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Electrophysiological insights into language processing in schizophrenia

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Abstract

Deficits in language comprehension in schizophrenia were examined using event-related potentials (ERPs). Schizophrenic and healthy participants read sentences in which the first clause ended with a homograph, and the second clause started with a target word that was semantically related to the homograph's dominant meaning (e.g., 1. Diving was forbidden from the bridge because the river had rocks in it. or 2. The guests played bridge because the river had rocks in it.). Processing of the targets (e.g., "river") was expected to be primarily influenced by the preceding overall sentence context (congruent in 1; incongruent in 2) in healthy participants, but to be inappropriately affected by the dominant meaning of homographs (e.g., the "structure" meaning of "bridge") in sentences like 2 in schizophrenic patients. The N400 ERP component that is known to be sensitive to contextual effects during language processing confirmed these predictions. This showed that language abnormalities in schizophrenia may be related to deficient processing of context-irrelevant semantic representations of words from the discourse.

Descriptors: Schizophrenia, Language, Context-irrelevant semantic associations, Event-related potentials, N400

For over a century, positive thought disorder has been considered one of the core symptoms of schizophrenia. The phenomenology of this symptom has been extensively documented and includes, primarily, a pattern of incoherent speech, but may also extend to deficits in language comprehension (American Psychiatric Association, 1994; Kuperberg, McGuire, & David, 1998; Maher, Manschreck, & Rucklos, 1980; Speed, Toner, Shugar, & Di Gasbarro, 1991). Unfortunately, the cognitive and neural processes underlying schizophrenic positive thought disorder are not well understood, and there have been a number of competing accounts that attempt to explain this deficit. Below, we review evidence for two proposals that attempt to explain positive thought disorder: defects in context sensitivity and problems in semantic memory.

According to one hypothesis, schizophrenic patients have a reduced sensitivity to the information provided by earlier elements in a conversation or text (so-called discourse context). For example, in one group of studies, schizophrenic patients have been shown to be impaired in using the context of sentences to determine an appropriate meaning of a homographic word (i.e., a word with multiple meanings; Benjamin & Watt, 1969; Blaney, 1974; Chapman, Chapman, & Miller, 1964; Strauss, 1975). Additional evidence for the context-insensitivity hypothesis comes from a recent report that found that contextual facilitation of word recognition was reduced in thought-disordered schizophrenic patients in comparison to healthy volunteers and schizophrenic patients with no thought disorder (Kuperberg et al., 1998).

There have also been attempts to pinpoint the specific problems that patients with schizophrenia have in processing contextual information. For example, Cohen and Servan-Schreiber (1992) demonstrated that schizophrenic patients have difficulty using sentence context to interpret correct meanings of multimeaning words, but only when the disambiguating context precedes the target homograph and not when it follows the homograph. These authors suggested that utilizing contextual information may be difficult for patients with schizophrenia because of their inability to maintain this information in memory. Another group of researchers (Titone, Levy, & Holzman, 2000) contrasted the ability of patients with schizophrenia to use context to facilitate processing of upcoming information and to suppress irrelevant information. Their study found that when a sentence context moderately biased a less

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frequently used meaning of a sentence final homographic word, postsentence target words that were semantically related to this meaning were primed in control subjects and schizophrenic patients alike. However, postsentence targets that were related to the alternative, more frequently used meaning of the homographs were primed only in patients with schizophrenia. This suggested that patients with schizophrenia may have a specific deficit in inhibiting context-inappropriate information, but are rather competent in detecting the relevant context. These authors suggested that the observed deficit in suppression might be related to general problems that schizophrenic patients have with inhibitory processing that also are observed in such tasks as the Stroop Test (e.g., Cohen, Barch, Carter, & Servan-Schreiber, 1999) and the Trail Making Task (e.g., Flashman, Flaum, Gupta, & Andreasen, 1996).

A second major account of positive thought disorder focuses on abnormalities in semantic memory. One version of this theory was generated to explain the greater facilitation in word-recognition speed that occurs in schizophrenic patients with positive thought disorder when target words are preceded by a semantically related rather than unrelated word (i.e., greater semantic priming; e.g., Kwapil, Hegley, Chapman, & Chapman, 1990; Manschreck et al., 1988; Spitzer, Braun, Hermle, & Maier, 1993). This so-called hyperpriming has been proposed to result from increased automatic activity within semantic memory in thought-disordered patients and might account for the context-inappropriate semantic associations that frequently intrude into patients' discourse (Maher, 1983). Unfortunately, a number of studies have failed to support this hypothesis, finding normal or reduced semantic priming in schizophrenia (e.g., Barch et al., 1996; Vinogradov, Ober, & Shenaut, 1992).

A second semantic-memory account holds that positive thought disorder results from an abnormal pattern of connections between entries in semantic memory. These abnormal connections are thought to lead to atypical organization of concepts in patients' speech. The evidence for this view comes from studies that have found an association between thought disorder and an impaired ability to use semantic-relatedness information for word generation (Goldberg et al., 1998; Kerns, Berenbaum, Barch, Banich, & Stolar, 1999). Moreover, schizophrenic patients with positive thought disorder, unlike healthy and non-thought-disordered patient controls, have been demonstrated to show less semantic priming with strongly related than with mildly related word pairs (Aloia et al., 1998), and word recall of schizophrenic patients cued by semantic associates is influenced less by the number of connections that each word has in semantic memory (Nestor et al., 1998).

Thus, a number of explanations ranging from general deficits in memory and inhibitory mechanisms (e.g., Cohen and Servan-Schreiber, 1992; Titone et al., 2000) to more specific impairments in semantic memory (e.g., Goldberg et al., 1998; Manschreck et al., 1988) have been proposed to account for the positive thought disorder in schizophrenia. However, it is still an open question how or if these seemingly somewhat contradictory hypotheses relate to each other.

