

Original article

## Functional analysis of the deficit in semantic context processes in schizophrenic patients: an event-related potentials study

### Analyse fonctionnelle du déficit des processus de traitement du contexte sémantique chez les schizophrènes : étude au moyen des potentiels évoqués cognitifs

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#### Abstract

**Aim.** – Schizophrenic patients exhibit a deficit in the semantic context processing strategies which might be responsible for the language and communication disorders that are characteristic of this condition. The aim of our study was to identify the nature of the contextualization processes which are lacking in schizophrenic patients, by distinguishing between processes for the generation of expectations and processes of semantic integration.

**Patients and method.** – Thirteen schizophrenic patients and 12 healthy controls performed two tasks: (a) a lexical decision task (LDT) with a highly structured sentence context and whose experimental characteristics made it possible to call strongly on predictive strategies, and (b) a LDT with classic semantic priming (the context being reduced to a single word). In this latter task, the small number of related words did not prompt the generation of expectations but instead called on the postlexical integration process. The event-related potentials (ERP) were recorded during the administration of the task.

**Results and conclusion.** – In the sentence task, we observed a modulation in the N400 amplitude due to the presence of expectations both in the schizophrenic and control participants: predictable words evoked a small N400 amplitude compared to the non-predictable words. In contrast, in the simple (priming) task, the semantic link evoked an N400 amplitude modulation in the control group exclusively. Our results indicate that schizophrenics could be able to use context to activate expectations for the most highly predictable item, and that their deficit appears when the processing strategy is based on the integration of the context stored in working memory.

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#### Résumé

**Objectif.** – Les schizophrènes présentent un déficit des stratégies de traitement du contexte sémantique qui pourrait être responsable des troubles du langage et de la communication caractéristiques de cette pathologie. Notre étude vise à préciser la nature des processus de contextualisation qui font défaut aux schizophrènes, en distinguant entre processus de génération d'attentes et processus d'intégration sémantique.

**Patients et méthode.** – Treize schizophrènes et 12 témoins sains ont réalisé deux tâches : une tâche de décision lexicale avec contexte phrastique fortement structuré, dont les conditions permettent de solliciter fortement les stratégies prédictives, et une tâche de décision lexicale avec amorçage sémantique classique (le contexte est réduit à un simple mot), dont la faible proportion de mots liés ne sollicite pas la génération d'attentes mais le processus intégratif postlexical. Les potentiels évoqués cognitifs ont été enregistrés de manière concomitante.

**Résultats et conclusion.** – Dans la tâche phrastique, nous avons observé une modulation d'amplitude de la N400 par les attentes : les mots prédictibles ont évoqué une N400 de plus faible amplitude comparés aux mots non prédictibles. Dans la tâche simple, en revanche, la modulation d'amplitude de la N400 par le lien sémantique a été observée seulement dans le groupe des témoins. Nos résultats indiquent que

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les schizophrènes pourraient être capables d'exploiter le contexte pour activer des attentes pour l'item le plus prédictible et que leur déficit apparaîtrait lorsque la stratégie de traitement est basée sur un mouvement intégratif du contexte maintenu en mémoire de travail.

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*Keywords:* Schizophrenia; Language; N400; Semantic context processing strategies

*Mots clés :* Schizophrénie ; Langage ; N400 ; Stratégies de traitement du contexte sémantique

## 1. Introduction

Within the context of the re-adoption of a Bleulerian perspective<sup>1</sup>, the language and communication disorders observed in patients suffering from schizophrenia are the subject of renewed interest and are considered to be a key prognostic factor [30]. A number of different models issuing from research into cognitive neuropsychology have established a link between these communication disorders and a deficit in the use of semantic context [14,38].

The psycholinguistic approach has revealed the importance of context in the understanding of language at a number of different processing levels [11,19,22]. For example, Marslen-Wilson [22] has shown that a word presented in a coherent context is identified at a very early stage, even before perception of the word has been completed. Similarly, various electrophysiological studies have indicated that lexical access and the semantic integration of the context operate in parallel and interactively during language processing [12,36,41].

The influence of the context can be considered at a variety of levels: lexical, sentence or discursive. At the lexical level, the most frequently used paradigm is lexical decision (deciding whether or not a target word forms part of the language). Usually, when the target word is preceded by a semantically related prime word then recognition time is reduced. This phenomenon, which is known as “semantic priming” [24], indicates the effect of the context, here in the form of the prime word, on the recognition of the target.

The model proposed for the lexical decision task (LDT) explains semantic priming in terms of the intervention of different mechanisms depending on the selected experimental conditions [27]. Thus the presentation of the prime would always activate, to a greater or lesser extent, the representation of the concepts related to the prime through the automatic spreading of activation through the semantic network [8]. If, in addition, the experimental material contains a high proportion of related words, strong relations between the words and a sufficiently long interval between the prime and the target (stimulus onset asynchrony, SOA), the priming effect would result from the implementation of a strategy which consists of generating a set of potential targets on the basis of the presented prime. The perceptual characteristics of the real target would then be compared with the predic-

tions and, if a correspondence is found, lexical access would be achieved faster. This phenomenon is known by the term “prelexical expectation generation mechanism” or the “predict and match” strategy [4,26]. Conversely, if the task conditions do not make any precise predictions possible (relation not salient between prime and target, shorter SOA) then semantic priming would result from the implementation of a postlexical integration process known as “semantic matching” [27], “meaning integration” [10] or “checking process” [31]. For example, in the semantic matching model proposed by Neely and Keefe [27], after lexical access and before lexical decision a word can be checked for its relationship to the context. If one of the candidate words is related to the prime then the word would be judged to be plausible in the context and its recognition facilitated.

The event-related potentials (ERP) method permits the on-line, detailed study of the stages involved in language processing and allows us to address the question of the areas of the brain in which the studied processes occur. Over the last 20 years or more, a very considerable volume of literature has been devoted to the N400 component of the ERPs [20]: it has been illustrated that it reflects, on the one hand, access to the representations stored in semantic memory and, on the other, the integration of context (for a review, see [19]). Indeed, the amplitude of the N400 component varies as a function of the ease of memory access: the simpler the access, the lower the N400 amplitude. This effect is at its greatest when the context is highly structured and permits the generation of precise expectations [12] and can be referred to as an “anticipation effect” or “semantic memory effect”. At the same time, N400 reflects semantic integration since its amplitude is modulated by the degree of congruence between the item and the target: integration is simpler and the N400 amplitude lower when the item makes sense in the local context (“semantic congruence effect”). In lexical decision, the presence of a semantic link between the prime and the target is accompanied by a modulation in N400 amplitude, which is equivalent to the semantic priming observed on the reaction times [5].

