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Abstract

Alcohol consumption has been associated with increases in aggressive behaviour. However, experimental evidence of a direct association is equivocal, and mechanisms that may underlie this relationship are poorly understood. One mechanism by which alcohol consumption may increase aggressive behaviour is via alterations in processing of emotional facial cues. We investigated the effects of acute alcohol consumption on sensitivity to facial expressions of emotion. Participants attended three experimental sessions where they consumed an alcoholic drink (0.0, 0.2 or 0.4 g/kg), and completed a psychophysical task to distinguish expressive from neutral faces. The level of emotion in the expressive face varied across trials the threshold at which the expressive face was reliably identified and measured. We observed a significant three-way interaction involving emotion, participant sex and alcohol dose. Male participants showed significantly higher perceptual thresholds for sad facial expressions compared with female participants following consumption of the highest dose of alcohol. Our data indicate sex differences in the processing of facial cues of emotional expression following alcohol consumption. There was no evidence that alcohol altered the processing of angry facial expressions. Future studies should examine effects of alcohol expectancy and investigate the effects of alcohol on the miscategorisation of emotional expressions.

Key words

alcohol; emotional expression; face processing; sex differences

Introduction

Alcohol consumption is widely associated with increased aggression and interpersonal violence (Plant, 2004), and has been implicated as an important contributing factor in violent behaviour and violent crime (Hoaken and Stewart, 2003). Although experimental research to date generally supports a link between alcohol and aggression (Bushman and Cooper, 1990; Chermack and Giancola, 1997; Parrott, *et al*., 2003), a consensus has yet to be found on the mechanisms underlying this relationship. Evidence of a direct pharmacological link is equivocal and alcohol may increase the likelihood of aggression indirectly by inducing alterations in a number of cognitive, physiological or affective states (Bushman and Cooper, 1990). Furthermore, these effects are potentially confounded by expectancy effects (Quigley, *et al*., 2002) and individual differences in both propensity to drink and propensity to engage in aggressive behaviours (Pihl, *et al*., 2003).

On the contrary, the detrimental effects of alcohol on cognition and information processing are well described (Hernandez, *et al*., 2006; Koelega, 1995; Maylor, *et al*., 1992; Nelson, *et al*., 1986; Rohrbaugh, *et al*., 1988), and these changes may underlie or mediate any effects of alcohol on aggression. The appraisal-disruption model of alcohol consumption asserts, for example, that alcohol dampens the initial appraisal of information and that this impairment is cognitively mediated (Sayette, 1993). Although this model specifically describes a dampening effect of alcohol on the response to stressful situations or stimuli, the model suggests that alcohol impairs the encoding of emotional information by restricting the spread of activation to related

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events in long-term memory. In a similar way, alcohol may influence the perceptual judgements made in response to emotional stimuli by impairing the encoding of these stimuli. For example, a potential mechanism by which alcohol may facilitate aggression is via alterations in the processing of the emotional content of facial cues. This model proposes that acute alcohol consumption may lead to a misattribution of emotional states, which in turn may increase the likelihood of an inappropriate behavioural response (e.g., aggressive behaviour in response to a *perceived* negative emotional facial cue). Although studies have reported impairments to the processing of emotional facial cues in alcohol dependent participants (Townshend and Duka, 2003), few have investigated the acute effects of alcohol consumption on the processing of facial expression of emotion in social alcohol users.

A recent study reported that low doses of alcohol speeded the discrimination of happy faces compared with a high dose of alcohol, with no significant effects on the discrimination of angry, surprised or sad faces (Kano, *et al.*, 2003). However, when compared with placebo, this effect of a low alcohol dose did not reach statistical significance. The interpretation of these results is further complicated by the use of reaction time as the dependent variable, as this provides little information on the mechanism by which performance is altered after alcohol. Furthermore, the facial stimuli comprised only four levels of emotional intensity for each emotion (0%, 33%, 66% and 100%), which may fail to detect more subtle changes in emotional processing after alcohol.

A more sensitive measure of emotional processing can be produced by modifying standard psychophysical tasks, typically used to measure perceptual sensitivity in visual psychophysics. This allows a standard facial stimulus (i.e., neutral face) to be presented alongside a second facial stimulus (of the same individual) that varies in the degree of emotional expression. By using a large range of stimuli varying in intensity between the neutral and emotional expression, across a number of emotional expressions, and asking participants to identify the stimulus containing the relevant emotional content over repeated trials, a measure of perceptual threshold can be obtained.

