, Sommer, & Hildebrandt, 2017). Further investigation into this possible electrophysiological and behavioral relationship is warranted.

Limitations of the current study include its cross-sectional nature, preventing any investigation into causative relationships with preexisting risk factors as well as any investigation into long term effects of sobriety. Further, the polysubstance use in the Alc-Drug group was heterogeneous and included several drug classes, challenging substance-specific interpretations. In the context of design, our task has both strong and weak aspects. With our task including multiple levels of emotional intensity, it offers greater ecological validity than others which only display very intense EFEs. However, the study of only three emotions and goal of discriminating between two given options separates task performance from the everyday need to interpret facial expressions.

### **Conclusion**

The current study highlights the importance of polysubstance use considerations in emotion processing in AUD populations. Behavioral results suggested polysubstance-associated increases in susceptibility to emotional processing deficits. Although our electrophysiological results did not reflect a similar susceptibility, our measures represent only a limited set of indicies with which to assess alcohol-associated neural consequences. Further work using a more broad selection of measures may clarify this inconsistency. Nonetheless, these findings contribute to the developing literature on emotional perceptive effects of AUD, polysubstance using AUD subgroup characterization, and possible targets for novel rehabilitation efforts in these populations.

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