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INSIGHTS FROM ERPS INTO EMOTIONAL DISORDERS: AN AFFECTIVE NEUROSCIENCE PERSPECTIVE

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Affective neuroscience disposes of complementary imaging tools, some identifying which neural regions are involved in a specific cognitive function, others defining the temporal sequences of these activations with an optimal temporal resolution. The aim of the present manuscript is to show how event-related potentials (ERPs) may help us to enhance our understanding of psychopathological conditions. To do so, three experiments from our laboratory will be presented. An emotional oddball design was used, in which participants are confronted with frequent stimuli (neutral faces) and deviant stimuli (emotional faces) which they have to detect as quickly as possible. These studies address anxiety, the long-term consequences of ecstasy consumption and schizophrenia. Our main purpose is to show that, if previous studies have shown for generalised anxiety disorder, as well as for drug abuse or schizophrenia, P300 alterations, the impaired processes leading to such an identical disturbance are different from one population to the other.

Introduction

In 1895, a still unknown Viennese neuropsychiatrist named Sigmund Freud wrote a manuscript entitled “A project for a Scientific Psychology”, in which he proposed that the cognitive mechanisms of normal and abnormal mental phenomena could be explained through orderly and rigorous study of brain systems. More than 100 years later, many researchers are still dealing with this complex task. Models describing various cognitive processes have been developed through the use of clinical observation, experimental paradigms, animal and human lesion studies, and anatomic studies of neural circuits by means of neuroimaging experiments. The principal aim of this venture is to achieve a ’scientific psychopathology’ in order to identify the neural mechanisms of normal cognitive processes and to understand how they are impaired in mental illnesses (Andreasen, 1997).

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In this perspective, emotional facial expressions (EFE) constitute a particular category of stimuli. Given the importance of non-verbal communication in everyday life, the efficiency of their detection and of their processing concurs to effective social communication, adaptive behaviour and interactions with other people (Persad & Polivy, 1993). However, several emotional disorders have been associated with disturbances in the processing of emotionally salient information, including biases or deficits in the detection and recognition of EFE (Philippot, Kornreich, & Blairy, 2003). Affective neuroscience is the discipline that examines the neural bases of mood and emotion in order to generate a new understanding of the brain circuitry underlying these disorders (Davidson, Pizzagalli, Nitschke, & Putnam, 2002).

To pursue this goal, affective neuroscience mainly relies on empirical data collected by means of brain imagery techniques. By using positron emission tomography (PET) or functional magnetic resonance imaging (fMRI), researchers try to localise the different brain structures that are involved in a specific cognitive function. In a meta-analysis of 55 PET and fMRI activation studies that investigated emotion in healthy subjects, Phan, Wager, Taylor, and Liberzon (2002) showed that, while the medial prefrontal cortex appears to have a general role in emotional processing, specific emotions involved different brain structures, such as the amygdala for fear, the subcallosal cingulate for sadness or the insula for disgust. This observation led several authors to consider that specific emotions are represented in distributed neural systems (e.g., Panksepp, 2003; Berridge, 2003), or, more precisely, that a limited number of emotions (generally including happiness, sadness, anger, fear and disgust) are represented by specific neural activations. This implies that each specific emotional state should be seen as resulting from the interactions among separate brain regions, so that a pathological behaviour could result from the failure of these interactions, and not necessarily from the impairment of a specific brain structure.

Affective neuroscience can thus rely on "anatomical" imaging techniques, such as PET or fMRI, to localise the neural structures implicated in emotional processing in healthy people. However, we also need to know *when* these structures are activated. Since cognitive psychologists consider a cognitive function as resulting from different parallel and/or sequential processes and cognitive neuroscientists link these mental processes to specific neural activations, it becomes highly relevant to define the temporal occurrence of these activations. Derived from the electroencephalogram (EEG) method, event-related potentials (ERPs) allow the investigation of the temporal course and the various stages of cognitive processing with a temporal resolution up to 1ms (Rugg & Coles, 1995). A great number of visual ERP studies had been devoted to emotional processing. For instance, participants in a study of Potter and Parker (1989) had to decide whether the second face of a pair

matched the first one in terms of expression (vs. identity). The ERPs showed a later difference in the 490-540 ms time range, only for a right parietal site. Accordingly, Hautecoeur, Debruyne, Forzy, Gallois, Hache, and Dereux (1993) showed a modulation of a parietal P400 when subjects were asked to look for emotional expression of the face (smiling or non-smiling) in comparison with a recognition task of the face as known or unknown. By using intracranial recordings in epileptic patients, Halgren and Marinkovic (1995) showed that significant differentiation among waveforms evoked by different facial emotions appears fronto-centrally in the 400-600 ms latency range.

