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Categorical perception of emotional facial expressions in alcohol-dependence

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ABSTRACT

Background: Emotional deficits have been widely described in alcohol-dependence, but several subtle and critical emotional decoding abilities remain to be investigated. In particular, the ability of alcohol-dependent individuals to process emotionally ambiguous facial stimuli, which are more frequent in everyday life than full emotional facial expressions, remains poorly understood. The present study used a categorical perception paradigm to evaluate the identification of mixed emotional facial expressions among alcohol-dependent participants.
Method: Nineteen recently detoxified participants with alcohol-dependence and 19 healthy controls were presented with facial stimuli depicting four emotional facial expressions (happy, angry, sad, and neutral), morphed along continua between each possible pair of emotions. Participants had to indicate the predominant emotion within the randomly presented facial stimuli. For each emotional category, a logistic function that estimated the percentage of identification according to the morph steps was adjusted for each participant's data.
Results: While there was no significant group difference regarding the response slope ($p = 0.502$, $\eta_p^2 = 0.014$), the identification threshold was significantly increased in alcohol-dependent participants compared to controls ($p = 0.007$, $\eta_p^2 = 0.204$), independently of the emotional category.
Conclusions: The categorical perception of emotional facial expression per se appeared preserved in alcohol-dependence, but alcohol-dependent participants exhibited a bias in emotional facial expression decoding characterized by a global under-identification. This study is the first to evidence a deficit of alcohol-dependent individuals in the processing of ambiguous emotional facial expressions by using this emotional continuum paradigm measuring the categorical perception effect.

1. Introduction

Emotional deficits have been largely described in alcohol-dependence (Maurage et al., 2009, 2012; Philippot et al., 1999) and play a crucial role in the development and maintenance of this disease (Clark et al., 2007; Zywiak et al., 2003). In fact, emotional or interpersonal difficulties are thought to be responsible for more than 60% of relapses after detoxification (Zywiak et al., 2003). In particular, impairments in emotional facial expression decoding may have serious deleterious effects for the everyday life of alcohol-dependent individuals (D'Hondt et al., 2014a) notably by affecting their interpersonal relationships (Kornreich et al., 2002). Emotional facial expression processing is indeed critical to establish and maintain social bonds as it enables the rapid decoding of the affective state expressed by others and adapted reactions to these social signals (D'Hondt et al., 2014b). Yet, fundamental questions about several subtle emotional decoding abilities remain to be investigated in alcohol-dependence.

Indeed, the large majority of earlier studies that assessed emotional decoding abilities among individuals with alcohol-dependent were interested in the processing of prototypical "full" emotional facial expressions. Most studies showed that alcohol-dependence is associated with impaired decoding of full-blown emotional facial expressions, particularly for negative ones, but strong discrepancies have been found in these results as recently underlined in a literature review (Donadon and de Lima Osório, 2014). Moreover, in everyday social life, emotional facial

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expressions are usually not entirely straightforward but are rather composed of a mix of different emotions (Townshend and Duka, 2003). Thus, blended emotional facial expressions require individuals to identify the predominantly expressed emotion in order to establish appropriate interpersonal interactions or to react suitably to others' emotions. These mixed facial emotions, which are thus the rule rather than the exception in everyday life's interactions, can be reproduced experimentally by using the morphing technique: two pictures of prototypical emotional facial expressions are morphed to create stimuli that vary monotonically from the first to the second by incremental changes. Contrasting results have been obtained among studies that used morphed stimuli to investigate emotional facial expression labelling in alcohol-dependence. O'Daly et al. (2012) observed that alcohol-dependent participants produced less fear recognition responses than healthy controls for facial stimuli expressing 50% of fear (and 50% of neutrality), but Trick et al. (2014) did not find group differences for the same morphing levels. Similarly, alcohol-dependent individuals were found to be impaired in decoding happy, sad and angry faces at moderate (30% and 70%) intensity levels (Kornreich et al., 2001; Philippot et al., 1999), but others studies observed that alcohol-dependent individuals did not significantly differed from controls in the decoding of happiness, anger, disgust and sadness at similar intensity levels (Foisy et al., 2007; Maurage et al., 2008a). However, alcohol-dependent individuals appear to be impaired in labelling both angry and happy facial stimuli that were morphed in 40:60 proportions (Maurage et al., 2007) and have been found to be slower than controls to decode overall ambiguous emotional facial expressions (anger, disgust, happiness, and sadness; Foisy et al., 2007; Maurage et al., 2008a) or for specific emotional facial expressions (angry, happy, neutral, sad, and surprised faces) and not for others (disgust and fear; Kumar et al., 2011).

