THE CROSS-MODAL FACILITATION EFFECT IS DISRUPTED IN ALCOHOLISM: A STUDY WITH EMOTIONAL STIMULI

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Abstract — Aims: Chronic alcoholism is classically associated with major deficits in the visual and auditory processing of emotions. However, the cross-modal (auditory-visual) processing of emotional stimuli, which occurs most frequently in everyday life, has not yet been explored. The aim of this study was to explore cross-modal processing in alcoholism, and specifically the auditory-visual facilitation effect. **Methods:** Twenty patients suffering from alcoholism, and 20 matched healthy controls had to detect the emotion (anger or happiness) displayed by auditory, visual or auditory-visual stimuli. The stimuli were designed to elicit a facilitation effect (namely, faster reaction times (RTs) for cross-modal condition than for uni-modal ones). RTs and performance were recorded. **Results:** While the control subjects elicited a significant facilitation effect, alcoholic individuals did not present this effect, as no significant differences between RTs according to the modality were shown. This lack of facilitation effect is the marker of an impaired auditory-visual processing. **Conclusions:** Cross-modal processing of complex social stimuli (such as faces and voices) is crucial for interpersonal relations. This first evidence for a cross-modal deficit in alcoholism contribute in explaining the contrast observed between experimental results describing, up to now, mild impairments in emotional facial expression (EFE) recognition in alcoholic subjects (e.g. Oscar-Berman *et al.*, 1990), and the many clinical observations suggesting massive problems.

INTRODUCTION

In their natural social surroundings, human beings are continually immersed in a complex stream of stimulations from different sensory modalities (sounds, pictures, odours, . . .), which interact to create an integrated representation of the environment. Cross-modal processes refer to this mechanism underlying the construction of an unified and coherent representation on the basis of different stimulations, issued from distinct sensory modalities but concerning the same object or situation (Driver and Spence, 2000). Experimental studies were mainly devoted to the exploration of 'uni-modal' phenomena. Recently, due to technical developments, and to the awareness that cross-modal processing (at behavioural and cerebral levels) constitutes a crucial ability in our daily interactions, these integrative processes became a central field of research in psychology and neuroscience (see Calvert, 2001; Lalanne and Lorenceau, 2004; Amedi *et al.*, 2005 for reviews).

At a behavioural level, many cross-modal studies described an 'inhibition effect'. This effect is determined by a deteriorated or biased performance in cross-modal conditions (i.e. when two stimuli from different modalities are presented simultaneously) as compared to uni-modal ones. For instance, in the auditory-visual domain, two striking examples of such interference are the McGurk (McGurk and McDonald, 1976) and the ventriloquist effects (e.g. Alais and Burr, 2004). In the first one, the simultaneous presentation of a syllable (e.g./ba/) and an incongruent lip movement (e.g./da/) leads to the false perception of the syllable/ga/. In the second one, the origin of a sound is attributed by mistake to the dummy and not to the

artist's mouth. These two examples show that vision can alter audition. Research in this domain (e.g. Joassin *et al.*, 2004) showed that the main factors leading to an inhibition effect are differences in the complexity, spatial distance and/or temporal asynchrony between the stimulations.

Conversely, a 'facilitation effect' (Frens *et al.*, 1995; Calvert *et al.*, 2001; Teder-Sälejärvi *et al.*, 2002), namely, shorter reaction times (RTs) when participants are confronted with congruent bi-modal stimuli as compared with uni-modal ones, is frequently observed when a spatio-temporal proximity and an identical complexity exist between stimuli. This effect recently led to a growing interest in the neuro-cognitive literature as it allows exploring the cognitive and cerebral correlates of an efficient cross-modal processing. Indeed, the facilitation effect is considered as the behavioural marker of a successful cross-modal integration between stimuli of different modalities (Calvert *et al.*, 2001). Co-activation models (Miller, 1982; Schröger and Widmann, 1998) explain this facilitation effect on the basis of an interaction between modalities, by postulating either a late interaction after modality-specific processing ('independent coactivation model') or an early integration and mutual influence between stimuli from the beginning of the process ('interactive coactivation model'). If the timing and localization of the integration process is still unclear, several studies, using basic stimuli (e.g. flashes and bursts) or even more ecological stimuli like emotional (Pourtois *et al.*, 2000) or neutral (Joassin *et al.*, 2004) faces and voices, described cerebral processes and areas specifically dedicated to the cross-modal integration (e.g. Miltner *et al.*, 1999; Calvert *et al.*, 2000; Bushara *et al.*, 2001; Molholm *et al.*, 2002). The existence of 'specific integrative activities', different from those generated in response to uni-modal activities, is suggested and these integrative processes seem to be disturbed in some psychiatric populations (e.g. schizophrenia, Surguladze *et al.*, 2001).