However, when reviewing the psychological and electrophysiological literature on emotions, a discrepancy emerges. In fact, if behavioural studies have demonstrated that emotions are extracted pre-attentively and influence subsequent perception (e.g., Kunst-Wilson & Zajonc, 1980), few studies (before 1999) have reported neurophysiological correlates for these 'early' processes. Rather, most prior studies found emotion-modulated ERP components considerably later, typically between 250 and 600 ms (Münte, Brack, Grootheer, Wieringa, Matzke, & Johannes, 1998). However, since 1999, many studies examined early markers and their modulations by emotions. For instance, Pizzagalli, Regard, and Lehmann (1999) showed that personal affective judgments of faces significantly modulated ERP responses at early stages, 80-116ms after right hemisphere stimulation and 104-160ms after left stimulation. More recent studies have confirmed these results in healthy subjects, showing for instance early modulations (around 100 ms) of brain electrical activity by, for example, threatening information (e.g., fearful faces) (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005). The greater attentional resource allocation to fearful faces is generally considered as adaptive, as it is important to correctly identify fear in order to understand what is at stake and how to cope with it. Such attentional allocation is also related to amygdala functions, as amygdala is thought to play some role in tuning the visual system to become more sensitive to threat cues by means of efferent projections to primary sensory areas (LeDoux, 1995).

In sum, affective neuroscience disposes of complementary imaging tools, some (PET, fMRI) identifying which neural regions are involved in a specific cognitive functions (high spatial resolution up to 3-4 mm but poor temporal sensitivity); others (ERPs, MEG) defining the temporal sequences of these activations with an optimal temporal resolution (but low spatial resolution). The aim of the present manuscript is to show how ERPs may help to enhance our understanding of psychopathological conditions. In the next sections, we will describe a particular ERP experimental design that we think to be highly relevant for studying affective disorders; then, we will exemplify some important data collected with this method.

Emotional oddball designs: rationale and procedure

Most ERP studies use an 'oddball' paradigm, in which participants are asked to detect, amongst a series of standard stimuli, an infrequent deviant stimulus. The detection of stimulus change may play a role in directing attention to events of biological importance (Garcia-Larrea, Lukaszewicz, & Mauguière, 1992). This is indexed by two main ERP components. First, when subjects are placed in attentive conditions, deviant visual stimuli evoke a N200 component, peaking at occipital electrodes around 250 ms, which indicates a switch of attention to biologically significant events in order to cope with them (e.g., Campanella, Gaspard, Debatisse, Bruyer, Crommelinck, & Guérit, 2002). Second, a P300 component is maximally recorded at parietal sites around 450 ms, which is functionally related to later conscious, decisional and premotor response stages (e.g., Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999).

Most ERP studies have focused on the P300 component. This is mainly due to the fact that, whatever the investigated sensorial modality (visual, auditive or somesthesic), this paradigm elicits a P300 wave that was first described by Sutton, Braren, Zubin, and John (1965). This P300 is of particular interest, as it is generally functionally related to different complex cognitive functions, such as decision-making process and cognitive closure phenomena, that are related to different types of attentional and memory processes (Ranganath & Rainer, 2003). Variations in amplitude and latency of this P300 have thus been extensively described in many studies on normal subjects, showing for instance that its amplitude and latency could be modulated by the complexity of a task (Bentin et al., 1999; Campanella, Gaspard et al., 2002) or by subjects-related factors such as age (Goodin, Squires, Henderson, & Starr, 1978), vigilance level or degree of motivation (for a review, see Hansenne, 2000).