These mixed results preclude drawing a formal conclusion concerning the ability of alcohol-dependent individuals to process ambiguous emotional stimuli, and the integrity of the specific underlying processes remains to be explored. Research among healthy individuals (e.g., Calder, 1996; Campanella et al., 2002; Etcoff and Magee, 1992; Young et al., 1997) has substantially shown that the categorical perception effect is a critical process to efficiently decode ambiguous emotional facial expressions. Indeed, categorical perception of emotional facial expressions allows individuals to perceive emotional stimuli varying monotonically along a continuum with a discrete category boundary at a certain location of this continuum (Freeman et al., 2010). The perception of differences between categories is enhanced around this category boundary at the expense of our perception of incremental changes in the stimulus within a category (Pollak and Kistler, 2002). This phenomenon is considered as a critical perceptive feature to adaptively respond to social cues in the environment (Etcoff and Magee, 1992; Kee et al., 2006), but it has not been effectively explored in alcohol-dependence despite it could clarify the precise nature of emotional facial expression decoding deficit in this pathology. To the best of our knowledge, this effect was only partially explored in one previous study (Maurage et al., 2008b), in which we suggested an impaired categorical perception effect for anger (compared to disgust) among alcohol-dependent participants. However, methodological limitations (notably a ceiling effect for performance due to the easiness of the task and the use of only one emotional continuum) hampered to draw strong conclusions regarding categorical perception in alcohol-dependence. We thus proposed that more sensitive paradigms were needed to confirm the behavioural deficit in alcohol-dependence for the categorical perception of emotional facial expressions.

The current study, thus, aimed at using an emotional continuum task allowing to compare alcohol-dependent individuals and healthy participants in their ability to decode facial emotions as a function of the ambiguity level of mixed emotional facial expressions. More precisely, we analysed participant's responses in an identification task by fitting logistic functions to each participant's data (Kee et al., 2006; Pollak and Kistler, 2002), as the proportion of healthy adults' responses (e.g., identification of one of the two emotional facial expressions) follows a non-linear function (typically a step-like sigmoidal function; Freeman et al., 2010) across successive morph steps representing the monotonic linear changes in the stimuli. By doing this, our objective was two-fold, as we wanted to determine whether: (1) alcohol-dependent individuals exhibit a bias in the identification of ambiguous emotional facial expressions, i.e., an under- or hyper-identification when mixed emotional facial expressions are highly ambiguous. This was done by analysing the identification threshold, corresponding to the estimated morph step within the continuum where the probability of responding in favour of one of the two emotional facial expressions (that constitute the extrema of the continuum) is equal. A decreased or elevated threshold in alcohol-dependent participants compared to controls would reveal an emotional bias that could be considered as a hyper- or an under-identification of ambiguous emotional facial expressions, respectively; and (2) the categorical perception effect is preserved or altered in alcohol-dependent individuals. This was done by analysing a reliable index of the categorical perception effect (Kee et al., 2006), namely the curve slope reflecting the abruptness in the sharp change of responses (normally around highly ambiguous stimuli). If this change of responses is less sharp in alcohol-dependent participants than healthy participants, this would suggest a less clear demarcation in the proportion of identifications, and thus an alteration of the categorical perception of emotional facial expressions in alcohol-dependence.

2. Material and methods

2.1. Participants

The sample included 38 right-handed adults (Oldfield, 1971) who had a normal-to-corrected vision: 19 patients diagnosed with alcohol-dependence according to DSM-IV criteria (American Psychiatric Association, 2000), and 19 healthy controls (see Table 1). Alcohol-dependence diagnosis was established during an exhaustive interview performed by a trained psychiatrist. This semi-structured interview was also used to precisely determine medical history, alcohol-consumption characteristics, and psychopathological comorbidities. Participants with alcohol-dependence were recruited during their third week of detoxification (Saint-Luc Hospital, Brussels, Belgium) and had all abstained from alcohol for at least 15 days. They were free of medication and of any other psychiatric diagnosis except nicotine dependence. Their mean alcohol consumption just before detoxification was 18.5 standard alcohol units per day (SD = 10.6), an alcohol unit corresponding to 10 g of pure ethanol, and the mean number of previous detoxification treatment was 2.2 (SD = 3.1). Healthy participants were free of any history of psychiatric disorder or drug/substance abuse (excluding nicotine dependence). The mean alcohol consumption in the control group was 1.4 standard alcohol units per day (SD = 1.6). Education level was assessed according to the number of years of education completed since starting primary school. Exclusion criteria for both groups included major medical problems, neurological disease and polysubstance abuse. Validated self-completion questionnaires were used to assess depression (Beck Depression Inventory; Beck and Steer, 1987), state and trait anxiety (State and Trait Anxiety Inventory; Spielberger et al., 1983), and alexithymia (Twenty-item Toronto Alexithymia Scale-II; Bagby et al., 1994). Participants were provided with full details regarding the aims of the study and the procedure and gave their informed consent. The

Table 1
Characteristics of the AD and HC groups: mean (SD).