In order to confirm the hypotheses concerning the context processing difficulties experienced by schizophrenic subjects, numerous studies have investigated the N400 anomalies observed in this disorder. Thus, the following was regularly reported: a reduction in N400 context effect and/or an increase in N400 amplitude for words that are congruent with the context [1,13,21,23,25,28,29,33,34,39]. Almost all the authors interpret these N400 anomalies as reflecting the ineffective use of the semantic context.

<sup>1</sup> According to Bleuler, language disorders are a direct reflection of dissociation, the core, organizing principle underlying the clinical presentations of schizophrenia.

However, these various studies have not proposed any functional analysis of the deficit in the use of the contextualization processes in schizophrenia: the authors have generally considered “context processing” to be a global phenomenon, in most cases associated with anomalies in the retention of information in working memory [28,37] or the allocation of attentional resources [1,25]. It is nevertheless clear that a number of distinct cognitive processes contribute to the context effects and it would appear to be crucial to identify the deficit observed in schizophrenic patients in greater detail.

In this study, we intend to investigate the nature of the semantic contextualization processes that are defective in schizophrenic subjects by differentiating between the expectation generation processes and semantic integration processes. The value of distinguishing between these two types of strategy, predictive and integrative, has recently been emphasized by Federmeier and Kutas [19] in their two processes model of language comprehension. A re-appraisal of the schizophrenia literature in the light of such a distinction reveals certain data that indicate that the N400 effect behaves normally in certain experimental situations which are particularly favorable for the implementation of predictive strategies—such as LDTs with a very high proportion of related words [9,17,18]—or under conditions which do not require the use of integrative strategies—such as passive reading tasks [3,25]. Conditions favorable only to the implementation of the integration mechanism (low proportion of related words and low salience of the relation between prime and target) have been used in a number of studies reporting behavioral data (analysis of response times) and which have all found a reduction in the priming effect in schizophrenics [6,32,35,42].

The aim of this research was to study how schizophrenics take account of the semantic context under two experimental conditions. The first experimental condition was a LDT with a highly structured sentence context: in 25% of cases, the sentence context permitted the successful prediction of the last word of the sentence. This experimental situation made it possible to call heavily on predictive strategies<sup>2</sup>. The second experimental condition consisted of a LDT with classic semantic priming (with the context reduced to a single word). In this case, the low proportion of related words did not prompt the generation of expectations but rather called on the postlexical integration process.

Our hypothesis is that the difficulties experienced by schizophrenics will be particularly evident when the experimental conditions require the use of postlexical integrative strategies whereas the performances of such subjects should be preserved under conditions, which require the mobiliza-

tion of predictive strategies. According to this hypothesis, our schizophrenic patients should exhibit, on one hand, a reduction of the effect of the context both on behavioral (reaction time, error rate) and neurophysiological (modulation of N400 amplitude) variables in the simple LDT and, on the other, a preservation of the “anticipation effect” (reduction of N400 amplitude for words predicted on the basis of the semantic context) in the LDT with sentence context. The presence of N400 anomalies in schizophrenic patients in the “integrative” condition, contrasting with the absence of such anomalies in the “predictive” condition, would argue in favor of the idea that the expectation-based processing strategies are spared while the integrative strategies are impaired.

## 2. Methods

### 2.1. Subjects

Thirteen schizophrenic patients (including five women) meeting the DSM IV diagnostic criteria took part in the study. The diagnosis was made by an experienced clinical practitioner who was not involved in the study (Professor J.F. Chevalier’s Psychiatric Department at Versailles Hospital). The subjects were included in the study either while hospitalized in the department or while being monitored as outpatients. All of them had entered a period of symptomatological stability. Their symptomatology was evaluated using positive and negative syndrome scale (PANSS) [16] and their language and communications disorders using thought, language and communication disorders scale (TLC) [2]. All the patients were receiving neuroleptic treatment, with the dosage being converted into the chlorpromazine equivalent [15]. One schizophrenic patient was excluded from the analyses because of the high number of errors made.

The control group consisted of 12 healthy controls (including four women) who were matched for age with the remaining 12 schizophrenics. The academic level (years of education) and vocabulary skills (evaluated using the Binois and Pichot test [7]), were slightly lower in the schizophrenics than in the control subjects. This is frequently the case and is the result of the advent of the schizophrenic disorder. Table 1 summarizes the clinical and socio-demographic characteristics of the participants.

Table 1  
Participants’ demographic, cognitive and clinical data<sup>a,b</sup>

	Schizophrenics	Controls	<i>F</i> (1,22)	<i>P</i>
Age	34.42 ± 9.86	27.25 ± 11.06	2.81	0.11
Years of education	11.25 ± 2.83	13.33 ± 2.15	4.12	0.05
Vocabulary	21.33 ± 6.14	25.00 ± 1.81	3.94	0.06
Total PANSS score	76.80 ± 17.31			
TLC	11.08 ± 6.08			
Neuroleptics	545.11 ± 213.42			

<sup>a</sup> Mean value ± standard deviation (S.D.).

<sup>b</sup> Vocabulary: Binois/Pichot vocabulary test; PANSS: positive and negative syndrome scale for schizophrenia; TLC: thought, language and communication disorders; Neuroleptics: chlorpromazine equivalent.

<sup>2</sup> The paradigm of the lexical decision with a sentence context was preferred to the more classical paradigm using a word context because of the difficulty of distinguishing, in the latter case, between the deliberate generation of a cohort of expected words and the automatic activation of the associated words.

The exclusion criteria for the two subject groups were: age less than 20 or greater than 50 years; neurological, and in particular epileptic, antecedents; alcoholic intoxication or regular use of toxic substances; electroconvulsive therapy during the 6 months preceding recording; treatment using antiepileptics; native language other than French; hospitalization ordered by an authority or at the request of a third-party.

## 2.2. Stimuli

### 2.2.1. Sentence-based lexical decision task (LDT)

Two hundred short sentences (five to seven words) were constructed in such a way that the last word was highly predictable from the global sentence context but was generally unrelated to any of the words it contained. The subjective probability of appearance of the final word was checked using 14 subjects who did not participate in the study. These subjects had to complete the sentence with the first word that came to mind (cloze procedure). The sentences were used for the experiment if the final word was correctly predicted by three subjects out of four (cloze probability  $\geq 75\%$ ).

