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ERPs of metaphoric, literal, and incongruous semantic processing in schizophrenia

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Abstract

The ability of schizophrenia patients to access metaphorical meaning was studied on the basis of psycholinguistic models of metaphor processing. ERPs were recorded from 20 schizophrenic and 20 control participants who were asked to read metaphorical, literal, and incongruous sentences and to judge their meaningfulness. In all participants, incongruous endings to sentences evoked the most negative N400 amplitude, whereas literal endings evoked more negative N400 amplitude than metaphorical ones, consistent with the direct model of metaphor processing. Although the patients had ERPs patterns that were similar to controls, they exhibited a more negative N400 amplitude for all sentences, LPC amplitude reduction, and latency delay in both components. The results suggest that schizophrenics have no specific anomalies in accessing the meaning of metaphors but are less efficient in integrating the semantic context of all sentences—both figurative and literal.

Descriptors: Metaphor, Schizophrenia, Context processing, Event-related potentials, N400, LPC

Since the first clinical descriptions of schizophrenia, clinical practitioners have been interested in the difficulties experienced in interpreting the figurative meaning of expressions (Bleuler, 1911; Chaslin, 1912; Kraepelin, 1919/1971). Metaphor interpretation tasks are often used to evaluate language and communication disorders in schizophrenia. When asked to interpret: "Don't judge a book by the cover," patients often produce unusual interpretations (e.g., literal, concrete, idiosyncratic, and bizarre responses) such as: "You're not supposed to do that; you're supposed to read it. Just like the Holy Koran" (Kay, 1991; see also Benjamin, 1944; Carpenter & Chapman, 1982; Gorham, 1956; Marengo, Harrow, Lanin-Kettering, & Wilson, 1986; Shimkunas, Gunther, & Smith, 1967; Sponheim, Surerus-Johnson, Leskela, & Dieperink, 2003). The study of difficulties with recognizing metaphors by patients with schizophrenia has been traditionally based on the assumption that nonliteral language is a deviant form of language use and thus it requires qualitatively different processing mechanisms than literal language.

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The goal of the present study was to test more specifically the processing of metaphors in patients with schizophrenia by means of a specific experimental task designed to establish links between clinical observations, behavioral responses, and measures of brain activity.

Adopting the cognitive approach, several studies provide evidence that difficulties with recognizing metaphors in patients with schizophrenia could be explained in terms of the impairment of certain underlying cognitive processes such as abnormal and/or degraded semantic activation (Langdon, Coltheart, Ward, & Catts, 2002), a reduction of working memory capacities (Spitzer, 1997; Titone, Holzman, & Levy, 2002), or/and a deficit in the processing of semantic context (Chapman, 1960; Cutting & Murphy, 1990).

Spitzer, Lukas, Maier, and Hermle (1994) tested whether schizophrenia patients preferred the abstract or concrete meaning of metaphors using the semantic decision task (for details, see Spitzer, Weisker, Winter, Maier, & Hermle, 1994). In this task, metaphorical statements used as primes were followed by target words that were either concretely related to the last (or the most prominent) word of the metaphor, metaphorically related, or unrelated. In the healthy control subjects, both the concrete and abstract meanings produced a significant priming effect. In contrast, only a concrete priming effect was observed in schizophrenia patients. The authors explained the so-called "concretism" in schizophrenics by a combined dysfunctioning of associative semantic and working memory. This conclusion is based on a type of multiple-stage model of figurative processing. These models

share the conception that accessing the metaphorical meaning requires a greater load on working memory because it needs to be constructed during a later stage of processing (i.e., after literal meaning verification and rejection; Searle, 1979).

Titone et al. (2002) adopted a similar semantic priming task to test the influence of the literal plausibility of idioms on the schizophrenia patients' ability to access figurative meaning. The authors observed that patients exhibited reduced figurative priming for literally plausible idioms but intact figurative priming for literally implausible idioms. This type of selective difficulty with literally plausible idioms was viewed as resulting from a difficulty in inhibiting the literal interpretation, which was always computed from the idiomatic string. Titone et al. suggest that the results may reflect working memory limitations and/or a controlled-processing deficit in context processing in patients. This conclusion is based on the "configuration hypothesis" of figurative processing (Cacciari & Tabossi, 1988), which postulates that the reader/comprehender begins by processing the sentence in a literal way up to the point at which the context makes it possible to activate the figurative meaning. Thus, access to idiomatic meaning requires intact working memory capacities and efficient controlled context processing if the potentially confounding literal sense is to be inhibited (Titone et al., 2002).

These abnormal semantic processing mechanisms in schizophrenia patients (i.e., working memory, controlled processing, context processing) are consistent with other language–based studies (Cohen & Servan–Schreiber, 1992; Hardy-Baylé, Sarfati, & Passerieux, 2003; Kuperberg, McGuire, & David, 1998). However, the question of whether metaphor processing requires additional cognitive effort compared to literal sentence processing is still debatable.

In fact, many recent publications in the psycholinguistic field suggest that no special stage nor any literal maintenance is necessary for figurative understanding. The "direct processing model" assumes that figurative meaning can be computed directly from the information available in the communicative context (e.g., Gibbs, 1994; Glucksberg & Keysar, 1990). Furthermore, a growing body of research has challenged the view that figurative and literal language are really distinct and, instead, have considered them to exist on a continuum of conventionality (see Kazmerski, Blasko, & Dessalegn, 2003) and/or salience of meaning (Giora, 1997). These heterogeneous models share the assumption that literal and nonliteral language invokes the same mechanisms (Coulson & Van Petten, 2002); Giora, 1997; Kintsch, 2000; Wolff & Genter, 2000). In consequence, when correctly matched, literal and metaphorical sentences impose equal processing mechanisms. Difficulties in comprehension may be better explained in terms of task-related factors (i.e., the characteristics of the sentences and their surrounding context) and/or individual differences (especially verbal abilities and working memory capacities; Kintsch, 2001; Kazmerski et al., 2003) rather than by the traditional figurative/literal dichotomy.

