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Impaired processing of emotion in music, faces and voices supports a generalized emotional decoding deficit in alcoholism

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ABSTRACT

Aim To test the generalized emotional decoding impairment hypothesis in alcoholism. **Design** Cross-sectional behavioural study comparing emotion recognition conveyed by faces, voices and musical excerpts. **Setting** Alcohol detoxification unit of Brugmann University Hospital. **Participants** Twenty-five recently detoxified alcohol-dependent patients were compared to 25 normal controls matched for sex, age and educational level. **Measurements** From faces, voices and musical excerpts, participants were instructed to rate the intensity of several emotions on a scale from 0 for 'absent' to 9 for 'highly present'. Depression, anxiety and sustained/selective attention capacities were controlled for. **Findings** Alcohol-dependent patients were less accurate than controls in identifying the target emotion in faces ($P < 0.001$), voices ($P < 0.001$) and musical excerpts ($P < 0.001$). **Conclusions** Alcohol-dependent patients who are completing detoxification are impaired in recognizing emotions conveyed by faces, voices and music; these results suggest a generalized emotional decoding impairment. Hypothetically, deficits in the fronto-parietal mirror neurone system could link all these disturbances together.

Keywords Alcohol, emotion, empathy, face, mirror neurone, music, theory of mind, voice.

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INTRODUCTION

Accurately inferring the mental and emotional states of other people is of particular importance for navigating the social world [1]. Alcohol-dependent patients are less accurate in recognizing emotions conveyed by humans in faces [2–10], voices [11–13] and postures [13]. However, behavioural studies do not always show generalized deficits: for example, Uekermann *et al*. [12] reported impaired recognition of affective prosody, but in the absence of impaired decoding of facial affect. These discrepancies could be due to differences in methods of evaluation, lengths of abstinence and/or samples. Individuals with alcoholism show deficits even when controlling for general visuospatial capabilities [10,12,14], indicating that impairments in non-verbal decoding are not due to basic perception deficits. These deficits persist, at least in part, after prolonged periods of abstinence [4,15,16]. Interpersonal problems have been associated with emotion recognition impairments [5] and such problems may lead to relapse [17], suggesting that the observed impairments in emotion recognition among individuals with alcoholism are of clinical significance.

No study has yet examined alcohol-dependent patients' capacity to recognize basic emotions in music. Music is a known means of emotional expression [18]. Like facial expressions, musical emotions (e.g. happy, sad and fearful) are universally recognized [19]. The ability to identify emotional expressions in music is presumably due at least partly to the universal ability to recognize non-verbal patterns of emotional expressiveness such as emotional prosody [20]. This view is supported by the fact that similar emotion-specific acoustic cues are used to communicate emotion in both speech and music [21,22]. Additionally, there is overlap between the brain regions used to analyse vocal and musical timbre, such as the superior temporal sulcus [23,24]. In this respect, it would not be surprising to find similarities between the abilities to recognize emotion in voices and in music in alcohol-dependent patients. However, the brain regions used to process voices and music do not overlap completely, consistent with the observation that the perception of musical (versus voice) timbre can be selectively impaired in neurological cases [25]. Furthermore, musically tone-deaf subjects, estimated to comprise about 4% of the population, do not have difficulties processing normal speech intonation [26]. It has also been shown that recognition of fearful faces may be preserved while recognition of scary music can be impaired in brain-damaged patients [27]. Finally, a study reported that people with Alzheimer disease were only impaired in emotional recognition from faces, while recognition of dynamic auditory emotions was preserved [28]. Hence, it cannot be inferred automatically from previous studies on emotion perception in voices or faces that emotion perception in music is necessarily impaired in alcoholic patients.

A deficit in the recognition of emotion in music would further our understanding of emotion perception in alcohol-dependent patients, whether in other people (perception of emotion in faces, voices and postures) or in themselves (i.e. alexithymia [29,30]). Impaired musical emotion perception in alcohol-dependent patients would suggest that a general, unifying model is needed to account for these deficits.