Two conditions must be fulfilled for the individual use of ERP component as a diagnostic tool of a pathological process. First, this component needs to be present and stable enough in normal individuals and, second, it must correspond to the brain functions that are altered in the pathology to be diagnosed. At first sight, the P300 component seems to be particularly well-suited for early diagnostic evaluations in psychopathology. However, empirical evidence showed that this is not the case, for three main reasons. First, clinical utility of the P300 component depends upon the identification of precise variations of its amplitude and latency. However, this condition is threatened by important inter-individual variations, due to gender, age, intelligence and personality (see Hansenne, 2000 for review). Second, the P300 refers to different mechanisms that can be indexed by different parts of this wave: a P3a, a P3b and P3-novelty components are classically described in the literature

(see Ranganath & Rainer, 2003 for review). As these components refer to different functional processes, it clearly appears that (1) we need to be able to discriminate as accurately as possible between these different components; and (2) each component could be independently altered in different pathological populations. Third, as many different functional processes are implied in the P300 complex, it clearly appears that it is generated by a distributed neural network. As a matter of fact, many neural generators have been postulated to account for the P300 wave, such as the orbitofrontal cortex, the hippocampus and/or the anterior cingulate gyrus (see Ranganath & Rainer, 2003 for review).

In sum, oddball designs allow us to generate in normal and pathological populations a cognitive potential, the P300, that reflects different cognitive processes. By comparing pathological populations and normal control subjects, the P300 can be considered as a tool providing us with a useful recording of patients' information processing. Differences in amplitude and latency could then indicate the severity of a clinical state and its possible evolution. However, due to its inter-individual variation, its functional heterogeneity and its distributed neuronal generation, its clinical value as diagnostic index is unfortunately weak.

Many studies investigating P300 in dementia, schizophrenia, depression, alcoholism, drug addiction, anxiety or personality disorders have described disturbances in recorded latency and amplitude values of this component (as compared to healthy individuals) (see Hansenne, 2000 for a review). However, it is important to outline that: (1) P300 modulations are general in any pathological as well as normal state; (2) classical oddball designs used very simple stimuli such as light flashes in the visual modality; and (3) earlier processing deficits may underlie the failure of later 'higher-level' processes (Foxe, Murray, & Javit, 2005). Thus, our aim was to create a task (1) which could show P300 impairment in pathological conditions; (2) by using more complex stimuli such as emotional faces; and (3) that could determine whether a P300 deficit can be attributed to an earlier deficit. It is therefore important to outline that our aim was not to use P300 disturbances themselves as diagnostic tool (to differentiate diverse pathological states), but to understand this deficit by highlighting the deficient processes leading to these P300 impairments.

For this purpose, we used the 'emotional oddball' task, in which participants are confronted with frequent stimuli (neutral faces) and deviant stimuli (emotional faces), the latter of which they have to detect as quickly as possible (and indicate this by pressing a button). With this procedure, different ERP components can be derived:

– The P100 component is typically recorded in visual ERP studies around 100 ms at occipital sites, and it is described as reflecting primary visual

analyses (Heinze et al., 1994);

– Among ERP studies related to face processing, a negative component, the N170, has probably been the most deeply investigated since 1990. This component is generated by the fusiform gyrus, recorded at occipito-temporal sites around 170 msec, and modulated by emotional and identity category (Campanella, Gaspard et al., 2000; Campanella, Quinet, Bruyer, Crommelinck, & Guérit, 2002). At a functional level, the N170 is generally interpreted as the structural encoding of the face leading to the generation of a complete facial representation. The particularity of this N170 has been to be described as being preferentially evoked (higher amplitude) in response to faces as compared to any other visual objects, as faces defined a class of stimuli for which humans have reached a high level of expertise;
– The N2/P3a complex is known as representing an 'attentional orienting complex' (Halgren & Marinkovic, 1995). The N2b component is generated around 250-300 ms at occipital sites and it refers to the attention switch needed to take new information into account, while the P3a component, recorded around 300 ms at frontal sites, is more sensitive to the degree of novelty of the deviant information;
– The N300 component is a negative deflexion peaking around 300ms at central sites, and it is supposed to be particularly sensitive to emotional stimulation. The N300 would reflect an affective processing as it reacts more to affective features of stimuli rather than to physical characteristics (Carretié & Iglesias, 1995);
– Finally, the P3b component, peaking at parietal sites around 450ms arises when an attended stimulus is detected, and should reflect decision-making and premotor response-related stages. It's important to note that classical ERP studies describing P300 disturbances do not discriminate between P3a and P3b subcomponents, and probably reflect P3b alterations.