The dependent variables in all of the studies cited above involved overt measures of behavior that are notorious for being sensitive to cognitive activity over and above the contextual and semantic processes of interest (e.g., activity related to the demands of an experimental task; see Kounios & Holcomb, 1992). One technique that offers considerable promise in providing a more pure measure of semantic processing is the recording of event-related potentials (ERPs). Of particular relevance are previous ERP studies of language comprehension in healthy individuals that have identified a negative-going deflection in the ERP wave peaking around 400 ms poststimulus onset (the N400 component; e.g., Kutas & Hillyard, 1980). According to one view, the N400 reflects cognitive processes whereby a word's meaning is integrated into a larger contextual framework (the context can be a single word, sentence, or larger discourse), the size of the N400 being proportional to mental effort required for such integration (Brown & Hagoort, 1993; Holcomb, 1993). These findings in healthy comprehenders suggest that ERPs might offer a more direct means to assess language processing in schizophrenia.

A number of studies have examined language comprehension in schizophrenia using ERPs. In many of these investigations, similar to healthy participants, patients with schizophrenia elicited larger N400s to words preceded by the incongruent than congruent context (i.e., a relatively intact *N400 congruity effect*; Andrews et al., 1993; Grillon, Ameli, & Glazer, 1991; Koyama et al., 1994; Nestor et al., 1997; Niznikiewicz et al., 1997; Olichney, Iragui, Kutas, Nowacki, & Jeste, 1997; Spitzer, 1997). However, three studies have reported a lack of the N400 contextual modulation in sentences (Adams et al., 1993; Ohta, Uchiyama, Matsushima, & Toru, 1999; Salisbury, O'Donnell, McCarley, Nestor, & Shenton, 2000), and two additional studies have observed a reduced N400 congruity effect in word pairs (Condray, Steinhauer, Cohen, van Kammen, & Kasparek, 1999; Strandburg et al., 1997). Taken together, these results suggest that although, in general, patients with schizophrenia may be able to process and utilize linguistic context, under certain experimental conditions, this ability may be impaired.

The goal of the present study was to use ERPs to investigate one set of the experimental variables that have been previously suggested to result in processing problems in patients with schizophrenia. That is, we examined whether ERPs would reveal abnormalities in the processing of sentences that included words that can potentially activate context-inappropriate semantic associations. Based on earlier research, we predicted that in schizophrenic patients, such associations may not be sufficiently inhibited due to their excessive activation (Maher, 1983) and/or due to a deficient suppression mechanism (Titone et al., 2000), and therefore would interfere with semantic integration of the stimuli.

More specifically, the present study attempted to advance our knowledge about the effects that such unsuppressed associations may have on natural language processing. Much of the earlier work reviewed above was restricted to word pairs (e.g., Manschreck et al., 1988) or measured responses to items outside of the sentences of interest (e.g., Titone et al., 2000). It is therefore unclear which effects would occur in more natural language tasks. Furthermore, the effects in these earlier studies were observed only over very brief time periods (e.g., semantic hyperpriming was detectable only with SOAs shorter than 500 ms; and in the suppression experiment, the targets immediately followed the critical words activating irrelevant associations). Nevertheless, some models of language processing suggest that these effects may have a longer time course during processing of natural language (e.g., Gernsbacher, Varner, & Faust, 1990). Thus, the goal of the present study was to determine if inadequate suppression of context-inappropriate associations has an effect on comprehension of words in sentences, and whether these effects have a prolonged time course.

To achieve this goal, we designed sentences that elicited context-inappropriate associations. Within these sentences, we embedded target words that could potentially be affected by these associations. Furthermore, we asked participants to read the sentences for comprehension.[1] To show that the effects of irrelevant associations may extend over longer time intervals, target words followed the critical words activating the context inappropriate associations with a time lag of at least 1,500 ms.

The design was based on earlier findings in healthy participants reading sentences containing homographs. In normal readers, when the preceding context biases a particular meaning of a homograph, activation of the alternative (context-inappropriate) meaning(s) has been shown to be suppressed[2] (e.g., Gernsbacher & Faust, 1990). However, in the absence of context, a more frequently used (dominant) meaning has been shown to be activated more strongly than less frequently used (subordinate) meaning(s) (Simpson & Burgess, 1985). The logic of the current study was based on these previous results. It was reasoned that because the activation of context-inappropriate meanings is suppressed when the homograph is integrated into the sentence context, these meanings normally should have no effect on the processing of later words in a sentence. However, when the homograph is not successfully integrated with the context, the effects of the context-inappropriate dominant meaning should be noticeable.

In the current experiment we used sentences such as the ones shown in [1] and [2]:

[1] The book must have great **stories** because the **author** won an *award/escape* for it.

[2] The skyscraper had ninety **stories** because the **author** won an award/escape for it.

In the *experimental* comparison, ERPs were recorded to target words at the beginning of the second clause (e.g., "**author**"). In 50% of the sentences, target words were congruent with the overall context of the first clause (see [1] above), and in the other 50%, target words were incongruent with the overall context of the first clause (see [2] above). However, in both cases, the target words were semantically related to the dominant meaning of the homograph that ended the first clause (e.g., "**stories**").