Event-related brain potentials (ERPs) are an effective technique to study cognitive processes involved in the access of the metaphorical meaning. By tracking the time course of cognitive processing with a time resolution in the range of milliseconds, ERPs make it possible to observe how the brain constructs meaning in real time (Coles, 2003).

The ERPs technique involves recording at scalp level the neural activity operating in various areas of the brain, relative to a specific temporal event. In language comprehension, a negative component emerging between 250 and 500 ms after the presentation of a potentially meaningful event and peaking around 400 ms after stimulus onset (the N400) has been shown to vary systematically with the processing of semantic information. Kutas and Hillyard (1980) reported that incongruous words elicit more negative N400 amplitudes than words that are congruous in their context ("congruity effect"). In congruous sentences, the N400 negativity is negatively correlated with the cloze probability of the final word (Kutas & Hillyard, 1984), reflecting finer gradations of the semantic constraints imposed on the word (see Kutas & Van Petten, 1994). Many ERPs results suggest that both the immediate language context held in working memory and the context-independent relationships between items in long-term semantic memory affect the neural process reflected in the N400 (Kutas & Federmeier, 2000; Kutas, Federmeier, Coulson, King, & Múnte, 2000). The N400 amplitude is less negative if context integration of the words that occur in sentences is facilitated by the simultaneous activation of background semantic knowledge during processing of the context (for a more detailed review, see Kutas & Federmeier, 2000; see also Hagoort, Hald, Bastiaansen, & Petersson, 2004). The N400 is followed by a late positive complex (LPC or P600). Generally, it is thought to be related to a more general process of attention and decision making, successful comprehension (Coulson & Kutas, 2001) and "confidence with judgement" (McCallum, Barrett, & Pocock, 1989). Van Petten, Kutas, Kluender, Mitchinier, and McIsaac (1991) also suggest that the LPC indexes "the extended retrieval of semantic and episodic information and the integration of that information with the contexts of working memory" (p. 145). The functional relation between the N400 and the LPC is difficult to determine mainly because of the frequent temporal and spatial overlap between these two components during sentence processing (Curran et al., 1993). Some authors (Van Petten et al., 1991) argue that the N400 and the LPC reflect discrete processes, but others suggest that they reflect different phases of the same general integrative mechanisms (Halgren, 1990).

Very few ERP studies have been specifically designed to test metaphorical/literal sentence processing in normal subjects. Pynte, Besson, Robichon, and Poli (1996) were the first to report that nominal form metaphors ("an X is a Y") elicit a more negative N400 component than matched literal sentences and suggest that N400 amplitude may reflect the first accessed incongruous literal meaning of these metaphors. In their task, the introduction of a supportive context reduced the amplitude of the N400 recorded for these metaphors. Coulson and Van Petten (2002) compared ERPs when subjects read for comprehension three kinds of sentences graduated for the conceptual mapping difficulty: poetic metaphors (highest mapping level), literal mapping (intermediate mapping level), and simple literal sentences. The negativity of the N400 amplitude was increased gradually as a function of the increasing extent of the conceptual mapping involved in the construction of meaning, whether metaphorical or literal. Kazmerski et al. (2003) provided ERP-based evidence for individual differences in the ease of metaphorical access. Using a rapid metaphor inference task in conjunction with recorded N400 amplitude measures, these authors demonstrated the direct activation of the meaning of metaphors in a high IQ group, a lesser activation in a moderate IQ group, and no activation in a low IQ group.

On-line language processing in schizophrenia has been studied by recording ERPs in tasks requiring explicit or implicit processing of semantic relations and of sentence comprehension.

In general, more N400 amplitude abnormalities have been observed in schizophrenia patients when explicit semantic judgments have been required (Condray, Steinhauer, Cohen, van Kammen, & Kasparek, 1999; Grillon, Ameli, & Glazer, 1991; Mitchell et al., 1991; Strandburg et al., 1997), thus suggesting that schizophrenics' language dysfunction may at least partially reflect a difficulty in actively directing attention. A consistent result of several studies that tested the processing of semantic relationships using a word priming paradigm in schizophrenia patients is the more negative N400 amplitude in the related word condition, compared with normal N400 on unrelated words. The various authors have suggested that the first word does not provide a sufficient context to reduce the N400 amplitude on the second word of congruous pairs (Condray et al., 1999; Koyama et al., 1991; Strandburg et al., 1997). ERPs studies of sentence level processing in schizophrenia reported a general increase in N400 amplitude for all sentence endings regardless of the meaning of the sentence (Nestor et al., 1997; Niznikiewicz et al., 1997; Niznikiewicz et al., 2004; Salisbury, O'Donnell, McCarley, Nestor, & Shenton, 2000; Salisbury, Shenton, Nestor, & McCarley, 2002).

One very consistent result found in ERP language processing studies is the prolongation of N400 latency in schizophrenia patients compared to control subjects (Adams et al., 1993; Andrews et al., 1993; Grillon et al., 1991; Hokama, Hiramatsu, Wang, O'Donnell, & Ogura, 2003; Koyama et al., 1991, 1994; Mitchell et al., 1991; Nestor et al., 1997; Ohta, Uchiyama, Matsushima, & Toru, 1999; Salisbury et al., 2000, 2002), as well as the LPC amplitude reduction (Grillon et al., 1991; Hokama et al., 2003; Niznikiewicz et al., 1997; Strandburg et al., 1997) and prolonged latency (Grillon et al., 1991; Hokama et al., 2003; Niznikiewicz et al., 1997).

Strandburg et al. (1997) recorded ERPs in schizophrenics and matched healthy participants during an idiom recognition task involving judgments of the meaningfulness of idiomatic (''pot luck''), literal (''vicious dog''), and nonsense (''square wind'') two-word pairs. The principal source of differences between schizophrenics and controls on N400 amplitude modulation for the second word was the patients' enhanced N400 (greater negativity) in response to idioms, compared to controls' N400. The authors explain these results in the light of the concept proposed by Cohen and Servan-Schreiber (1992) in terms of the disturbance of the internal representation of context in schizophrenia and the reduced ''gain'' in the neural network module that maintains contextual information.