	Alcohol-dependent patients (*N* = 19)	Healthy controls (*N* = 19)	Group comparison; *p* value
Demographic measures			
Gender ratio (M/F)	11/8	6/13	0.103
Age (in years)	51.1 (10.8)	49.8 (13.6)	0.742
Educational level (in years)	14.6 (2.8)	16.2 (1.9)	0.032
Psychopathological measures			
BDI[a]	5.2 (6.5)	3.3 (4.2)	0.304
STAI-A[b]	51.9 (8.1)	44.4 (10.0)	0.048
STAI-B[b]	45.6 (10.6)	37.3 (10.7)	0.002
TAS-20[c]	55.2 (9.8)	41.7 (12.9)	0.001

[a] BDI, Beck Depression Inventory (Beck and Steer, 1987).
[b] STAI, State and Trait Anxiety Inventory (Spielberger et al., 1983).
[c] TAS-20, Twenty-item Toronto Alexithymia Scale-II (Bagby et al., 1994).

study was approved by the Ethical Committee of the Medical School and carried out according to the Declaration of Helsinki.

2.2. Stimuli

The facial stimuli were elaborated specifically for this experiment. First, four realistic faces (two females, two males) depicting four different emotional facial expressions (happy, angry, sad, and neutral) were generated using the Face-Gen Modeller 3.1 software (Singular inversions, 2006), which allows to construct and modulate realistic emotional facial expressions on the basis of the FACS system (Ekman and Friesen, 1976). Then, using the MorphMan 2000 software (STOIK), the facial stimuli were morphed to create a linear continuum of ten facial images between two endpoints. The morphed faces were based on the blending of each possible pair of emotional facial expressions in the proportions 5:95 (i.e., 5% "angry" and 95% "happy"), 15:85, 25:75, 35:65, 45:55, 55:45, 65:35, 75:25, 85:15, and 95:5 (Fig. 1). As a result, each intermediate image was transformed by a 10% increment (for a total of 10 morph steps) and six continua were created: angry–happy, angry–neutral, angry–sad, happy–neutral, happy–sad, and neutral–sad. It should be noted that, despite neutral stimuli cannot be considered as emotional ones because they are rather indicating an absence of emotion, they are classically included in emotional decoding studies (e.g., Kornreich et al., 2001; Philippot et al., 1999) as: (1) they are often considered as "baseline stimuli" allowing to create morphs with a large-range of emotional intensities [ranging from low emotional stimuli (e.g., 80% neutral and 20% emotional) to high emotional ones (e.g., 20% neutral and 80% emotional)]; (2) they allow to efficiently detect under-estimation (i.e., considering an emotional stimulus as being neutral) and over-estimation (i.e., considering a neutral stimulus as expressing an emotion) biases, notably in alcohol-dependent participants (e.g., Maurage et al., 2009). All facial stimuli (225 × 300 pixels) were placed on a grey background and were presented on a Dell Latitude E5530 laptop (15.6-in. screen, resolution: 1366 × 768 pixels), at a distance of 60 cm from the participant (stimuli subtended a visual angle of 7.6° × 8.6°). The six continua are illustrated in Fig. 1.

2.3. Procedure

E-Prime 2 (Psychology Software Tools, Inc., Pittsburgh) was used to present the stimuli and record each participant's responses. Each session started with a training phase comprising 15 trials. Each trial started with a grey screen lasting for 700 ms, which indicated that a facial stimulus was about to be presented. Then, this facial stimulus was presented during 800 ms, followed by a grey screen with the question "What was the predominant emotion expressed by the face?" and participants had to give their response (happy, angry, sad, or neutral) by pressing one of the four possible keys. The order of the keys used was counterbalanced across participants. The following trial started after a blank grey screen lasting for 1000 ms. The 240 trials (4 facial identities × 6 continua × 10 morph steps) were fully randomized.

2.4. Data analysis

To measure the ability of participants to identify each emotional facial expression (happy, angry, sad, and neutral), the percentage of identifications (number of identifications for a given emotional facial expression divided by the number of trials in which this particular emotional facial expression was present) was calculated for each of the 10 morph steps. Then, a logistic function (i.e., a sigmoid function with four parameters) that estimated the percentage of identifications according to the morph steps was adjusted for each participant's data. The sigmoid function equation was calculated with SigmaPlot version 11.0 (Systat Software, Inc., San Jose, California) by using the following formula:

$$y = a + \frac{b}{1 + c^{\frac{-(x-xc)}{d}}}$$

where y is the probability of the response, x is the morph step, a is the lower asymptote, b is the difference between upper and lower asymptotes, xc is the identification threshold and $1/d$ is the slope. On the one hand, the identification threshold corresponds to the shift point in the responses of the participant, i.e., an estimated morphing step corresponding to $y = 50$. Thus, at this estimated morphing step, the probability of identifying one given emotional facial expression (e.g., happy face) is equal to the probability of identifying one of the three other possible emotional facial expressions (e.g., angry, sad, or neutral faces). Fifty percent can be considered as an idealistic identification threshold at which there is an equal probability to identify or not one given emotional facial expression, while this particular emotional facial expression and the other are equally expressed within the continuum. A threshold significantly lower or higher than 50% suggests a tendency towards under-identification (participants need a higher signal strength) or hyper-identification (participants need a lower signal strength), respectively. On the other hand, the slope provides information about the abruptness of the change in the responses. The higher the value of the slope, the more abruptly the change in the responses happens. A high value for the slope can be considered as an index of a typical pattern of categorical perception while a low value for the slope is representative of a more continuous perception (Kee et al., 2006; Pollak and Kistler, 2002).

The statistical analyses were performed using IBM SPSS Statistics for Windows (Version 22.0, IBM Corp., Armonk, NY), and the following strategy was used. First, between group comparisons were performed on demographic (age, gender and educational level) and psychopathological (trait and state anxiety, depression

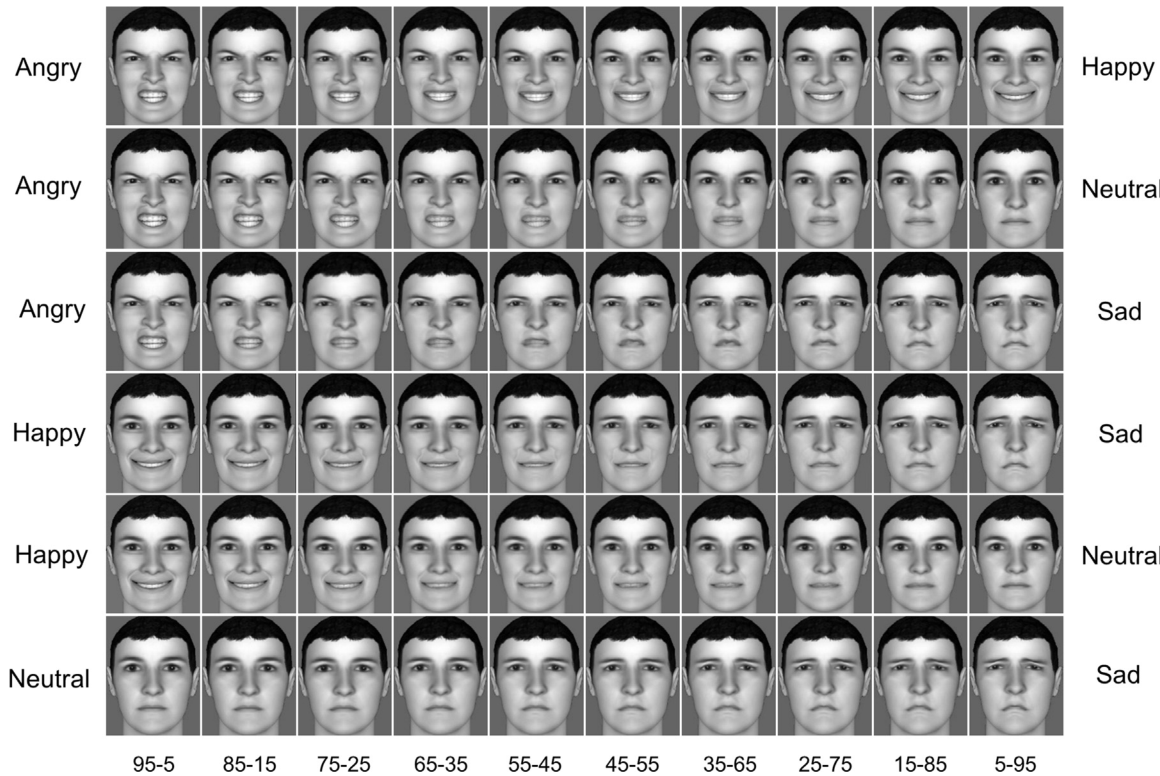

Fig. 1. Examples of the six morphing continua (angry–happy, angry–neutral, angry–sad, happy–neutral, happy–sad, and neutral–sad) for one identity. The percentage of each emotion contained in each of the 10 morph step is mentioned at the bottom of the figure (e.g., 95%:5% for the anger–happy continuum means that this stimulus contains 95% of anger and 5% of happy emotion).

and alexythimia) characteristics. Second, repeated measures analyses of variance (ANOVA; a Greenhouse–Geisser correction was applied when appropriate) were performed on the identification thresholds and slopes, respectively. Third, we performed one sample *t*-tests on identification threshold measures to determine whether identification thresholds of each group significantly differed from 50%. The alpha level was set at 0.05.

