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Impaired decision making in schizophrenia and orbitofrontal cortex lesion patients

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ABSTRACT

Background: The aim of this study was to examine impaired decision making in patients with schizophrenia and in patients with orbitofrontal cortex lesions.
Methods: Schizophrenia patients ($N=21$), healthy controls ($N=20$) and an independent group of orbitofrontal patients ($N=10$) underwent a computerized version of the "Regret Gambling Task". Participants chose between two gambles, each having different probabilities and different expected monetary outcomes, and rated their emotional states after seeing the obtained outcome. Regret was induced by providing information about the outcome of the unchosen gamble.
Results: Healthy controls reported emotional responses consistent with counterfactual reasoning between obtained and unobtained outcomes; they chose minimizing future regret and were able to learn from their emotional experience. In contrast, orbitofrontal patients and schizophrenia patients with prominent positive symptoms did not report any regret and did not anticipate any negative consequences of their choices. Our results demonstrate first the presence of very different behavioural deficits within the spectrum of schizophrenia patients which may have contributed to the discrepancies observed in previous studies. Second, the results suggest that a subgroup of schizophrenia patients might have an orbitofrontal dysfunction, in fact, schizophrenia patients with positive symptoms have a behavioural dysfunction analogous to that of the orbitofrontal patients.
Conclusion: Schizophrenia patients with prominent positive symptoms were unable to integrate cognitive and emotional components of decision making which may contribute to their inability to generate adaptive behaviours in social and individual environments.

1. Introduction

Recent findings in clinical neuroscience have emphasized the critical role of the orbitofrontal cortex (OFC) in complex decision-making processes (Bechara et al., 2000; Rolls, 2004). The OFC is involved in the evaluation of relative reward values (Breiter et al., 2001; O'Doherty et al., 2001; Padoa-Schioppa and Assad, 2006; Tremblay and Schultz, 1999), and is crucial for assigning affective values to choice alternatives (Kringelbach and Rolls, 2004; Kringelbach, 2005). Patients with OFC lesions show poor social and individual decision-making skills, and abnormal anticipatory emotional responses (Bechara et al., 1994, 1997).

Evidence from brain imaging studies (Pantelis et al., 2003; Quintana et al., 2003) has suggested OFC abnormalities or dysfunctions in schizophrenia patients. The OFC dysfunction might contribute to social and individual maladaptive

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behaviours observed in schizophrenia patients (Chemerinski et al., 2002; Shurman et al., 2005).

OFC lesion patients and some subtypes of schizophrenia patients might be unable to adequately represent the context of choice and to assign affective values to the consequences of their decision. The 'representational' functions of the OFC (in defining preferences of choice (Padoa-Schioppa and Assad, 2006) or assigning relative values (Tremblay and Schultz, 1999)) are clearly different from the 'processing' components of decision making (e.g., working memory, task switching), usually attributed to other parts of the prefrontal cortex (i.e. the dorsolateral prefrontal cortex (DLPFC)).

In this study, we expected to be able to make a clear distinction between different types of schizophrenia patients, based on the nature of their decision-making impairments; and to distinguish patients with a 'representational' dysfunction (i.e. analogous to OFC lesion patients) versus patients with a dysfunction in the 'processing' component of decision making. Moreover, this distinction might explain conflicting evidence and the high variability in individual performance of schizophrenia patients in decision-making tasks, such as the Iowa gambling task (IGT) (Ritter et al., 2004; Wilder et al., 1998).

