Article

Emotional Face Processing among Treatment-Seeking Individuals with Alcohol Use Disorders: Investigating Sex Differences and Relationships with Interpersonal Functioning

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Abstract

Background: Individuals in treatment for alcohol use disorder (AUD) display deficits across a broad range of cognitive processes. Disruptions in affective processing are understudied, but may be particularly important for interpersonal functioning and post-treatment adaptation. In particular, the role of sex in AUD-associated emotion processing deficits remains largely unaddressed and was a focus of the current investigation.

Methods: Fifty-six treatment seekers with AUD and 54 healthy community controls ($N = 110$) were administered an emotional face discrimination task. Non-affective tasks included a sex-discrimination task and two brief measures of executive functioning. Two measures of interpersonal function were included.

Results: Emotion processing deficits were evident among women with AUD relative to other groups. This sex-contingent relationship was not observed in measures of executive function, sex-discrimination or interpersonal problems, although individuals with AUD performed more poorly on these measures.

Conclusions: Results were consistent with extant literatures examining cognitive, affective and interpersonal functioning among individuals with AUD, and provided novel evidence of vulnerability to alcohol-associated deficits in emotion processing among women. While similar sex-contingent effects were not apparent among other measures, results support modest interrelationships, specifically including the import of emotion processing to interpersonal functioning in AUD. These data offer guidance for further systematic investigation and highlight important considerations for future relapse-prevention and recovery-facilitation efforts.

BACKGROUND

Individuals in treatment for alcohol use disorder (AUD) evince impairments in neurocognitive function, frequently involving deficits

in executive function and memory (e.g. Tarter and Parsons, 1971; Nixon and Parsons, 1991; Sullivan *et al.*, 1993; for reviews see Bates *et al.*, 2002; Sullivan *et al.*, 2010; Oscar-Berman *et al.*, 2014;

Le Berre *et al.*, 2017). Although heterogeneous in nature and severity, current estimates indicate 50–80% of AUD individuals are affected (Bates *et al.*, 2002). Over the last two decades, an emerging literature has described concomitant disruptions in social cognition, including processes underlying perception, understanding and implementation of cues communicating interpersonal information. Affective theory of mind, the capacity to predict and interpret affective states, feelings and emotions of others, appears particularly vulnerable to alcohol-associated perturbations (e.g. Philippot *et al.*, 1999; Kornreich *et al.*, 2001; Maurage *et al.*, 2011a; for reviews see Uekermann and Daum, 2008; Onuoha *et al.*, 2016). Although theory of mind paradigms lacking emotionality have been less frequently examined in AUD populations (but see Maurage *et al.*, 2015), studies directly comparing affective and cognitive components suggest specific vulnerabilities in emotion processing (Maurage *et al.* 2011b, 2016).

Individuals with AUD make atypical judgments on tasks requiring the decoding of humor (Uekermann *et al.*, 2007; Amenta *et al.*, 2013), social error (Cox *et al.*, 2018), affective prosody and body postures (Monnot *et al.*, 2001, 2002; Maurage *et al.*, 2009) and emotional facial expressions (EFEs; e.g. Frigerio *et al.*, 2002; Oscar-Berman *et al.*, 1990; Philippot *et al.*, 1999; Townshend and Duka, 2003; Foisy *et al.*, 2005; for review see Donadon and Osorio, 2014). EFE processing has received particular attention, with investigations revealing alterations in neurophysiological responses (e.g. Salloum *et al.*, 2007; Maurage *et al.* 2008a; Marinkovic *et al.*, 2009), deficits in emotion judgment accuracy (e.g. Maurage *et al.*, 2008b, Maurage *et al.*, 2008c; Kornreich *et al.*, 2003; Foisy *et al.*, 2007; for meta analyses see Castellano *et al.*, 2015; Bora and Zorlu, 2017) and differential sensitivities to emotional intensity (e.g. Oscar-Berman *et al.*, 1990).