3. Results

3.1. Demographic and psychopathological measures

As shown in Table 1, there were no significant group differences for age [$t(36) = 0.331$, $p = 0.742$], depression [$t(36) = 1.042$, $p = 0.304$], or gender [$\chi^2(1) = 2.661$, $p = 0.103$], but the two groups significantly differed for educational level [$t(36) = -2.238$, $p = 0.032$], anxiety state [$t(36) = 2.047$, $p = 0.048$], anxiety trait [$t(36) = 3.332$, $p = 0.002$], and alexithymia [$t(36) = 3.599$, $p = 0.001$].

3.2. Identification task

Both the participants with alcohol-dependence and controls showed a clear shift in emotional facial expression identification (Fig. 2). Repeated measures analyses of variance (ANOVA) were performed on the identification thresholds and slopes, respectively (see Table 2), with the emotional facial expressions (angry, neutral, happy, and sad) as within-subjects factor and the groups (alcohol-dependent individuals, and healthy controls) as between-subjects factor. Given the significant group differences that were observed for educational level, anxiety state, anxiety trait, and alexithymia, these variables were included as covariables in the analyses.

3.2.1. Identification threshold. As illustrated in Fig. 2, there was no significant influence of psychopathological measures or education level on identification threshold (all p's > 0.075). There was neither a significant interaction between emotional facial expression and group [$F(3,96) = 0.535$, $p = 0.659$, $\eta_p^2 = 0.016$], nor a main effect of emotional facial expression [$F(3,96) = 2.080$, $p = 0.108$, $\eta_p^2 = 0.061$]. The main effect of group showed that there was a significant difference in identification threshold between groups [$F(1,32) = 8.212$, $p = 0.007$, $\eta_p^2 = 0.204$] as threshold was significantly higher in alcohol-dependent participants than controls (see Table 2). One-sample *t*-tests were run to determine whether identification threshold of participants in each group significantly differed, independently of the emotional facial expression category, from the idealistic threshold as defined by an identification threshold of 50%. Identification threshold in alcohol-dependent participants was significantly higher by 4.39 (95% CI, 2.68–6.09) than the idealistic threshold [$t(18) = 5.406$, $p < 0.001$, $d = 1.24$]. Identification threshold in healthy participants did not significantly differ from the idealistic threshold [$t(18) = 1.921$, $p = 0.071$, $d = 0.44$].

3.2.2. Slope. There was no significant influence of psychopathological measures or education level on slope (all p's > 0.137). There was neither a significant interaction between emotional facial expression and group [$F(3,96) = 1.003$, $p = 0.395$, $\eta_p^2 = 0.030$], nor a main effect of emotional facial expression [$F(3,96) = 1.193$, $p = 0.317$, $\eta_p^2 = 0.036$], nor a main effect of group [$F(1,32) = 0.461$, $p = 0.502$, $\eta_p^2 = 0.014$] on slope.

4. Discussion

The aim of this study was to investigate subtle emotional decoding skills among individuals with alcohol-dependence by using an emotional continuum paradigm allowing to measure the