The present study extends these results to a larger, more natural sentence context. To remain within the paradigm of earlier clinically motivated tests of the understanding of metaphor in schizophrenia, we asked our participants to judge the meaningfulness of a list of commonly used French metaphors together with literal and incongruous sentences. This study was designed to address two general questions. The first was whether metaphors involve some additional processing mechanisms not acquired by literal sentences. The second question was whether schizophrenia patients exhibit specific cognitive difficulties in figurative processing.

We addressed these issues by comparing the on–line semantic processing of three types of matched sentences: familiar metaphors, literal sentences, and incongruous sentences. ERPs and behavior measures (mean response time and correct judgments) were recorded and compared between schizophrenic patients and healthy participants.

According to the figurative/literal dichotomy, the multiple stage processing model predicts that N400 amplitude will be equal for incongruous and metaphoric sentences given that in the early processing stage, metaphorical meaning is not constructed and that the N400 reflects literal incongruity (Pynte et al., 1996). Titone's reference model predicts that literal and metaphoric statements will evoke the same N400 amplitude, because the literal meaning is processed in parallel with the figurative meaning (Titone & Connine, 1994). If schizophrenia patients have a specific deficit in constructing the figurative meaning or inhibiting the literal one, they will exhibit specific abnormalities in both metaphor context processing (N400 and LPC measures) and metaphor meaningfulness judgments (percentage of correct responses and reaction time) when compared to healthy participants. On the other hand, if metaphors do not imply any specific processing mechanisms to literal sentences, schizophrenia patients will not exhibit specific abnormalities in metaphor processing.

Methods

Participants

Twenty right-handed schizophrenia patients whose symptoms met the DSM-IV criteria for schizophrenia (American Psychiatric Association, 1994) took part in the study (6 disorganized, 1 undifferentiated, 3 residual, 10 paranoid schizophrenics). All the patients were being treated in the psychiatric unit of Versailles Hospital (Psychiatric department, Professor Chevalier JF) and the diagnosis of schizophrenia was confirmed by a short semi-structured diagnostic interview (MINI, French version, Lecrubier et al., 1997). The patients were included in the study either while hospitalized or as outpatients. All of them were receiving stable doses of medication (9 patients were receiving a typical antipsychotic: haloperidol, amisulpride, cyamemazine, clozapine, or zuclopenthixol; mean chlorpromazine equivalent per day = 752.59 mg ($\pm$ 477 mg), and 11 patients had an atypical antipsychotic: olanzapine, mean = 13 mg per day ($\pm$ 5.13). Clinical symptoms were evaluated using the Positive and Negative Syndrome Scale (Kay, Fiszbein, and Opler, 1987) and the Scale for Thought, Language and Communication Disorders (Andreasen, 1979).

Twenty right-handed healthy volunteers were recruited from the local community (Versailles, France) via a newspaper advertisement. They were strictly matched with the patients on sociodemographic factors: age, academic level (number of years of education), and vocabulary skills, and assessed using the Binois and Pichot vocabulary scale (Binois-Pichot, 1947). They were evaluated by means of a short semi-structured interview (MINI, French version, Lecrubier et al., 1997) to ensure that they had no past or present psychiatric disorders. The control subjects were paid 30.50 euros for participating. The demographic and clinical data are given in Table 1. The exclusion criteria for all subjects were: age less than 18 or greater than 54 years; neurological, and in particular epileptic antecedents, alcoholic intoxication, or regular drug use; electroconvulsive therapy during the 6 months preceding the follow-up; nonnative French language speakers; involuntary hospitalization. The demographic variables were compared in one-way analyses of variance (ANOVA) that revealed no significant differences in age or educational and verbal levels between groups (see Table 1). The participants were informed of the general aims of the study and signed a written consent form.

Table 1. *Clinical and Demographic Characteristics of the Participants (Mean ± SD)*

	Schizophrenia patients				
	Typical antipsychotics ($n = 9$)	Atypical antipsychotics ($n = 11$)	All ($n = 20$)	Controls ($n = 20$)	p[a]
Age	32.2 (± 11)	34.1 (± 10)	33 (± 10.05)	30 (± 8.22)	$p^* < .33$ $p^{**} < .69$
Education (years)	12.2 (± 2.6)	11.6 (± 2.3)	12 (± 2.36)	13 (± 2.69)	$p^* < .22$ $p^{**} < .59$
Vocabulary	25.3 (± 4)	25.8 (± 4)	26 (± 4.00	26 (± 3.95)	$p^* < .61$ $p^{**} < .92$
Length of illness (years)	12.4 (± 10.6)	14.5 (± 6.9)	13.6 (± 8.19)		$p^{**} < .59$
Sex	5 men, 4 women	8 men, 3 women	13 men, 7 women	13 men, 7 women	
TLC[b]	12.3 (± 4.3)	13.3 (± 6.9)	12.85 (± 5.80)		$p^{**} < .72$
PANSS[c]					
Positive scale	18 (± 8.4)	20.5 (± 5.5)	19.35 (± 6.84)		$p^{**} < .44$
Negative scale	20.2 (± 11)	22 (± 7.6)	20.7 (± 9.94)		$p^{**} < .84$
General scale	38.6 (± 14)	41 (± 7)	39.7 (± 10.78)		$p^{**} < .67$

[a] p^*: Controls versus patients ($n = 20$); p^{**}: patients receiving typical class antipsychotics versus patients receiving atypical class antipsychotics.
[b] Scale for Thought, Language and Communication Disorders (Andreasen, 1979).
[c] Positive and Negative Syndrome Scale (Kay, Fiszbein, & Opler, 1987).

Material

Four hundred and eighty common French sentences were used to construct 160 incongruous sentences, 160 literal sentences, and 160 metaphors. The entire set of sentences was divided into two separate lists, each containing the same 160 incongruous sentences, half ($n = 80$) of the metaphors and half of the literal sentences ($n = 80$) that were counterbalanced on their last word, with the result that in each list, the literal and metaphorical sentences ended with the same target words.