In order to study hypothetical OFC dysfunctions in schizophrenia, we used a gambling task where the involvement of the OFC has previously been demonstrated in patients (Camille et al., 2004) and neuroimaging studies (Coricelli et al., 2005). This task is based on a recent theory of decision-making called decision affect theory (Mellers et al., 1997) that emphasizes the role of anticipated affective impact of outcomes in guiding choices, and the effects of comparisons with alternative outcomes, i.e. counterfactual effects (Roese and Olson, 1995). For instance, regret is elicited by a counterfactual comparison between the outcome of a choice and the better outcome of a foregone rejected alternative (what might have been). The key adaptive role of counterfactual emotions, like regret, is to bring into the evaluation of our future decisions the information on the outcome of our alternative choices previously rejected (Coricelli et al., 2007). Thus, the expected finding of impairment in experiencing and anticipating regret in schizophrenia patients will clarify an important feature of their maladaptive behaviour. We made the additional hypothesis that the lack of regret is independent from generic impairments in executive and motivational functions assessed respectively using neuropsychological tests and an anhedonia scale.

2. Materials and methods

2.1. Subjects

Fifty-one subjects participated in the study (21 schizophrenia patients, 20 healthy controls and an independent group of 10 patients with lesions in the orbitofrontal cortex). All the subjects gave written informed consent and the study was approved by the Ethical Committee of Upper *Normandy*.

2.1.1. Schizophrenia patients (SCZ)

Twenty-one schizophrenia patients (DSM IV criteria), ranging from 23 to 63 years old, participated in the study. The mean duration of the disease was 12.1 years (9.7 SD). They were recruited from our psychiatric hospital. At the time of assessment, all patients had been stabilized on antipsychotic medication for at least 30 days: 11 were taking atypical antipsychotic drugs (clozapine in 2 cases) and 10 were receiving typical neuroleptics. Psychiatric assessments included the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1986), and the Schedule for the Deficit Syndrome (SDS) (Kirkpatrick et al., 1989; Ribeyre et al., 1994). Schizophrenia patients were classified into different subgroups (12 deficit and 9 non deficit patients using the SDS; 7 negative (all were deficit patients), 7 positive and 7 mixed using the PANSS). Using the PANSS, patients were classified into negative, mixed and positive subgroups. The criteria for being in the negative subgroup on the PANSS were the following: at least three scores ≥ 4 on the negative subscale and less than three scores ≥ 4 on the positive subscale of the PANSS. The criteria for being in the positive subgroup on the PANSS were the following: at least three scores ≥ 4 on the positive subscale and less than three scores ≥ 4 on the negative subscale of the PANSS. Others belong to the mixed group. The patients were also categorized into deficit and non deficit subgroups using the French translation of the SDS, a semi structured interview which provides specific criteria for assessing the presence of negative symptoms, the duration of these symptoms and whether the symptoms are primary or secondary.

2.1.2. Healthy controls (H)

Twenty healthy controls ranging in age from 22 to 53 years were recruited from hospital employees and students.

2.1.3. Independent group of patients with orbitofrontal cortex lesion (OFCL)

Ten patients with lesions of the orbitofrontal cortex (28–75 years), recruited from the Neurology and Neurosurgery departments, were included. The types of lesions were: meningioma ($N=2$), venous angioma ($N=4$), traumatic lesion ($N=2$), and unexplored tumors ($N=2$). The mean time elapsed since the patients had sustained their lesion was 5.8 years (individual values: 2; 1; 1; 4; 5; 1; 25; 10; 1; and 8). All the lesions were still present at the time of the test.

Exclusion criteria were: for controls and OFC lesion patients: (i) a history of current or past psychiatric disorder (DSM IV), (ii) a family history of psychiatric disorder; for controls and schizophrenia patients: (iii) a history of neurological illness or head injury with loss of consciousness; and for all subjects: (iv) a history of substance abuse or pathological gambling (DSM IV).

2.2. Materials and procedures

All subjects underwent the Chapman Social and Physical Anhedonia Scale (Chapman et al., 1976), the Counterfactual Inference Test (CIT), and the Regret Gambling Task (RGT).