While AUD-associated disruptions in emotion processing are well-accepted, substantial gaps in understanding persist. Many emotion judgment tasks lack face validity, challenging direct estimation of their functional import. Despite their paucity, the few available investigations addressing these issues provide meaningful results. Maurage and colleagues (2016) demonstrated the persistence of deficits in a video-based paradigm with high face validity. Moreover, inverse associations between emotion processing capacity and both interpersonal difficulties (Kornreich *et al.*, 2002) and relapse (Rupp *et al.*, 2017) have been identified. While provocative, replication and extension of this work remains critical. Equivocation persists with regard to the sensitivity/specificity of decoding deficits for particular emotions (e.g. anger), as well relationships between affective and executive processing deficits. Factors remaining largely unaddressed include speed/accuracy trade-offs in performance and characterization of sex effects.

There is a rich literature regarding sex differences in response to emotional stimuli and specifically EFE tasks among community samples (e.g. Hall, 1978). Compared to men, women are generally more accurate in their assessments (Hall and Matsumoto, 2004; Hoffmann *et al.*, 2010), particularly in the detection of positive affect (Donges *et al.*, 2012). These outcomes are often cited as being consistent with noted sex differences in interpersonal styles and processing (e.g. Barrett *et al.*, 2000). Given these findings, and the recognized import of sex to AUD progression, vulnerability and treatment (e.g. Brady and Randall, 1999; Lewis and Nixon, 2014), the lack of attention to sex in AUD-associated emotion processing deficits is somewhat puzzling. Though examined by Fein and colleagues (2010) in long-term abstinence, to our knowledge, only three published analyses have directly addressed this issue in recently detoxified populations. Preliminary analyses by both Philippot *et al.*

(1999) and Foisy *et al.* (2007) failed to detect sex effects, however both works included less than 10 AUD women. Importantly, Frigerio and colleagues (2002) noted a sex-contingent interaction, such that control women displayed an emotion decoding advantage, requiring less emotional intensity to make judgments than other groups, while AUD women required the greatest. This finding is thus consistent with both sex-dependent advantages noted in the affect perception literature as well as sex-dependent vulnerabilities observed in the alcohol literature. A recent meta-analysis provides further, albeit indirect, evidence of vulnerability among women; Onuoha *et al.* (2016) found that across experiments, effect sizes for AUD-associated emotion processing deficits were increased consistent with the proportion of women represented in the AUD groups.

The aforementioned findings provide evidence for two alternative hypotheses. Sex-contingent advantages observed among community samples suggest potential protection from alcohol-associated decrements in emotion processing among women with AUD. In contrast, the limited available evidence from AUD samples suggests potential vulnerability. The current study utilized an EFE judgment task to explore these hypotheses. Based on the extant literature, we expected deficits in EFE decoding among recently detoxified individuals with AUD, relative to controls, and explicitly examined whether such deficits would be more severe as a function of sex. Further, we hypothesized that EFE performance deficits would be specific to emotionality, and not reflected in face processing tasks lacking an affective component or neuropsychological measures of executive function. Finally, given the relationship between emotion processing and interpersonal function noted by Kornreich and colleagues (2002), we hypothesized that if sex differences were observed in EFE processing, similar patterns would be evident in measures of interpersonal function.

MATERIALS AND METHODS

The University of Florida Medical IRB approved all procedures. Participants provided written informed consent prior to data collection and were compensated for participating.

Participants

Participants ($N = 110$) included 56 inpatient treatment seekers with alcohol use disorders (AUDs) and 54 healthy community controls (CCs). Participants provided demographic information (e.g. age, education) and substance use histories, including chronicity, quantity and frequency of alcohol use (Quantity Frequency Index; QFI; Cahalan *et al.*, 1969). Self-reported medical histories were collected. Probabilistic psychiatric disorders were assessed using the computerized Diagnostic Interview Schedule, Version IV (Robins *et al.*, 2000). The alcohol craving questionnaire (Singleton *et al.*, 2000) facilitated confirmation of DSM-5 AUD symptomatology.