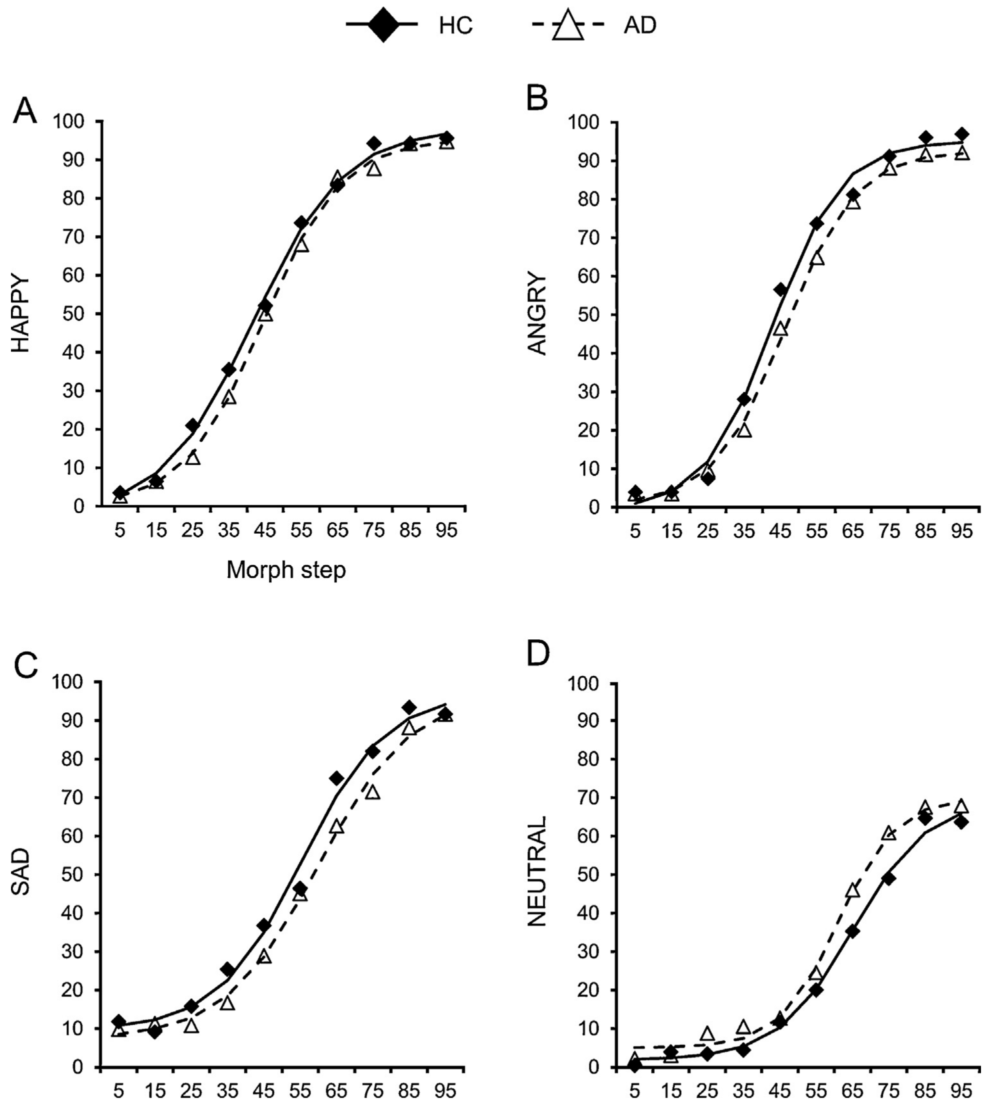

Fig. 2. Experimental results for the identification task. The percentage of happy (A), angry (B), sad (C), and neutral (D) responses (*Y*-axis) are represented as a function of morph step (*X*-axis) for the associated stimuli among healthy controls (HC, diamond dots) and alcohol-dependent individuals (AD, triangle dots). For the analyses, the sigmoid functions were fitted to each participant's data individually to obtain the slope and threshold values for each participant. However, for illustration, the sigmoid functions were fit to average group accuracy.

categorical perception effect. Indeed, while the ability of alcohol-dependent individuals to decode prototypical emotional facial expressions has been widely investigated (Donadon and de Lima Osório, 2014), it remained unknown whether categorical perception of emotional facial expressions is altered in these individuals and whether they exhibit an emotional bias when decoding ambiguous emotional facial expressions. The present results mainly showed that: (1) alcohol-dependent participants did not significantly differ from controls regarding the response slope, which suggests that the categorical perception

Table 2
Unadjusted and adjusted threshold and slope means among alcohol-dependent (AD) and healthy controls (HC) groups for each EFE (happy, angry, sad, neutral) with educational level, state and trait anxiety (STAI-A and STAI-B) as well as alexithymia (TAS-20) measures as covariates.

	Unadjusted [mean (standard deviation)]					Adjusted [mean (standard error)][a]				
	Happy	Angry	Sad	Neutral	Mean	Happy	Angry	Sad	Neutral	Mean
Threshold										
AD	45.99 (11.35)	48.18 (7.87)	61.99 (9.55)	61.48 (7.35)	54.39 (3.54)	45.37 (3.16)	47.73 (2.39)	64.21 (2.88)	65.51 (3.58)	55.70 (1.10)
HC	42.47 (8.85)	44.97 (7.19)	55.63 (8.57)	63.45 (14.86)	51.63 (3.70)	43.09 (3.16)	45.42 (2.39)	53.32 (2.88)	59.42 (3.58)	50.31 (1.10)
MEAN	44.23 (10.20)	46.58 (7.61)	58.77 (9.49)	62.47 (11.61)		44.23 (1.65)	46.58 (1.25)	58.77 (1.50)	62.47 (1.87)	
Slope[b]										
AD	12.90 (11.87)	9.98 (6.34)	12.01 (4.47)	7.10 (5.27)	10.50 (4.01)	11.46 (2.72)	9.53 (1.94)	13.64 (1.48)	8.51 (1.70)	10.78 (1.06)
HC	11.65 (2.82)	10.72 (5.80)	10.32 (4.94)	6.69 (5.83)	9.84 (2.24)	13.09 (2.72)	11.17 (1.94)	8.68 (1.48)	5.28 (1.70)	9.55 (1.06)
MEAN	12.28 (8.53)	10.35 (6.01)	11.16 (4.72)	6.89 (5.49)		12.28 (1.42)	10.35 (1.01)	11.16 (0.77)	6.89 (0.89)	