The mean cloze probability (rated by 30 participants not included in the study) was 0.5% for the metaphors, 0.47% for the literal sentences, and 0.01% for the incongruous endings.

Other factors that can affect the N400 amplitude were controlled for and remained unchanged between conditions: the sentences' mean length (mean 7 words [$SD = 2$]), the last word's mean length (5.4 letters [$SD = 3$]), and the frequency of use of the last word according to the French liguistic database BRULEX (Content, Musty, & Radeau, 1990) (mean: 19,722). The metaphors were commonly used French metaphors that were only meaningful metaphorically and were, therefore, literally implausible sentences. The average familiarity of these metaphors (rated by 30 participants not included in the study) was 75%. The metaphors were extracted from the following French dictionaries: *Le bouquets des expressions imagées* (Duneton and Claval, 1990) and *Le Dictionnaire des expressions et locutions* (Rey & Chantreau, 1993). Following are examples (with an English translation): *Metaphorical*: ''Il est parti dans les nuages'' [He's away in the clouds]; ''Ces élèves sont des anges'' [These pupils are angels]; ''A la maison elle tient les ficelles'' [She wears the trousers in that house]; ''Ce travail est dans sa poche'' [He's got the job wrapped up]. *Literal*: ''Les maçons construisent une cabane'' [The builders are building a hut]; ''Il range les dominos dans leur boîte'' [He's putting the dominos back in their box]; ''A la montagne elle emporte une tente'' [She takes a tent to the mountains]; ''La souris est dans le placard'' [The mouse is in the cupboard]. *Incongruous*: ''Elle a des bagues sur les villages'' [She has rings on her villages]; ''Le savon lui pique les sapins'' [The soap stings his pine trees]; ''Il sort les allumettes de leur plante'' [He takes matches out of the plant]; ''La rue est éclairée par un lion'' [The road is lit by a lion].

Procedure

The participants were seated comfortably approximately 80 cm in front of a computer screen. They had to read the sentences and judge whether they made sense or not. Each sentence was presented visually in four successive blocks (example: (1) Cette fillette (2) est une (3) petite (4) fée—(1) This girl (2) is a (3) little (4) fairy). The last block contained the sentence ending (that is one word to which the decision [button press] was required). The left button corresponded to a ''yes'' response and the right button to a ''no'' response. Each block was displayed for 200 ms followed by a white screen that was displayed for 350 ms (SOA of 550 ms). The second sentence followed a white screen displayed for 2200 ms. The ITI was 4050 ms. A training phase was conducted before the task.

ERP Recording and Data Analysis

The EEG recording was performed using 12 electrodes (Ag/AgCl) arranged on the scalp in accordance with international standards (10–20 system): in the frontal region (F3, Fz, F4), in the central region (C3, Cz, C4), in the parietal region (P3, Pz, P4), in the left (T3) and the right (T4) temporal regions, and one electrode in the occipital midline site (Oz). Four additional electrodes were used to record the EOG: two in the vicinity of the external canthus and one above and one below the eye. The reference electrodes were interconnected at the two ear lobes. All the impedances were kept below 1.8 kΩ. The EEG was continuously recorded using the InstEP system at a frequency of 512 points per second with an initial bandwidth of 0.15–60 Hz. Single trials exceeding ± 100 μV were rejected (mean number of rejected trials was 1.9% of all trials). The remaining trials were corrected off- line for the effects of eyeblinks and eye movements by means of an automatic program. The data were digitally filtered at a bandwidth of 0.80–12 Hz.

A visual inspection of the recorded plots of the event-related potentials for each subject and each condition made it possible to identify two separate windows corresponding to an analysis of the N400 and the LPC for each subject group. The mean amplitude of ERP components elicited by the last word of correctly judged sentences was determined as signed deviations from the baseline and was quantified as the mean of the voltage value at each electrode relative to a 200-ms prestimulus baseline over a 200–400-ms poststimulus onset (N400 window) in controls and a 300–500-ms poststimulus onset in schizophrenics, as well as over 400–700 ms in controls and over 500–800 ms in patients (LPC window). A preliminary analysis of the ERP measures at all the recording sites indicated that the amplitude and the latency of the N400 and LPC components of relevance for this article were best

Table 2. *Mean Reaction Times (in Milliseconds) and Accuracy (Percentages of Correct Judgments) on Sentences for the Control Participants and Schizophrenia Patients*

	Controls ($n = 20$)		Schizophrenia patients ($n = 20$)	
	Accuracy	Reaction times	Accuracy	Reaction times
Metaphors	87 ± 11.8	686 ± 233	74 ± 12.2	967 ± 200
Literals	98 ± 4.7	656 ± 258	87 ± 7.6	961 ± 167
Incongruous	98 ± 3.7	700 ± 237	80 ± 19.4	996 ± 145

illustrated by the midline electrode sites (Fz, Cz, Pz). For the sake of concision, we therefore only report the electrophysiological patterns observed for midline sites.

Statistical Analysis

The mean N400 and LPC amplitudes to correct responses were analyzed using separate repeated-measures ANOVAs with one between-group factor (group: schizophrenics and controls) and two within-subject factors (sentence type: metaphor, literal, incongruous; and electrode site: Fz, Cz, Pz).

The accuracy of the semantic judgments (mean percentage of correct judgments) and the response latencies for correct responses (mean reaction times) were analyzed using two separate repeated-measures ANOVAs with one between-group factor (group: schizophrenics and controls) and one within-subject factor (sentence type: metaphor, literal, incongruous). The significant interactions were analyzed using the Tukey HSD post hoc test. The conventional significance level of $\alpha = .05$ was used for the overall ANOVAs. The Greenhouse–Geisser corrections were used for the overall ANOVAs. Pearson product-moment correlations using a stringent level of $\alpha = .01$ were calculated between the demographic and clinical variables (schizophrenia patients) and the behavioral (%CR and RTs) and electrophysiological data (the mean N400 and LPC amplitudes at Pz).