Study inclusion was limited to individuals between 25 and 59 years of age. Age criteria were selected to avoid potential confounds associated with factors unique to college drinking and aging contexts. Inclusion was limited to individuals with between 10 and 16 years of education. Education criteria were utilized to facilitate appropriate selection of control participants, as our previous work indicated this range would reflect typical values among treatment-seeking participants. Exclusionary conditions included (a) significant neurologic disorder/insult; (b) medical or psychiatric conditions challenging interpretation of neurobehavioral function (e.g. epilepsy); (c) medications compromising neurobehavioral function (i.e. benzodiazepines); (d) lifetime

psychotic or bipolar disorder; and (e) current social phobias or panic disorders. AUDs met criteria for moderate-to-severe AUD (DSM-5), had completed medical detoxification (if required) and were 21–90 days abstinent. Among CCs, histories of substance use disorders were exclusionary, as were recent drinking histories suggesting consumption patterns significantly exceeding ‘low-risk’ guidelines (i.e. >2/3 drink per day average, for women/men, respectively). On testing day, negative results for breath alcohol content (Intoxilyzer® 400PA; CMI, Inc., Owensboro, KY), urine toxicology screen for illicit substance use and pregnancy tests were required for continued participation.

Face processing tasks

EFE processing was assessed by analyzing accuracy and reaction time in an emotion judgment task (EJT; adapted from [Maurage et al., 2008b](#)). To facilitate interpretation of EJT outcomes, a sex judgment task (SJT) was used to provide control for non-emotional facial identification processes. Foveal presentation was utilized for both tasks (E-Prime software), with all stimuli subtending $6^\circ \times 8^\circ$ visual angles. Equal numbers of male and female posers (ages 30–50 years) were utilized in both tasks. A two-choice discrimination procedure was used, requiring button-press with the index finger of the dominant hand. Task instructions emphasized the importance of response speed and accuracy. Task stimuli were adapted from the Ekman stimulus set ([Ekman, 1976](#)). Response windows were initiated and terminated at stimulus onset and offset, respectively (1500 ms presentation time). Interstimulus intervals were 300 ms.

Emotion judgment task. For each poser, four facial expressions were utilized from the Ekman set to create the experimental stimuli, including happy, angry, sad and neutral expressions. Task stimuli were created using digital morphing software (FantaMorph) to combine each of eight (four men; four women) posers’ neutral images with each of their emotional images, at two levels of intensity. Thus, six stimuli were generated for each poser, including combinations of happy/neutral, angry/neutral and sad/neutral at 65% and 95% morph levels (see Fig. 1A for exemplar stimulus). Preceding each task block, participants were informed of the two emotions to be discriminated (e.g. Sad vs. Happy) and their corresponding response buttons, which alternated across blocks. Each block contained only a single pair of emotions to be discriminated, with all combinations of unique poser (8), emotion (2) and morph level (2) included (32 trials/block). No stimulus was repeated within a given block. Pseudorandomized distribution of stimuli presentation insured sequential repetition of images containing either the same poser or same sex/morph/emotion combination was rare (<5% chance per block). Each of the three emotion pairs were repeated across five blocks (15 blocks total), with no sequential repetition of pairs.

Sex judgment task. Stimuli were created from pairs of male and female posers. Posers in the SJT task were unique from those used in the EJT. Each of the eight posers was used in only one male/female pair. Neutral faces from each of the four unique pairs were used to generate morphed face stimuli at 65% and 95% morph levels for each sex: (a) 95% male, (b) 65% male, (c) 65% female and (d) 95% female (see Fig. 1B). Thus, 16 unique stimuli were generated. Each was presented once per block, with pseudorandom distribution to avoid sequential pair/morph repetitions. In all trials (256 total trials/16 blocks), participants indicated whether the face was more masculine or feminine.

Fig. 1. (A) An exemplar trial from the emotion judgment task (EJT), including face stimuli and instructional cue. The depicted trial includes an angry face at the 65% morph level presented during a ‘Sad or Angry’ block. (B) An exemplar trial from the sex judgment task (SJT). The depicted trial includes a male face at the 65% morph level. For both tasks, instructional cues were maintained on-screen throughout all trials. Position of on-screen cues was kept consistent with response button position (e.g. ‘Sad or Angry’ for blocks in which sad and angry responses used the left and right response buttons, respectively).