In this study we sought to determine the effects of alcohol dose on perceptual thresholds for detection of facial expressions of emotion using a modified psychophysical task of the kind described above. Participants attended three sessions, separated by approximately 1 week, and were tested after consumption of a drink containing 0.0, 0.2 and 0.4 g/kg of alcohol in a randomised order. On the basis of evidence suggesting that there may be sex differences in the lateralisation of the processing of affective facial stimuli (Harrison, *et al.*, 1990), the cerebral organisation of systems involved in facial processing (Killgore and Gangestad, 1999) and the patterns of neural activation in response to affective facial stimuli (Lee, *et al.*, 2002), we explored differences between male and female participants, using male and female cues of emotional facial expressions.

Methods

Participants

Forty (50% men) social alcohol drinkers (defined as between 10 and 50 units/week for men, and five and 35 units/week for women) were recruited from the staff and students of the University of Bristol and from the general population by means of poster and flyer advertisements, and word-of-mouth. Participants were required to be in good psychological and physical health, aged between 18 and 40 years, and not currently taking any psychiatric medication, as verified by self-report. Exclusion criteria included current use of illicit substances (excluding cannabis) and a direct family history of alcoholism (defined as parent and/or sibling). Participants were asked to abstain from alcohol consumption for 12 h before each test session, and recent alcohol consumption confirmed by a breath test. Participants were paid £10 or awarded course credits as appropriate at the end of the study.

Materials

For the emotion discrimination task, morphed stimuli continua were created that changed from a neutral face to a full exemplar emotional expression. These sequences were generated from a database of films of actors performing facial expressions in front of a Dalsa DS-25-02M30 colour camera (Benton, *et al.*, 2007). The camera captured high-definition frames (1920×1080 pixels) at 25 Hz. We created six such continua using one male and one female actor for the expressions of happiness, sadness and anger.

For each continuum (men and women of happy, sad and angry), we selected 28 frames (i.e., just over 1 s) from the video footage that covered the development of each emotional expression from neutral to the full exemplar. We selected 10 key frames from these 28 (i.e., every third frame), which were delineated by marking 172 feature points on easily identifiable facial features (e.g., corner of eyes, outline of lips, etc.) using Psychomorph software (Tiddeman, *et al.*, 2001). The shape information from these delineations was used to create morph sequences of 18 images between each key frame using established techniques (Rowland and Perrett, 1995; Tiddeman, *et al.*, 2001). This generated a sequence of 172 images that closely follows the actual development of the expression and avoids morph-induced artefacts that may occur when creating morphs between a neutral and a full exemplar emotional expression without considering the time course of expression development.

Each threshold, therefore, represents a point along a sequence of 172 images; the sequence contains a facial expression developing between neutral and the full exemplar emotional expression over a period of 1.12 s. There is no particular expectation that, within the 1.12 s window, expression onset or offset occurs at the same time for all actors and their expressions. There is also no expectation that the different expressions

should develop at the same rate. In the present task, it is, therefore, meaningless to, for example, directly compare the thresholds obtained for different expressions.

Images were greyscaled and the edges were blurred to display mean luminance (using Gaussian blur of standard deviation 10 pixels) so that no hard image edges would be present when the images were displayed on the mean luminance background. Examples taken from our morph sequences are shown in Figure 1.

The questionnaire measures comprised the Eysenck Personality Questionnaire – Revised (EPQ-R) (Eysenck and Eysenck, 1991), the Spielberger State-Trait Anxiety Inventory (STAI State and Trait) (Spielberger, *et al*., 1983), the Alcohol Use Disorders Identification Test (AUDIT) (Bohn, *et al*., 1995), the Alcohol Urges Questionnaire (AUQ) and visual analogue scales measuring ratings of 'happy', 'drowsy', 'depressed', 'anxious', 'energetic', 'irritable' and 'craving a drink' on a 100 mm scale ranging from 'Not at all' to 'Extremely'.