Additional Subanalysis

Because the patients with schizophrenia were taking two general classes of medication that are thought to operate differently in the brain (typical antipsychotics: blockage of dopamine receptors of the D2 type; atypical antipsychotics: potent 5HT and weaker D2 receptor antagonism; Meltzer & McGurk, 1999), additional subanalyses comparing the two groups of patients ($n = 9$ taking typical antipsychotics versus $n = 11$ taking atypical antipsychotics) were conducted on all behavioral (percentage of correct judgments, reaction times) and electrophysiological data (N400, LPC amplitudes). The first aim of this subanalysis was to analyze whether the two classes of antipsychotics influence the cognitive processes differently. The second aim was to test the specific hypothesis suggested by Meltzer and McGurk (1999) that patients taking atypical antipsychotics have better cognitive functioning than patients taking typical antipsychotics.

Results

All the behavioral data are presented in Table 2. All the ERP data are presented in Table 3 (N400) and Table 4(LPC). The grand average ERP waveforms for the final word of correctly judged sentences are presented in Figure 1 (controls) and in Figure 2 (patients with schizophrenia).

Behavioral Data

The accuracy of the semantic judgments varied as a function of the sentence type as well as between groups. A Group × Sentence Type ANOVA of percentage of correct judgments revealed significant sentence type, $F(2,76) = 25.75$, $p < .00001$, and group, $F(1,38) = 22.61$, $p < .0002$, effects, whereas the interaction was not significant. Across the two groups, metaphors (80%) were judged less accurately than literal (93%) and incongruous sentences (89%) (metaphors > literals, $p < .0001$, metaphors > incongruous: $p < .0001$, literals = incongruous, $p < .1$, n.s.). The control subjects correctly identified a larger percentage of sentence meaningfulness than the schizophrenia patients (controls: 94% vs. patients: 80%). The reaction time did not vary as a function of sentence type. A Group × Sentence Type ANOVA on reaction times revealed only a significant group effect, $F(1,38) = 25.69$, $p < .0001$, which indicated that schizophrenics had longer reaction time latencies than controls (patients: 975 ms vs. controls: 681 ms).

Electrophysiological Data

N400 amplitude. A repeated-measures ANOVA on the mean N400 amplitudes for correct responses indicated that the N400 amplitude along the midline varied as a function of the sentence type and between groups. A significant effect of sentence type, $F(2,76) = 57.65$, $p < .0001$, $\varepsilon = .97$, and Sentence Type × Electrode interaction, $F(4,152) = 28.41$, $p < .0001$, were observed. Table 3 lists the mean amplitude for sentence type and electrode. A post hoc Tukey HSD test indicated that the midline N400 amplitude was significantly higher (more negative) for the incongruous sentence endings than for either of the congruous endings (incongruous vs. metaphorical, $p < .0001$; incongruous vs. literal, $p < .0001$; metaphorical vs. literal, $p < .1$), and that it was less negative for metaphors than for literal sentence endings at the central and parietal sites (Cz, metaphors vs. literals, $p < .006$; Pz, metaphors vs. literals, $p < .0001$). Incongruous endings elicited centro-parietal gradient of the negative values (Fz < Cz < Pz) whereas metaphors elicited centro-parietal gradient of the positive values (Fz < Cz < Pz), displaying overlapping early positive components. Amplitudes elicited by literal sentence endings did not vary across electrode sites (Fz, Cz, Pz).

The N400 amplitude was more negative in the schizophrenia patients compared to control participants: a significant effect of group was observed, $F(1,38) = 7.44$, $p < .01$, patients: -0.04 μV vs. controls: 1.34 μV). The Group × Condition, $F(2,76) = 0.71$, $p < .49$, n.s.) and Group × Condition × Electrode interactions, $F(4,152) = 1.83$, $p < .09$, were not significant.

Late positive component (LPC amplitude). A repeated-measures ANOVA of the mean LPC amplitudes for correct responses indicated that the LPC amplitude varied along the midline as a function of the congruity of the sentences and differed between

Table 3. *Mean Amplitude in Microvolts (± SD) of the N400 to Correctly Judged Metaphorical, Literal, and Incongruous Sentence Endings at the Midline Electrode Sites (Fz, Cz, Pz) in Both Participant Groups (Controls and Schizophrenics)*

		Sentence type		
N400 amplitude	Participants	Metaphor	Literal	Incongruous
Fz				
	Controls	1.70 ± 1.3	1.60 ± 1.5	0.58 ± 1.9
	Schizophrenics	0.31 ± 1.9	0.48 ± 2.0	− 1.1 ± 1.6
	Mean	1.00	1.04	− 0.26
Cz				
	Controls	2.63 ± 1.9	1.77 ± 2.0	− 0.28 ± 2.6
	Schizophrenics	0.83 ± 2.0	0.75 ± 2.2	− 1.52 ± 1.6
	Mean	1.73	1.26	− 0.9
Pz				
	Controls	2.86 ± 3.4	1.68 ± 2.3	− 0.46 ± 2.9
	Schizophrenics	1.10 ± 2.0	0.52 ± 2.2	− 1.70 ± 1.6
	Mean	1.98	1.10	− 1.1
Average N400		1.57	1.13	− 0.75

groups. This analysis indicated a significant effect of sentence type, $F(2,76) = 26.37$, $p < .0001$, $\varepsilon = .81$, and Sentence Type × Electrode interaction, $F(4,152) = 3.78$, $p < .005$. Table 4 lists the mean amplitude for sentence type and electrode. The amplitude of the LPC was more positive for incongruous sentence endings than for the both congruous endings (metaphorical < incongruous, $p < .0001$, literal < incongruous, $p < .0001$, literal vs. metaphorical, $p < .97$, n.s.). The post hoc test of the Sentence Type × Electrode interaction indicated that although the metaphors and the literal sentences elicited similar LPC amplitude on the Fz, Cz, Pz electrode sites, each of them differed from the LPC elicited by the incongruous endings on these sites. The classical central-parietal distribution of the LPC was observed on the incongruous and on the metaphor sentence endings, but not on the literal sentence endings. The midline LPC amplitude was more positive in controls than in schizophrenics. There was a significant effect of group, $F(1,38) = 20.62$, $p < .0001$, patients: 0.49 μV vs. controls: 2.27 μV. The Group × Condition interaction, $F(2,76) = 3.90$, $p < .02$, $\varepsilon = .81$) tested by the Tukey HSD post hoc test indicated that the LPC amplitude varied as a function of the congruity in controls (metaphors [1.76 μV], literals [1.72 μV], incongruous [3.34 μV]) but not in schizophrenia patients (metaphors [0.19 μV], literals [0.32 μV], incongruous [0.97 μV]).