From these 200 sentences, 100 sentences with a cloze probability of 100% were then selected and the last word was replaced by a word which none of the subjects had predicted but was nevertheless plausible given the meaning of the sentence: for example, “Il dépose son argent à la HATE” (he pays in his money at the double) instead of the predicted word “BANQUE” (bank). The plausibility of these new sentences was verified using 45 subjects who were different from those who had taken part in the cloze probability test. These subjects had to read the sentences and then decide on the extent to which the last word accorded with the meaning of the sentence (0 corresponding to “not at all plausible” and 100 to “perfectly plausible”). The mean plausibility of the sentences was evaluated as 33.90 (83.82–0.18). The last word of the remaining 100 sentences was replaced by a pseudo-word.

Two experimental lists were then formed by counterbalancing the ends of the predictable and non-predictable sentences in such a way that a sentence, which appeared with a predictable target in one list was presented with a non-predictable target in the second list. The mean length of the sentences and the frequency of usage of the last word was balanced both between the different conditions within one and the same list and between the two lists. No targets were repeated in any given list.

Finally, the 100 sentences ending with a pseudo-word were added to the two lists. Each list thus contained 200 sentences: 50% ending with a pseudo-word, 25% with a word that was highly predictable on the basis of the sentence context (100% probability) and 25% ending with a plausible but non-predictable word (0% probability). The absence of a list effect was verified using the response times obtained from 20 control subjects who did not take part in the experi-

ment itself. A training list was constructed using the same rules. An example of the material is presented in Appendix 1.

### 2.2.2. Word-pairs LDT

The material used in this task consisted of two lists of 300 pairs of items each: 150 word–pseudo-word pairs and 150 word–word pairs consisting, in turn, of 50 pairs of related words, 50 unrelated pairs and 50 unrelated filler pairs which were excluded from the analyses. The proportion of related pairs was, therefore, 16.7%. All the words were frequent; and the mean length was five letters per word (three to seven letters). The material was tested on 10 healthy subjects who did not participate in the experimental phase in order to eliminate any bias associated with the construction of the lists. A training list was constructed using the same rules. Appendix 2 contains an extract from this material.

## 2.3. Procedure

The subjects performed two LDTs, one simple (with word context) and one sentence-based—the order of which was counterbalanced in such a way that half of the subjects performed the simple task first followed by the sentence task while the other half followed the opposite sequence. All the subjects had been informed of the general aims of the study and signed a written consent form.

The subjects were seated comfortably at approximately 80 cm from a computer screen. In the simple task, they were told that they were going to see two sequences of letters and that they had to decide, as quickly and accurately as possible, whether or not the second sequence of letters was a French word. In the sentence task, the instructions were very similar but the subjects were told that they were going to see a sentence ending with a word which they had to categorize as belonging or not to the French language. The subjects could use two mouse buttons with the left button corresponding to a “yes” and the right button to a “no” response.

In the simple task, the first stimulus was displayed in black, lowercase letters against a white screen background for 200 ms. The screen then became white again for 250 ms before the second stimulus was displayed (SOA of 450 ms). This stimulus was displayed for 1200 ms. The interval between two pairs of items (intertrial interval, ITI) was 2000 ms. In the sentence task, the prime sentence was presented in three successive blocks. Each block was displayed for 200 ms followed by a white screen which was displayed for 350 ms (SOA of 550 ms) and then the target which was displayed for 200 ms. The ITI was 4050 ms. The procedure used is illustrated in Fig. 1.

A training phase was conducted before the tasks themselves. Overall, the recording session took approximately 30 min.

## 2.4. ERP recording and analysis

The EEG recording was performed using 11 electrodes arranged on the scalp in accordance with international stan-