We suggest that using ERPs in this emotional detection task will allow us to separate the attentional or perceptual (preparation-to-process) and the response-related (preparation-to-respond) steps implied during the task. Our principal aim is then to define the level of the information processing system (perceptive, attentional or decisional) at which the observed differences originate. An effect circumscribed to response-related stages (decision-making, response premotor preparation) implies a modulation of the P300 component (but not of earlier ERP components). However, a behavioural effect originating at the attentional level and extending to behavioural responses should affect both components (N2b and P3b modulations) (see for instance, Campanella et al., 2004).

In order to illustrate this method, three experiments from our laboratory

will be presented. They address successively anxiety, ecstasy consumption and schizophrenia. These studies are presented in order to provide a general sense of our rationale. For more theoretical or methodological aspects of these studies please refer to some recent publications (Campanella, Montedoro, Streel, Verbanck, & Rosier, in press; Mejias et al., 2005; Rossignol, Philippot, Douilliez, Crommelinck, & Campanella, 2005).

Emotional oddball designs and psychopathological populations

Generalised Anxiety Disorder

Different lines of evidence suggest that anxiety interferes with emotion processing, in such a way that anxious subjects are particularly sensitive to threatening information (Mogg & Bradley, 2002). In the present study, we focused on sub-clinical generalised anxiety, because some studies have already confirmed the presence of a bias towards threatening information in sub-clinically anxious individuals (Carretié, Mercado, Hinojosa, Martin-Loeches, & Sotillo, 2004). The perception of fear has been shown to be modified by anxiety, in such a way that increased attentional resources seem to be devoted to fearful faces, even in preattentive condition, in sub-clinical high anxious subjects (Fox, 2002). Studying the role of such a bias in the aetiology and persistence of anxiety has thus revealed to be of the greatest relevance (Mogg & Bradley, 2002). Our aim in this study was to investigate how sub-clinical anxiety affects emotional processing, more particularly with regard to emotional facial expressions (EFE) of fear and happiness (Rossignol et al., 2005). Event-related potentials (ERPs; 32 channels) can help to answer this question as they allow to investigate the temporal course of the various stages implied in any cognitive processing. Therefore, by comparing high and low anxious subjects, we might precisely locate the cognitive level at which the above mentioned bias occurs, and for which EFE (fear or/and happiness) it can be described.

For this purpose, we used an emotional oddball paradigm, in which participants have to detect two infrequent deviant stimuli (fearful or happy faces) among a series of frequent standard stimuli (neutral faces). Twenty participants were recruited among University of Louvain students according to their score on the Spielberger State and Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, & Lusthene, 1983). Ten students were grouped as low-anxious (LA: mean state anxiety: 46.4; mean trait anxiety: 38.9), and ten as high-anxious (HA: mean state anxiety: 54.8; mean trait anxiety: 59.7). Behavioural results suggest that anxious participants were faster than controls in the detection of rare stimuli, independently of their valence

(Rossignol et al., 2005). The main interest of our study is to define the neurophysiological correlates of this general enhanced processing. Its origin does not seem to be of an attentional nature, since participants did not differ in attentional resources allocated to the stimuli (no effect of group on the N2b/P3a complex). However, the modulation of emotional processing began during the specific evaluation of emotion: anxious participants produced reduced N300 amplitude on the right side compared to control participants, for happy as well as for fearful EFE. N300 has been described as more responding to emotional value attributed to stimuli by subjects, than to physical and configurational characteristics. Thus, our results suggest that anxious individuals are less responsive to the emotional content of fearful and happy faces. Nevertheless, despite a worse emotional processing indexed by a decreased N300, the P3b latency appears *significantly earlier* in the anxious participants. In his review, Hansenne (2000) recalls the important influence of vigilance and arousal on P300, and its frequent alterations in psychopathology. However, to date, no studies had investigated P3b on sub-clinically anxious subjects. We interpret this effect of anxiety on P3b as a way to overcome the deficient emotional appraisal (on N300), leading to a more salient conscious processing.

To summarise, anxious individuals display a faster detection of deviant stimuli. The main interest of our study is to define the neurophysiological correlates of this general enhanced processing. Contrary to what we can expect from behavioural studies, its origin does not seem to be of an attentional nature, since we show that subjects do not differ on attentional resources allocated to the stimuli (no effect of group on the N2b component). While anxiety does not effect upon the basic analysis of the face-stimulus (P100, N100, N170) or the attentional resources allocated to the task (N2b/P3a), it modulates the emotional load of the stimulus (N300), and the decision-making process of answer-preparation (P3b). We propose that anxious individuals allocate less resources to direct evaluation of the emotionality of the stimuli (decreased N300), but increase their conscious processing, associated to an accelerated decision-making, indexed by the P3b.