[a] Covariates appearing in the model are evaluated at the following values: educational level = 15.34, STAI-A = 48.76, STAI-B = 43.24, and TAS-20 = 48.47.
[b] It should be noted that *d* values are reported here but the slope value is given by $1/d$.

of emotional facial expressions per se is preserved in alcohol-dependence; (2) the identification threshold was significantly higher in alcohol-dependent individuals than controls, independently of the emotional facial expression category, showing that alcohol-dependent individuals exhibit a bias in emotional facial expression decoding characterized by an under-identification of the predominant emotional facial expression within ambiguous facial emotions. This result does not appear to be affected by potentially biasing effects of demographic and psychopathological variables.

First, the current study revealed a clear shift in the percentage of emotional facial expression identifications around intermediate morph steps, both in alcohol-dependent individuals and healthy participants. Given that this sharp change of response constitutes the typical pattern of response that reflects the categorical perception effect, and that there was no significant difference in the slope between alcohol-dependent participants and controls, this result leads to the proposal that the categorical perception of emotional facial expression is preserved in alcohol-dependence. Previous studies have concluded that categorical perception of emotional facial expressions was impaired in schizophrenia (Kee et al., 2006) or in autism (for angry–sad and angry–afraid continua, but nor for happy–sad; Teunisse and de Gelder, 2001) by showing significant lower values of slope in patients compared to healthy controls. These lower slope values effectively suggested that demarcations in the identification responses at intermediate morph steps (i.e., when the facial stimuli are highly ambiguous) were less clear in psychopathological populations than in controls. This deficit is not found in alcohol-dependent participants, whom still benefit from categorical perception of emotional facial expressions, a critical feature allowing to respond rapidly and accurately to social cues. The present study, by using a much more sensitive task well suited to assess categorical perception, partly denies our previous suggestion of impaired categorical perception effect for anger (Maurage et al., 2008b), since no significant group difference was found in slope values (independently of the emotional facial expression concerned). However, the impaired categorical perception effect for anger was observed in our previous study when this emotion was mixed with disgust. As this emotion was not studied here, it cannot be formally excluded that the categorical perception of anger would be impaired for an anger–disgust continuum. Future studies should thus confirm the preserved categorical perception of overall emotional facial expressions in alcohol-dependence by exploring disgust as well as fear and surprise, which are basic emotions that were not included in our experimental design. Moreover, to go further, future studies should investigate the categorical perception effect among alcohol-dependent individuals by using, for instance, both an identification task and an ABX discrimination task (Campanella et al., 2001). In a first step, the identification task would allow to assess the individual identification thresholds of alcohol-dependent and healthy participants. In a second step, the ABX discrimination task would allow to determine whether alcohol-dependent individuals discriminate more easily stimuli from each side of the identification threshold than stimuli belonging to the same side of this threshold (e.g., Kiffel et al., 2005).

Second, on the basis of the result showing a higher identification threshold in alcohol-dependent participants compared to controls, we propose that alcohol-dependence is characterized by a bias in the identification of ambiguous facial emotions, independently of the emotional facial expression category. Compared to healthy controls, alcohol-dependent individuals exhibited a significant increase in the estimated morph step at which their response switches from an emotion to another: participants with alcohol-dependence needed more signal strength (i.e., a higher morphing step) than healthy participants to start identifying the predominant emotional facial expression within the ambiguous stimuli. Moreover, while identification threshold of controls did not significantly differ from the idealistic threshold (i.e., 50%, when there is an equal probability to identify one of the two emotional facial expressions at a morph step where these two emotional facial expressions are equally expressed), it was the case for alcohol-dependent individuals whom exhibited a significantly higher identification threshold than the idealistic one. This shows that emotional bias among alcohol-dependent participants is characterized by an under-identification of the predominant emotional facial expression within ambiguous facial emotions. Thus, while alcohol-dependent individuals appear to present the typical pattern of categorical perception, they exhibit an impairment in the decoding of ambiguous emotional facial expressions. This under-identification bias may have critical consequences in interpersonal relationships of alcohol-dependent individuals, since facial emotions in real world are often mixing different emotions, like the facial stimuli that were used in the current study. A new research avenue should thus investigate whether this subtle emotional identification bias can alter interpersonal relationships. This link between emotional decoding and social abilities was not directly explored in the present study (as no measure of interpersonal problems was conducted), but it has already been suggested in earlier studies (e.g., Kornreich et al., 2002) and should thus be further explored given the critical role of emotional facial expressions in social interactions (Frith, 2009) and the interpersonal difficulties reported in alcohol-dependence (Uekermann and Daum, 2008; Maurage et al., 2012).