Neuropsychological & interpersonal measures

Executive functions were assessed with standard administrations of the Digit Symbol Substitution Task (DSST; [Wechsler, 1981](#)) and Trail-Making Test Form B (TMT-A/B; [Reitan, 1955](#)). Interpersonal functioning was assessed via administration of the Inventory of Interpersonal Problems (IIP-64; [Horowitz et al., 2000](#)) and the Adaptive Skills Battery (ASB; [Jones and Lanyon, 1981](#); [Nixon et al., 1992](#)). The IIP-64 indexes interpersonal difficulties across 8 domains. Responses to each item (e.g. ‘I try to control other people too much’) use a 5-point agreement scale. The ASB assesses both interpersonal problem-solving capacity and typical behavior. Twelve vignettes of situations including interpersonal stress/conflict in social or workplace contexts were presented (all unrelated to drinking). Individuals were asked to describe how they would typically respond to each. Upon completion, six vignettes were repeated, with individuals instructed to describe the most appropriate, or ‘best’ response for each situation. All responses were scored on a 3-point scale using published criteria ([Jones and Lanyon, 1981](#)).

Data analysis

Planned analyses were conducted using PROC MIXED in SAS Version 9.4. All models were fit using restricted maximum-likelihood estimation. Unplanned/exploratory analyses were conducted using PROC REG with stepwise selection. Alpha was set at $P = 0.05$.

Analyses of EJT and SJT performance were conducted using Sex (Male vs. Female), Group (AUD vs. CC), and their interaction as fixed factors. Face Content ([In EJT: Happy vs. Angry vs. Sad]; [In SJT: Male vs. Female]) and Face Morph (65% vs. 95%) were fixed and repeated factors. Accuracy and reaction time (correct responses only) were dependent measures. SJT and EJT performance were analyzed separately, as violation of assumptions of heterogeneity of regression precluded the use of SJT performance as a covariate in EJT analysis. This limitation contributed to our inclusion of unplanned exploratory analyses, which facilitate interpretation of

EJT/SJT relationships. Cognitive and interpersonal indices were analyzed using Sex and Group as fixed factors.

Following examinations of primary and secondary hypotheses, exploratory analyses were conducted using stepwise regressions to further examine interrelationships between DVs. Informed by results from planned analyses, regression models were constructed for EJT (mean accuracy), IIP-64 (total score) and ASB (typical response score). Where appropriate, predictors included measures of cognitive performance (TMT-B/DSST), face processing performance (EJT/SJT accuracy and RT), interpersonal function (ASB/IIP-64) and Sex. These analyses served to both aid interpretation and provide preliminary guidance for future investigations.

RESULTS

Participants

Participants ($N = 110$; 56 AUDs [14 women]; 54 CCs [30 women]) included Caucasian ($n = 82$), Black/African-American ($n = 21$) and Asian/Asian American ($n = 2$) individuals. Five participants endorsed 'Other', or failed to endorse a racial group. 5 participants endorsed Hispanic ethnicity. Age did not differ by Group. As

anticipated, and consistent with the extant literature, group differences in education, affective symptomatology, and measures of alcohol consumption were observed. Correlation analyses revealed no significant associations between these measures and the experimental DVs. No Group by Sex interactions were observed for any measure. Descriptive statistics and summary of results are presented in Table 1.