METHOD

Participants

The alcohol-dependent patient group (A) consisted of 25 in-patients (17 men and eight women). Patients were recruited in the addiction unit at Brugmann University Hospital in Brussels. They were not paid for their participation. A clinical interview, as well as a mental state examination, was conducted systematically to ascertain that inclusion/exclusion criteria were met. Inclusion criteria included subjects with alcohol dependence problems according to the DSM IV-TR [31] in their third week of detoxification, with no current use of psychotropic medications. Participants with a history of bipolar disorder, schizophrenia, dependence on other drugs besides tobacco, or dementia, assessed during the intake interview, were excluded. The control group consisted of 25 volunteers (17 men, eight women) with no psychiatric record or personal history of alcoholism. The control group (C) was recruited from the investigator's social environment and participants were not paid. They were matched for age, sex and education level with the patients in the alcoholic group. Demographic and clinical variables for the two groups were recorded (see Table 1).

Current clinical status

Severity of alcoholism was assessed using the Michigan Alcohol Screening self-administered Test–revised (MAST). The Beck Depression Inventory, second edition (BDI-II) [32] was used as a self-report measure of depression. Spielberger's State–Trait Anxiety Inventory [33] was administered to control for anxiety. The D2 attention test [34] was used to control for concentration ability. In this task, participants were shown 14 lines and 47 signs ('Ps' and 'Ds') with one or two apostrophes above or below the signs and were asked to identify all 'Ds' with two apostrophes in 20 seconds per line.

Table 1 Characteristics of recently detoxified alcoholic and normal control subjects.

	Alcohol group (n = 25)	*Control group (n = 25)*
Sex (male/female)	17/8	17/8
Age	Mean = 43.52; SD = 9.11	Mean = 42.12; SD = 9.6
Education level 1/2/3[a]	8/5/12	8/5/12
Alcoholism duration (in years)	Mean = 12.08; SD = 10.04	–
Abstinence (in weeks)	3.16 (0.37)	–
Drinks per day	Mean = 16.20; SD = 9.54	Mean = 1.12; SD = 0.93
Number of in-patient stays	Mean = 3; SD = 2.5	
Familial history of alcohol[b]	18/25	8/25
MAST****	Mean = 12.84; SD = 3.33	Mean = 0.92; SD = 1.19
BECK****	Mean = 17.88; SD = 9.15	Mean = 4,12; SD = 3.64
STAI-A state**	Mean = 32.84; SD = 10.52	Mean = 25.24; SD = 4.98
STAI-B trait****	Mean = 49.32; SD = 10.89	Mean = 32.96; SD = 7.46
D2, percentiles****	Mean = 37.60%: SD = 25.24	Mean = 81.16%; SD = 19.73

[a]Education level: 1: junior or vocational; 2: college; 3: graduate studies. [b]Presence of at least one first-degree relative (father and/or mother) with alcohol dependence was considered as evidence for positive familial history. Difference between the average of the two groups (Student's *t*) **significant at 0.01; ****significant at 0.0001. MAST: Michigan Alcohol Scoring Test; BECK: Beck Depression Inventory; STAI: State–Trait Anxiety Inventory; SD: standard deviation.

Experimental tasks

Musical emotion recognition task

The musical material consisted of 56 excerpts, 14 in each of four categories of emotion (happiness, sadness, threat and peacefulness) [35]. They were all computer-generated and recorded in a piano timbre. For each excerpt, the participants were instructed to rate the intensity of the four emotions on a scale from 0 for 'absent' to 9 for 'highly present'. The musical excerpts could only be listened to once, but the subject had unlimited time between each excerpt to rate the emotions.

Vocal emotion recognition task

A validated test of non-verbal affect bursts [36] using computer-recorded voices from five male and five female actors was used. The actors express six different emotions: anger, disgust, fear, sadness, surprise and happiness, in addition to a neutral condition. We used 35 excerpts, five for each of the six emotions, as well as five for neutral voices. The participants were asked to rate the intensity of the six emotions for each excerpt on a scale from 0 for 'absent' to 9 for 'highly present'.

Facial emotion recognition task

A range of 25 validated facial stimuli (three men and two women) [37] were presented on a computer: five faces for each different emotion (happiness, sadness, fear, anger) and five neutral faces. Faces were presented for 0.5 seconds. Again, the participants were asked to rate the intensity of the four emotions for each face on a scale ranging from 0 for 'absent' to 9 for 'highly present'.

Scoring

For each test, 1 point was awarded when the target emotion obtained the highest mark (in terms of perceived intensity). The same intensity given to two or more emotions for one single item (one music excerpt, voice or face) led to a 0 point mark (because there had to be one dominant emotion per stimulus). The subject also received 0 points when he/she awarded the highest score to an emotion that was not the target one.