Healthy participants were predicted to produce the typical N400 congruity effect when the target words that were congruent with the context set up by the first clause were compared to the target words that were semantically incongruent with first-clause meaning (e.g., when words like "author" in [1] were compared to words like "author" in [2]). In contrast, this N400 congruity effect was predicted to be attenuated or absent in patients with schizophrenia. This could be the case due to either of two deficits hypothesized in schizophrenia: (a) because of an inadequate contextual suppression mechanism; and/or (b) because of increased levels of word-meaning activation (semantic hyperactivity). In either case, the context-inappropriate dominant meaning of the homograph in sentences like [2] was expected to be insufficiently inhibited and to affect processing of target words to which it was semantically related (e.g., the "tales" meaning of "stories" in [2] was expected to affect processing of "author"). More specifically, the context-inappropriate dominant meaning of the homograph in sentences like [2] was hypothesized to provide a congruent context for the target word, and therefore, semantic integration of the incongruent target words was expected to be relatively easy. As a result, the N400 was predicted to be small not only in the congruent but also in the incongruent condition, which would serve to reduce the N400 congruity effect at the target words.

The present study also recorded ERPs to words at the end of sentences like [1]. In half of the sentences, these items were congruent with the preceding context (e.g., "*award*" in "The book must have great stories because the author won an *award* for it.") and in half they were incongruent (e.g., "*escape*" in "The book must have great stories because the author won an *escape* for it.").[3] In this *control* condition, the incongruent target words were semantically unrelated to all words preceding them in the sentence, and therefore were less likely to be semantically primed by any item in the prior context. The rationale for including this comparison was as a control for contextual effects in the absence of context-irrelevant associations. If, in general, contextual effects are preserved in schizophrenic patients, then there should be no difference in the size of the control N400 effect between patients and healthy participants.

Methods

Participants

Twelve patients with schizophrenia recruited at McLean psychiatric hospital and 12 healthy participants took part in this study. The diagnosis of schizophrenia was established according to clinical charts and the Structured Clinical Interview for the DSM-IIIR (SCID; Spitzer, Williams, Gibbon & First, 1990a). Healthy participants were recruited with newspaper advertisements and were invited to participate if they had no lifetime and family history of psychopathology based on the Structured Clinical Interview for DSM-IIIR—Non-Patient Edition (SCID-NP; Spitzer, Williams, Gibbon & First., 1990b). Additional inclusion criteria applied to all participants were: native English speaker, normal or corrected-to-normal vision, and no lifetime history of head trauma, neurological disorder, or substance abuse.

Demographic, cognitive, and clinical characteristics of participants are shown in Table 1. The cognitive measures that included the Mini-Mental State Examination (MMSE; Folstein, Folstein, &

[1]After reading each sentence, participants were required to decide whether a test word presented after the offset of the sentence referred to one of the ideas in the sentence. This task was chosen because arguably it encourages reading for comprehension but does not engage strategic processes other than those involved during normal reading.

[2]Three major types of models of word-meaning ambiguity resolution have been proposed. *Selective-access* models hold that only a context-appropriate meaning of a word gets activated (e.g., Perfetti and Goodman, 1970); *exhaustive-access* models maintain that all meanings of a word are initially activated, but thereafter context-inappropriate meanings are inhibited (e.g., Gernsbacher and Faust, 1990); and *ordered-access* models posit that the dominant meaning is generally retrieved more readily than the subordinate meaning (e.g., Hogaboam and Perfetti, 1975). The hypotheses proposed in this article are compatible with all three views. The target words in the present study were presented at least 1,500 ms after the onset of homographs: all three kinds of models hold that in healthy participants, the context-appropriate meaning of a visually presented word is selected within 750 ms. Furthermore, selective-access models generally maintain that contextual influence simply prevents irrelevant meanings from activation, whereas exhaustive-access models posit that contextual effects inhibit irrelevant meanings that initially are automatically activated. Again, both conceptions are compatible with the present hypotheses: We assume that the contextual inhibitory mechanism is responsible for keeping irrelevant meanings from interfering with language processing, should they be prevented from being activated, or suppressed after being activated automatically.

[3]To achieve a more balanced design, we included incongruent words like "escape" at the end of the sentences like [2] as well as in sentences like [1]. However, we collected ERPs to words at the end of the second clause only in sentences like [1]. Thus, these control target words were preceded by a coherent sentence stem.

Table 1. *Demographic, Cognitive, and Clinical Characteristics of Participants*

Variable	Schizophrenia patients	Healthy volunteers
Gender (M/F)	11/1	11/1
Age (years)	37.7 (7.9)[a]	25.5 (8.0)
Hand preference[b]	0.7 (0.5)	0.8 (0.2)
SES[c]	4.3 (0.9)[a]	1.7 (1.1)
Parental SES	2.4 (0.9)	1.7 (0.8)
MMSE, total	27.9 (2.2)[a]	29.7 (0.4)
WAIS-R, Information	15.0 (6.2)[a]	21.0 (3.6)
WAIS-R, Vocabulary	29.5 (13.1)[a]	44.4 (9.1)
BPRS, total	32.0 (7.9)	
Positive thought disorder	4.8 (4.0)	
Neuroleptic dose (mg CPZE daily)	432.5 (315.1)	
Length of illness (years)	13.7 (10.6)	

Note: Values for continuous variables represent means (with *SD*).
[a]Patients significantly different from healthy controls, $p < .05$ (t test).
[b]Oldfield (1971). −1: left-handed; 1: right-handed.
[c]Socioeconomic status; Hollingshead (1965). 5: lowest; 1: highest.

McHugh, 1975) and Information and Vocabulary subscales of the Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler, 1981) were administered to all participants. The clinical state of patients with schizophrenia was evaluated using the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962), the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984a), and the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1984b). The total BPRS score was used to assess general level of psychopathology. Positive thought disorder was determined as a composite of SAPS and SANS scales measuring derailment, poverty of content of speech, circumstantiality, tangentiality, and incoherence (a similar procedure for assessment of positive thought disorder was used in Goldberg et al., 1998).