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The current study will explore cross-modal processing in alcoholism on the basis of emotional auditory and visual stimuli. Indeed, chronic alcoholism is associated with a wide range of cognitive, psychological and interpersonal impairments (e.g. Wegner *et al.*, 2001). Behavioural studies showed that alcoholic individuals present general deficits in visual (Blusewicz *et al.*, 1977; Kramer *et al.*, 1989) and auditory (Spitzer and Ventry, 1980; Spitzer, 1981) processing, and this impairment has been notably confirmed by electrophysiological explorations (e.g. Cadaveira *et al.*, 1991; Ogura and Miyazato, 1991; Bijl *et al.*, 2005; Marco *et al.*, 2005; Maurage *et al.*, 2007). More specifically, alcoholic individuals are particularly impaired for the decoding of emotions. Concerning the visual modality, many studies (e.g. Philippot *et al.*, 1999; Frigerio *et al.*, 2002; Townshend and Duka, 2003) showed that alcoholism is associated with a misinterpretation and overestimation of the emotions expressed by the human face, namely the emotional facial expressions (EFE), (e.g. Ekman, 1972, 1977; Ekman *et al.*, 1980). Similarly, at the auditory level, alcoholism leads to deficits in the decoding of emotional prosody (Monnot *et al.*, 2001; Uekermann *et al.*, 2005). To sum up, it has been established that alcoholism is associated with deficits in the decoding of visual and auditory emotional stimuli, when these stimuli are presented in isolation (i.e. in uni-modal paradigms).

However, it is unclear whether this deficit is maintained, reduced or even increased when alcoholic individuals are, as in everyday life, confronted simultaneously with congruent visual and auditory stimulations. Exploring these cross-modal processing with emotional stimuli thus seems crucial, as the ubiquity of the cross-modal interactions is particularly apparent in the field of emotional processing. Emotional feelings and the ability to interpret and correctly react to emotional situations are always based on several sensory aspects: EFE, affective prosody, postures, or even gustatory and olfactory stimuli with an affective valence (e.g. Winston *et al.*, 2005; Greimel *et al.*, 2006; Shepherd, 2006). The uni-modal exploration is thus clearly insufficient to apprehend the complexity of the emotional processes. Only a few studies have explored the cross-modal integration of complex emotional stimuli, among healthy (e.g. Dolan *et al.*, 2001; Pourtois *et al.*, 2005) and psychopathological populations (e.g. Surguladze *et al.*, 2001). As the cross-modal processing of emotional information has not yet been investigated in chronic alcoholism, the present study explored this issue. Moreover, as the facilitation effect is a marker of cross-modal integration (Calvert, 2001), this study was based on the elicitation of this effect. Cross-modal integration of the stimuli in chronic alcoholism was assessed behaviourally.

Cross-modal (auditory-visual) stimuli were used in order to determine to which extent the 'uni-modal' emotional deficit described in alcoholism (in visual and auditory modalities) is present in situations with higher ecological validity, namely, when patients are confronted with synchronized visual and auditory emotional signals. This study is thus the first attempt to explore, in chronic alcoholism, the potential deficit of the mechanisms by which the brain establishes relationships between auditory and visual stimuli.

METHODS AND SUBJECTS

Participants

Twenty inpatients (three of them women), diagnosed with alcohol dependence according to DSM-IV criteria, were recruited during the third week of their treatment in a detoxification centre ('Les Marronniers' Hospital, Tournai, Belgium). They had all abstained from alcohol for at least two weeks (the number of days since last drink ranged from 15 to 22 days; mean 18.4, SD 3.47), were free of any other psychiatric diagnosis (the presence of a comorbidity with any other psychiatric disease constituted an exclusion criteria), and were all right-handed. The mean alcohol consumption among patients just before detoxification was 17.9 standard drinks per day (SD 5.32), the mean number of prior detoxification treatments was 3.1 (SD 1.4), and the mean duration of alcohol dependence was 15.6 years (SD 10.8, ranging from 7 to 29 years of abuse). Patients were matched for age, gender and education with a control group composed of 20 volunteers who were free of any history of psychiatric disorder or drug/substance abuse, and whose personal alcohol consumption was lower than five standard drinks per week. Control subjects abstained from any alcohol consumption at least three days before testing. Moreover, patients and control subjects were assessed for several psychological measures, in order to evaluate the presence of sub-clinical comorbid psychopathologies and deficits. The following variables were evaluated using validated self-completion questionnaires (mentioned in brackets): State and trait anxiety (State and Trait Anxiety Inventory, form A and B, Spielberger *et al.*, 1983), depression (Beck Depression Inventory, short version, Beck and Steer, 1987), interpersonal problems (Inventory of Interpersonal Problems, Horowitz *et al.*, 1988) and alexithymia (20-item Toronto Alexithymia Scale, Bagby *et al.*, 1994). Exclusion criteria for both groups included major medical problems, central nervous system disease (including epilepsy), visual or auditory impairment and polysubstance abuse. Each participant had a normal-to-corrected vision and a normal audition. Education level was assessed according to the number of years of education completed since starting primary school. Participants were provided with full details regarding the aims of the study and the procedure to be followed. After receiving this information, all participants gave their informed consent. The study was approved by the ethical committee of the medical school.

Task and procedure

We used an emotion-detection task in which participants were confronted with faces and voices, presented separately (uni-modal conditions) or simultaneously (cross-modal condition). Two categories of faces and voices were used and varied in terms of emotional content (anger or happiness). In the cross-modal condition, faces and voices were always congruent (i.e. depicting the same emotion).