For stimuli expressing neutrality (in vocal and facial excerpts), 1 point was awarded if the subject chose the same intensity for all emotions or if he/she circled a total absence of emotion for the concerned item ('0' for each emotion).

Emotional intensities were obtained by computing the mean intensity scores across all excerpts for all emotions.

Analyses

A series of repeated-measures multivariate analyses of variance (ANOVAs) were conducted across the three modalities (music, voices and faces), with accuracy and mean intensity ratings as dependent variables. For each of these analyses, emotion was entered as a within-subjects factor and group (A or C) as a between-subjects factor.

Only significant interactions involving group have been reported. Greenhouse Geisser corrections have been used where appropriate. ANOVAs have been used in *post-hoc* tests when appropriate. Influence of the control measures (BDI-II, STAI-A, STAI-B and D2), as well as the influence of gender, has been explored systematically using analyses of covariance (ANCOVAs) when differences between groups on these measures were significant. Similarly, correlations between Beck, STAI-A, STAI-B, D2, duration of consumption, MAST scores, mean daily usual consumption and accuracy or intensity scores were explored in the alcoholic group when differences from the control group appeared on these variables.

Procedure

Written informed consent was obtained from all participants. The Ethical committee of the Medical Faculty of the Université Libre de Bruxelles approved the design of the study.

RESULTS

Musical emotion recognition

Emotion recognition accuracy (percentage correct)

Accuracy in musical emotion recognition for A [mean = 0.58, standard deviation (SD) = 0.03] was significantly lower than in C (mean = 0.72, SD = 0.03; $F_{(1,48)} = 12.03$, $P < 0.001$, $\eta^2 = 0.2$). There were no other significant results and no significant emotion × group interactions.

Emotional intensity ratings

There was no significant difference between A (mean = 2.69, SD = 0.16) and C (mean = 2.70, SD = 0.16) for the averaged intensity rating across all emotions. There was also no significant intensity × group interaction. However, there was a significant excerpt × emotion × group interaction, $F_{(3.582,\ 171.928)} = 4.56$, $P < 0.01$; $\eta^2 = 0.09$. More specifically, for peaceful excerpts, we observed a greater intensity rating of threat in A (mean = 0.92, SD = 1.25) compared to C (mean = 0.31, SD = 0.45; $F_{(1,48)} = 5.27$, $P < 0.05$) and a lower intensity rating of peacefulness in A (mean = 4.6, SD = 2.11) compared to C (mean = 5.72, SD = 1.25; $F_{(1,48)} = 5.02$; $P < 0.05$). For sad excerpts, there was a greater intensity rating of threat in A (mean = 1.94, SD = 0.39) compared to C (mean = 1.06, SD = 0.21;

$F_{(1,48)} = 6.29$, $P < 0.01$). None of the covariates influenced the results significantly.

Vocal emotion recognition

Emotion recognition accuracy (percentage correct)

A (mean = 0.54, SD = 0.11) were significantly less accurate than C (mean = 0.68, SD = 0.1; $F_{(1,48)} = 19.55$, $P < 0.001$, $\eta^2 = 0.29$). There was a significant group × emotion interaction, $F_{(4.75,\ 228.23)} = 3.06$, $P < 0.05$, $\eta^2 = 0.06$ (see Fig. 1). A one-way ANOVA showed that A were significantly less accurate in identifying anger (mean = 0.13, SD = 0.15), happiness (mean = 0.74, SD = 0.34) and neutrality (mean = 0.35, SD = 0.33) compared to C (anger: mean = 0.29, SD = 0.24; $F_{(1,48)} = 8.01$, $P < 0.001$; happiness: mean = 0.91, SD = 0.13; $F_{(1,48)} = 5.99$, $P < 0.05$; neutrality: mean = 0.71, SD = 0.25; $F_{(1,48)} = 18.56$; $P < 0.001$). There were no group differences in identifying disgust, fear, sadness or surprise. None of the covariates influenced the results significantly.