Materials

Materials included 120 foursomes of sentences that were 11 to 14 words long and consisted of two clauses interconnected with the conjunction "because." Examples of sentences are given in sentences [3] to [6].

[3] Diving was forbidden from the **bridge** because the **river** had *rocks* in it.

[4] Diving was forbidden from the **bridge** because the **river** had *cracks* in it.

[5] Guests played **bridge** because the **river** had rocks in it.

[6] Guests played **bridge** because the **river** had cracks in it.

In all sentences, the first clause ended with a homograph (e.g., **bridge**), and the second clause started with a strong semantic associate of the homograph's dominant meaning (e.g., **river**). The latter served as a target word in the *experimental* condition. Homographs and target words were selected based on published normative studies where participants were asked to produce a word association for each homograph (Geis & Winograd, 1974; Gorfein, Viviani, & Leddo, 1982; Kausler & Kollasch, 1970; Nelson, McEvoy, Walling, & Wheeler, 1980; Twilley, Dixon, Taylor, & Clark, 1994). Homographs were chosen if they had two alternative noun meanings, and if they prompted an uneven distribution of responses across these meanings, that is, more than 70% of participants responded with a word semantically related to one of the homograph's meanings. This meaning was considered dominant, whereas an alternative meaning that received less than 30% of responses was considered subordinate. The most frequent noun response produced for the dominant meaning was used as a target word.

Although the sentences in each foursome had the same target word, their first clauses were different. In two sentences, the first clause biased the homograph's dominant meaning and was congruent with the target word (e.g., sentences like [3] and [4]), whereas in the other two sentences, it biased the subordinate meaning and was incongruent with the target word (e.g., sentences like [5] and [6]). The dominant-meaning biasing clauses and the subordinate-meaning biasing clauses did not differ in their length ($p > 1$; on average they were 6.5 words long), or cloze probability of the homograph within the clause ($p > 1$; on average the cloze probability was .25). The cloze probability was determined in a separate sample of healthy readers ($N = 15$), who were given the first clause of the sentences with a blank in place of the homograph, and were asked to fill in the blank with the first word fitting the context that came to their mind.

First, we designed sentences in which the second clause was in itself coherent (e.g., sentences like [3] and [5]). Then, in these sentences, we chose one noun towards the end of the second clause (e.g., "rocks"), and created sentences like [4] and [6] by rearranging the selected words across the sentences so that they were incongruent with the prior context and were not preceded by any words that were semantically related to them (e.g., "rocks" was replaced by "cracks" in sentences like [3] and [5] to form sentences like [4] and [6]). The words in the end of the second clause in sentences like [3] and [4] served as *control* target words (i.e., in the control condition words like "*rock*" in [3] were compared to words like "*cracks*" in [4]). However, ERPs were not recorded to words like "rocks" and "cracks" in sentences like [5] and [6]. To confirm that no semantically related words preceded incongruent words like "cracks" in the sentences, we collected normative data in a sample of healthy readers ($N = 10$). Participants were presented with content words (nouns, verbs, and adjectives) preceding the incongruent word in each sentence. For a given sentence, these content words were arranged in a random order, and were followed by the incongruent word itself that was underlined. Participants were instructed to circle the words that were related to the underlined word (on average 0.5 words were circled—both in sentences like [4] and sentences like [6]).

The sentences were arranged into four lists, each consisting of 30 sentences of each type (120 sentences in each list; for a full set of materials visit http://neurocog.psy.tufts.edu/papers). The assignment of sentences to lists was such that only one sentence from each sentence foursome was included in each list. Across each group of participants, each list was presented to the same number of people. Twelve additional sentences were constructed to be used in a practice session.

Finally, test words were selected for each sentence that either referred to one of the ides in a sentence or were inconsistent with the sentence (e.g., "prohibition" was chosen as a consistent test word for the sample sentence [3], and "thief" was used as an inconsistent one). Each participant was given consistent test words with one half of each type of sentences. Further, one half of consistent test words for sentences like [5] and [6] referred to the first clause and the other half referred to the second clause. A word that was used as an inconsistent test word with one sentence was used as a consistent test word with another sentence.

Procedure

Participants were seated in a comfortable chair in a sound-attenuated chamber approximately 1 m from the computer monitor used for a sentence presentation. Viewing of each sentence started with a fixation point (a cross) presented for 650 ms and followed by a blank screen for 100 ms. Then, each word of the sentence was presented for 650 ms followed by a blank screen for 100 ms. After the sentence final word, the screen was blank for 800 ms, and then the test word appeared in capital letters for 3,000 ms followed by a blank screen for 1,100 ms, after which the next sentence was shown.

Participants were instructed to read each sentence naturally as they would a newspaper or a novel, and decide whether the test word presented shortly after the sentence referred to one of the main ideas in the sentence (semantic judgment task). Participants were asked to signal their decision by pressing a "YES" or "NO" button at the time they saw the test word. Before the experiment, participants were familiarized with the task in a practice session.

Recording Procedure

An elastic cap (Electrode-Cap International) with 28 tin electrodes was fitted to the participant's head. Six additional electrodes were attached to the left and right linked earlobes (serving as a reference), above and below the right eye (to monitor vertical eye movements and eye blinks), and at the outer canthi of the eyes (to monitor horizontal eye movements). The impedance of all electrodes was below 3 kΩ, and the earlobe electrodes were matches within 1 kΩ. The recorded electroencephalogram (EEG) and electro-oculogram (EOG) was amplified with a bandpass of 0.15 to 40 Hz and was digitized at a sampling rate of 3.5 ms/sample for a sampling epoch of 1,000 ms duration (100 ms prestimulus and 900 ms poststimulus).