2.2.1. The Counterfactual Inference Test

We measured counterfactual thinking (comparing "what is with what might have been") using a four item scale, based on two variables: normality and goal proximity (Roese and

Olson, 1995; for review Zeelenberg and Van Dijk, 2004). This test assumes that counterfactuals are more pronounced when the relationship between previous actions and outcome is abnormal, or when there is increased physical and temporal proximity between the alternative situations. Examples of items are: (i) “Ann gets sick after eating at a restaurant she often visits. Sarah gets sick after eating at a restaurant she has never visited before. Who is more upset about their choice of restaurant?” (ii) “Ed is attacked by a mugger only 10 feet from his house. James is attacked by a mugger a mile from his house. Who is more upset by the mugging?”. In a normal population target responses are: “Sarah” for the first item, and “Ed” for the second item. The scale ranges from 0 (no counterfactual thinking) to 4 (perfect ability in counterfactual thinking).

2.2.2. The Regret Gambling Task

The Regret Gambling Task (RGT) required subjects to choose between two gambles (resembling “wheels of fortune”, see Supplementary Figure 1) (Camille et al., 2004). Each subject sat in front of a computer. Two wheels appeared on the computer screen (gamble 1 and gamble 2). Each wheel had two sectors associated with different value pairs. The size of each sector indicated the outcome probability. Each individual gamble presented paired combinations of the following values: +50, −50, +200, and −200 (units correspond to cents of Euros), associated with different outcome probabilities (0.8, 0.2, and 0.5). Displayed and actual probabilities were identical (see Supplementary Table 1). The preferred gamble was indicated by the subject via a left or right button-press (choice period). A rectangular box appeared around the selected wheel. A rotating arrow then appeared in the center of the gamble circle (wait period), stopping after few seconds. The outcome of the selected gamble, indicated by the resting position of the arrow, resulted in financial gain or loss (outcome period). At the end of each trial all participants were asked to indicate their emotional response to the outcome of their choice (emotional scale ranging from −50, extremely sad, to +50, extremely happy). Two types of trials were performed. In the “partial feedback” (30 trials), the outcome (and spinning arrow) was apparent for the selected gamble alone. We predicted that in this condition, the unfavorable comparison (upward counterfactual) between the obtained outcome and a more favorable unobtained outcome might elicit disappointment. In the “complete feedback” (30 trials), spinning arrow and outcome of both the selected and unselected gambles were available to the participants. Complete feedback trials enabled the subject to judge not only the financial consequence of their decision (disappointment), but also the outcome that would occur had they selected the other option (regret effect). Favorable comparisons (downward counterfactual) determine elation or relief depending on the context, partial or complete feedback, respectively. The subjects were paid according to the outcome of the chosen gamble with stacks of coins (10×5 or 10×20 cents) in order to maintain a high motivational level. Money was given back in case of losses. For ethical reasons, we were not able to pay different amounts to participants; thus, in practice, each participant earned 15 Euros.

2.2.3. Neuropsychological assessment

Cognitive functions were evaluated in schizophrenia and in OFCL patients during the week following the gambling task. The IQ was measured using the WAIS III (Wechsler Adult Intelligence Scale), and executive functions were assessed by a trained neuropsychologist using four tasks: (i) the Stroop Color–Word interference test; (ii) the Trail Making Test (TMT B); (iii) the Verbal Fluency test; and (iv) the Wisconsin Card Sorting Test (WCST).

2.2.4. The scales for social and physical anhedonia

Anhedonia is the lack of interest and the withdrawal from pleasant activities. Chapman (Chapman et al., 1976; French translation Assouly-Besse et al., 1995) distinguished two types of anhedonia, physical and social anhedonia. Physical anhedonia is expressed by the inability of experiencing physical pleasure, such as the pleasure of touching, eating, smelling etc.; while, social anhedonia refers to the inability of experiencing interpersonal pleasure, such as the pleasure of being and talking with others. We measured physical (40 items) and social anhedonia (48 items) with items in true–false format.