Procedure

Each participant attended three sessions, approximately 1-week apart, at which they received a drink containing 0.0, 0.2 or 0.4 g/kg of alcohol, in a randomised order. The drinks were made by an experimental collaborator, and administration was double-blind. Drinks were made using vodka at 37.5% alcohol, with one part vodka to three parts tonic water, or a placebo consisting of an equal total volume of tonic water. All drinks were flavoured using lime cordial and chilled before serving. Previous studies in our laboratory have indicated that this is an effective placebo-controlled design, with participants identifying the drink they were administered at chance level during consumption. Test sessions were held between 12:00 a.m. and 06:00 p.m. and participants attended all their sessions at approximately the same time of day.

Upon arrival at the first test session participants gave informed consent and completed a screening procedure to confirm their eligibility to take part and were weighed. At the start of all sessions, readings of exhaled alcohol and carbon monoxide were taken. Baseline ratings of mood and craving were taken (STAI-State, AUQ, VAS). Participants were then presented with the drink and were given 20 min to consume all the drink. At session one only, participants also completed additional self-report measures of drinking behaviour and personality (AUDIT, EPQ-R and STAI-Trait) during this period. At the end of the 20-min consumption period, participants completed post-drink ratings of STAI-State, AUQ and VAS, before beginning the discrimination task.

Absolute thresholds for the detection of facial expressions were measured using a two alternative forced choice (2AFC) task (Goren and Wilson, 2006). Stimuli were displayed on a visual display unit using the Cogent Graphics extension to MATLAB (The MathWorks Inc., Natick, Massachusetts, USA). For each participant, we gathered the following six thresholds: angry female, happy female, sad female, angry male, happy male and sad male. Thresholds were gathered one at a time (i.e., they were not interleaved), and the order of presentation counter-balanced across participants. As is typical in a 2AFC task, one of the faces was stimulus-absent (i.e., neutral), whereas the other was stimulus-present (i.e., expressive).

Figure 1 Example subset of series of angry, happy and sad emotional expressions.

For each threshold, the neutral and expressive faces were taken from the same composite. The expressive faces were taken from the interpolated image sequences running between the neutral and full exemplar emotional expression. The level of expression chosen (the distance along the morph sequence) was determined using the PEST adaptive psychophysical procedure (Findlay, 1978). Image choice was determined by a modified staircase procedure (Cornsweet, 1962; Levitt, 1971), using two interleaved staircases, one starting above threshold and one starting below threshold. Each staircase operates by judging (based on a number of previous trials) whether the images displayed lie below or above threshold. If there is sufficient evidence that one of these is the case, then the level is increased or decreased as appropriate. If the levels cross the threshold, then the step size (i.e., the amount of change between levels) is decreased so that the procedure gradually hones in on the threshold over time (Findlay, 1978). We take the mean of the finishing points of the two staircases as our estimate of threshold. A high threshold score, for example, suggests low sensitivity to an emotional expression, as substantial emotional content is required before the expressive face is reliably distinguished from the neutral face. Participants were instructed to identify which of the two faces contained the relevant emotional expression (i.e., identify the expressive face from the neutral face) using the arrow keys on a keyboard. Participants were given feedback after each trial by presenting the word 'yes' or 'no' as appropriate. Each stimulus was presented for 3000 ms and there was a minimum of a 500-ms gap between stimuli. The display resolution was set to 1024 × 768 pixels and the face images measured by 569 × 410 pixels. The mean interocular distance was 162 pixels.

On completion of the task, the STAI-State, AUQ and VAS were completed again. Participants were then reminded that they may have consumed alcohol and therefore should not drive, operate heavy machinery or engage in any activity that they would not normally do after taking alcohol. At the end of the third session, participants were debriefed and reimbursed as appropriate.

Statistical analysis

All analyses were performed using SPSS v.12.0 (SPSS Inc., Chicago, Illinois, USA). Data were analysed using a 3 × 2 mixed model repeated measures ANOVA, with alcohol dose (0.0, 0.2, 0.4 g/kg alcohol) as a within-subjects factor and participant sex (male, female) as a between-subjects factor. For the analysis of threshold data, target sex (male, female) and target emotion (angry, happy, sad) were included as additional within-subjects factors, whereas for the analysis of questionnaire data, time (baseline, pre-task, post-task) was included as a within-subjects factor. Significant interaction effects were explored using simple effects ANOVA.