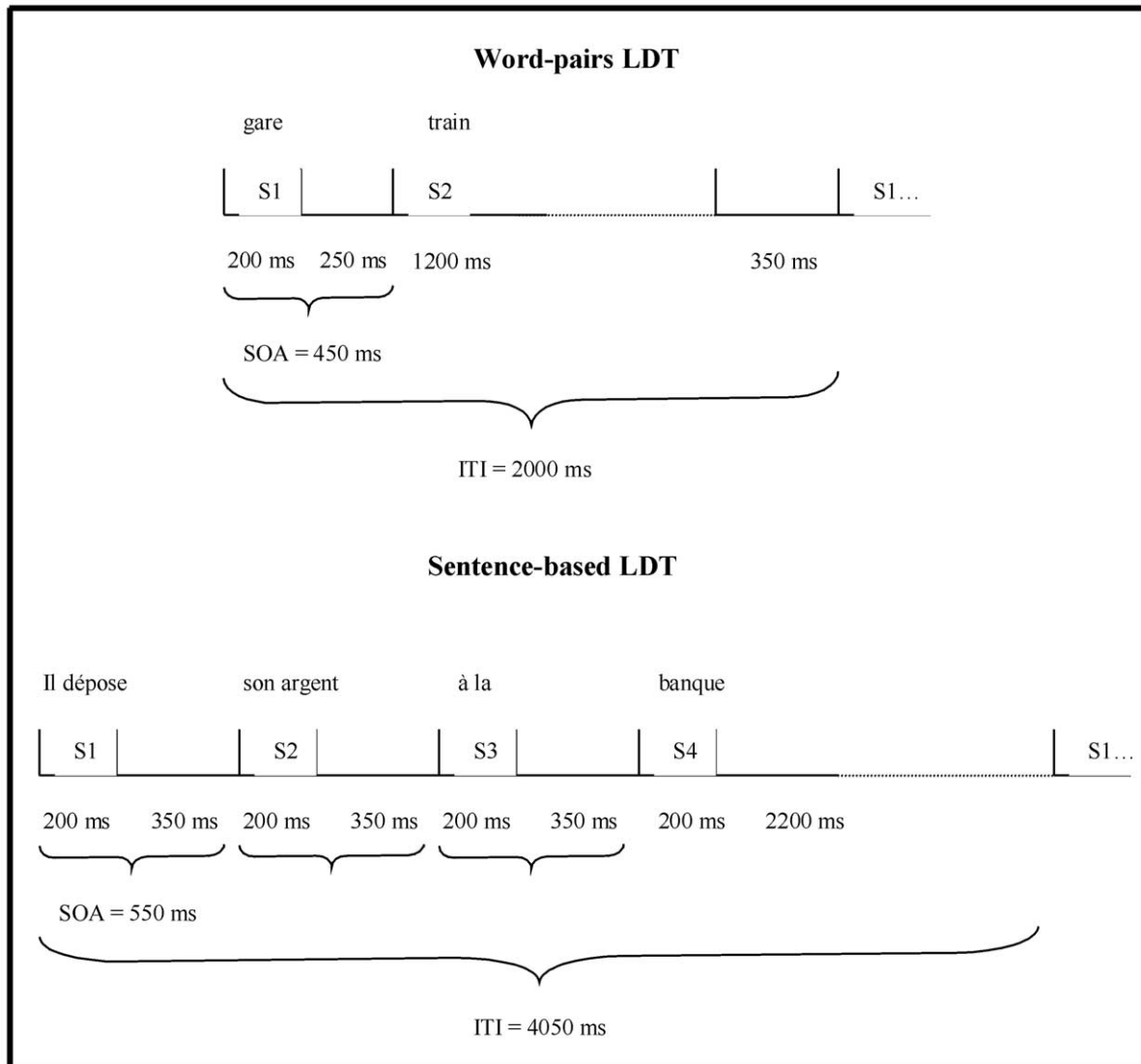


Fig. 1. Experimental design. SOA, stimulus onset asynchrony; ITI, intertrial interval.

dards: three electrodes in the frontal region (F3, Fz, F4), three in the central region (C3, Cz, C4), three in the parietal region (P3, Pz, P4) and two in the left (T3) and right (T4) temporal regions. Four electrodes were used to record the EOG: two in the vicinity of the external canthus, one above and one below the eye. The reference electrode was the two interconnected ears' lobes. All the impedances were held below 1.8 k $\Omega$ . The EEG was continuously recorded using the InstEP system at a frequency of 512 points per second with an initial bandpass of 0.15–60 Hz and the eye movements were then corrected off-line by an automatic program. Finally, the data were digitally filtered at a bandpass of 0.80–12 Hz.

The mean amplitude of the points of the evoked potential was calculated relative to a 200 ms prestimulus baseline over 250–400 ms epoch after stimulus onset separately for each subject, stimulus type and for midline recording site (Fz, Cz, Pz). The N400 window was determined after a visual inspection of the plots. The behavioral data (reaction times and error percentages) and ERPs were analyzed by means of

analyses of variance (ANOVAs) using the Statistica software. The reaction times for correct responses and error levels were analyzed using three-way repeated-measure ANOVAs with two between-group factors (group and task) and one within-subject factor (stimulus type). ERPs for correct responses were analyzed by four-way repeated-measure ANOVAs with two between-group factors (group and task) and two within-subject factors (stimulus type and electrode site). The significant interactions were analyzed using post-hoc LSD tests. A significance level of  $P < 0.05$  was adopted for all such tests.

### 3. Results

#### 3.1. Behavioral results

The analyses of the reaction times (Table 2) reveal the presence of a main effect of group [ $F(1, 22) = 49.36$ ,

Table 2  
Reaction times (ms) and error rates (%) for each group as a function of the stimulus type in the two LDTs <sup>a</sup>

	Word-pairs LDT		Sentence-based LDT	
	Related	Unrelated	Predictable	Non-predictable
Reaction times				
Schizophrenics	867 ± 93	840 ± 104	976 ± 162	1100 ± 211
Controls	608 ± 72	633 ± 87	651 ± 97	733 ± 100
Error rates				
Schizophrenics	9.7 ± 9.3	11.5 ± 11.3	10.5 ± 8.7	19.2 ± 11.6
Controls	2.2 ± 3.4	2.5 ± 2.6	0.5 ± 0.9	7.8 ± 5.3

<sup>a</sup> Mean value ± S.D.

$P < 0.0001$ ] due to a general extension in the reaction times in the schizophrenic group compared to the controls (946 and 656 ms, respectively). We observed a main effect of the task [ $F(1, 22) = 24.24, P < 0.0001$ ] due to a longer reaction time for sentence-based LDT than for word-pairs LDT (865 and 737 ms, respectively). The task by stimulus type interaction was also significant [ $F(1, 22) = 47.75, P < 0.0001$ ] indicating that in the word-pairs LDT there was no difference between related and unrelated words (related words: 737 ms; unrelated words: 737 ms) whereas in the sentence-based LDT there is a significant effect of the stimulus type (predictable words: 814 ms; non-predictable words: 917 ms,  $P < 0.0001$ ).

Finally, the analysis of the semantic priming effect (RTs for unrelated or non-predictable words—RTs for related or predictable words) reveals the presence of a significant group by task interaction [ $F(1, 22) = 9.72, P < 0.005$ ]: in the word-pairs LDT, the semantic priming was absent, and even inverted in the schizophrenic group unlike in the controls (schizophrenics:  $-27$  ms; controls:  $27$  ms,  $P < 0.02$ ) whereas in the sentence-based LDT, the difference between the groups was reversed and only marginally significant (schizophrenics:  $121$  ms; controls:  $82$  ms,  $P < 0.08$ ).

The analyses of the error rates reveal a main effect of group [ $F(1, 22) = 19.17, P < 0.0002$ ] with a higher error percentage being observed in the schizophrenic group than in the control group (12.7 and 3.3%, respectively). As was the case for the reaction times, we observed an interaction between the task and stimulus type factors [ $F(1, 22) = 14.62, P < 0.0009$ ]: in the word-pairs LDT, there was no difference in the error rates between the related and unrelated words (related words: 5.9%; unrelated words: 7.0%) while in the sentence-based LDT, we observed fewer errors on the predictable than on the non-predictable words (predictable

words: 5.5%; non-predictable words: 13.5%,  $P < 0.0001$ ). No other effect or interaction was significant.

### 3.2. Electrophysiological results

The mean N400 amplitude in the two tasks as a function of group and stimulus type is presented for Fz, Cz and Pz in Table 3. The ERP curves are presented in Figs. 2 and 3.