2.3. Statistical analyses

The statistical analysis was conducted using the statistical software package Stata (Stata Corp, College Station, TX, Release 9/SE). Non-parametric tests were applied on the data sets. The significance of the difference between behavioural variables, subjective evaluations is estimated with the Wilcoxon signed rank test (non-parametric test); the hypothesis tested is that the distribution of two random variables for matched pairs is the same. Between groups (H vs. SCZ) differences were tested using Kruskal–Wallis equality-of-populations rank test. Analysis of covariance showed that the differences in mean scores for each variable of interest were not affected by gender and age between groups (H and SCZ) effects. We used a correlation analysis (Pearson correlation with Bonferroni adjusted significance level) for the variables of interests. Due to substantial differences in terms of demographical characteristics and neuropsychological tests, we did not perform any direct statistical comparison including the OFCL group.

2.3.1. Analysis of choice behaviour

We tested (by regression analysis, using a panel logit procedure with individual random effect,) a model of choice that incorporates the effects of anticipating disappointment and regret in addition to the maximization of expected values (see Table 1). The panel data analysis takes each subject as the unit and the trial as time. The model estimated is the random effects model, and the parameters are estimated by maximum likelihood.

3. Results

3.1. Neuropsychological tests

Results from the neuropsychological tests are shown in Supplementary Table 2.

Table 1
Choice behaviour (regression analyses, panel logit with individual random effect).

Variable name	Healthy controls	Schizophrenia patients (SCZ)	Positive SCZ	Negative SCZ	OFCL patients
	$N=20$	$N=21$	$N=7$	$N=7$	$N=10$
Constant	0.17 (0.13)	0.18 (0.127)	0.21 (0.20)	0.1 (0.30)	0.23 (0.13)
d	−0.0025 (0.002)	−0.0023 (0.0015)	−0.00065 (0.0024)	−0.011 (0.004) [a]	−0.003 (0.002)
r	0.0073 (0.001) [b]	0.0058 (0.0011) [b]	0.0013 (0.0016)	0.012 (0.003) [b]	0.0006 (0.001)
e	0.0316 (0.004) [b]	0.027 (0.003) [b]	0.024 (0.004) [b]	0.049 (0.009) [b]	0.011 (0.003) [b]

Note: numbers indicate coefficients, and standard errors in parentheses. SCZ: schizophrenia patients, OFCL: orbitofrontal cortex lesion patients.
Positive and Negative refer to schizophrenia patients categorization using the PANSS.
Table 1 regression analysis of choice behaviour in the regret gambling task. Given that $\Pr(g_1)=1-\Pr(g_2)$, where $\Pr(g_{1it})$ and $\Pr(g_2)$, are the probabilities of choosing gamble 1 (g_1) and gamble 2 (g_2), respectively; we define the probability of choosing g_1 in terms of three factors affecting the choice: anticipated disappointment (d), anticipated regret (r), and expected value (e). Let us call x_1, y_1, and x_2, y_2 the two possible outcomes of the first (g_1) and the second (g_2) gambles, respectively, with $x_1>y_1$, and $x_2>y_2$. The probability of x_1 is p and the probability of y_1 is $(1-p)$. The probability of x_2 is q and the probability of y_2 is $(1-q)$. The model is $\Pr(g_{1it})=1-\Pr(g_{2it})=F[d_{it}, r_{it}, e_{it}]$. where i is individual and t is time. The dependent variable, "choice of g_1," is 1 when the subject chooses g_1 and 0 when the subject chooses g_2. Independent variables are d, r, e, where anticipated disappointment choosing g_1, $d=(|y_2-x_2|(1-q))-(|y_1-x_1|(1-p))$; anticipated regret choosing g_1, $r=|y_2-x_1|-|y_1-x2|$; and maximizing expected value choosing g_1, $e=\mathrm{EV}(g_1)-\mathrm{EV}(g_2)=(px_1+(1-p)y_1)-(qx_2+(1-q)y_2)$. EV, expected value. Panel logit procedure with individual random effects yields the following results.
[a] $p<0.05$.
[b] $p<0.0001$.