Age was included as a covariate in the analysis of threshold data. Additional analyses were run with STAI-Trait (for the analysis of STAI-State data only) and AUDIT scores (for the analyses of threshold and questionnaire data) included as covariates, and these results are reported where effects differed from the unadjusted analysis. Order of alcohol dose administration was included, but removed if non-significant.

Where there was evidence of a violation of the assumption of sphericity, as assessed by Mauchly's test, statistics corrected using the Greenhouse Geisser method are reported. An α-level of 0.05 was maintained throughout, except in the case of VAS data where an α-level of 0.007 was used, corrected for seven independent tests using Bonferroni's method.

Results

Participant characteristics

Participants had a mean age of 23 years (SD = 4, range 19–38) a mean AUDIT score of 13 (SD = 6, range 4–33) and a mean STAI-Trait score of 38 (SD = 10, range 21–61). Male and female participants did not differ significantly on age, STAI-Trait score or EPQ-R score ($P > 0.09$); however, there was a significant difference on AUDIT score between male (M = 15, SD = 6) and female (M = 11, SD = 5) participants ($P = 0.034$).

Questionnaire data

Summary questionnaire data for STAI-State, AUQ and VAS ratings are presented in Table 1.

For STAI-State data, there was a significant main effect of time ($F[1.6, 61.9] = 4.57$, $P = 0.020$) indicating higher scores post-task (M = 32, SD = 10), compared with pre-task (M = 30, SD = 9, $P = 0.001$) but not baseline (M = 31, SD = 8, $P = 0.23$). There was also a trend towards a significant time × alcohol dose interaction ($F[2.7, 103.6] = 2.34$, $P = 0.084$). No other main effects or interactions were significant ($P > 0.25$). When STAI-Trait and AUDIT scores were included as covariates, the main effect of time and the time × alcohol dose interaction were no longer significant ($P > 0.13$).

For AUQ data, there was a significant alcohol dose × participant sex interaction ($F[2, 76] = 3.37$, $P = 0.040$), and a trend towards a significant time × alcohol dose interaction ($F[3.1, 119.1] = 2.29$, $P = 0.079$). No other main effects or interactions were significant ($P > 0.12$). When AUDIT score was included as a covariate, the alcohol dose × sex and time × alcohol dose interactions were no longer significant ($P > 0.10$).

For the VAS data, there was a main effect of time on ratings of 'happy' ($F[1.4, 53.9] = 10.36$, $P = 0.001$), 'drowsy' ($F[2, 76] = 12.65$, $P < 0.001$) and 'energetic' ($F[2, 76] = 28.77$, $P < 0.001$), reflecting a decrease in ratings of 'happy' and 'energetic', and an increase in ratings of 'drowsy' over time. There was also a significant time × participant sex × alcohol dose interaction for ratings of 'happy' ($F[5, 152] = 4.53$; $P = 0.002$). Post-hoc tests indicated that the alcohol dose × participant sex interaction was significant post-task ($F[2, 76] = 7.40$, $P = 0.001$), but not at baseline or pre-task ($P > 0.13$). Further

Table 1 Mean (SD) STAI-State, AUQ and VAS ratings of 'drowsy', 'energetic' and 'happy', by time, alcohol dose and participant sex