The analyses of the mean N400 reveal the presence of a significant effect of group [ $F(1, 22) = 5.30, P < 0.03$ ] due to the global increase in the N400 amplitude in the schizophrenic group compared to the controls (0.4 and 3.2  $\mu\text{V}$ , respectively). The effect of stimulus type (N400 effect) was also significant [ $F(1, 22) = 24.93, P < 0.0001$ ]. We observed an interaction between the group and stimulus type factors [ $F(1, 22) = 8.34, P < 0.009$ ]: the N400 amplitude for the related or predictable words was significantly higher in the schizophrenic group than in the controls (0.8 and 4.7  $\mu\text{V}$ , respectively,  $P < 0.0001$ ) as was the N400 amplitude for the unrelated or non-predictable words (0.0 and 1.7  $\mu\text{V}$ , respectively,  $P < 0.004$ ). As far as the N400 effect is concerned, this was significant only in the control group ( $P < 0.0001$ ). The task by stimulus type interaction was also significant [ $F(1, 22) = 17.57, P < 0.0004$ ]: the N400 effect approached significance in the word-pairs LDT (related words: 2.0  $\mu\text{V}$ ; unrelated words: 1.3  $\mu\text{V}$ ,  $P < 0.06$ ) whereas it was highly significant in the sentence-based LDT (predictable words: 3.5  $\mu\text{V}$ ; non-predictable words: 0.5  $\mu\text{V}$ ,  $P < 0.0001$ ).

Even though the group by task by stimulus type interaction was not significant, we performed separate analyses for each subject group in order to be able to evaluate the modulation in N400 amplitude more precisely as a function of task

Table 3  
N400 amplitude ( $\mu\text{V}$ ) for each group as a function of the stimulus type in the two LDTs <sup>a</sup>

	Controls		Schizophrenics	
	Related/predictable	Unrelated/non-predictable	Related/predictable	Unrelated/non-predictable
Word-pairs LDT				
Fz	3.5 ± 2.7	1.7 ± 3.3	0.8 ± 2.1	1.0 ± 2.3
Cz	3.8 ± 3.6	1.8 ± 3.6	0.1 ± 2.1	0.7 ± 2.4
Pz	3.7 ± 4.1	2.0 ± 3.9	0.2 ± 2.8	0.2 ± 2.0
Sentence-based LDT				
Fz	5.8 ± 4.3	1.7 ± 3.4	2.1 ± 3.6	-0.3 ± 2.3
Cz	5.8 ± 6.1	1.6 ± 4.0	1.7 ± 3.9	-0.4 ± 3.0
Pz	5.4 ± 6.5	1.6 ± 4.2	0.1 ± 2.5	-1.0 ± 2.6

<sup>a</sup> Mean value ± S.D.

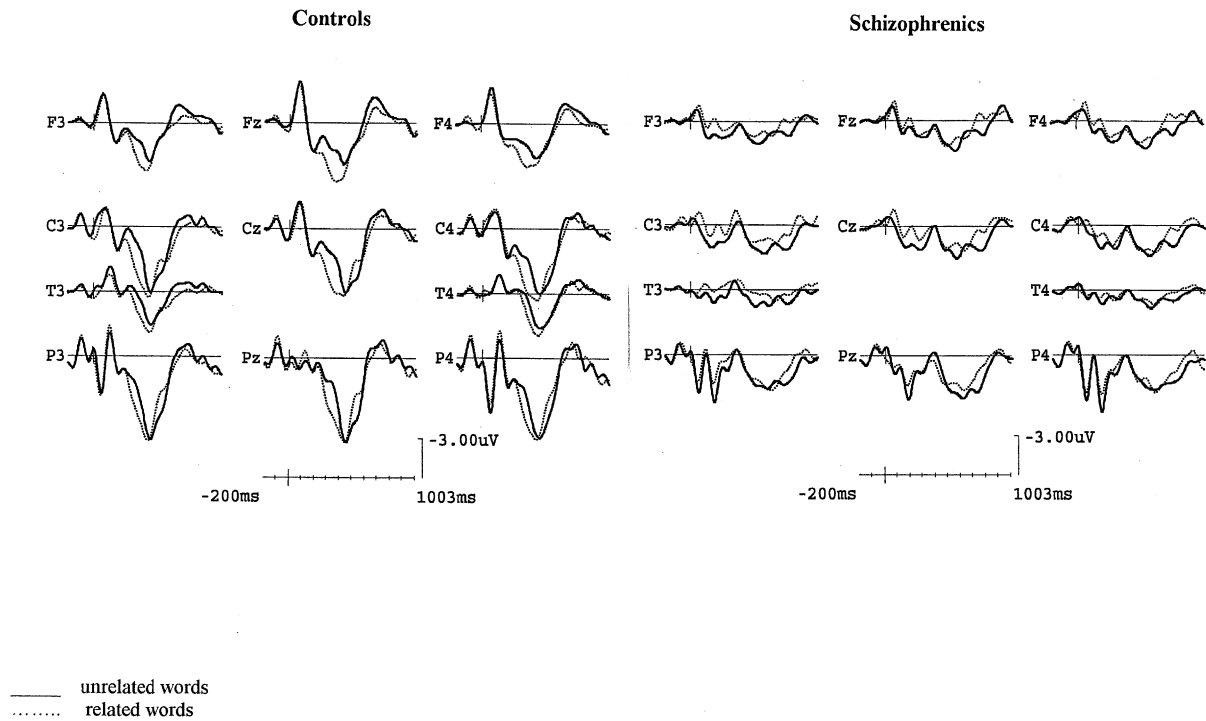


Fig. 2. ERPs for controls and schizophrenics in the word-pairs LDT.