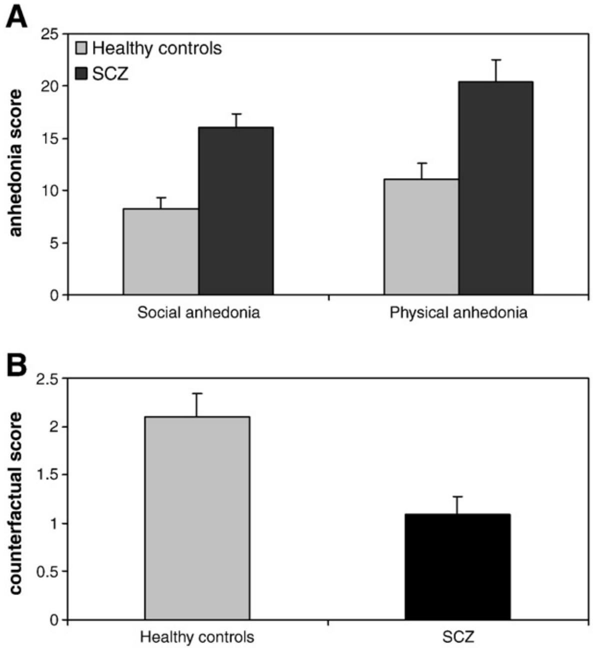


Fig. 1. A. *Social and physical anhedonia.* Mean values (±standard error) of a measure of social and physical anhedonia for control subjects and schizophrenia patients (SCZ). Patients with schizophrenia showed significantly higher levels of social and physical anhedonia than control subjects. B. *Counterfactual thinking.* Mean values (±standard error) of a measure of counterfactual thinking for groups of subjects: normal controls and schizophrenia patients (SCZ). Schizophrenia patients showed a lower level of counterfactual score than control subjects.

3.1.1. Social and physical anhedonia

We found a difference between the schizophrenia patients and healthy control subjects in terms of the level of social anhedonia (Fig. 1A and Supplementary Table 2, Kruskal–Wallis test $p<0.001$) and physical anhedonia (Fig. 1A Kruskal–Wallis test, $p<0.01$). Results suggested that patients with schizophrenia were impaired in physical and social anhedonia. Notably, schizophrenia patients with negative symptoms (PANSS) were more impaired in social anhedonia compared to patients with positive symptoms (Kruskal–Wallis test, $p<0.05$).

3.1.2. Counterfactual Inference Test

Kruskal–Wallis rank sum test revealed a significant difference between healthy controls and schizophrenia patients (Fig. 1B and Supplementary Table 2, Kruskal–Wallis test, $p<0.01$). We did not observe any difference in counterfactual score between subgroups of schizophrenia patients; for instance there was no difference between patients with positive symptoms (PANSS) and other schizophrenia patients (Kruskal–Wallis test, $p=0.35$). This result reveals an important difference between the schizophrenia and the normal control participants in terms of their ability to reason counterfactually.