Ecstasy Users

Ecstasy (3,4 - methylenedioxymethamphetamine) or MDMA is a popular recreational drug among young people because of its proprieties of mood enhancement, especially in discotheques. This drug benefits from the widespread idea that its use is quite safe (Dowling, McDonough, & Bost, 1987). However, during the last few years, many researchers have investigated the damages generated by MDMA. A great part of MDMA studies have been conducted on animals (rodents, dogs, large variety of primates) and many of

those studies concern MDMA toxic and long-lasting effects on brain serotonin (5-HT) neurons (Steele, McCann, & Ricaurte, 1994 for a review). Nevertheless, the applicability of those findings on humans have been contested for several reasons: (1) the doses used in animal studies are much higher than the ones taken by humans; and (2) the drug administrations (injection versus pills) differ between animals and humans and there are potential species differences (see Ricaurte, Yan, & McCann, 2000 for a discussion). As a consequence, a recent review of the literature suggests that the impact of MDMA consumption on human cognition is not yet clearly circumscribed (Mejias et al., 2005). Indeed, current neuroimaging studies on humans have not been able, at least up to now, clearly to define whether MDMA consumption automatically leads to cognitive impairments.

Due to the ever-increasing problem of drug abuse among young people and adolescents (Neiman, Haajaniemi, & Hillbom, 2000), it seems particularly relevant to clarify whether MDMA users show cognitive deficits. In the present study, we choose to confront MDMA users and controls non-abusers to the same variation of the visual oddball paradigm as the one used in the previous study, in which participants were confronted with one frequent stimulus (a neutral face) and two deviant stimuli they have to detect as quickly as possible (a happy and a fearful face). We know that emotions are important in our everyday life in social interaction, adjustment and coordination of our behaviour with respect to others. Failure to adequately communicate one's emotional and motivational state and/or adequately perceive the internal state of others is likely to result in interpersonal and personal problems. We used then emotional faces in order to increase the ecological validity of our stimuli.

ERPs were recorded in 14 ecstasy users (MDMA users) and 14 paired control participants. MDMA users were recruited. Both groups had to answer a questionnaire that asked to list the different drugs they were presently consuming or had been consuming. Participants had to report the quantities and frequencies of drug consumption, when they started and for how long they stopped using drug(s) if they did stop. We didn't reveal that we were looking for participants exclusively using MDMA. This was only partially possible as many MDMA users also use cannabis. Both groups were paired on age, depression, anxiety and cannabis consumption.

At the behavioural level, it was shown that fear is detected faster than happiness in both groups of participants. However, control participants are globally faster than MDMA users to detect rare stimuli, and longer response latencies were observed in High-MDMA users (consumption of more than 100 pills) as compared to Low-ones.

At the neurophysiological level, the pattern is clear for normal controls, and it conforms to what has already been described in the literature (see for

instance, Campanella et al., 2004). Due to more salient physical differences, fear stimuli are detected faster than happy ones, and ERP correlates of this behavioural effect are defined by a delay in the P3b component (reflecting the response-related stage), that originates in the greater attentional resources (reflected by a N2 of shorter latency onset) devoted to fearful faces. However, the situation is different when MDMA users are considered. First, it was shown that MDMA users displayed longer latencies than normal controls to detect rare stimuli. This is neurophysiologically indexed by a delayed P3b component (mean latencies for MDMA: 471 ms and for CONTROLS: 433 ms). Second, even if fearful stimuli were detected faster than happy ones in both groups, it is suggested in the present study that *this effect did not originate at the attentional level in MDMA users*. Indeed, there was no latency effect on the N2 component when happy and fearful faces were compared in MDMA group (Fear: 248 ms; Happy: 250 ms), but only an effect on the P3b component (Fear: 460 ms; Happy: 484 ms).