Emotional intensity rating

There was no significant difference in global intensity rating between A (mean = 1.7, SD = 0.1) and C (mean = 1.46, SD = 0.10; $F_{(1,48)} = 2.66$, $P = 0.11$). However, there was a significant group × emotion interaction, $F_{(2.95,\ 141.73)} = 3.23$, $P < 0.05$, $\eta^2 = 0.06$ (see Fig. 2). A one-way ANOVA showed that A attributed more intensity to fear (mean = 2.20, SD = 0.85) and to surprise (mean = 3.04, SD = 1.38) across all voices than did C (fear: mean = 1.69, SD = 0.76; $F_{(1,48)} = 5.09$, $P < 0.05$; surprise: mean = 2.27, SD = 1.22; $F_{(1,48)} = 4.43$, $P < 0.05$). There were no group differences in intensity ratings for anger, disgust, sadness or happiness. None of the covariates influenced the results significantly.

Intensity ratings for neutral stimuli

A attributed more emotional intensity (mean = 1.25, *SD* = 0.18) to neutral excerpts than C (mean = 0.31, SD = 0.18, $F_{(1,48)} = 27.84$, $P < 0.001$; $\eta^2 = 0.37$). There was a significant group × emotion interaction,

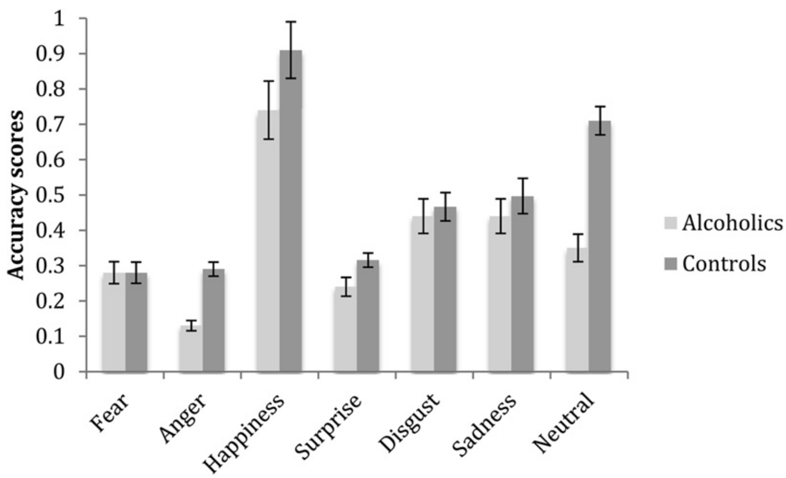

Figure 1 Accuracy scores (%) for vocal emotions in alcoholics and healthy controls. Error bars are the standard errors of the mean

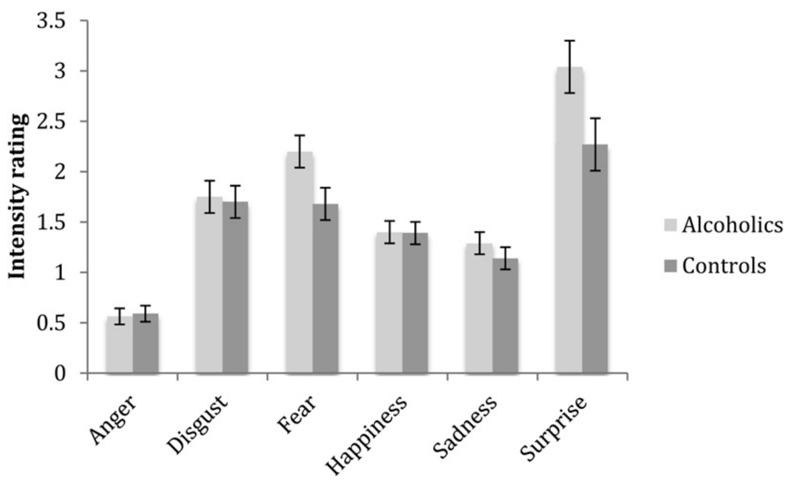

Figure 2 Averaged intensity ratings (mean on a total of 9) across all excerpts for vocal emotions in alcoholics and healthy controls. Error bars are the standard errors of the mean