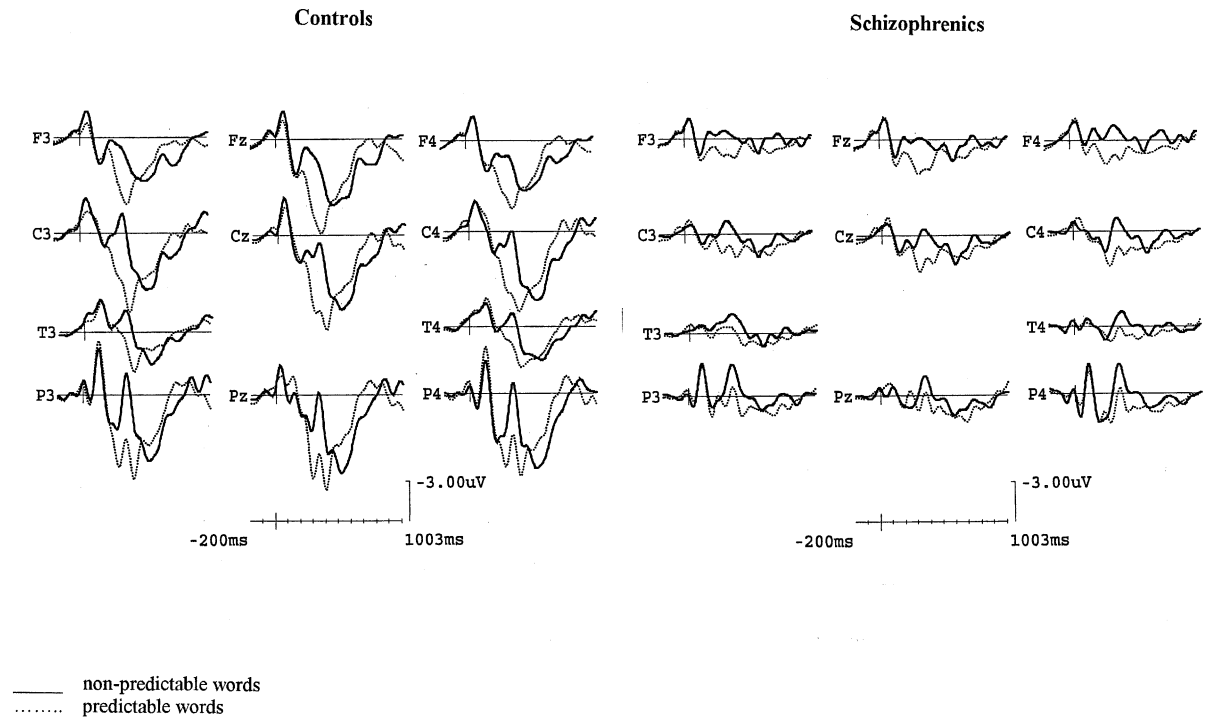
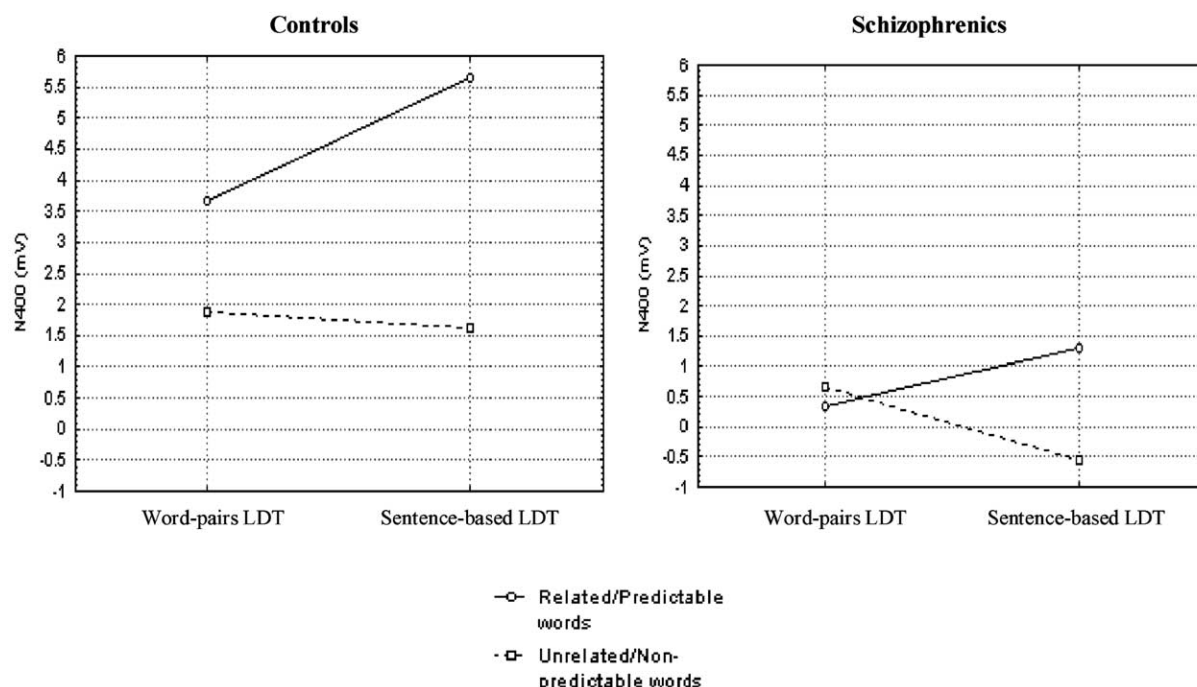


Fig. 3. ERPs for controls and schizophrenics in the sentence-based LDT.

and stimulus type. Thus the separate analysis conducted for the schizophrenic group indicated the presence of a significant task by stimulus type interaction [ $F(1, 11) = 11.33$ ,  $P < 0.006$ ]: in the word-pairs LDT, the N400 effect was completely absent due to the presence of N400 both on the related and unrelated words (related words:  $0.3 \mu\text{V}$ , unrelated

words:  $0.7 \mu\text{V}$ ) whereas this effect is highly significant in the sentence-based LDT (predictable words:  $1.3 \mu\text{V}$ , non-predictable words:  $-0.6 \mu\text{V}$ ,  $P < 0.002$ ). The predictable words in the sentence-based LDT evoked more positive amplitudes than the related words in the word-pairs LDT ( $P < 0.06$ ) while the non-predictable words in the sentence-



Graph 1. N400 amplitude ( $\mu\text{V}$ ) as a function of the stimulus type for each group and for each task.

based LDT evoked more negative amplitudes than the unrelated words in the word-pairs LDT ( $P < 0.02$ ).

The separate analysis for the control group also indicates the presence of a significant task by stimulus type interaction [ $F(1, 11) = 7.29, P < 0.02$ ]: the N400 effect was significant in both tasks (word-pairs LDT: related words:  $3.7 \mu\text{V}$ ; unrelated words:  $1.9 \mu\text{V}$ ,  $P < 0.01$ ; sentence-based LDT: predictable words:  $5.7 \mu\text{V}$ ; non-predictable words:  $1.6 \mu\text{V}$ ,  $P < 0.0001$ ), and only the N400 amplitude on the related or predictable words differed between the two tasks ( $P < 0.006$ ) (see Graph 1).

### 3.3. Global analysis of the difference waveform

Finally, to compare the magnitude of the N400 effect in the two tasks and between the two groups, we performed a complementary analysis on the amplitude of the difference waveform (N400 for unrelated or non-predictable words—N400 for related or predictable words). The ANOVAs were performed with one inter-group factor (the diagnostic group) and two intra-group factors (task and electrode).