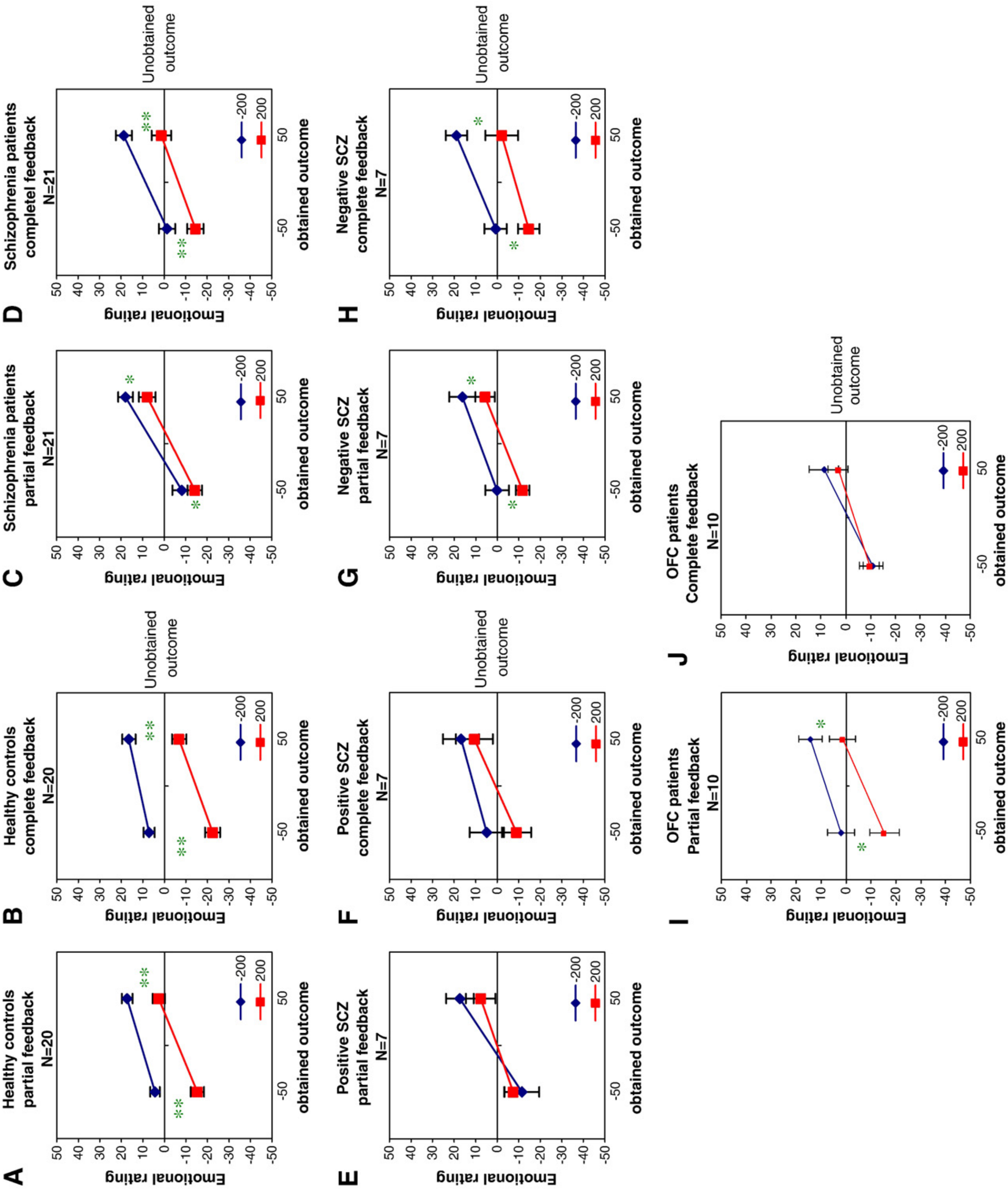
3.2. Behavioral results

During the Regret Gambling Task we recorded the subjects' choice behaviour and the emotional response to the outcome of their choice. We first analyzed the emotional evaluation of the outcome of choice, and then we conducted a further analysis on the choice behaviour in order to investigate whether emotional experience would be predictive of decisions made in the gambling task.

3.2.1. Emotional evaluation

Healthy controls showed a pattern of emotional ratings consistent with the presence of disappointment (in partial feedback condition) and regret (in complete feedback condition). For instance, controls evaluated as more negative a loss of −50 (or a win of +50) when the alternative outcome was +200 compared with an alternative outcome of −200. As shown in Fig. 2, this effect was 'amplified' in the complete feedback condition when the subjects might have felt responsible for the wrong choice (regret effect). The OFCL patients did not report any regret (Fig. 2J), as also shown in Camille et al. (2004). The schizophrenia patients, considered as a single group ($N=21$) showed a pattern of emotional evaluation similar to that of normal controls (Fig. 2C and D).