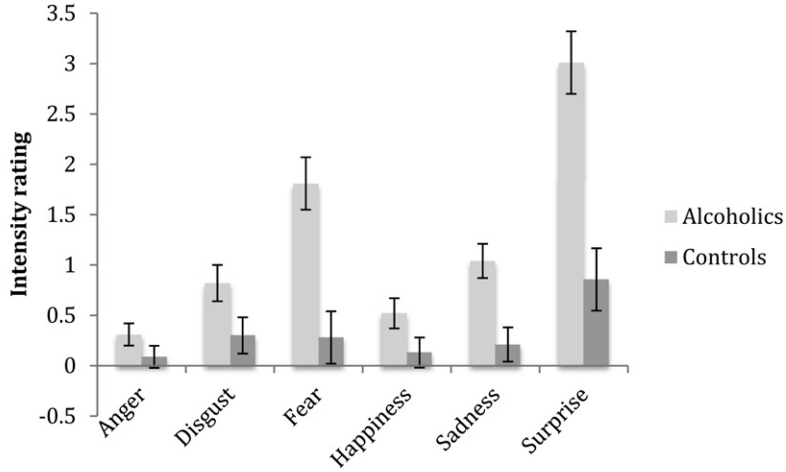

Figure 3 Intensity rating of neutral voices (mean on a total of 9) in alcoholics and healthy controls. Error bars are the standard errors of the mean

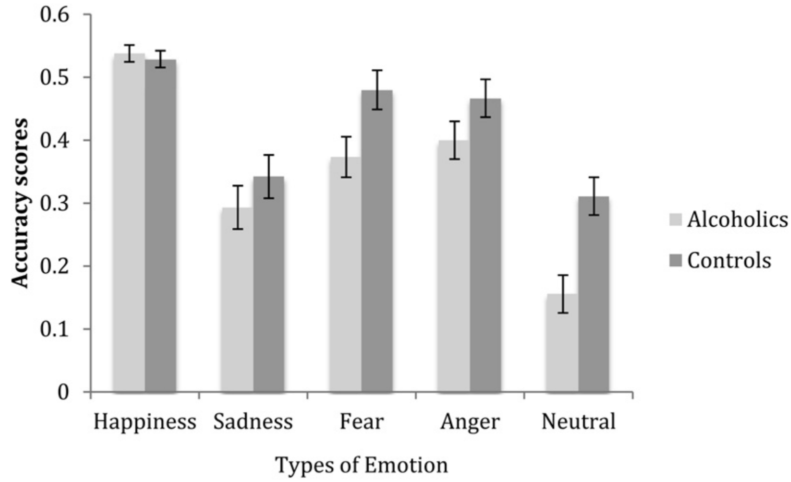

Figure 4 Accuracy scores (%) for facial emotions in alcoholics and healthy controls. Error bars are the standard errors of the mean

$F_{(3.51,\ 168.28)} = 8.50$, $P < 0.001$ (see Fig. 3). A one-way ANOVA showed that A attributed more emotional intensity to neutral stimuli judged as disgust (mean = 0.82, SD = 0.91), fear (mean = 1.73, SD = 0.35), sadness (mean = 1.05, SD = 1.0) and surprise (mean = 3.02, SD = 1.90) than did C (disgust: mean = 0.3, SD = 0.9; $F_{(1,48)} = 4.03$, $P = 0.05$; fear: mean = 0.66, SD = 0.13, $F_{(1,48)} = 16.95$, $P < 0.001$; sadness: mean = 0.22, SD = 0.62; $F_{(1,48)} = 12.44$, $P < 0.001$; surprise: mean = 0.86, SD = 1.13; $F_{(1,48)} = 23.94$, $P < 0.001$). There were no group differences in intensity ratings for anger or happiness. None of the covariates influenced the results significantly.

Facial emotion recognition

Emotion recognition accuracy (percentage correct)

Overall, A (mean = 0.63, SD = 0.03) were significantly less accurate than C (mean = 0.77, SD = 0.03; $F_{(1,48)} = 11.467$, $P < 0.001$, $\eta^2 = 0.19$). There was a significant group × emotion interaction, $F_{(4,192)} = 2.53$, $P < 0.05$, $\eta^2 = 0.05$ (see Fig. 4). A one-way ANOVA showed that A were less accurate in identifying fear (mean = 0.67, SD = 0.33) and neutrality (mean = 0.28; SD = 0.30) compared to C (fear: mean = 0.86, SD = 0.24; $F_{(1,48)} = 5.69$, $P < 0.05$; neutrality: mean = 0.56, SD = 0.24; $F_{(1,48)} = 13.36$, $P < 0.001$). There were no group differences in identifying joy, sadness or anger. None of the covariates influenced the results significantly.