In other words, the present data suggest that, in normal controls, the behavioural effect that consists in detecting more rapidly fearful faces than happy ones originates at the attentional level of the information-processing system (delayed N2 extending to delayed P3b), whereas it is postponed to the decisional level in MDMA users (only delayed P3b). We suggest that this difference originates in MDMA neurotoxic effect, and that this neurotoxicity particularly affects attentional processes (neurophysiologically indexed by the absence of effect on the N2 component). This is particularly important, as previous studies investigating the effect of MDMA consumption on cognition have been mainly focused on impairments for different aspects of memory, central executive functions, reasoning and semantic recognition (Montoya, Sorrentino, Lukas, & Price, 2002 for review). The present ERPs study suggests that the cognitive deficits due to MDMA abuse could be due to an earlier deficit situated at the attentional level of information processing. Note that this attentional interpretation could also account for the fact that normal controls were faster to detect deviant stimuli than MDMA users. This is in perfect agreement with a recent study of McCardle, Luebbers, Carter, Croft, & Stough (2004), showing, at a behavioural level, that MDMA users are more easily distracted and are less efficient at focusing attention on complex tasks. By using ERPs, the present study furnishes preliminary data suggesting that the use of MDMA could lead to attentional deficits, which may underlie more severe cognitive alterations.

Chronic Schizophrenia

Disturbances in the perception of facial emotion are amongst the most pervasive aspects of schizophrenia impairments in interpersonal communi-

cation (Suslow, Roestel, Ohrman, & Arolt, 2003). Many studies pointed out that schizophrenic patients show a generalised deficit in the recognition of both positive and negative EFE (Johnston, Katsikitis, & Carr, 2001), and exhibit diminished observable facial expressiveness in response to emotional stimuli (Kring, Kerr, Smith, & Neale, 1993). However, the factors underlying these deficits in performance are not well understood (Sachs, Steger-Wusche, Kryspin-Exner, Gur, & Katschnig, 2004).

With this in mind, we used an emotional oddball design, in which participants were confronted with one frequent stimulus (a neutral face) and four deviant ones they had to detect as quickly as possible by pressing on a key button with their right finger. Deviant faces changed either on identity (different identity, neutral expression), or on emotion (same identity, happy, fearful or sad expression). The neutral face used as frequent stimulus was then always the same during a block of stimuli (100 stimuli, with 76 frequent and 24 rare stimuli). Fourteen inpatients (5 females) meeting DSM-IV criteria for schizophrenia were recruited from the Psychiatric Sans-Souci Hospital (Brussels, Belgium) and participated to the study. Symptoms were rated immediately prior to testing using the Positive and Negative Syndrome Scale (PANSS) (Kay, Fisbein, & Opler, 1987). The sample of 14 patients was split in two subgroups (n=7) of "low symptom severity" vs. "high symptom severity" schizophrenics on the basis of their PANSS score (general psychopathology scale) (Campanella et al., in press). The two subgroups significantly differed on the PANSS, but did not differ on their level of medication, nor on duration of hospitalisation. Moreover, in order to assess potential statistical differences between the low- and high-groups, both subgroups of schizophrenic patients were compared to a group (n=7) of normal control subjects, so that 21 participants took part in our study, i.e. 7 normative people, 7 patients with low PANSS scores, and 7 with high PANSS scores. Healthy control subjects (all right-handed, no psychiatric disease and normal-to-corrected vision) were selected from the author's acquaintances in order to match the two schizophrenic subgroups, so that the three subgroups were matched on age and on the 13-items Beck Inventory Depressive Scale, as affective disorders could alter emotion perception.

At a behavioural level, results showed that, as described in previous studies, the fear deviant face is the fastest to be detected in each subgroup. Deviant faces were more quickly detected by normal participants as compared to low- and high-patients, assessing the greater difficulty for schizophrenic patients to detect deviant faces. If this heightened difficulty to process emotional facial information is classically described in the literature, this increase of response latencies among our three subgroups could also be linked to levels of medication. However, this is unlikely as no positive correlations were found between medication and latencies of response for each deviant face.