The analyses reveal the presence of a group effect [ $F(1, 22) = 8.28, P < 0.009$ ] due to the global reduction in the N400 effect in the schizophrenic group compared to the controls ( $-0.8$  and  $-2.9 \mu\text{V}$ , respectively). We also observed a task effect [ $F(1, 22) = 17.56, P < 0.0004$ ]: the magnitude of the N400 effect was significantly greater in the sentence-based LDT than in the word-pairs LDT ( $-3.0$  and  $-0.7 \mu\text{V}$ , respectively). We did not observe any group by task interaction, thus indicating, firstly, that the reduction in the N400 effect in the schizophrenic group was observed in both tasks and, secondly, that the increase in the N400 effect between

the lexical and sentence-based tasks was of the same order in the two groups of subjects. Graph 2 illustrates this result.

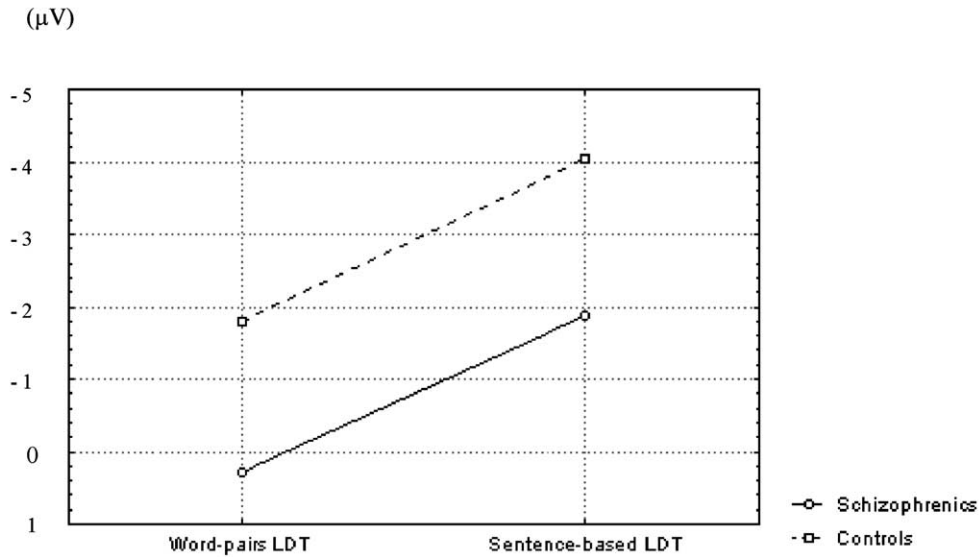
## 4. Discussion

The aim of this study was to test the hypothesis that the prediction-based context processing strategies are preserved in schizophrenic patients whereas anomalies can be observed in the strategies used for the integration of the semantic context. We studied the response patterns produced by schizophrenics in a LDT with a sentence context (sentence-level LDT) which greatly favored the expectation generation process and in a LDT using a word context (word-pairs LDT) which prompted the implementation of the postlexical integrative mechanism.

Our behavioral and electrophysiological results for the word-pairs LDT reveal the total absence of a context effect in schizophrenics, unlike in control subjects. The experimental variables that we chose (average SOA duration, relatively low proportion of related word pairs) leads us to imagine that the context processing deficit exhibited by schizophrenics specifically relates to the postlexical integrative mechanism that, depending on the author in question, has been referred to as “semantic matching”, “meaning integration” or “checking process” (see Section 1).

In contrast, in the sentence-based LDT, these same patients exhibited a context-modulated N400 component and a significant effect on the behavioral variables. In this task, half of the target words were very highly predictable on the basis of the preceding context thus favoring the massive use of the “predict and match” strategy.

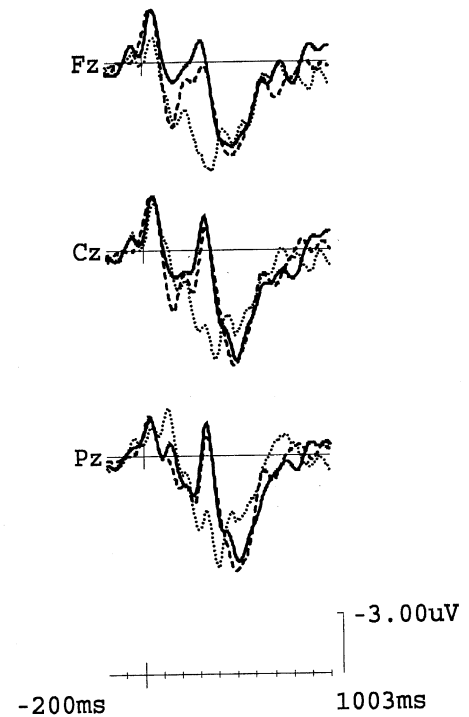




Graph 2. Amplitude of the N400 effect (N400 for unrelated or non-predictable words—N400 for related or predictable words) for each task in controls and schizophrenics (µV).

The fact that the control group predominantly used the predictive strategy is indicated by a complementary analysis performed on the electrophysiological results obtained from the control subjects<sup>3</sup>. We subdivided the category of non-predictable targets as a function of their plausibility in the local context<sup>4</sup>. We thus formed one sub-category consisting of “non-predictable, highly plausible” targets ( $n = 20$ ; mean plausibility of  $50.96 \pm 13.20$ ) and another sub-category of “non-predictable, implausible” targets ( $n = 20$ ; mean plausibility of  $13.93 \pm 6.53$ ). It must be accepted that the degree of plausibility is inversely proportional to the difficulty of integrating the word in its context [12]. As Fig. 4 illustrates, there is no difference in the amplitude of the N400 evoked by unexpected yet plausible words and that evoked by unexpected and implausible words. The only effect observed was due to semantic expectations. This result accords perfectly with those obtained from a meta-analysis performed by Taft [40], based on behavioral variables, which concludes that in LDTs with a sentence context there is no facilitation for target words that match the context but are unexpected. In other words, in this task, which did not require an explicit semantic judgement, the subjects processed the targets simply on the basis of whether they were expected or unexpected and did not perform any integrative processing of the meaning.

Thus, the functional analysis of the task provides considerable support for the idea that the presence of an N400 effect in the patients reflects their use of predictive strategies.



— non-predictable, implausible words  
 - - - non-predictable, plausible words  
 ..... predictable words

Fig. 4. ERPs as a function of the predictability and plausibility of the target word in the control group.

<sup>3</sup> This analysis was not possible in the schizophrenics due to the high number of errors of the non-predictable words.

<sup>4</sup> The procedure for evaluating plausibility is described in the “Methodology” section.