Measure	Dose g/kg	Males (n = 20)			Females (n = 20)			Combined (n = 40)		
		Time 1	Time 2	Time 3	Time 1	Time 2	Time 3	Time 1	Time 2	Time 3
		Pre-drink	Post-drink	Post-task	Pre-drink	Post-drink	Post-task	Pre-drink	Post-drink	Post-task
STAI-State	0.0	31 (12)	31 (7)	30 (9)	31 (6)	30 (11)	33 (12)	31 (9)	31 (9)	32 (11)
	0.2	31 (12	30 (12)	30 (7)	30 (7)	30 (8)	31 (11)	31 (10)	30 (10)	30 (9)
	0.4	30 (11)	29 (9)	33 (11)	33 (8)	31 (12)	35 (12)	32 (10)	30 (10)	34 (12)
AUQ	0.0	12 (13)	14 (13)	14 (12)	13 (8)	11 (9)	9 (7)	13 (11)	13 (11)	11 (10)
	0.2	8 (9)	9 (9)	8 (11)	13 (9)	12 (10)	13 (10)	10 (9)	11 (10)	11 (11)
	0.4	11 (12)	13 (14)	16 (3)	9 (9)	11 (12)	12 (13)	10 (10)	12 (13)	14 (13)
VAS 'drowsy'	0.0	40 (24)	41 (22)	43 (22)	38 (23)	45 (21)	46 (24)	39 (23)	43 (22)	45 (23)
	0.2	41 (26)	43 (21)	50 (28)	39 (25)	39 (24)	52 (25)	40 (25)	41 (23)	51 (26)
	0.4	40 (27)	45 (27)	56 (28)	41 (24)	42 (26)	56 (26)	40 (25)	44 (26)	56 (27)
VAS 'energetic'	0.0	64 (17)	61 (16)	52 (23)	51 (16)	49 (16)	40 (14)	57 (18)	55 (17)	46 (20)
	0.2	66 (21)	60 (18)	53 (21)	51 (16)	46 (18)	42 (18)	58 (20)	53 (19)	48 (20)
	0.4	57 (18)	52 (18)	43 (20)	53 (18)	48 (22)	39 (24)	55 (18)	50 (20)	41 (22)
VAS 'happy'	0.0	74 (19)	76 (15)	78 (14)	73 (11)	69 (16)	64 (17)	73 (16)	73 (15)	71 (17)
	0.2	75 (21)	71 (20)	67 (21)	74 (13)	75 (12)	71 (14)	74 (17)	73 (16)	69 (18)
	0.4	76 (17)	72 (18)	67 (19)	71 (13)	72 (16)	67 (19)	74 (15)	72 (17)	67 (19)

post-hoc tests indicated that post-task ratings of 'happy' were higher among men (M = 78, SD = 14) compared with women (M = 64, SD = 17) participants in the 0.0 g/kg condition ($P = 0.006$), but not in the 0.2 g/kg or 0.4 g/kg conditions ($P > 0.50$). No other main effects or interactions were significant ($P > 0.10$). When AUDIT score was included as a covariate, these results were not altered substantially.

Threshold data

For the threshold data, there were significant main effects of target sex ($F[1, 37] = 12.71$, $P = 0.001$) and emotion ($F[1.5, 53.7] = 18.79$, $P < 0.001$). There were also significant emotion × target sex ($F[1.3, 46.3] = 4.09$ $P = 0.040$) and emotion × participant sex ($F[2, 74] = 4.60$, $P = 0.013$) interactions, but these were not explored further, in the former case because of difficulty interpreting absolute differences between stimulus types (see above), and in the latter case because this was subsumed under a significant three-way interaction (see below).

There was a significant emotion × alcohol dose × participant sex interaction ($F[4, 148] = 3.34$, $P = 0.012$). Post-hoc tests stratified by emotion showed a significant alcohol dose × participant sex interaction for sad expressions ($F[2, 74] = 3.95$, $P = 0.024$), but not for other expressions ($P > 0.39$). Further post-hoc tests for sad expressions only indicated that male and female participants did not differ in the 0.0 g/kg or 0.2 g/kg conditions ($P > 0.11$) alcohol dose conditions. However, men showed significantly higher thresholds compared with women in the 0.4 g/kg condition ($P = 0.005$). These data are presented graphically in Figure 2.

No other main effects or interactions were significant ($P > 0.08$). The inclusion of AUDIT score as a covariate did not alter these results substantially.