At a neurophysiological level, the P3b component, generally referred to later decisional "response-related" stages, showed decreased amplitudes for the High-group as compared to the Low- and Control-groups (as classically described in ERP studies on schizophrenia). More interestingly, behavioural data suggest that normal subjects detect deviant faces more quickly than do patients from the low- and high-groups. This is in perfect agreement with P3b latencies, as statistical analyses showed that the control-group has an earlier P3b maximum peak latency as compared to both Low- and High-schizophrenic groups. However, in agreement with Foxe et al. (2005), deficient early processes may underlie the failure of later "higher-level" processes. With this in mind, we compared the N170 generated in response to different deviant faces in normal vs. low- and high-patients with schizophrenia. A reduction of the N170 component was observed in high-schizophrenic patients as compared to low- and control ones, giving more support to the idea that the N170 decrease is linked to the severity of the schizophrenic trouble. As the N170 is functionally referred to the configural (structural) analysis of face components, this result has been interpreted as reflecting a perceptual early-stage dysfunction in face processing for patients with schizophrenia (Herrmann, Ellgring, & Fallgater, 2004; Campanella et al., in press). Furthermore, it is important to outline that medication is not correlated with N170 amplitudes, so that the N170 decrement could not be attributed to a pharmacological effect. But more interestingly, we also observed that this N170 reduction may be attributed to an earlier decrease of more general visual processing (indexed by a smaller P100 component). Indeed, the reduction of the N170 between low- and high-patients and between normal controls and high-patients was preceded by a deficit on the P100 amplitude, suggesting that the deficit of face processing (indexed by a decreased N170) may be due to an earlier alteration of general visual processing (decreased P100).

Consequently, the present study gives some support to the idea that the cognitive impairment seen in schizophrenia is not just due to deficits in higher order aspects of cognition but also encompasses significant deficits in early sensory processing, as the decrement of P100 and N170 components may underlie the decreased amplitudes and the higher onset latencies recorded for later P3b component. Indeed, the normal functioning of decisional (P3b) processes might be dependent on the fidelity of inputs from early visual ones, and that impairment of these critical inputs might underlie the failure of "higher-level" processes in schizophrenic people.

Conclusions

The principal aim of these studies was to define whether the deficits in the recognition of emotional facial expressions in some psychopathological conditions are situated at the attentional, perceptive or executive levels, and to index these deficits at the neurophysiological level.

Many studies have shown deficits in emotion recognition by psychiatric populations, and many ERP studies have linked this deficit with P300 (P3b) alterations (see Hansenne, 2000 for a review). By using an ERP emotional oddball task, our principal aim was to confront patients with complex stimuli (faces), for which they have (or could have) some processing difficulties, in order to localise where in the information-processing stream the deficit originates.

By presenting the above examples, we intended to show that, if previous studies have shown for generalised anxiety disorder, as well as for drug abuse or schizophrenia, P300 alterations, the processes leading to such a disturbance could vary from one population to the other. Indeed, the three studies we briefly described showed P3b alterations. However, if anxiety only modulates P3b (and not ERP components before 300 ms), ecstasy use also underlies attentional impairment (N2 alteration) while long-lasting schizophrenia also suggests general cognitive processing decline (P100, N170 decreases). Therefore, it seems particularly important in future ERP studies to investigate all the ERP components, and not to limit 'a priori' investigations to the P300 component. Understanding the functional origin of these deficits and their neural correlates will help us to have a better understanding of the clinical symptomatology of these patients, the final goal being to optimise our therapeutical approach.

Indeed, if we consider specifically the first study on anxious and non-anxious participants, we showed that, contrary to behavioural studies' expectations, anxiety does not modulate attentional components (N2/P3a) but well later 'decisional' ones (P3b). This seems to us particularly important as it can orient the way therapy should proceed to alleviate anxious state. Indeed, if these results are confirmed in further studies, they suggest that anxious people are not 'hypervigilant' to threatening information, but mainly have troubles to manage or disengage from these stimuli (Koster, Verschuere, Crombez, & Van Damme, 2005).

We are aware that these results should be considered cautiously, and that many other important questions should also be tackled, such as (1) the face-specificity of these results; (2) the amodality of these effects; and (3) the neural networks underlying these effects. Indeed, for instance, if the perception of stimuli within single sensory modalities begins to be well known, very little is known about the neural mechanisms by which the brain is able

to establish relationships between sensory events and how it integrates them into a unified representation in order to interact properly with the objects of our environment. Cross-modal interactions between different cortical areas are one of the main cerebral processes contributing to our daily adapted behaviours. These processes begin now to be well known in healthy subjects (e.g., Joassin, Maurage, Bruyer, Crommelinck, & Campanella, 2004), and define a promising way for future research in psychopathological populations. Brain research on mental illnesses has made substantial advances in recent years, and this should go on if complementary techniques (fMRI, ERPs) were used with a convergence of efforts from multiple domains such as psychiatry, cognitive psychology, neuropsychology, i.e. neurosciences.

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