THE CROSSMODAL 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. In this study, we investigated the crossmodal (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 crossmodal 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 crossmodal condition than for unimodal 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: Crossmodal processing of complex social stimuli (such as faces and voices) is crucial for interpersonal relations. This first evidence for a crossmodal 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. Crossmodal 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 ‘unimodal’ phenomena. Recently, due to technical developments, and to the awareness that crossmodal 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 crossmodal studies described an ‘inhibition effect’. This effect is determined by a deteriorated or biased performance in crossmodal conditions (i.e. when two stimuli from different modalities are presented simultaneously) as compared to unimodal 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’ (Fréns 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 unimodal 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 crossmodal processing. Indeed, the facilitation effect is considered as the behavioural marker of a successful crossmodal 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 crossmodal 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 unimodal activities, is suggested and these integrative processes seem to be disturbed in some psychiatric populations (e.g. schizophrenia, Surguladze et al., 2001).
The current study will explore crossmodal 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 unimodal 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 crossmodal processing with emotional stimuli thus seems crucial, as the ubiquity of the crossmodal 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 unimodal exploration is thus clearly insufficient to apprehend the complexity of the emotional processes. Only a few studies have explored the crossmodal 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 crossmodal 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 crossmodal integration (Calvert, 2001), this study was based on the elicitation of this effect. Crossmodal integration of the stimuli in chronic alcoholism was assessed behaviourally.

Crossmodal (auditory-visual) stimuli were used in order to determine to which extent the ‘unimodal’ 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 criterion), 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., 1985), 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 (unimodal conditions) or simultaneously (crossmodal condition). Two categories of faces and voices were used and varied in terms of emotional content (anger or happiness). In the crossmodal 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 crossmodal 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) ≥ 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., in press), 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 of

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

Four auditory-visual (crossmodal) 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 × 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 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.

**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 × 2 × 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, η² = 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, η² = 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, N.S.] and audio-visual ones [t(19) = 0.77, N.S.].
Finally, and more importantly, an interaction effect was found between group and modality [\(\eta^2 = 0.39\), \(P < 0.001\)]. RTs were longer for the crossmodal condition than for the unimodal ones, which did not differ [\(t(19) = 3.45\), \(P < 0.001\)]. Complementary analysis

Complementary analysis

Finally, it should be noted that, as the gender ratio and group did not significantly differ, the results can be interpreted as being consistent across the groups. Gender and group 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 relationship between the results and these variables. We did not find any significant relationship between the results and these variables. We did not find any significant relationship between the results and these variables. We did not find any significant relationship between the results and these variables. We did not find any significant relationship between the results and these variables.

DISCUSSION

The central aim of this study was to explore the integrity of the crossmodal 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 unimodal auditory or visual stimuli), no study has been conducted yet to determine whether alcoholism hampers crossmodal processing. This lack of research is surprising because crossmodal situations are the most frequent in everyday life, particularly when emotional abilities are involved. Thus, as alcoholism is associated with a wide range of cognitive and neuropsychological impairments (and notably a deficit in the processing of unimodal auditory or visual stimuli), no study has been conducted yet to determine whether alcoholism hampers crossmodal processing.
This first observation of an absence of facilitation effect in alcoholism, indexing an impaired crossmodal integration, may have important clinical implications. Indeed, as the crossmodal situations are very frequent in everyday life, we suggest that earlier studies based on unimodal stimulations (and often using basic stimuli) have underestimated the deficits in alcoholism. This crossmodal 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 crossmodal 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 crossmodal 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 unimodal stimuli and showing limited impairments in chronic alcoholics. Also, these results should encourage future studies to use crossmodal 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 crossmodal 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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