Emotion judgment task

Consistent with the extant literature, AUDs were less accurate in emotion discriminations than CCs [$F(1,106) = 5.16$, $P = 0.02$]. However, this main effect was qualified by a Group by Sex interaction [$F(1,106) = 5.47$, $P = 0.02$]. Consistent with our hypothesis, contrasts suggested this effect was driven by lower accuracies among AUD women, relative to all other groups [$t_s \geq 2.32$, $P_s \leq 0.02$]. Results are depicted in Fig. 2A. Accuracy differed by Emotion [Happy > Angry > Sad; $P_s < 0.01$] and Morph [95% > 65%; $P = 0.03$]. Women responded more quickly than men [$F(1,106) = 4.99$, $P = 0.03$]. A trend toward more rapid responding among AUDs [$F(1,106) = 3.35$, $P = 0.07$] was noted; however, post hoc analyses suggested that both main effects were driven by AUD women, who

Table 1. Demographic, affective and alcohol-related measures

Measure	Community controls		AUD Individuals		Group M.E.
	Men M (SD)	Women M (SD)	Men M (SD)	Women M (SD)	
Age (years)	40.7 (12.0)	45.5 (12.5)	41.7 (8.4)	39.0 (9.5)	<i>ns</i>
Education (years)	14.8 (1.4)	15.2 (1.3)	13.1 (1.5)	13.3 (2.2)	AUD < CC; $P < 0.01$
Depressive symptoms ^a	4.1 (4.2)	5.0 (5.7)	14.6 (9.2)	15.6 (9.9)	AUD > CC; $P < 0.01$
Anxiety symptoms ^b	42.5 (6.4)	42.2 (6.9)	55.8 (13.1)	58.5 (15.8)	AUD > CC; $P < 0.01$
Avg. alcohol (oz./day) ^c	0.3 (.3)	0.2 (0.2)	16.2 (10.1)	14.0 (12.4)	AUD > CC; $P < 0.01$
Max. alcohol (single day)	2.4 (1.8)	1.9 (1.1)	21.0 (9.3)	14.3 (10.4)	AUD > CC; $P < 0.01$
Length of sobriety (days) ^d	–	–	18.2 (11.5)	19.8 (14.8)	–
Polysubstance use (%) ^e	–	–	69.0	57.1	–

^aBeck Depression Inventory-II.

^bSpielberger State Anxiety Index (age-adjusted scores).

^cAlcohol Quantity/Frequency Index—averaged across 6 months prior to treatment initiation.

^dAt screening.

^eRecent (6-month) use, at least weekly frequency.

Fig. 2. EJT and SJT accuracy by Group and Sex (LS means $\pm$ SE). *Denotes differences ($P_s < .06$) detected by post hoc analyses for accuracy among AUD women relative to other groups.

responded more rapidly than other groups [$t_s \geq 2.14$, $P_s \leq 0.03$; difference vs. CC women was trend-level, $t = 1.79$, $P = 0.07$]. Data are presented in Fig. 3A. Reaction times differed by Morph [95% < 65%; $P < 0.01$] and Emotion [Happy > Angry/Sad; $P_s < 0.01$].

Potential three-way interactions among group, sex and face emotion were not hypothesized; however given current interest in the emotion-specificity of affective processing deficits, we incorporated this interaction term in follow-up analyses. No three-way interaction were detected. Figures and results from these analyses are included as Supplementary materials, see online supplementary material for a color version of this figure.

Sex judgment task

To afford comparison with EJT findings, post hoc contrasts were conducted for SJT models regardless of significant interactions. Similarly, SJT outcomes are presented including P -values for all results, regardless of significance. No group by sex interaction was observed for SJT accuracy ($P = 0.12$). However, accuracy among AUD women differed from AUD men [$t(104) = 2.48$, $P = 0.01$] and CC men [trend-level; $t(104) = 1.89$, $P = 0.06$], but not CC women ($P = 0.12$). Accuracy decrements among AUD women appeared to

drive the sex main effect [$F(1,104) = 4.76$, $P = 0.03$]. No group effect was observed [$P = 0.36$]. Accuracy differed by Morph [95% > 65%; $P < 0.01$] and Face Sex [Female > Male faces; $P < 0.01$]. Accuracy data are presented in Fig. 2B. SJT responses were more rapid among women [$F(1,106) = 4.98$, $P = 0.03$]. No Group effect [$P = 0.75$] or interaction [$P = 0.56$] was evident for reaction times. Post hoc analyses revealed no differences between groups [$P_s \geq 0.08$]. Reaction times differed by Morph [95% < 65%; $P < 0.01$], but not Face Sex [$P = 0.56$]. Data are presented in Fig. 3B.