Comparison of Schizophrenia Patients Taking Atypical versus Typical Antipsychotics

Both groups of patients had very comparable sociodemographic and clinical characteristics (see Table 1). Several separate repeated-measures ANOVAs were computed to compare behavioral and psychophysiological results of patients taking typical and atypical antipsychotic medication. It should be noted that only the results relating to between-group comparisons are reported. A behavioral analysis indicated that the two groups exhibited similar performances on percentage of correct judgments (group, $F[1,18] = 0.72$, $p < .41$, n.s.; Group × Condition, $F[2,36] = 0.30$, $p < .74$, n.s.) and similar reaction time (group, $F(1,18) = 0.03$, $p < .87$, n.s.; Group × Condition, $F[2.36] = 1.75$, $p < .19$, n.s.). None of the ERP amplitude analyses indicated a significant group effect (N400: group, $F[1,18] = 0.51$, $p < .49$, n.s.; LPC: group, $F[1.18] = 0.74$, $p < .40$, n.s.). None of the subsequent interactions between the group and the condition and/or electrode factors were significant.

Correlations

Pearson-product moment correlations (using a stringent $\alpha = .01$) indicated that the percentage of correct metaphor judgments in

Table 4. *Mean Amplitude in Microvolts (± SD) of the LPC to Correctly Judged Metaphorical, Literal, and Incongruous Sentence Endings at the Midline Electrode Sites (Fz, Cz, Pz) in Both Participant Groups (Controls and Schizophrenics)*

		Sentence type		
LPC amplitude	Participants	Metaphor	Literal	Incongruous
Fz				
	Controls	1.48 ± 1.2	1.82 ± 1.3	2.94 ± 1.7
	Schizophrenics	0.13 ± 1.3	0.18 ± 1.6	0.86 ± 1.0
	Mean	0.68	1.00	1.90
Cz				
	Controls	2.07 ± 1.7	1.87 ± 1.8	3.53 ± 2.2
	Schizophrenics	0.22 ± 1.4	0.43 ± 1.4	1.10 ± 1.2
	Mean	1.15	1.15	2.31
Pz				
	Controls	1.72 ± 1.8	1.46 ± 1.6	3.54 ± 2.3
	Schizophrenics	0.49 ± 1.2	0.34 ± 1.3	0.96 ± 1.4
	Mean	1.11	0.90	2.25
Average LPC		0.98	1.02	2.15

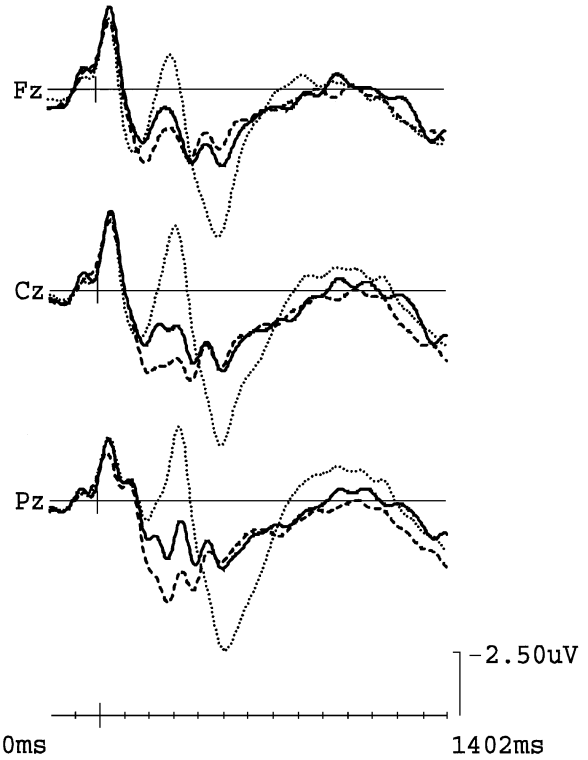

Figure 1. Grand average ERP waveforms for control participants ($n = 20$) recorded at Fz, Cz, Pz sites during processing of the correctly accepted incongruous (dotted line), literal (solid line), and metaphorical (dashed line) sentence endings.

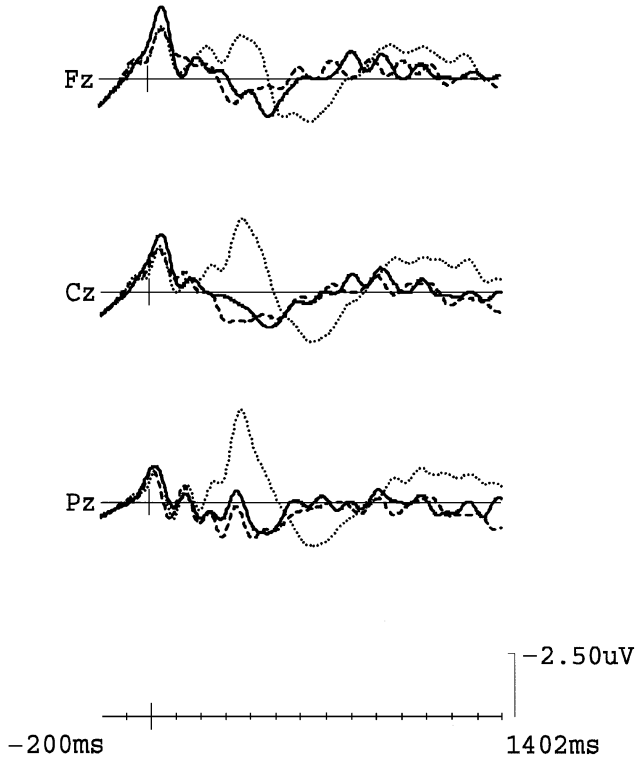

Figure 2. Grand average ERP waveforms for schizophrenia patients ($n = 20$) recorded at Fz, Cz, Pz sites during processing of the correctly accepted incongruous (dotted line), literal (solid line), and metaphorical (dashed line) sentence endings.

schizophrenia patients was positively correlated with their verbal score on the Binois-Pichot (1947) verbal test: $r = .61$, $p < .004$.