The visual stimuli, namely EFE, were selected from the standardized set of Ekman and Friesen (1976) pictures: Two 'persons' (one male), each displaying two emotions (anger and happiness) were chosen. Facial characteristics have been found to be recognized more rapidly than vocal

ones (Ellis *et al.*, 1997; Schweinberger *et al.*, 1997; Joassin *et al.*, 2004), but it has been shown that increasing the perceptual difficulty of faces can make them more difficult to recognize than voices (Hanley *et al.*, 1998; Hanley and Turner, 2000). We thus decided to complicate the visual stimuli in order to obtain a similar difficulty level in vision and audition, leading to a facilitation (rather than an interference) effect in cross-modal conditions. On the basis of a morphing software (Morph 2.5., Gryffon Software Corp.), a continuum between the happy (H) and angry (A) faces was computed for each 'person', leading to pictures depicting different levels of morphing (i.e. 10%H–90%A, 20%H–80A, . . .). These blended faces were presented in a preliminary study to 40 participants (32 females, mean age = 19.32, SD: 1.72) in order to find the morphing level leading to similar results (RTs and error rates) as the auditory stimuli. These participants had a normal audition and a normal-to-corrected vision, were free of any history of psychiatric disorder or drug/substance abuse (including binge drinking habits), and their personal alcohol consumption was lower than seven

standard drinks per week. Participants had to determine as quickly as possible which emotion was displayed in the stimulus. At the lower morphing levels (i.e. 10, 20 and 30% of an emotion, and 90, 80 and 70% of the other, respectively), RTs and accuracy figures remained better for visual than for auditory stimuli ($t(39) \geq 2.61$, $P<0.05$), indicating that faces were not complex enough. However the morphing levels '40%H–60%A' and '60%H–40%A' led to similar RTs ($t(39) = 1.15$, NS) and accuracy ($t(39) = 0.93$, NS) in visual and auditory conditions. These two levels were thus chosen for the experiment. As illustrated in Figure 1, four visual stimuli (2 morphing levels ×2 persons) were used in the task.

The auditory stimuli were audiotapes consisting in the enunciation of a semantically neutral name (namely 'paper') with an emotional prosody. These stimuli were selected from a standardized battery of emotional prosody (Maurage *et al.*, submitted), based on a pilot study (conducted on 70 participants, 43 females, mean age = 18.74, SD = 0.89). Four auditory stimuli were selected as best expressing the emotions
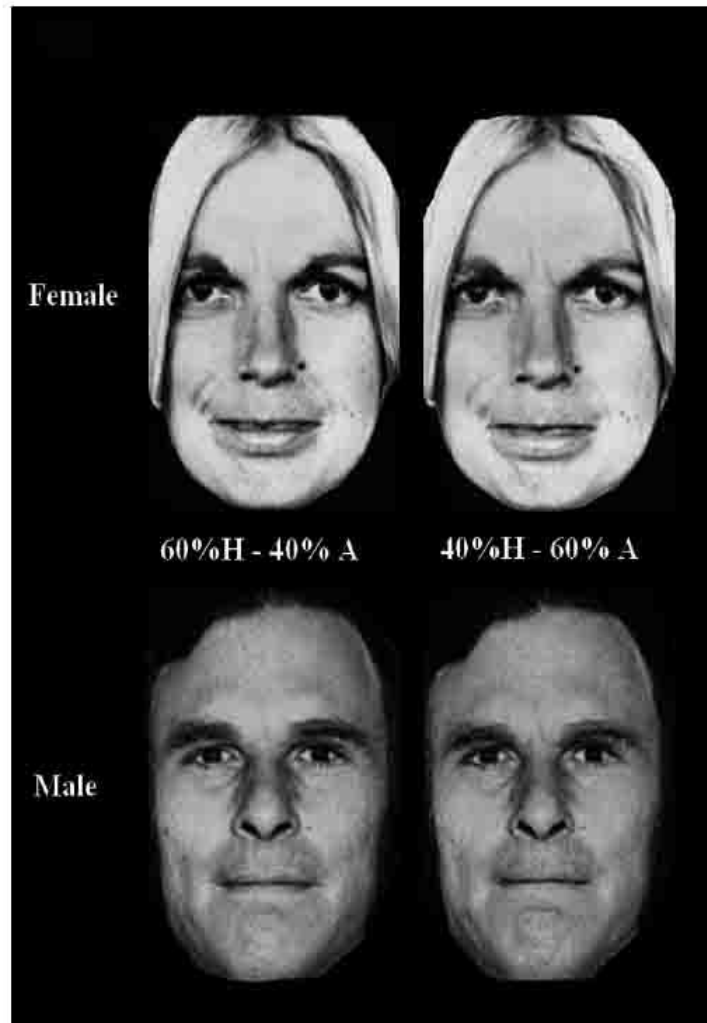

Fig. 1. Illustration of the visual stimuli used in this study, varying according to the gender (female above, male below) and to the dominant emotion (happiness on the left, anger on the right).

of interest: Two voices (one male), and two audiotapes for each (angry and happy prosody).

Four auditory-visual (cross-modal) stimuli were also created, based on the combination of a visual and an auditory stimuli (congruent for emotion and gender). The study thus comprised 12 stimuli and 6 experimental conditions (2 emotions ×3 stimulus modalities).