Data Analysis

The EEG data were corrected for eye-movement artifacts using regression-based weighting coefficients (Semlitsch, Anderer, Schuster, & Presslich, 1986) and were averaged time locked to the onset of stimuli of interest. For each participant, separate average ERPs were acquired at the congruent and incongruent target words in the experimental and control conditions (i.e., in the experimental comparison, average ERPs to the words like "**river**" were obtained across sentences like [3] and [4] in the congruent condition, and across sentences like [5] and [6] in the incongruent condition; in the control comparison, average ERPs to the words like "*rocks*" in sentences like [3] were obtained in the congruent condition, and to the words like "cracks" in sentences like [4] in the incongruent condition).

Mixed design analyses of variance (ANOVAs) having within-subjects factor of Congruity (congruent and incongruent) and a between-subjects factor of Group (patients with schizophrenia and healthy participants) were used to analyze group differences in the N400. The N400 magnitude was determined as a mean voltage value (relative to a 100-ms prestimulus baseline) for the ERP points in the time window between 300 and 550 ms poststimulus onset (the N400 window). Mean ERPs in 0–300-ms and 550–800-ms windows were also measured. The analyses in the experimental and control conditions included four separate ANOVAs each. These ANOVAs were conducted to examine parasagittal columns of scalp electrodes along the anterior–posterior axis of the head. The midline analysis included four levels of electrode site (Fz, Cz, Pz, Oz). The medial-parietal analysis had two levels of electrode site and two levels of hemisphere (C3/C4, CP1/CP2). The lateral analysis had five levels of electrode site and two levels of hemisphere (F3/F4, FC5/FC6, CP5/CP6, P3/P4, PO1/PO2). The peripheral analysis had five levels of electrode site and two levels of hemisphere (FP1/FP2, F7/F8, T3/T4, T5/T6, O1/O2). The Geisser–Greenhouse correction was applied when repeated measures analyses had more than one degree of freedom (Geisser & Greenhouse, 1959).

Response accuracy on the semantic judgment task was determined for each participant. Further, because schizophrenia and healthy groups were not matched on a number of demographic and cognitive variables (see Table 1), the potential confounding effects of these variables on the N400 group differences were assessed by computing Pearson's correlations between these variables and the N400 congruity effect at the target words in the experimental condition in the overall sample of participants (i.e., healthy and schizophrenic participants combined). For this analysis, the N400 was computed as an average voltage across Fz, Cz, Pz, Oz, F7, F8, T5, and T6 electrode sites.

Results

Event-Related Potential Data

Target words—experimental condition. The average ERPs time-locked to the target words in the experimental condition are shown for healthy participants in Figure 1A and for patients with schizophrenia in Figure 1B. The waveforms were similar between congruent and incongruent target words and the participant groups until about 300 ms poststimulus onset. No differences in the average ERPs between 0 and 300 ms were significant. Note that robust sensory potentials (N1 and P2) could be seen both in healthy participants and patients with schizophrenia.

In the 300–550-ms time window, the ERP pattern was different between healthy and schizophrenia groups (Congruity × Group interaction: midline $F(1,22) = 8.596$, $p < .01$, effect size = .281; medial-parietal $F(1,22) = 9.641$, $p < .01$, effect size = .305; lateral $F(1,22) = 10.324$, $p < .01$, effect size = .319). Follow-up analyses demonstrated that in healthy participants, a negative-going deflection that occurred during this time interval (the N400) was larger at incongruent than congruent target words (main effect of Congruity: midline $F(1,11) = 10.704$, $p < .01$, effect size = .493; medial-parietal $F(1,11) = 12.625$, $p < .01$, effect size = .534; lateral $F(1,11) = 9.826$, $p < .01$, effect size = .472; peripheral $F(1,11) = 4.912$, $p = .049$, effect size = .309). In contrast, in patients with schizophrenia, there was no significant N400 difference between the two types of words (main effect of Congruity: midline $F(1,11) = 0.462$, n.s., effect size = .040; medial-parietal $F(1,11) = 0.241$, n.s., effect size = .021; lateral $F(1,11) = 0.948$, n.s., effect size = .079; peripheral $F(1,11) = 0.000$, n.s., effect size = .000). Furthermore, whereas there were no significant difference in the congruent targets between patients with schizophrenia and healthy participants (main effect of Group: midline: $F(1,22) = 0.051$, n.s., effect size = .002; medial-parietal $F(1,22) = 0.223$, n.s., effect size = .010; lateral $F(1,22) = 0.000$, n.s., effect size = .000; peripheral $F(1,22) = 0.046$, n.s., effect size = .002), the N400 to the incongruent words was significantly smaller in patients with schizophrenia (main effect of Group: midline $F(1,22) = 4.557$, $p = .044$, effect size = .172; medial-parietal $F(1,22) =$