Discussion

The purpose of the present study was to examine (a) whether metaphors involve some additional processing mechanisms not mobilized by literal sentences and (b) whether schizophrenia patients exhibit specific cognitive difficulties in figurative processing.

The pattern of behavioral responses and ERP results suggested that metaphors used in this task were not more difficult to process when compared to literal and incongruous sentences. Schizophrenia patients did not perform as well as the healthy participants in their judgment of the meaningfulness of the sentences. However, in both groups, the behavioral responses were modulated in a similar way. Although schizophrenia patients elicited less efficient on-line context processing (N400 and LPC amplitude and latency abnormalities), there was no evidence of specific deficit in figurative processing.

The reduced accuracy and response delay observed in schizophrenia participants is consistent with other sentence judgment studies (see Bagner, Melinder, & Barch, 2003; Condray et al., 1999; Kuperberg et al., 1998; Strandburg et al., 1997). The reaction times in the schizophrenic patients, relative to the control participants, matched the general N400 and LPC delay. It was suggested that this result may reflect the general slowing in cognitive processing, in particularly a slowed semantic search in schizophrenia patients (Hokama et al., 2003; Nestor et al., 1997; Niznikiewicz et al., 2004; Strandburg et al., 1997).

The data show that despite quantitative differences in behavioral performance between the two groups, the schizophrenia patients seem to use judgment strategies similar to those of the control participants (Mitchell et al., 1991). In fact, in both groups the three sentence types required equal reaction time latencies.

As evidenced by the ERP waveforms (Figures 1 and 2), incongruent sentence endings elicited a centro-parietal negative component (the N400) followed by a late centro-parietal positive component (LPC). Congruent sentence endings (metaphorical and literal) elicited a positive going component that temporally overlaps with the subsequent N400 component (N400 window). In contrast to incongruous sentence endings, both congruent ones (metaphors and literals) did not elicit late positive amplitude modulation in the LPC latency window (Kutas & Hillyard, 1980; Van Petten & Kutas, 1990).

Behavioral results with conjunction to electrophysiological patterns help to reveal the cognitive strategy used by participants during the task. In fact, the metaphors were more frequently rejected than both the literal and incongruous sentences. However, ERPs showed that when accepted as meaningful, these sentences elicited more positive potential on both central and parietal sites than did the literal and the incongruous sentence endings (in the N400 latency window). This result may indicate that the participants adopted a more conservative ("all or nothing") processing strategy: To satisfy the task instructions (rapid judgment and precision), they rejected all of the sentences having semantic uncertainty (especially less usual metaphors) and accepted only obviously meaningful sentences (as also noted by Strandburg et al., 1997). Given that metaphorical and literal sentences were well matched on several factors that influence the

N400 amplitude (number of words per sentence, familiarity, length of the last word, percentage of cloze predictability of the last word), the facilitation on metaphor integration cannot be explained by any differences in sentence characteristics. It might be suggested that during on-line comprehension, the figurative meaning of familiar metaphors was more rapidly preactivated on the basis of each participant's background word knowledge (i.e., semantic memory). This result supports the view that during on-line sentence comprehension, both word meaning and word knowledge are mobilized and integrated at the same time (Hagoort et al., 2004).

Although schizophrenic patients elicited more negative N400 amplitudes than control subjects, they showed a difference between congruent and incongruent sentences (with respect to the N400 amplitude: incongruous > literals and incongruous > metaphors) and between metaphor and literal sentence endings on Cz and Pz sites (see Figures 1 and 2; Table 3) (as indexed by the absence of a significant Group × Condition and Group × Condition × Electrode interactions). These results contrast with previously reported evidence (Strandburg et al., 1997) of absent N400 modulation across idiomatic, literal, and incongruous sentences in schizophrenia patients compared to healthy participants. Given the difference in the size of the sentence context used in the two studies (multiple-word sentence context in the present study vs. two-word sentence context in the study of Strandburg et al., 1997), it might be suggested that, during semantic judgment tasks, schizophrenia patients use more efficient semantic strategies when the sentence context is rich (long) than when the context is poor (short).

The general amplitude increase of the N400 amplitude (Hokama et al., 2003; Nestor et al., 1997; Niznikiewicz et al., 1997, 2004; Salisbury et al., 2000, 2002) as well the LPC reduction (Grillon et al., 1991; Hokama et al., 2003; Niznikiewicz et al., 1997; Strandburg et al., 1997) we have observed in schizophrenia patients compared to controls were consistently reported in prior reports. The presence of greater N400 to sentence endings in the schizophrenic patients suggest an abnormality that is independent of the content of the sentence, arguing a more generalized processing dysfunction (as previously observed by Salisbury et al., 2000,using a homograph task). However, the fact that the schizophrenia patients in the present study exhibited modulation of the percentage of correct judgments, reaction times, and the N400 amplitude similar to controls argues against the hypothesis of a generalized deficit. A clear conclusion about the functional significance of the observed N400 and LPC amplitude abnormalities in schizophrenia patients is difficult to determine for two main reasons. First, the N400 and the LPC may overlap temporally and spatially. Second, there is not a consensus as to whether these components reflect similar or different cognitive processes.

As explained by Curran et al. (1993) and Frishkoff et al. (2004, p. 331) an important influence on the N400 effect to sentence final word is latency shifting of the LPC, "opening up a *relative* negativity for the incongruous words." This relative negativity contrasts with the rapidly developing positivity of LPC, which begins at the N400 window. Whereas a broad LPC emerges in the incongruous condition, the LPC to the congruous word are starting to wane.