Despite this observed similarity, the behaviour of the schizophrenia patients was primarily heterogeneous. A subgroup of schizophrenia patients with positive symptoms demonstrated a pattern of emotional ratings (Fig. 2F) similar to the one of the OFCL patients (Fig. 2J), thus they did not


A
Healthy controls partial feedback N=20
B
Healthy controls complete feedback N=20
C
Schizophrenia patients partial feedback N=21
D
Schizophrenia patients completel feedback N=21
E
Positive SCZ partial feedback N=7
F
Positive SCZ complete feedback N=7
G
Negative SCZ partial feedback N=7
H
Negative SCZ complete feedback N=7
I
OFC patients Partial feedback N=10
J
OFC patients Complete feedback N=10
Emotional rating
obtained outcome
Unobtained outcome
-200
200

report any regret. In contrast, the group of schizophrenia patients with negative symptoms behaved like control subjects (Fig. 2H). Similarly, schizophrenia patients classified as non deficit showed a pattern of emotional evaluation analogous to the OFCL patients.

3.2.2. Choice behaviour

Results based on regression analysis (Table 1) showed that healthy controls chose anticipating regret and maximizing the expected values, while OFCL patients did not anticipate regret. Schizophrenia patients as a whole ($N = 21$) showed a pattern of behaviour similar to that of the healthy controls. When schizophrenia patients were analyzed according to positive or negative symptoms, we observed that the group of patients with positive symptoms did not anticipate regret, thus they chose in the same way as the OFCL patients; whereas, schizophrenia patients with negative symptoms chose maximizing expected values and maximizing risk (i.e., the coefficient of the variable d is significant with a negative sign, thus they more frequently chose the gambles with the higher variance between the two outcomes). In the same way, a group ($N = 9$) of non deficit patients did not anticipate regret (the coefficient of r was not significant, $p = 0.1$), while patients classified as deficit behaved similarly to normal control subjects (the coefficients of r and e were significant, both $p < 0.0001$).

3.3. Correlation analysis

Results based on correlation analysis (see Supplementary Table 3, data from patients with schizophrenia, $N = 21$) showed no significant correlations between the neuropsychological (WCST, Stroop test, Trail Making Test, Fluency test), and the cognitive and behavioural measures of interest (anhedonia, counterfactual thinking, and regret effect).

4. Discussion

Our results showed: (1) the presence of different decision-making deficits within the spectrum of schizophrenia patients which may have contributed to the discrepancies observed in previous studies (for review, see Dunn et al., 2006), and (2) they suggest that a subgroup of schizophrenia patients might have an OFC dysfunction. Indeed, when the subgroups of schizophrenia patients were compared, we observed major differences between positive (or non deficit patients) and negative (or deficit patients) subgroups. The former group exhibited a pattern of behaviour analogous to that of the OFCL patients while the latter groups behaved in a way similar to healthy controls. However, negative and deficit patients exhibited risk seeking behaviour in our study. This latter result is consistent with previous findings reported using the Iowa Gambling Task (Ritter et al., 2004), where schizophrenia patients more frequently selected cards from the two decks with low frequency and high magnitude of punishment, thus the more risky ones. Moreover, Rodriguez-Sanchez et al. (2005) reported a negative correlation between the severity of negative symptoms and the IGT performance.

The nature of the impairment that positive or non deficit patients exhibited in the Regret Gambling Task was not due to purely executive dysfunctions, such as working memory deficit (possibly due to DLPFC dysfunction). In fact, in our task there was no need for loading information, considering that all the information required for making a decision and evaluating the outcome of a choice was constantly available to the subjects on the computer screen. Moreover, in our study, regret effect was not correlated with any standard measures of executive functions. Similarly, in previous studies, performance deficits on the IGT were not related to the deficits on neurocognitive tasks that were sensitive to DLPFC functioning (Bechara et al., 1998; for review see Brand et al., 2005; Kestler et al., 2006; Ritter et al., 2004; Rodriguez-Sanchez et al., 2005; Shurman et al., 2005; Wilder et al., 1998).