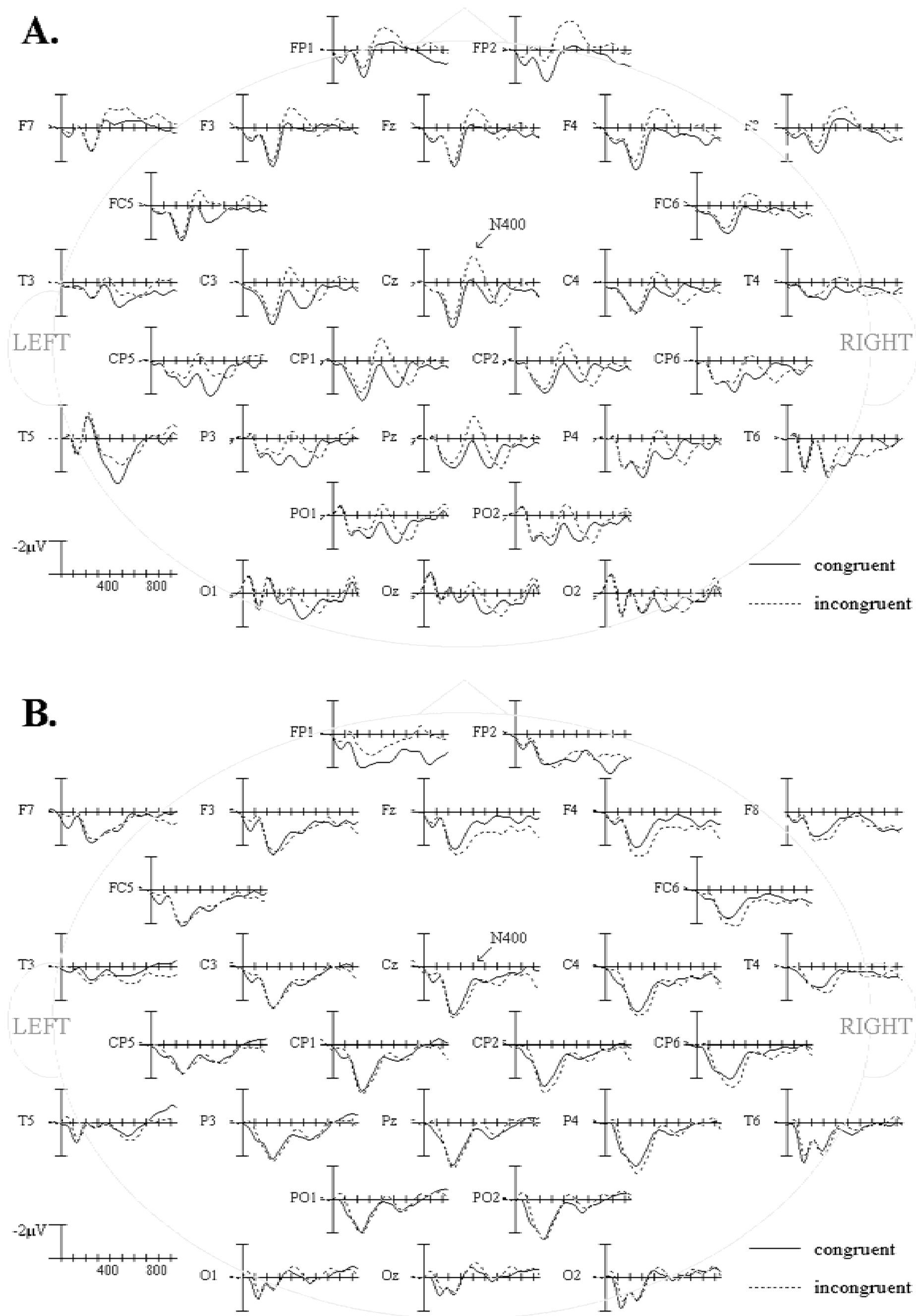

Figure 1. A: Average ERPs elicited by target words in the experimental condition in healthy participants. **B:** Average ERPs elicited by target words in the experimental condition in patients with schizophrenia.

5.819, $p = .025$, effect size = .209; lateral $F(1,22) = 5.380$, $p = .030$, effect size = .197).

In the 550–800-ms time window, the waveforms were similar between healthy and schizophrenia groups. Further, no differences were obtained between the congruent and incongruent conditions.

Target words—control condition. Figure 2 shows the average ERPs elicited by the targets in the control condition in healthy and schizophrenia groups. Again, no significant differences were obtained for the average ERPs between 0 and 300 ms after stimulus onset.

In the 300–550-ms window, a negative-going wave (the N400) was larger to the incongruent than congruent words (main effect of Congruity: midline $F(1,22) = 26.008$, $p < .01$, effect size = .542; medial-parietal $F(1,22) = 25.509$, $p < .01$, effect size = .537; lateral $F(1,22) = 26.844$, $p < .01$, effect size = .550; peripheral $F(1,22) = 17.000$, $p < .01$, effect size = .436). Importantly, this congruity effect did not interact with the Group factor (midline: $F(1,22) = 1.468$, n.s., effect size = .063; medial-parietal $F(1,22) = 1.290$, n.s., effect size = .055; lateral $F(1,22) = 1.137$, n.s., effect size = .049; peripheral $F(1,22) = 1.044$, n.s., effect size = .045), and there was no significant main effect of Group (midline $F(1,22) =$