Emotion intensity rating

In general, the intensity rating was higher in A (mean = 2.0, SD = 0.14) compared to C (mean = 1.62, SD = 0.14;, $F_{(1,48)} = 3.83$, $P = 0.056$; $\eta^2 = 0.07$. However, there was a significant emotion × group interaction, $F_{(2.44,116.94)} = 4.20$, $P < 0.05$; $\eta^2 = 0.08$ (see Fig. 5). A one-way ANOVA revealed that A gave greater intensity ratings to sadness (mean = 1.86, SD = 1.22) and to fear (mean = 2.87; SD = 1.16) across all faces than did C (sad: mean = 1.23, SD = 0.68; $F_{(1,48)} = 5.01$, $P < 0.05$; fearful: mean = 2.19; SD = 1.14, $F_{(1,48)} = 4.30$, $P < 0.05$).

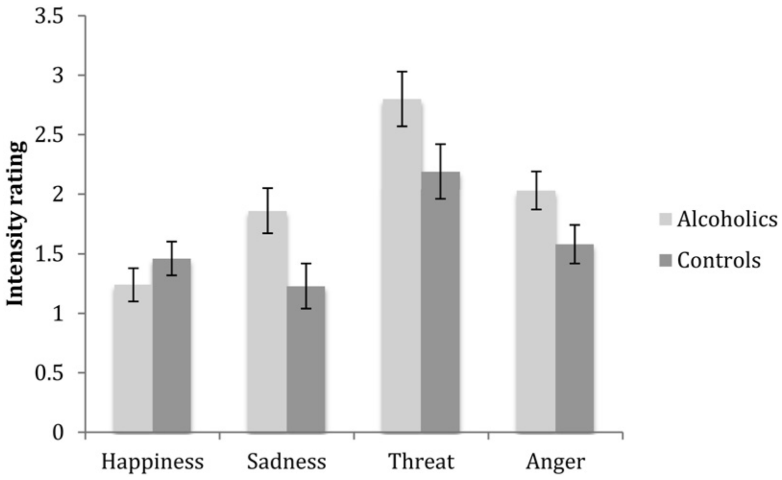

Figure 5 Average intensity rating (mean on a total of 9) for facial emotions across all faces in alcoholics and healthy controls. Error bars are the standard errors of the mean

There were no differences in intensity ratings for happiness or anger across faces. None of the covariates influenced the results significantly.

Emotion intensity ratings for neutral faces

A attributed higher averaged emotional intensities to neutral faces (mean = 1.13, SD = 0.15) compared to C (mean = 0.48, SD = 0.15; $F_{(1,48)} = 9.58$, $P < 0.01$; $\eta^2 = 0.17$). There was an effect of attention (D2 test) on the difference between A and C for the emotional intensity ratings of neutral faces. Indeed, when attention ability was entered as a covariate, the difference between groups was no longer significant, $F_{(1,47)} = 0.46$; $P = 0.053$; $\eta^2 = 0.10$. There were no other significant results.

Correlations with MAST, duration of alcoholism, number of previous detoxification treatments and total quantity of alcohol/day

Among A there were no significant correlations between the accuracy of recognizing emotions or ratings of mean intensity and their scores on the severity of alcoholism measures for any of the three modalities.

DISCUSSION

Overall, alcohol-dependent individuals who are completing detoxification were less accurate than controls in categorizing emotions conveyed by faces, voices and music. For musical excerpts, they were less accurate than controls in recognizing all the tested emotions. Further analyses revealed an overestimation of threat across several excerpts.

Emotion decoding accuracy was impaired significantly in voices and faces. Some emotions were particularly difficult for patients to recognize in voices (i.e. anger and happiness) and in faces (i.e. fear). Neutral voices and faces were also more difficult for patients to recognize than for controls.

Importantly, non-verbal decoding is used as a means to understand emotions, feelings and intentions in others. Difficulties to decode such signals accurately could lead to misunderstandings and frustrations in interpersonal relationships [5,17]. The misattribution of emotions to neutral faces and voices is particularly striking, as it might lead alcohol-dependent patients to form distorted representations of other's intentions, impair social interactions and to increase risk of relapse.

Alcohol detoxification is associated with impairment across many cognitive functions, and most of them remain stable for up to 1 year of abstinence before diminishing [38]. Some impairment in emotion decoding persists with mid-term abstinence [4,15,16], but data are lacking regarding its long-term evolution.