Neuropsychological tasks

TMT-B analysis revealed longer time-to-completion among AUDs [$F(1,106) = 8.27$, $P < 0.01$], but no interaction with Sex. Similarly, AUDs translated fewer symbols than CCs in the DSST [$F(1,106) = 4.30$, $P = 0.04$], but no interaction with Sex was noted. Data are presented in Fig. 4A and B.

Interpersonal Measures

Analysis of 'Best' responses in the ASB indicated equivalent capacity for interpersonal problem solving between AUDs and CCs. In

Fig. 3. EJT and SJT reaction time by Group and Sex (LS means $\pm$ SE). *Denotes differences ($P_s < .07$) detected by post hoc analyses for response time among AUD women relative to all other groups.

Fig. 4. Performance on DSST (# symbols translated within time limit) and TMT-B (time to completion) by Group and Sex (LS means $\pm$ SE). *Denotes significant group differences in DSST symbol translations and TMT-B completion times ($P_s > 0.05$).

contrast, descriptions of 'Typical' responses to similar situations appeared substantially less adaptive among AUDs [$F(1,99) = 55.98$, $P < 0.01$]. A similar pattern was observed for endorsement of interpersonal problems; IIP-64 analysis indicated marked increases in endorsement of problems among AUDs [$F(1,104) = 22.39$, $P < 0.01$]. In contrast to our hypotheses, no interactions with Sex were detected in any interpersonal measure. Data are presented in Fig. 5A and B.

Exploratory analyses

To better characterize the potential contributions of measures addressed in planned analyses to interpersonal functioning and emotional processing, regression models were constructed using stepwise selection procedures for ASB typical responses, IIP-64 scores and EJT accuracy, among AUDs. Where significant relationships were identified, stepwise analyses were repeated for CCs to facilitate comparison.

IIP-64

As presented in Table 2, only EJT accuracy accounted for significant variance in AUDs' endorsement of interpersonal problems. Among CCs, no significant predictors were identified.

ASB

Analysis of ASB typical responding revealed no significant relationships.

EJT

As presented in Table 2, four predictors accounted for significant variance in EJT performance among the AUD group, including DSST performance, Sex, IIP-64 score and SJT accuracy. When repeated among CCs, significant relationships were observed only for DSST performance and SJT accuracy.

DISCUSSION

AUD women displayed emotion processing deficits, relative to both AUD men and community controls. These results support the hypothesis that women may be particularly vulnerable to alcohol-associated perturbations in social/affective cognition. Results from cognitive and face processing tasks lacking affective components failed to detect sex-specific deficits. However, exploratory analyses indicated interrelatedness among emotional, facial and cognitive processes. Our secondary hypothesis, that EFE deficits would be reflected as more severe problems in interpersonal functioning, was largely unsupported. Unlike EJT performance, no sex-specific deficits were noted by either the IIP-64 or ASB measures. However, exploratory analyses provided evidence for a modest relationship between emotion processing and interpersonal problems among AUD individuals, but not community controls.

Although emotion processing deficits in AUD are well-accepted, the accumulated evidence remains insufficient to properly characterize their severity, extent or impact on daily life functions. The current study contributes to this characterization by providing evidence

Fig. 5. ASB and IIP-64 scores by Group and Sex (LS means $\pm$ SE). *Denotes significant group differences ($P > 0.05$) in adaptiveness of typical responses to work/social stress situations (ASB) and endorsement of interpersonal problems (IIP-64).