Our results argue thus in favor of a distinction, in schizophrenic subjects, between anticipation-based context processing strategies and context integration strategies and suggest that there is a deficit, which overwhelmingly affects the second type of strategy. However, it is necessary to make a number of important comments.

Firstly, even though the increase in the N400 effect between the lexical and the sentence-based tasks was of the same order in the two groups of subjects (“gain” of 2.2  $\mu$ V), thus indicating that the mechanisms that are specifically mobilized by the sentence-based task function normally in schizophrenic subjects, the N400 effect is nevertheless reduced in these patients and remains so in this task. This result indicates that the patients nevertheless exhibit a permanent difficulty in semantic processing, a difficulty which is observed in both experimental tasks.

It should be noted that our results are comparable to those obtained by Condray et al. [9] using two word-pairs LDTs which favored the expectation generation mechanism from moderately to strongly. These authors observed an increase in the N400 effect in the condition, which strongly encouraged the generation of expectations that, was comparable in the schizophrenic and control groups, alongside a global reduction in the N400 effect in the patients. The authors interpreted this result as reflecting the preservation of context processing based on expectations within the framework of the diffuse activation of the semantic network responsible for slow-down and the reduced efficiency of the semantic processing.

Secondly, even though the different context processing strategies appear to be affected to different extents in the schizophrenics, as the absence of an N400 effect in the “integrative” task and the presence of this effect in the “predictive” task indicate, it should be noted that the N400 amplitude for the related (or predictable) and unrelated (or non-predictable) words was always abnormally high in the patient group. These anomalies could reflect precisely this reduced efficiency in semantic processing in general since the schizophrenics subjects appear to make an additional search effort in order to process all words, irrespective of whether they are related or unrelated to the context.

Finally, it is important to note that the anomalies of the N400 effect in the schizophrenics are greater in the task which uses a lexical context than in the task using a sentence context since the sentence context imposes a greater working memory load and its processing is more costly in terms of the allocation of attentional resources than that required by a lexical context. This result emphasizes even more strongly the relevance of our hypothesis according to which the anomalies in semantic processing in schizophrenics should be analyzed at least in part in terms of the type of context processing strategies mobilized by the task rather than in terms of a working memory or attentional deficit.

In effect, various studies using semantic judgement tasks with a sentence [1,25,33,34] or lexical [13,39] context, i.e. contexts which impose different memory loads and atten-

tional demands, all report anomalies in the N400 effect in the schizophrenic subjects. It should be remembered that the semantic judgement task consists of deciding whether a word is semantically related to the word or sentence that precedes it and thus obliges subjects to perform the integrative processing of the word. This was also the case in our LDT with word context. The N400 anomalies observed under these conditions might reflect the deficit in the processes for the integration of context in schizophrenic subjects.

Conversely, when the task could be performed primarily on the basis of the expectation generation mechanism irrespective of the nature of the context, schizophrenics exhibited a context-modulated N400 component (lexical decision with word context [9,17,18], passive sentence reading [3,25]).

In conclusion, in the light of our results it seems clear that schizophrenic patients are able to use the context in order to activate expectations of the most predictable item and that their deficit appears especially when the processing strategy is based on an attempt to integrate the context stored in working memory. The loosening of associations, the loss of the goal, associations by assonance or semantic contiguity, i.e. the formal thought disorders, could reflect schizophrenic patients’ tendency to rely on context when predicting and anticipating and their inability to revise context-induced expectations in a retrospective attempt to integrate the global representation of speech.

## Appendix 1

### Example of the material used in the sentence-based LDT

Context phrase	Target	Category
Il s’assit sans dire un seul	mot	Predictable
L’ascenseur était toujours en	panne	Predictable
Il dépose son argent à la	banque	Predictable
Il porte sa fille dans ses	bras	Predictable
Ce chauffard allait trop	vite	Predictable
Il emprunte un livre à la	bibliothèque	Predictable
Elle suspend sa robe à un	cintre	Predictable
Le navire rentre dans le	port	Predictable
Charles parle cinq	langues	Predictable
Il remue son sucre dans sa	tasse	Predictable
La nuit est claire à la pleine	saison	Unpredictable/plausible
Dans le métro il y a beaucoup de	souris	Unpredictable/plausible
Il gratte les cordes de sa	basse	Unpredictable/plausible
Il vérifie l’orthographe dans le	doute	Unpredictable/plausible
Ce livre m’a beaucoup	rapporté	Unpredictable/plausible
Le lit est au milieu de sa	cour	Unpredictable/improbable
Le veuf porte le deuil de son	chat	Unpredictable/improbable
Il étale du beurre sur sa	chemise	Unpredictable/improbable
La poule protège ses petits	mollement	Unpredictable/improbable
Il lave ses dents après chaque	carie	Unpredictable/improbable
Elle porte des bracelets à ses	pilins	Pseudo-word
Le savon lui pique fort les	romales	Pseudo-word
Cette voiture ne roule pas assez	chabre	Pseudo-word
Au café il s’installe debout au	vamier	Pseudo-word
Géné Mathieu détourne le	bode	Pseudo-word

Context phrase	Target	Category
La fillette serre l'ours dans ses	faumures	Pseudo-word
Il est jaloux de tout le	ballut	Pseudo-word
Inquiet le chien dresse les	trameuilles	Pseudo-word
L'écolier traîne un lourd	cominte	Pseudo-word
Il sort les allumettes de leur	nale	Pseudo-word

## Appendix 2

### Example of the material used in the word-pairs LDT

Amorce	Cible	Catégorie
beaucoup	peu	mot lié
nuage	pluie	mot lié
épine	rose	mot lié
clair	sombre	mot lié
cité	ville	mot lié
dé	jeu	mot lié
toujours	jamais	mot lié
jour	nuit	mot lié
gare	train	mot lié
orange	jus	mot lié
avenue	raison	mot non lié
myope	billet	mot non lié
été	près	mot non lié
lourd	étoile	mot non lié
mie	fleuve	mot non lié
midi	vache	mot non lié
nord	unique	mot non lié
laid	pain	mot non lié
parent	hiver	mot non lié
mort	maigre	mot non lié
exact	zion	pseudo-mot
fouet	narlu	pseudo-mot
blouse	lorpie	pseudo-mot
coffre	leurbe	pseudo-mot
combat	houme	pseudo-mot
crème	gimane	pseudo-mot
thé	jorille	pseudo-mot
devis	olar	pseudo-mot
pièce	lason	pseudo-mot
nature	delade	pseudo-mot

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