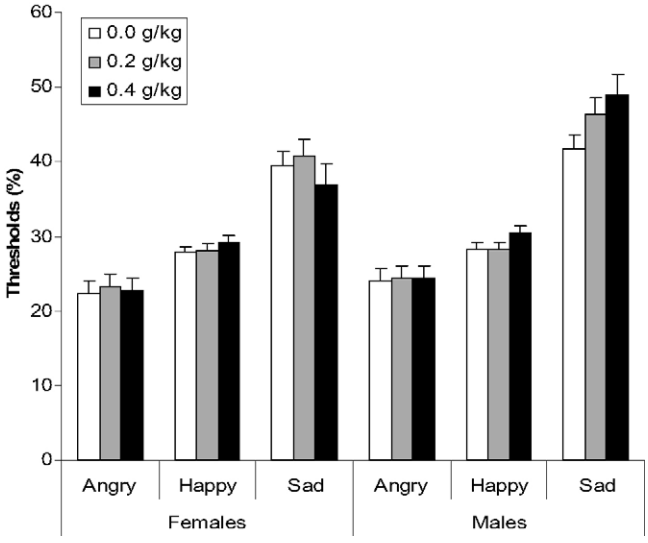

Figure 2 Detection thresholds for angry, happy and sad facial expressions of emotion among female and male participants by alcohol dose. Detection thresholds for angry, happy and sad emotional expressions among male and female participants are presented by alcohol dose (0.0, 0.2 and 0.4 g/kg). Higher thresholds of detection were observed for men compared with women in the highest dose of alcohol condition. Error bars represent SEM.

Discussion

Our data indicate that alcohol modifies the perceptual threshold for facial expressions of sadness among male compared with female participants. These effects did not appear to be due to alterations in subjective mood ratings or differences between male and female participants in self-reported alcohol consumption behaviour.

Kano, *et al.* (2003) reported faster discrimination of happy facial expressions in male participants following a low dose (0.14 g/kg) compared with a higher dose (0.56 g/kg) of alcohol, with no effects of alcohol on sad, angry or surprised facial expressions. These authors argue that the dose-related effects that they observed on the processing of happy facial expressions might have been mediated by the biphasic effects of alcohol, whereby low doses of alcohol induce stimulant-like effects that may selectively influence the processing of happy facial stimuli, compared with higher doses that induce depressant effects. In comparison, using the threshold task, our study did not find any effects on the processing of happy emotional expressions after the lower alcohol dose, although impairment in the processing of sad emotional expressions was observed in male participants compared with female participants in the higher dose of alcohol condition. Our visual analogue mood data also did not show the biphasic dose effects discussed by Kano, *et al.* (2003). For example, male participants reported lower ratings of happiness after alcohol compared with placebo and to baseline. However, these effects occurred in both 0.2 and 0.4 g/kg alcohol conditions to a comparable degree. The lack of biphasic dose effects in this study may be due to our lower dose of alcohol (0.2 g/kg) being higher than the 'low' dose (0.14 g/kg) used by Kano, *et al.* (2003). However, Kano, *et al.* (2003) also failed to report dose-dependent effects on self-reported ratings of 'depressed' ('happiness' was not measured). Although other measures may be required to fully explore the role of any biphasic effects of alcohol, our findings provide little evidence to suggest that the mood-altering effects of alcohol mediated the effects observed on the processing of emotional expressions.

Comparisons between our findings and those of Kano, *et al.* (2003) are complicated by the differences in the design of the two studies, and the different tasks used. Kano, *et al.* (2003) presented participants with sequential single stimuli, which had to be classified according to the emotion. One problem with such methodologies is that they can tell us little about the mechanisms leading to differences in performance on the tasks. For example, with these tasks we cannot determine whether alcohol-related changes in performance are the result of changes in the perceptual processing of the stimuli or are a consequence of differences in later cognitive processes. In traditional psychophysics, the 2AFC method is used to determine a criterion-free estimate of the 'Just Noticeable Difference' between two stimuli. However, one should be aware that one cannot guarantee what information is being used by subjects to make their decisions. A judgment might be based on a general impairment of the detection of low-level spatial differences between the images that correspond with the increasing expression, rather than upon the expression itself. However, our findings of sex differences in the detection of sad, but not other, emotional expressions following alcohol consumption suggest that participants based their judgments on the emotional content of the faces. If, for example, decisions were based on low-spatial information, there would be no reason to expect different results across emotional expressions.