Participants were confronted with a total of 4 blocks, each defined by 6 series of 12 stimuli, so that the study consisted in 288 stimuli (48 per condition). Within a series, all stimuli were presented in the same modality (auditory, visual or both). The order of the 4 blocks varied across participants. Participants sat in a dark room on a chair placed 50 cm from the screen. Visual stimuli subtended a visual angle of $6 \times 8°$. Auditory stimuli were presented via binaural headphones. Each stimulus (face, voice or both) was presented for 700 ms. The stimuli were followed by a black screen (during 1,800 ms). From the stimulus onset, participants had 2,000 ms to answer. Participants had to decide as quickly as possible which emotion was displayed in the stimulus by pressing the button corresponding to this emotion (for example, 'anger') with their right forefinger. RTs and error rates were recorded. Emphasis was made on speed and accuracy. Only correct responses were considered for analysis of RTs.

Pretest

In order to ensure that the present procedure generates a facilitation effect in the cross-modal condition, a pre-test was conducted on 20 control subjects (mean age: 19.4, SD: 1.38). These control subjects were free of any history of psychiatric disorder or drug/substance abuse (including binge drinking habits), and their personal alcohol consumption was lower than seven standard drinks per week. As predicted, the selected stimuli gave rise to a significant facilitation effect. Concerning accuracy, auditory-visual stimuli led to lower error rates than auditory [$t(19) = 2.39$, $P < 0.05$] and visual ones [$t(19) = 5.89$, $P < 0.001$]. Moreover, the RTs (presented in Figure 2) showed similar results: auditory-visual conditions led to shorter RTs than auditory [$t(19) = 3.17$, $P < 0.01$] and visual [$t(19) = 4.76$, $P < 0.001$] ones, which did not differ [$t(19) = 0.71$, NS]. This pre-test thus confirmed that the selected design is associated with a facilitation effect in the

control population, and that an efficient integration processing is demonstrated in this experimental paradigm.

RESULTS

Psychological measures

As shown in Table 1, alcoholic individuals and controls were similar in terms of age [$F(1, 38) = 0.001$, N.S.], gender and education [$F(1, 38) = 0.19$, N.S.]. Moreover, the two groups did not significantly differ on anxiety state [$F(1, 38) = 0.96$, N.S.], anxiety trait [$F(1, 38) = 0.89$, N.S.], interpersonal problems [$F(1, 38) = 0.38$, N.S.] and alexithymia [$F(1, 38) = 0.14$, N.S.]. In fact, the only significant difference between groups concerned the depression scale [$F(1, 38) = 23.53$, $P < 0.001$], showing higher scores for alcoholics as compared to controls. However, these differences are unlikely to have influenced the experimental results, as (i) no significant Pearson's correlations were shown between any psychological measure and any behavioural data ($P > 0.05$ for every correlation) and (ii) a complementary analysis was conducted, including the depression score as covariable in our ANOVA statistical analyses, and showing no significant influence of this factor on the results ($P > 0.05$ for every test).

Accuracy. These results are shown in Table 2. A $3 \times 2 \times 2$ ANOVA with modality (auditory, visual and auditory-visual) and emotion (anger and happiness) as within-factors and group (alcoholic individuals and controls) as between-factor was carried out. A main effect of modality [$F(2, 76) = 59.119$, $P < 0.001$, $\eta^2 = 0.61$] was found: There were more errors for visual than for auditory [$t(39) = 8.52$, $P < 0.01$] and auditory-visual [$t(39) = 7.33$, $P < 0.01$] stimuli. Moreover, we found an interaction effect between group and modality [$F(2, 76) = 5,00$, $P < 0.05$, $\eta^2 = 0.12$]: Alcoholic subjects made more errors than controls in the visual conditions [$t(19) = 2.22$, $P < 0.05$], but not in the auditory [$t(19) = 0.62$, NS] and audio-visual ones [$t(19) = 0.77$, NS].

Latencies. A $3 \times 2 \times 2$ ANOVA with modality and emotion as within-factors, and group as between-factors was computed. As shown in Table 2 and Figure 3, two main effects were found: (i) group [$F(1, 38) = 31.97$, $P < 0.001$, $\eta^2 = 0.45$], indicating longer RTs for the alcoholic group;
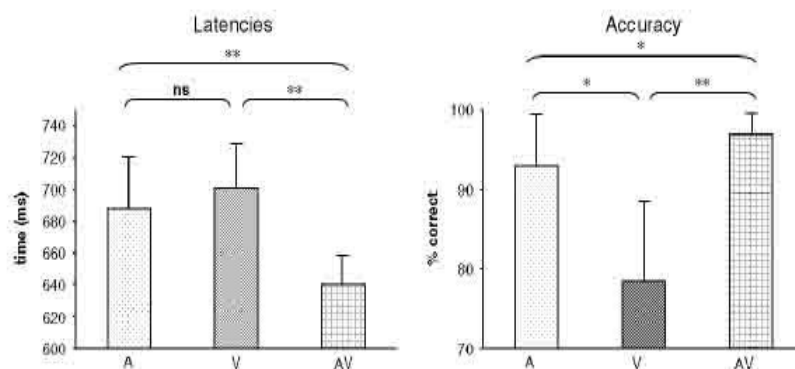

Fig. 2. Behavioural results of the pre-test phase for the three modalities (A = Auditory, V = Visual, AV = Auditory-Visual). Latencies (on the left) and accuracy (on the right) illustrates the facilitation effect observed (*$P < 0.05$, **$P < 0.01$).