Consistent with this interpretation, the increased N400 amplitude in the schizophrenia patients may be due to the reduced or lacking early LPC component (Adams et al., 1993; Andrews et al., 1993; Salisbury et al., 2002). Because the LPC is known to reflect the analysis of global sentence meaning (Neville, Mills, & Lawson, 1992), general attention, and working memory processes, deficit of these processes in schizophrenia patients may be consistent with their poorer performance and response time delay in several semantic tasks.

However, some authors reported normal N400 contrasted with abnormal LPC amplitudes in the schizophrenia patients (Koyama et al., 1994; Ruchsow, Trippel, Groen, Spitzer, & Kiefer, 2003) or an abnormal N400 contrasted with normal LPC (Matsumoto et al., 2001; Niznikiewicz et al., 1997). These results support the view that the N400 and the LPC in schizophrenia patients might reflect independent components' dysfunctions (Bobes, Lei, Ibanez, Yi, & Valdes-Sosa, 1996; Mitchell et al., 1991; Strandburg et al., 1997).

It is largely accepted that the N400 amplitude is modulated by the ease of integration of the semantic information with the local context (see Kutas et al., 2000) whereas the late positive component is classically assumed to reflect a later stage of integrative processes (Coulson & Kutas, 2001; Guillem et al., 2001; Van Petten et al., 1991). It has been suggested that these components are differently sensitive to particular stimulus manipulations (Van Petten et al., 1991). The ERP data in the present study consistently show that components occurring in the N400 latency window were modulated by the sentence type (Cz and Pz: metaphors < literals < incongruous) in both groups whereas in the LPC window they were modulated across the sentence congruity ([metaphors = literals] < incongruous) only in healthy subjects. The three sentence types required equal reaction time. The well-known strong relationships between the reaction time and the latency of the LPC (McCallum et al., 1989) may speculatively suggest that the differences on the N400 amplitudes between the three types of sentences cannot be explained only by differences in the LPC latency.

The increased negativity observed in schizophrenia patients in the N400 window may reflect abnormal context integration of semantic information occurring within the local context (Grillon et al., 1991; Strandburg et al., 1997), a phenomenon which may reduce the volume of information to be reanalyzed during the later LPC elaborative phase of semantic processing (see also Guillem et al., 2001).

Like in other studies (Ohta et al., 1999; Salisbury et al., 2002;see also the review of Kumar et al., 2004), the present data are unable to definitely answer whether the ERP differences between groups to sentence ending type reflect a differential N400 effect, a differential LPC effect, or abnormalities of both components. Further studies are needed to better differentiate these effects, by screening on the neural generators of the N400 and the LPC.

The possibility that the administered drugs might influence cognitive functioning in schizophrenics in different ways was examined by comparing patients receiving atypical (i.e., olanzapine) and typical (i.e., haloperidol) classes of antipsychotics, which were presumed to operate differently on the dopamine receptors in the brain (Meltzer & McGurk, 1999). Earlier studies reported evidence of better cognitive functioning (especially improvement in executive function, attention, verbal learning and memory, and verbal fluency) in patients receiving atypical antipsychotics compared to patients receiving typical antipsychotics (see Meltzer & McGurk, 1999). However, the results of the subanalysis in the present report did not support this hypothesis. The fact that all the patients exhibited very homogeneous sociodemographic and clinical characteristics may explain the homogeneity of their global pattern of cognitive functioning. It should be noted that in the present study, no clear-cut interpre-

tation of the results is possible given the small sample of patients receiving each class of antipsychotics and in view of the fact that there was no random assignment to the two types of drug.

With reference to the linguistic debate concerning the cognitive mechanisms involved in metaphor processing, the overall pattern of results does not support multiple-stage models. In line with other electrophysiological studies (Kazmerski et al., 2003; Tartter, Gomes, Dubrovsky, Molholm, & Stewart, 2002), the present ERP results indicate that figurative meaning is directly computed during context processing. Importantly, the ERPs associated with literal and metaphorical final words began to diverge at a very early stage, only 200 ms after presentation of the last word of the sentence. This pattern indicates that literal meaning is not maintained during metaphor processing, contrary to the configurational hypothesis of figurative processing (Cacciari & Tabossi, 1988; Titone & Connine, 1994). The present results support the direct class models of metaphor processing, in which figurative meaning is directly accessed during sentence processing. The semantic network structure could flexibly interact with contextual information and task demands, in line with modern accounts of figurative processing (Kazmerski et al., 2003; Kintsch, 2000) and the observed electrophysiological data (Hagoort et al., 2004; Kutas & Federmeier, 2000). However, it is noteworthy that in our study, direct activation on metaphors may have resulted from the strategy adopted by the participants in the given task instruction (rapid judgment and decision). Consequently, the present results should be confirmed in a task that does not require explicit decision–related processes.

Taken together, these results suggest that one aspect of language dysfunctioning in schizophrenia may be related to less efficient context integration processes and slowed semantic search, which affect the three sentence types and not specifically the metaphors. Our results are consistent with Titone et al.'s (2002) observation that schizophrenic participants process literally implausible idioms normally but not with the previously reported "concretism" in schizophrenics (Spitzer, 1997). The percentage of metaphor meaning acceptance in schizophrenia patients was positively correlated with the level of verbal performance (as measured by the Binois-Pichot, 1947, verbal test). Other authors have previously shown that verbal IQ plays a major role for correct metaphorical proverb understanding in patients with schizophrenia (Sponheim et al., 2003).

The absence of a specific cognitive dysfunction in the processing of metaphors contrasts with clinical observations of schizophrenia patients' difficulties in interpreting metaphorical proverbs (Carpenter & Chapman, 1982; Marengo et al., 1986; Shimkunas et al., 1967). A recent pathogenic model hypothesized that communication disorders in schizophrenia (e.g., the defective interpretations of metaphors observed in interpersonal clinical contexts) may be explained by two related pathophysiological mechanisms: a deficit in the integration of context information and a theory of mind deficit (Hardy-Baylé et al., 2003). Further studies are needed to better understand how the possible combination of the two deficits can help explain schizophrenia patients' difficulties in interpreting metaphors.

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