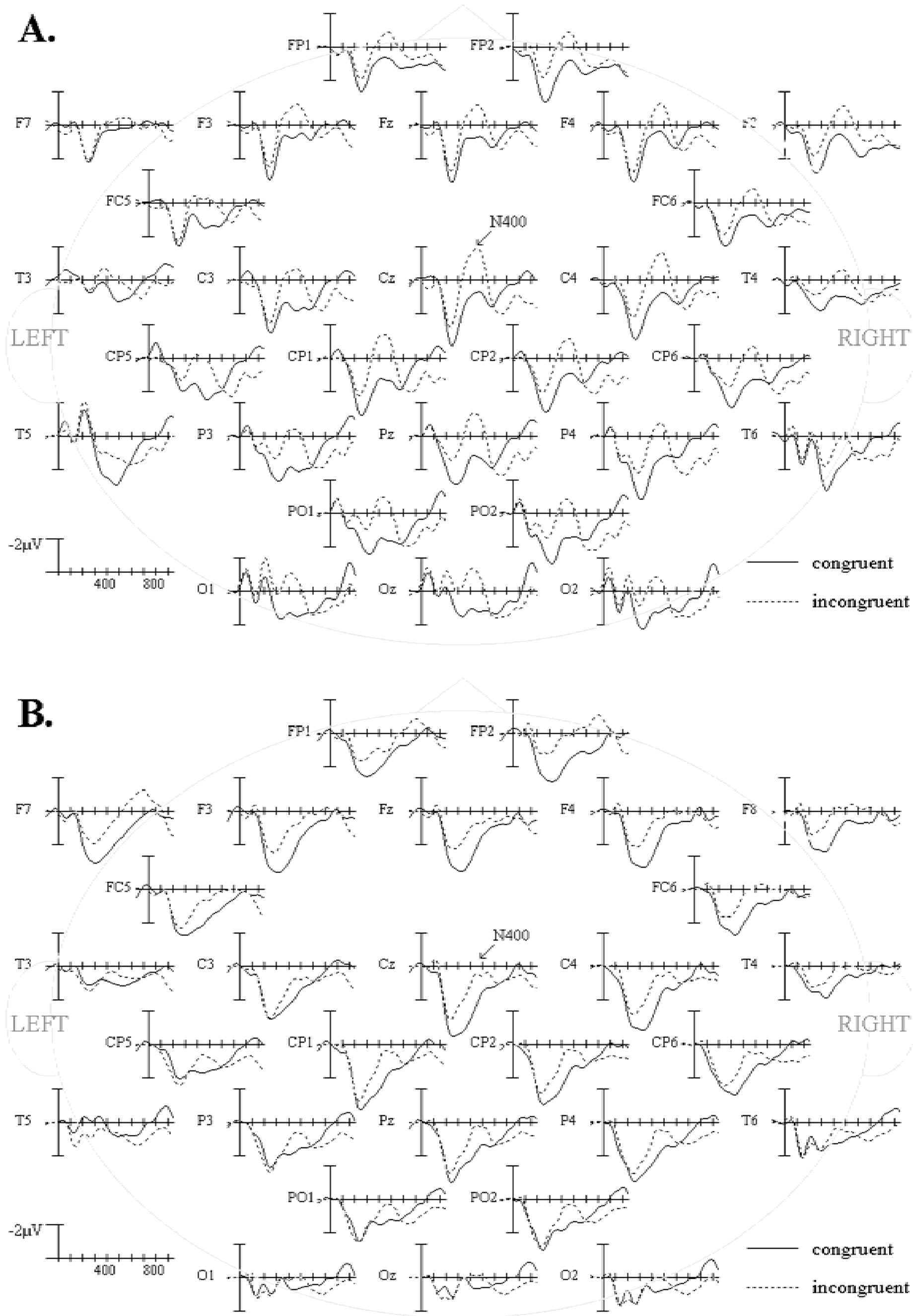

Figure 2. **A:** Average ERPs elicited by target words in the control condition in healthy participants. **B:** Average ERPs elicited by target words in the control condition in patients with schizophrenia.

3.351, n.s., effect size = .132; medial-parietal $F(1,22) = 3.424$, n.s., effect size = .135; lateral $F(1,22) = 1.947$, n.s., effect size = .081; peripheral $F(1,22) = 0.201$, n.s., effect size = .009). In both participant groups, the N400 effect at Cz and Pz electrodes peaked around 410 ms after the target-word onset (the peak latency was defined as the point where the difference in the ERPs between congruent and incongruent conditions was maximal). A mixed-design ANOVA with a within-subjects factor of Electrode (Cz and Pz) and a between-subjects factor of Group revealed no latency differences—no main effects (Electrode: $F(1,22) = 2.481$, n.s., effect size = .101; Group: $F(1,22) = 0.083$, n.s., effect size = .004) and no interaction between the factors, $F(1,22) = 0.870$, n.s., effect size = .038.

The average ERPs between 550 and 800 ms after stimulus onset were more positive at the incongruent than congruent words at the posterior electrode sites in both participant groups. However, this difference did not reach significance.

Behavioral Data

Patients with schizophrenia made more errors in semantic judgments about the sentences than healthy participants. The accuracy rate was 92.7 ± 3.5% in healthy participants and 78.3 ± 12.9% in patients with schizophrenia. However, both healthy and schizophrenic participants were better in their judgments about sentences in which the first clause biased the dominant meaning of the homograph (sentences like [3] and [4]; accuracy rate: healthy controls 95.2 ± 4.6%; schizophrenic patients 80.9 ± 13.5%) than about sentences in which the first clause biased the subordinate meaning (sentences like [5] and [6]; accuracy rate: healthy controls 90.3 ± 4.6%; schizophrenic patients 75.8 ± 13.5%). This was determined in a mixed design ANOVA with a within-subjects factor of Sentence Type (dominant vs. subordinate meaning biasing first clause) and a between-subjects factor of Group. This analysis revealed significant main effects of Sentence Type, $F(1,22) = 11.990$, $p < .01$, effect size = .353, and Group, $F(1,22) = 14.000$, $p < .01$, effect size = .389, but no significant interaction between these factors, $F(1,22) = 0.009$, n.s., effect size = .000.

Potential Confounding Variables

The analysis of Pearson correlations between the potential confounding demographic/cognitive variables and the N400 congruity effect in the experimental condition conducted in the overall sample of participants revealed no significant results. The correlations were: age, −.179, $p > 1$; SES, −.338, $p > 1$; mental state, .328, $p > 1$; WAIS-R Information score, .336, $p > 1$; and WAIS-R Vocabulary score, .321, $p > 1$.