Table 1. Patient and control characteristics: mean (SD)

Group	Age	Age range	EL[a]	% female[b]	MAC[c]	BDI[d]	Stai[e] A	Stai[e] B	IIP[f]	TAS-20[g]
Controls ($N = 20$)	44.6 (13.1)	24–62	14.45 (2.1)	15	0.57 (0.2)	2.05 (2.16)	30 (8.10)	35.45 (8.38)	1.03 (0.59)	40,10 (8.22)
Alcoholics ($N = 20$)	44.6 (8.5)	26–57	14.35 (2.5)	15	17.92 (5.3)	8.25 (5.29)	32.7 (9.21)	38.2 (9.97)	1.14 (0.52)	43,05 (9.32)

[a] EL = Education Level.
[b] % female = Percentage of female subjects in the group.
[c] MAC = Mean Alcohol Consumption (number of standard drinks per day) just before detoxification.
[d] BDI = Beck Depression Inventory (Beck and Steer, 1987).
[e] STAI = State and Trait Anxiety Inventory (Spielberger et al., 1983).
[f] IIP = Inventory of Interpersonal Problems (Horowitz et al., 1988).
[g] TAS-20 = Twenty-item Toronto Alexithymia Scale–II (Bagby et al., 1994).

Table 2. Behavioural results: Reaction Times [RTs; ms, (SD)] and Performance [Perf.; % of correct responses, (SD)]

Modality	Emotion	Control subjects ($N = 20$)		Alcoholic subjects ($N = 20$)	
		RTs	Perf.	RTs	Perf.
Auditory	Anger	857 (142)	95.5 (6.8)	1095 (233)	93.5 (11.3)
	Happiness	754 (152)	94.7 (8.6)	1051 (229)	93.2 (11.0)
Visual	Anger	809 (127)	82.8 (15.1)	1087 (237)	69.1 (23)
	Happiness	795 (128)	81.8 (18.2)	1065 (224)	71.7 (17.5)
Auditory-visual	Anger	761 (126)	93.4 (11.5)	1073 (210)	92.1 (14.8)
	Happiness	713 (140)	92.9 (10.0)	1136 (257)	88.1 (16.0)

(ii) emotion [$F(1, 38) = 10.69$, $P < 0.01$, $\eta^2 = 0.22$], indicating longer RTs for the anger than for happiness stimuli. This emotion main effect was modulated by an interaction effect, namely emotion X modality [$F(2, 76) = 14.86$, $P < 0.001$, $\eta^2 = 0.28$]: The 'auditory anger' condition led to longer RTs than the five other conditions [$t(19) \geq 2.51$, $P < 0.05$]. Finally, and more importantly, an interaction effect was found between group and modality [$F(2, 76) = 3.59$, $P < 0.05$, $\eta^2 = 0.09$]: while in the alcoholic group, no differences were found between modalities, in the control group auditory-visual condition led to shorter RTs than auditory [$t(19) = 4.88$, $P < 0.05$] and visual [$t(19) \geq 5.59$, $P < 0.05$] conditions, thus showing a facilitation effect, absent among alcoholics.

In order to confirm that alcoholic subjects were significantly more impaired for the cross-modal condition as compared to uni-modal ones, an ANOVA analysis was conducted to compare the differential deficit (namely, Alcoholics RTs minus Controls RTs) for each condition. A significant effect was found [$F(1, 19) = 38.41$, $P < 0.001$, $\eta^2 = 0.37$], confirmed by paired t-tests: Cross-modal conditions led to significantly higher RT differences between controls and alcoholics than auditory [$t(19) = 3.45$, $P < 0.01$] and visual [$t(19) = 2.99$, $P < 0.01$] ones, which did not differ [$t(19) = 0.22$, NS].

Complementary analysis. Finally, it should be noted that, as the gender ratio and age range varied between the pre-test and experimental phases, and could have influenced the results, these potential bias have been explored. Indeed, gender and age were introduced as covariables in our ANOVA statistical analyses (for the preliminary study, for the pre-test as well as for the experiment itself), and Pearson's correlations were computed between the results and these variables. We did not find any significant influence of the gender or age variables on the results ($P > 0.05$ for every test and correlation).

DISCUSSION

The central aim of this study was to explore the integrity of the cross-modal processing among alcoholic subjects. Indeed, while it has been extensively observed that alcoholism is associated with a wide range of cognitive and neuropsychological impairments (and notably a deficit in the processing of uni-modal auditory or visual stimuli), no study has been conducted yet to determine whether alcoholism hampers cross-modal processing. This lack of research is surprising because cross-modal situations are the most frequent in everyday life, particularly when emotional abilities are involved. Thus, as alcoholism is associated with various problems in ecological contexts (notably in emotional and social situations), and as our social environment is characterized by multi-modal stimulations, the cross-modal processing was tested on the basis of complex social stimuli, namely emotional faces and voices. The use of modified visual stimuli (as shown in the pre-test) resulted in the use of identical complexity in both visual and auditory stimulations. This technique resulted in the facilitation effect presumed to be the marker of the cross-modal integration.