Our task was not directly sensitive to the involvement of purely emotional brain substrates, such as the amygdala. As previously shown by Camille et al. (2004) patients with amygdala lesions performed normally in the Regret Gambling Task. Furthermore, schizophrenia patients with negative symptoms, impaired in more basic emotional processing (and also more impaired in anhedonia), performed normally in our gambling task. Notably, also the level of anhedonia does not seem to play an important role in our task. We found that the behavioural responses in the Regret Gambling Task were not correlated with measures of physical and social anhedonia.

In fact, as demonstrated in previous studies, our task was extremely sensitive to the OFC lesions (Camille et al., 2004). The dysfunction of the OFC determines the inability to correctly represent the contexts of choice such as the relative values of choice alternatives (Tremblay and Schultz, 1999), preferences (Padoa-Schioppa and Assad, 2006) and the consequences of choice (Camille et al., 2004). The OFC has a peculiar representational function, which clearly differentiates, at a neurofunctional level, this region from other parts of the prefrontal cortex (e.g., DLPFC) commonly associated with processing function (Dunn et al., 2006). The OFC is an interface of emotion and cognition, and mechanisms such as counterfactual thinking (impaired in schizophrenia patients, as shown in our data) may participate in the control of emotional experience.

The results of our study suggested that schizophrenia patients with positive symptoms, similarly to OFCL patients, might fail in the representational aspects of decision making (i.e. their inability to integrate emotional and cognitive components of decision making, and to correctly represent the decisional contexts in which they were involved). Disruption of the ability to generate affective representations

Fig. 2. *Lack of regret in schizophrenia patients with positive symptoms.* We plotted the mean emotional ratings for the two obtained outcome (−50 and +50) as a function of the foregone outcomes of −200 (blue) and +200 (red), in partial and complete feedback conditions, respectively. Data from: healthy control subjects (A and B), schizophrenia patients (C and D), schizophrenia patients classified as positive (E and F), negative (G and H) symptoms (PANSS), and orbitofrontal cortex lesion patients (I and J). Healthy control subjects reported disappointment and regret; orbitofrontal cortex lesion patients did not report disappointment neither regret; schizophrenia patients ($N = 21$) reported disappointment and regret. Schizophrenia patients with positive symptoms did not report disappointment neither regret; while patients with negative symptoms reported disappointment and regret. Wilcoxon sign rank test between the emotional ratings of the two unobtained outcomes (−200 vs. +200) for each obtained outcome (−50 or +50): $^{*}p < 0.05$, $^{**}p < 0.001$.

might also contribute to the abnormal pattern observed in schizophrenia patients during other gambling tasks (Lee et al., 2007; Shurman et al., 2005).

This study has several limitations. First, we acknowledge that we do not provide any direct neurofunctional or neuroanatomical evidence in favour of the OFC dysfunction in schizophrenia patients with prominent positive symptoms. Our methodology is limited to the use of a behavioural task (the regret gambling task) where the involvement of the OFC has been previously demonstrated (Camille et al., 2004; Coricelli et al., 2005). Second, the sample size of schizophrenia patients that we tested is not large, and its subgroups are quite small, thus, our conclusions should be confirmed by future studies.

5. Conclusion

For healthy control subjects, the experience of regret in our experimental task had a major impact on the process of choice, inducing them to choose avoiding the feeling of highly negative emotions. Schizophrenia patients with prominent positive symptoms were unable to feel regret, and to learn from what they could have obtained with a different choice. This impairment contributes strongly to the inability of these patients to generate adaptive behaviour in individual and social environments.

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Contributors

G Coricelli and M Larquet designed the study and wrote the protocol. G Coricelli and F Thibaut managed the literature searches and analyses. G Coricelli undertook the statistical analysis, G Opolczynski undertook the neuropsychological analyses and G Coricelli and F Thibaut wrote the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.schres.2009.11.010.

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