Interestingly, the under-identification bias was not modulated by the valence of the emotional facial expression category, contrary to previous observations with full-blown emotional facial expressions for which deficits were mainly evidenced for negative ones (see Donadon and de Lima Osório, 2014 for a review). Thus, we confirm the idea that, when sufficiently sensitive tasks are used, emotion decoding deficits in alcohol-dependence may be not restricted to a specific valence but rather generalized to overall emotional facial expressions (D'Hondt et al., 2014a). Future studies should confirm this by investigating whether the emotional bias evidenced here can be observed with continua involving other emotions. It should also be underlined that neutral stimuli lead to the same global response pattern than emotional ones among controls and alcohol-dependent participants, with an abrupt change around intermediate morphing levels. As no significant main effect of emotional facial expressions was observed for the slopes, this suggests that neutral faces are categorically perceived, confirming previous observations (Etcoff and Magee, 1992; Young et al., 1997). However, identification responses for neutral faces appear graphically different from the other conditions, as identification never reaches 100% for neutral stimuli, whatever the group or the morph step considered. It therefore suggests that even if "neutral" can be considered as a category like other emotional ones, it somewhat behaves differently. As already described in earlier studies (e.g., Philippot et al., 1999), this can be explained by the fact that neutral-emotional continua (see Fig. 1 for an illustration of these continua) always contain a level of emotional intensity, which can lead the participant to categorize a mainly neutral stimulus as emotional (e.g., considering 80% neutral – 20% happy as depicting happiness). Moreover, it also appears (as illustrated in Fig. 2) that the response patterns diverge across groups between emotional (where healthy controls have higher identification rates than alcohol-dependent individuals) and neutral stimuli (where the reverse pattern is graphically observed). This suggests that the bias could differ when alcohol-dependent participants have to identify emotional or neutral faces, and that they tend to identify neutral faces more efficiently than healthy controls. This result is actually totally in line with the proposal of a decoding deficit in alcohol-dependence, as this higher identification of neutral stimuli represents the direct counterpart of lower identification of emotional ones, related to higher identification threshold in this group: alcohol-dependent individuals will need more emotional information than controls to consider a stimulus as emotional (and will thus more often consider it as neutral), simultaneously leading to an under-estimation of emotional expressions and an over-estimation of neutral expressions. However, no significant interaction between facial expression categories and groups were observed for threshold values, this graphical difference thus not being confirmed statistically.

Finally, two main conclusions can be drawn from the present study. On the one hand, individuals with alcohol-dependence exhibit an emotional bias that is characterized by an under-identification of the predominant emotional facial expression within ambiguous facial emotions. As we recently proposed (D'Hondt et al., 2014a), future studies in alcohol-dependence should go below (by investigating the putative role played by deficits of early visual processing and vision–emotion interactions; D'Hondt et al., 2014b) and beyond (by investigating emotional processing from other sensory modalities for instance) these emotional facial expression identification deficits, in order to explore the roots of those alterations and their consequences on the development and maintenance of interpersonal relationships, given their critical role for an adapted social integration. On the other hand, the phenomenon of categorical perception of emotional facial expressions is preserved in alcohol-dependent individuals. This observation is interesting both at the fundamental and clinical levels as it suggests that: (1) categorical perception of emotions is a robust process that can be preserved in certain psychopathologies. Investigations of both the threshold and slope should thus be undertaken to have a clear picture of subtle emotional decoding abilities in different diseases; (2) psychiatric diseases showing common deficits in simple emotional decoding (such as schizophrenia, autism and alcohol-dependence) could nonetheless be differentiated on more subtle emotional decoding abilities (the categorical perception effect is preserved in alcohol-dependence but not in schizophrenia and autism). In alcohol-dependence, we propose that the preservation of the categorical perception effect could serve as a therapeutic lever for the rehabilitation of emotional decoding capabilities. As a whole, and although further studies are needed, this study is the first to explore categorical perception of emotional facial expressions in alcohol-dependence and sheds new lights on the emotion decoding deficits by showing a subtle pattern including both preservation and deficit in the disease.

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Contributors

YB, FDH, and PM designed the study and wrote the protocols. YB and FDH collected the data. FDH, PdT, and PM performed the literature review and analyses. PdT contributed to the participants recruitment. FDH and PM completed the statistical analysis. All authors participated to the writing of the manuscript and approved the final version.

Conflict of interest

None declared.

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