This study first confirmed the uni-modal deficit, namely the impaired processing of EFE and emotional prosody; Alcoholic subjects were slower to determine the emotion presented in the stimuli, and the deficit did not differ in intensity between auditory and visual stimuli. This cannot be explained by the fact that alcoholism is associated with an impairment of visuo-motor abilities, as accuracy scores confirmed this uni-modal
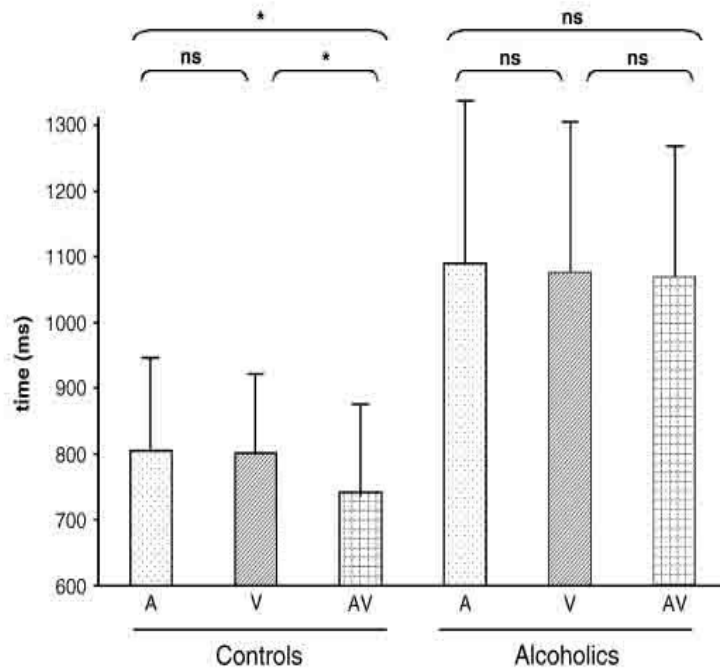
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Fig. 3. Reaction times observed among control (on the left) and alcoholic subjects (on the right) for the three modalities (A = Auditory, V = Visual, AV = Auditory-Visual), showing the group main effect (shorter RTs among controls) and the interaction effect, namely the facilitation effect among controls, which is absent among alcoholics ($^*P$ <0.05).

impairment. Indeed, alcoholic subjects made more errors than controls, particularly in the visual conditions (a ceiling effect was observed in auditory and auditory-visual conditions and the two groups did not significantly differ on these modalities). These results are in line with previous ones (e.g. Philippot et al., 1999; Monnot et al., 2001; Townshend and Duka, 2003), and confirm that alcoholism leads to deleterious effects for the processing of visual and auditory emotional stimuli.

The main result of this study concerns cross-modal processing. Indeed, while a facilitation effect was found among control subjects (namely faster RTs for the cross-modal conditions as compared to uni-modal ones), no differences between modalities were observed in the alcoholic group. As the facilitation effect is the behavioural marker of the efficient cross-modal processing, these results showed that alcoholism is associated with an impaired auditory-visual integration of complex and ecological stimuli. Moreover, a complementary analysis, directly comparing the alcoholics' deficit for each modality, confirmed that this cross-modal deficit is significantly more extensive than the uni-modal (auditory and visual) impairment.

This first observation of an absence of facilitation effect in alcoholism, indexing an impaired cross-modal integration, may have important clinical implications. Indeed, as the cross-modal situations are very frequent in everyday life, we suggest that earlier studies based on uni-modal stimulations (and often using basic stimuli) have underestimated the deficits in alcoholism. This cross-modal impairment could also explain the hiatus between the relatively mild deficit frequently observed in experimental situations among alcoholic subjects (e.g. Oscar-Berman et al., 1990; Beatty et al., 2000; Uekermann et al., 2005) and the patent impairments observed

in ecological situations, and notably in clinical observations. Moreover, as emotions are often expressed simultaneously in different modalities (particularly in vocal and facial expression) and as the efficient decoding of emotions is a crucial ability to develop and maintain satisfactory interpersonal relations (e.g. Feldman et al., 1991), the impairment of emotional cross-modal processing in alcoholism could have deleterious consequences on social integration (Nixon et al., 1992), leading to a vicious circle: A deficit in the decoding of emotional signs (particularly in cross-modal situations), provoked by alcoholism, worsens interpersonal problems (Kornreich et al., 2002), which in turn could increase alcohol consumption used as a coping strategy (Kornreich et al., 2001).

The implications of such results for both experimental and clinical endeavours are the following: In research on alcoholism, these results should lead to a re-evaluation of earlier studies using uni-modal stimuli and showing limited impairments in chronic alcoholics. Also, these results should encourage future studies to use cross-modal stimuli in order to correctly evaluate any cognitive and emotional deficits in social stimuli processing. For clinical settings, these study results should encourage the incorporation of cross-modal aspects of communication during the patient's evaluation, notably by developing more realistic testing of emotion comprehension in alcoholics. Therapeutic interventions could also be improved through communication re-education programmes, focusing on cross-modal processing of the expression and identification of emotions in social settings.

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REFERENCES

Alais, D. and Burr, D. (2004) The ventriloquist effect results from near-optical bimodal integration. *Current Biology* 14, 257–262.

Amedi, A., von Kriegstein, K., van Atteveldt, N. M. *et al.* (2005) Functional imaging of human crossmodal identification and object recognition. *Experimental Brain Research* 166, 559–571.