Our data provide no evidence that alcohol increases sensitivity to emotional expressions of anger. Therefore, the hypothesis that an alcohol-induced disruption to the processing of facial emotional expressions directly influences the aggressive behaviour associated with alcohol consumption is not supported. It is plausible that this effect may be mediated by other factors such as level of intoxication, individual drinking patterns or expectancy. One explanation for the impaired processing of sad facial expressions in men compared with women following alcohol consumption that we observed in our study may be that these effects are mediated by alcohol-induced disruption of a brain region that is selectively involved in the processing of sad emotional expressions. In support, neurobiological evidence suggests that separate cognitive systems may be involved in the processing of different emotional expressions (Adolphs, *et al.*, 1996; Adolphs, *et al.*, 1994). In a study of 37 patients with brain damage, Adolphs, *et al.* (1996) reported greater impairment of the recognition of sad and fearful faces compared with other negative expressions, including angry faces, whereas processing of happy facial expressions was relatively unimpaired. The amygdala has been identified as being involved in the processing of fearful facial expressions in both clinical (Adolphs, *et al.*, 1994, 1999) and healthy samples (Morris, *et al.*, 1996). Although, less research has been conducted on other emotional expressions, the amygdala has also been implicated as being involved in the processing of sad facial expressions, whereas the orbitofrontal cortex and anterior cingulate cortex have been implicated in the processing of angry facial expressions (Blair, *et al.*, 1999).

On the contrary, however, the pharmacological effects of alcohol are widespread, affecting several important neurotransmitter systems including GABA, glutamate, serotonin and dopamine (Chastain, 2006; Nutt and Peters, 1994). Therefore, alcohol may influence the processing of sad facial expressions differentially in men and women via a less-selective mechanism. For example, Adolphs, *et al.* (1996) suggest that negative emotions, particularly those of fear and sadness, are more difficult to identify and therefore potentially more prone to disruption in patients with brain damage. Therefore, our finding of impaired processing of sad facial expressions in men compared with women following alcohol consumption, but not of happy and angry facial expressions, may be due to the greater difficulty associated with this version of the task. Alternatively, the sex differences we observed may be in part because of the greater levels of empathy and empathic behaviours reported in women (Hoffman, 1977; Toussaint and Webb, 2005). Female participants may be less impaired by alcohol consumption

when presented with sad facial expressions because of a greater responsiveness to negative emotions in others.

There are some limitations to our study which should be considered. First, there was a significant difference between the AUDIT scores of male and female participants. However, higher rates of alcohol consumption among men, compared with women, are not uncommon, particularly in an undergraduate student population. Additional statistical analyses were conducted including AUDIT as a covariate, which did not change the results of our threshold data analysis substantially but did render many of the effects observed in our analyses of questionnaire data non-significant. Second, our sample showed high AUDIT scores that are indicative of potential problem drinking. This may be due to a high proportion of our participants coming from a student population. A weekly alcohol consumption criterion was enforced to explicitly exclude very light and very heavy alcohol consumers; however, future studies should directly compare the effects of high and low alcohol consumption, or compare alcohol dependent and non-dependent groups, using the current paradigm. Third, although we investigated thresholds for the detection of facial expressions of emotion, with respect to our primary hypotheses on the possible mechanisms that mediate any relationship between alcohol consumption and aggression, it might be more appropriate to investigate the mis-categorisation of one emotion as another (e.g., happy as angry). Future studies should therefore include measures of categorisation and threshold. Fourth, and finally, our data provide no information on the impact of expectancy on the processing of emotional face cues, and it is not clear whether merely being *told* that one is drinking alcohol would elicit a similar effect. Expectancy has consistently been shown to play an important role in the effects of many drugs. However, it is difficult to effectively manipulate expectancy in a dose–response study where there are more than two drink conditions, and also difficult to manipulate when using a within-subjects design, in part for ethical reasons. A future study should examine the effects of alcohol and alcohol expectancy on the 2AFC task using a balanced-placebo design.

Despite these limitations our study provides some important findings. Specifically, our data suggest that men may differ from women in the perceptual processing of sad emotional expressions, but not happy or angry emotional expression, following the consumption of alcohol, which may be related to the lower levels of empathy often reported in men (Toussaint and Webb, 2005). The differential effects obtained in threshold scores between male and female participants support previous work, suggesting that sex differences exist in the recognition and processing of emotional content of facial expressions (Guntekin and Basar, 2007), and emphasise the importance of grouping participants by sex in future studies and exercising caution when generalising results from single-sex studies to the wider population. Further research should establish whether the effect of alcohol on the perception of emotion is mediated by other factors such as drinking history, but the present data suggest that if a relationship exists between the disruption of the processing of angry facial stimuli and aggression, it is, at best, indirect.

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