Interestingly, even though depression scores (i.e. BDI questionnaire) were used as a covariate in all our analyses, our results are very similar to those obtained in depressed patients [39]. Alcoholism and depression may lead to difficulties in emotional evaluation through distinct pathways. For instance, event-related potential (ERP) studies have shown that recognition of emotion in faces does not lead to the same electrophysiological signature in alcohol-dependent patients as it does in depressive patients [14]. The neurofunctional mapping of emotional facial processing has highlighted the role of a number of visual, limbic, temporo-parietal and prefrontal areas [40], thus making it plausible that emotional impairments observed at the behavioural level could be due to a number of combinations of underlying brain and cognitive processes. Nevertheless, the high scores of depression and anxiety levels in our patients constitute a limitation, and future studies comparing depressed and non-depressed alcohol-dependent patients should aim to disentangle those aspects.

The presence of severe impairments in emotion recognition from music suggests that the neural networks engaged by music may be disrupted in alcohol-dependent patients. Altogether, it is tempting to propose a unifying model, taking into account what we know about emotion perception by alcohol-dependent patients whether in others (perception of emotion in faces, voices and postures), in themselves (i.e. alexithymia [29,30]) or in music. Such a model should also explain difficulties those patients display in inferring thoughts and intentions in others (problems in humour comprehension [41], theory of mind [42], emotional empathy [42] and emotional intelligence [43]. Molnar-Szakacs and Overy [44] have proposed that a common neural substrate for music, language and motor functions involves a fronto-parietal mirror neurone system. This mirror neurone system is involved in not only the intersubjective representations of actions but also in emotion representations that allow people to feel connected with other agents. Perception of emotion in music may arise in part from its relation to physical posture and gesture [45]. For example, expressive music can induce subliminal facial expressions in listeners [46]. Emotion, especially as communicated by the face, the body and the voice, is an active motor process. A motor-affective coupling may provide the neural basis of empathy [47,48], especially the aspect of empathy that requires motor identification or inner imitation of the actions of others [49]. This model would be consistent with the correlation observed between emotion perception accuracy in music and emotional intelligence scores [50].

Other regions of interest include the amygdala [51,52], the prefrontal cortex (PFC) [52] and the anterior cingulate cortex [53].

The causal mechanism of these disruptions in emotional processing remains an open issue. Excessive chronic alcohol consumption and associated withdrawals are toxic for the brain, especially for the PFC [54]. Alternatively, biological vulnerability (e.g. smaller amygdala volumes [55] and/or decreased grey matter concentration in the orbitofrontal cortices [56]) may predate the onset of alcoholism. Indeed, some functional impairments have been found in offspring of alcohol-dependent patients [30,57].

Our study has some limitations, and its results should be interpreted with caution.

Our sample sizes are relatively small, and the many analyses performed could result in elevated type 1 error rate. Controls were recruited in the investigator's social circle, thereby allowing for some bias in response. Performance on the D2 attention task was generally worse in patients than in controls, and future studies should control further for determining if executive functioning deficits affect recognition and/or evaluation of emotional expressions. We cannot rule out the possibility that the observed group differences are due mainly to an 'affect labelling' impairment. As alcohol-dependent patients display deficits in metacognition they are unaware of their deficits, at least for emotion perception [4] and memory [58], and could be overconfident in their perceptions, thereby assigning higher intensity levels to stimuli.

However, overestimation of intensity was not found systematically across all modalities (faces, voices and music) or emotions, and thus these results are not consistent with the idea of a general overestimation propensity. Unlike emotion recognition, which is largely automatic [59], emotion labelling is dependent on language, and thus semantic access limitations may also drive alcohol-dependent patients' impaired performance. However, a recent study exploring the identification of emotions depicted in semantic stimuli [13] found preservation of this capacity in alcohol-dependent patients. Nevertheless, future studies should use other tools to evaluate emotional perception, besides an emotional intensity-rating task. There are indications that women have better emotion recognition ability; however, gender did not influence our results. Gender differences may be subtler and thus only observable in larger samples.

To sum up, alcohol-dependent patients who are completing detoxification exhibit poor capacity in recognizing emotions from faces, voices and music, which is consistent with a generalized emotion decoding impairment. Alcoholism has also been associated with difficulties of identifying emotions in self (alexithymia), as well as problems in humour comprehension, theory of mind and emotional empathy. Deficits in the fronto-parietal mirror neurone system may link all these disturbances together.

Clinical consequences include potential misattributions of emotions to others, with possible interpersonal relationships difficulties and higher risk of relapse.

Declarations of interest

None.

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