Bagby, R. M., Taylor, G. J. and Parker, J. D. (1994) The Twenty-item Toronto Alexithymia Scale–II. Convergent discriminant and concurrent validity. *Journal of Psychosomatic Research* 38, 33–40.

Beatty, W. W., Tivis, R., Stott, D. *et al.* (2000) Neuropsychological deficits in sober alcoholics: influences of chronicity and recent alcohol consumption. *Alcoholism-Clinical and Experimental Research* 24, 149–154.

Beck, A. T. and Steer, R. A. (1987) *Beck Depression Inventory Manual*, 1st edn. pp. 125. Psychological Corporation, San Antonio, TX.

Bijl, S., de Bruin, E. A., Kenemans, J. L. *et al.* (2005) Effects of chronic alcohol consumption in a visual attention task and an auditory oddball task: an event-related potential study. *Alcoholism-Clinical and Experimental Research* 29, 2029–2038.

Blusewicz, M. J., Dustman, R. E., Schenkenberg, T. *et al.* (1977) Neuropsychological correlates of chronic alcoholism and aging. *Journal of Nervous and Mental Disorders* 165, 348–355.

Bushara, K. O., Grafman, J. and Hallett, M. (2001) Neural correlates of auditory-visual stimulus onset asynchrony detection. *Journal of Neuroscience* 21, 300–304.

Cadaveira, F., Grau, C., Roso, M. *et al.* (1991) Multimodality exploration of event-related potentials in chronic alcoholics. *Alcoholism-Clinical and Experimental Research* 15, 607–611.

Calvert, G. A. (2001) Crossmodal processing in the human brain: insights from functional neuroimaging studies. *Cerebral Cortex* 11, 1110–1123.

Calvert, G. A., Campbell, R. and Brammer, M. J. (2000) Evidence from functional magnetic resonance imaging of crossmodal binding in the human heteromodal cortex. *Current Biology* 10, 649–657.

Calvert, G. A., Hansen, P. C., Iversen, S. D. *et al.* (2001) Detection of auditory-visual integration sites in humans by application of electrophysiological criteria to the BOLD effect. *Neuroimage* 14, 427–438.

Dolan, R. J., Morris, J. S. and de Gelder, B. (2001) Crossmodal binding of fear in voice and face. *Proceedings of the National Academy of Sciences of the United States of America* 98, 10006–10010.

Driver, J. and Spence, C. (2000) Multisensory perception: Beyond modularity and convergence. *Current Biology* 10, 731–735.

Ekman, P. (1972) Universals and cultural differences in facial expressions of emotion. In *Nebraska Symposium on Motivation*, Cole, J. ed., pp. 207–283. University of Nebraska Press, Lincoln, NE.

Ekman, P. (1977) Facial expression. In *Nonverbal Behavior and Communication*, Siegman, A., Feldstein, S. eds, pp. 158–179. Lawrence Erlbaum Association, Hillsdale, NJ.

Ekman, P. and Friesen, W. V. (1976) *Pictures of Facial Affect*. Consulting Psychologists Press, Palo Alto, CA.

Ekman, P., Friesen, W. V. and Ancoli, S. (1980) Facial signs of emotional experience. *Journal of Personality and Social Psychology* 39, 1125–1134.

Ellis, H. D., Jones, D. M. and Mosdell, N. (1997) Intra- and inter-modal repetition priming of familiar faces and voices. *British Journal of Psychology* 88, 143–156.

Feldman, R. S., Philippot, P. and Custrini, R. J. (1991) Social competence and non-verbal behaviour. In *Fundamentals of Non-verbal Behavior*, Feldman, R. S. ed., pp. 329–350. Cambridge University Press, New York.

Frens, M. A., Van Opstal, A. J. and Van der Willigen, R. F. (1995) Spatial and temporal factors determine auditory-visual interactions in human saccadic eye movements. *Perception & Psychophysics* 57, 802–816.

Frigerio, E., Burt, D. M., Montagne, B. *et al.* (2002) Facial affect perception in alcoholics. *Psychiatry Research* 113, 161–171.

Greimel, E., Macht, M., Krumhuber, E. *et al.* (2006) Facial and affective reactions to tastes and their modulation by sadness and joy. *Physiology & Behavior* 89, 261–269.

Hanley, J. R. and Turner, J. M. (2000) Why are familiar-only experiences more frequent for voices than for faces? *Quarterly Journal of Experimental Psychology* 53, 1105–1116.

Hanley, J. R., Smith, S. T. and Hadfield, J. (1998) I recognise you but I can't place you: An investigation of familiar-only experiences during tests of voice and face recognition. *Quarterly Journal of Experimental Psychology* 51, 179–195.

Horowitz, L. M., Rosenberg, S. E., Baer, B. A. *et al.* (1988) Inventory of interpersonal problems: Psychometric properties and clinical applications. *Journal of Consulting and Clinical Psychology* 56, 885–892.

Joassin, F., Maurage, P., Bruyer, R. *et al.* (2004) When audition alters vision: an event-related potential study of the cross-modal interactions between faces and voices. *Neuroscience Letters* 369, 132–137.

Kornreich, C., Blairy, S., Philippot, P. *et al.* (2001) Impaired emotional facial expression recognition in alcoholism compared with obsessive-compulsive disorder and normal controls. *Psychiatry Research* 102, 235–248.