Table 2. Exploratory stepwise results

Model	Group	Predictor	β	SPcorr ² (t2)	Pcorr ² (t2)	<i>t</i>	<i>P</i>	Model <i>R</i> ²
IIP-64	AUDs	EJT Accuracy		.106	.106	6.04	.02	.106
EJT	AUDs	DSST	.46	.151	.252	4.02	<.01	.551
		SJT Accuracy	.31	.075	.144	2.84	<.01	
		IIP-64	-.25	.063	.123	-2.59	.01	
		Sex	-.23	.047	.094	-2.24	.03	
	CCs	DSST	.43	.187	.199	3.35	<.01	
		SJT Accuracy	.28	.077	.093	2.14	<.01	

SPcorr²(t2) = squared semi-partial correlations computed using Type II sums of squares.

Pcorr²(t2) = squared partial correlations computed using Type II sums of squares.

of dysfunction even under conditions in which emotional expressions are highly salient and easily discriminable. The available literature commonly utilizes tasks in which EFEs are partially obscured (e.g. Reading the Mind in the Eyes Test; Baron-Cohen *et al.*, 2001) or require challenging discriminations (e.g. Fear vs. Surprise). As described by Fein *et al.* (2010), similarly complex tasks are more likely to reveal group differences in EFE decoding. The nature of the exaggerated emotionality and limited discrimination choices in the current task (adapted from Maurage *et al.*, 2008b) may thus be sub-optimal for indexing the extent of emotion processing deficits in this population, but may retain utility for detecting within-group differences, as demonstrated in the current work. Through this lens, it is less surprising that EJT performance in AUD males appeared equivalent to controls, or that accuracy decrements in AUD women appeared smaller than between-group differences observed in more complex/difficult tasks (e.g. Philippot *et al.*, 1999). However, while the magnitude of difference observed in the current work was modest relative to other examinations, the proportional increase in emotion judgment errors among AUD women was substantial, representing a ~40–50% increase relative to controls.

The current EJT paradigm was highly similar to that utilized by Maurage and colleagues (2008b). Their team found no differences in EJT accuracy between groups, but detected longer reaction times in AUD individuals. In the current work, we observed a group effect in accuracy. Though underlain by different dependent measures, both studies support the interpretation of alcohol-associated decrements in emotion processing. In contrast to Maurage's work (2008b), the current results demonstrate shorter reaction times among AUD individuals. This discrepancy is likely related to subtle but important differences in task instructions. Given the import of affective processing speed in social interactions (e.g. Bar *et al.*, 2006) and speed/accuracy trade-offs in chronic alcohol effects (e.g. Nixon and Parsons, 1991; Ceballos *et al.*, 2006), participants in the current study were instructed to respond 'as quickly and accurately as possible'. In contrast, Maurage and colleagues (2008b) informed participants that speed was important, but not at the cost of accuracy. Taken together, these investigations provide complementary evidence for deficits in emotion processing under varied conditions of speed/accuracy valuation. However, the relatively small AUD sample utilized in the Maurage study (2008b) may have limited power to detect group differences in accuracy similar to our observations. Future work may clarify the strength and persistence of decrements in accuracy and/or reaction time under varied instructional sets.

In addition to direct examination of our primary hypothesis via analysis of EFE performance, we explored whether similar deficits would be noted in non-affective tasks. Examinations of a sex-discrimination face processing task and two neuropsychological measures of executive function failed to reveal sex by group interactions. However, the pattern of results were similar in the EJT and SJT tasks regarding performance decrements in AUD women, and exploratory analyses supported a relationship between performance on the face processing tasks. These results are consistent with two interpretations. Implicit processing of emotional features occurs following presentation of face stimuli, even under conditions in which the emotional content is not task-relevant (e.g. Cohen *et al.*, 2016). Thus, emotion decoding deficits may detract from processing capacity in non-affective (i.e. neutral) face discrimination tasks. An alternative, though not mutually exclusive, interpretation involves implicit attentional bias to emotionality, an under-studied aspect of social cognition deficits which may impede non-affective face processing. Implicit attentional biases are likely to include neutral

stimuli, as AUD individuals appear less able to accurately identify emotional neutrality and attribute greater emotional intensity to neutral stimuli (Maurage *et al.*, 2009; Kornreich *et al.*, 2013). Unpublished evidence from our recent work supports susceptibility to neutral face distractors among AUD individuals. While the data are consistent with both of these interpretations, and provide important guidance for future investigation, they lack direct supportive evidence. Taken together, our results support a specific sex-contingent vulnerability to alcohol-associated deficits in emotion processing which was not observed in executive function tasks, but mixed support for specific vulnerability in affective vs. non-affective face processing.