Kornreich, C., Philippot, P., Foisy, M. L. *et al.* (2002) Impaired emotional facial expression recognition is associated with interpersonal problems in alcoholism. *Alcohol and Alcoholism* 37, 394–400.

Kramer, J. H., Blusewicz, M. J., Robertson, L. C. *et al.* (1989) Effects of chronic alcoholism on perception of hierarchical visual stimuli. *Alcoholism-Clinical and Experimental Research* 13, 240–245.

Lalanne, C. and Lorenceau, J. (2004) Crossmodal integration for perception and action. *Journal of Physiology* 98, 265–279.

Marco, J., Fuentemilla, L. and Grau, C. (2005) Auditory sensory gating deficit in abstinent chronic alcoholics. *Neuroscience Letters* 375, 174–177.

Maurage, P., Philippot, P., Verbanck, P. *et al.* (2007) The P300 deficit in alcoholism associated with early visual impairments (P100, N170)? An oddball paradigm. *Clinical Neurophysiology* 118, 633–644.

McGurk, H. and McDonald, J. (1976) Hearing lips and seeing voices. *Nature* 264, 746–747.

Miller, J. (1982) Divided attention: evidence for coactivation with redundant signals. *Cognitive Psychology* 14, 247–279.

Miltner, W. H., Braun, C., Arnold, M. *et al.* (1999) Coherence of gamma-band EEG activity as a basis for associative learning. *Nature* 397, 434–436.

Molholm, S., Ritter, W., Murray, M. M. *et al.* (2002) Multisensory auditory-visual interactions during early sensory processing in humans: a high-density electrical mapping study. *Brain Research-Cognive Brain Research* 14, 115–128.

Monnot, M., Nixon, S., Lovallo, W. *et al.* (2001) Altered emotional perception in alcoholics: deficits in affective prosody comprehension. *Alcoholism-Clinical and Experimental Research* 25, 362–369.

Nixon, S. J., Tivis, R. and Parsons, O. A. (1992) Interpersonal problem-solving in male and female alcoholics. *Alcoholism-Clinical and Experimental Research* 16, 684–687.

Ogura, C. and Miyazato, Y. (1991) Cognitive dysfunctions of alcohol dependence using event related potentials. *Arukoru Kenkyuto Yakubutsu Ison* 26, 331–340.

Oscar-Berman, M., Hancock, M., Mildworf, B. *et al.* (1990) Emotional perception and memory in alcoholism and aging. *Alcoholism-Clinical and Experimental Research* 14, 383–393.

Philippot, P., Kornreich, C., Blairy, S. *et al.* (1999) Alcoholics' deficits in the decoding of emotional facial expression. *Alcoholism-Clinical and Experimental Research* 23, 1031–1038.

Pourtois, G., de Gelder, B., Vroomen, J. *et al.* (2000) The time-course of intermodal binding between seeing and hearing affective information. *Neuroreport* 11, 1329–1333.

Pourtois, G., De Gelder, B., Bol, A. *et al.* (2005) Perception of facial expressions and voices and of their combination in the human brain. *Cortex* **41**, 49–59.

Schroger, E. and Widmann, A. (1998) Speeded responses to audiovisual signal changes result from bimodal integration. *Psychophysiology* **35**, 755–759.

Schweinberger, S. R., Herholz, A. and Sommer, W. (1997) Recognizing famous voices: Influence of stimulus duration and different types of retrieval cues. *Journal of Speech Language and Hearing Research* **40**, 453–463.

Shepherd, G. M. (2006) Smell images and the flavour system in the human brain. *Nature* **444**, 316–321.

Spielberger, D. C., Gorsuch, R. L., Lushene, R. *et al.* (1983) *Manual for the State-Trait Anxiety Inventory*, 1st edn, 223 Consulting Psychology Press, Palo Alto, CA.

Spitzer, J. B. (1981) Auditory effects of chronic alcoholism. *Drug and Alcohol Dependence* **8**, 317–335.

Spitzer, J. B. and Ventry, I. M. (1980) Central auditory dysfunction among chronic alcoholics. *Archives of Otolaryngology* **106**, 224–229.

Surguladze, S. A., Calvert, G. A., Brammer, M. J. *et al.* (2001) Auditory-visual speech perception in schizophrenia: an fMRI study. *Psychiatry Research* **106**, 1–14.

Teder-Salejarvi, W. A., McDonald, J. J., Di Russo, F. *et al.* (2002) An analysis of auditory-visual crossmodal integration by means of event-related potential (ERP) recordings. *Brain Research-Cognitive Brain Research* **14**, 106–114.

Townshend, J. M. and Duka, T. (2003) Mixed emotions: alcoholics' impairments in the recognition of specific emotional facial expressions. *Neuropsychologia* **41**, 773–782.

Uekermann, J., Daum, I., Schlebusch, P. *et al.* (2005) Processing of affective stimuli in alcoholism. *Cortex* **41**, 189–194.

Wegner, A. J., Gunthner, A. and Fahle, M. (2001) Visual performance and recovery in recently detoxified alcoholics. *Alcohol and Alcoholism* **36**, 171–179.

Winston, J. S., Gottfried, J. A., Kilner, J. M. *et al.* (2005) Integrated neural representations of odor intensity and affective valence in human amygdala. *Journal of Neuroscience* **25**, 8903–8907.