Our secondary hypothesis was based on work conducted by Kornreich and colleagues (2002), demonstrating impaired EFE decoding is associated with interpersonal difficulties. We hypothesized that if sex-dependent susceptibility to emotion processing deficits were observed, this vulnerability would result in sex-dependent interpersonal difficulties among the AUD group. However, no evidence for sex-contingent decrements among AUD women were observed in analyses of typical responding to interpersonal conflict or endorsement of interpersonal problems. Despite these negative results, relative to men, AUD women reported approximately 5% greater interpersonal problems, a magnitude similar to the 5% accuracy decrement observed in EJT performance. Thus, while the hypothesized consistency between these outcomes was unsupported, interrogation of this relationship may require more sensitive measures of interpersonal conflict and/or greater statistical power. Alternatively, the lack of observed differences in interpersonal problems may reflect a sex-dependent difference in the relationship between emotion processing deficits and interpersonal difficulties among AUD individuals. AUD women may compensate for deficits in emotion processing more effectively than men, attenuating some difference in resultant interpersonal difficulties. While seemingly plausible, both of these potential explanations remain speculative and highlight the need for further investigation.

Despite the absence of hypothesized group by sex interactions, results underscore the extent and severity of interpersonal challenges among individuals with AUDs. Further, they suggest decrements in interpersonal functioning may be attributable to difficulties in response selection rather than response repertoire (i.e. differences in typical responding despite equivalent knowledge of appropriate response). Exploratory analyses support the import of emotion processing to interpersonal function observed by Kornreich (2002). This relationship was evident for interpersonal problems (IIP-64), but not in typical responding to situations of interpersonal conflict (ASB). The ASB vignettes describe situations in which emotions are unambiguous (e.g. 'His tone sounded really anxious'). Thus, these results may suggest that among AUD individuals, relationships between social cognition and interpersonal problems are likely driven more by difficulties in emotional evaluation than by difficulties in either response selection or repertoire.

Several limitations bear consideration. (a) The sample sizes of our groups/subgroups represent substantive increases compared to those examined in much of the available EFE literature (e.g. Philippot *et al.* 1999; Foisy *et al.* 2007). However, power remained insufficient to examine complex relationships between measures in the sample of AUD women. (b) The cross-sectional nature of this work precludes estimation of potential pre-existing differences in emotion processing prior to AUD onset. Similarly, while our data aid in characterizing recently detoxified individuals, they do not estimate affective functioning in mid- to long-term sobriety. (c) Our

work focuses on treatment-seeking individuals. It does not include community-dwelling individuals with AUDs, thus generalization of findings to this group may be limited. (d) While the employment of a well-validated and commonly-used stimuli set is a strength of this study, the set is limited to images of Caucasian individuals. The use of multi-racial stimuli sets or racially ambiguous stimuli would improve the generalizability of findings. (e) The current work includes only behavioral and self-report data. Similar sex-contingent analyses remain largely unaddressed with neuroimaging, electrophysiological or neuroendocrine methods, each of which provide critical tools toward investigating neural mechanisms underlying the behavioral differences.

Taken together, our results support and extend the current literature. They aid in characterizing emotion processing in AUD, highlight implications for interpersonal function among treatment-seeking individuals and provide evidence for the import of sex in chronic alcohol effects on social cognition. Although our data constitute meaningful contribution, the systematic investigation of relationships between affective processing, interpersonal function, treatment outcome and relapse to drinking remains critical to relapse-prevention and recovery-facilitation efforts.

SUPPLEMENTARY MATERIAL

Supplementary data are available at *Alcohol And Alcoholism* online

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CONFLICT OF INTEREST STATEMENT

None declared.

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