Discussion

The present study focused on the effects of inadequate suppression of context-irrelevant information on language comprehension in schizophrenia. In the primary experimental comparison, ERPs were recorded to target words that were semantically related to the dominant meaning of a preceding homographic word and were either congruent or incongruent with prior sentence context. In a control comparison, ERPs were also recorded to target words that either were congruent or incongruent with the context of the prior sentence stem. However, in this comparison, the incongruent targets were not preceded by semantically related words. In the experimental condition, the N400 component discriminated between target words from congruent and incongruent sentences in healthy but not schizophrenic participants. Conversely, the N400 to target words in the control condition revealed N400 congruity effects in both participant groups. This suggested that sentence processing was impaired in schizophrenia only when it was interfered with by the effects of the context-inappropriate meanings of homographs. This finding is important because it shows that deficient processing of words that activate multiple semantic representations may make an important contribution to language problems in schizophrenia.

More specifically, the absence of the N400 congruity effect for the schizophrenic group in the experimental condition suggests that patients failed to suppress activation of the context-inappropriate representations of homographs. The experimental comparison was designed so that, if not suppressed, context-inappropriate dominant meanings of homographs would provide a congruent context for the target words that were otherwise incongruent with the overall preceding sentence context. Therefore, the attenuated N400 to these incongruent targets can account for the lack of the N400 effect due to the overall-context congruity. This interpretation was supported by the results of a comparison of the amplitude of the N400 component in the experimental condition between schizophrenic and healthy participant groups. Although the N400 at the congruent targets was similar between the groups, the N400 at the incongruent targets was significantly smaller in patients than in healthy controls.

The present finding of an inadequate suppression of context-irrelevant information is in line with prior research suggesting that linguistic deficits of schizophrenic patients may be caused by their less potent contextual suppression mechanism (Titone et al., 2000). One possibility is that such weakened effects of linguistic context may be caused by a more general impairment of inhibitory neural processes that, in earlier studies, has been argued to underlie abnormal performance of patients with schizophrenia on a number of nonverbal tasks (e.g., Flashman et al., 1996). In addition, a lack of suppression of context-inappropriate associations is consistent with the hypothesis about hyperactivity in semantic memory of schizophrenic patients. When the presentation of homographs triggered retrieval of their meanings from semantic memory, all of the meanings could be abnormally strongly activated. This would account for the inability of the sentence context to suppress irrelevant dominant meanings of the homographs.

An important aspect of the present study is that it demonstrates the effects of unsuppressed context-irrelevant semantic representations on processing of words embedded within a sentence context during normal reading (i.e., under conditions typical of natural language processing). Furthermore, these effects were observed even though there was a time-lag of over 1,500 ms between the presentation of words that activated context-irrelevant associations and the target words that were influenced by these associations. One potential mechanism that could mediate such prolonged priming effects is the “structure building” process proposed by Gernsbacher et al. (1990). In their formulation, language comprehension generally involves building semantic representations with multiple substructures, with shifting to a new substructure occurring every time the incoming information does not cohere with the current substructure. According to these authors, uninhibited context-inappropriate associations may be integrated into the created representation of a discourse. These associations, however, are incoherent with the preceding context, and therefore usually tend to trigger shifting to a new substructure. In the present experiment, the uninhibited contextually irrelevant dominant meaning of homographs could become a basis for a new representational substructure, which then would be held in working memory available for the incoming information to be mapped on it. Thus, the target words, even though they arrived after a considerable time-lag, could be integrated into this alternative substructure. Note that a structure building account also explains why the context-appropriate dominant meanings, even though they might have been hyperactivated, did not exert excessive influence on the processing of target words (i.e., the N400s to congruent targets in the experimental condition were similar between the patients and healthy participants). These meanings were likely integrated into the representational structure of the first clause, and it was this structure rather than the dominant meanings themselves that the target words were integrated with.

It is noteworthy that whereas homographs represent one end of the spectrum of words with multiple meanings, most content words are polysemous (e.g., the word “apple” may activate representations including either “gardening” or “baking” attributes of an apple concept; Gernsbacher & Faust, 1990). The present results suggest that in patients with schizophrenia, all representations of a word are active and may have effects on processing of subsequent words independently of the discourse context.

Further studies are required to examine the relationship between the present findings obtained during language comprehension and positive thought disorder that usually is diagnosed based on abnormal language production. Nevertheless, some models of normal language processing hold that semantic processes/representations are shared by comprehension and production systems (e.g., Ellis & Young, 1988; MacKay, 1987). Thus, the deficient processing of multimeaning words observed in the present study may also be at the root of the problem of speech production in patients with schizophrenia. In language production, where the words used are under the control of the speaker, such effects might be expected to result in seemingly unpredictable changes in the theme of an utterance.

A potential criticism of the present study could be that the schizophrenic and healthy groups were not matched for a number of demographic and cognitive variables. Of particular concern could be that, because of their inferior verbal skills (suggested by the scores on the WAIS-R), schizophrenic patients might have mental representations of homographs that were of poorer quality than was characteristic of healthy controls (Perfetti & Hart, 1999). Therefore, patients might activate only dominant meanings of homographs in all sentences, which, on its own, might disrupt semantic integration of the clauses that biased the subordinate meanings. Nevertheless, the results of several previous studies demonstrating that schizophrenic patients who had comparable verbal skills to the present sample could access subordinate meanings of homographs (e.g., Chapman et al., 1964; Titone et al., 2000) argue against this possibility. Moreover, in the study by Titone and colleagues, schizophrenic patients activated subordinate meanings rather quickly (these meanings were found to prime processing of visual targets presented immediately after the offset of the spoken homograph). Further, in the present study, patients with schizophrenia elicited the N400 effect in the control condition that did not differ in size or latency from that of healthy participants. If representations of words in semantic memory of patients were of poorer quality, then patients would be expected to take more time to access the word meanings, and their N400 effect should have been delayed. Finally, correlations conducted on the overall sample of participants in the present study revealed no relationships between the N400 in the experimental condition and available demographic/cognitive variables. This also suggested that the imperfect match between the study groups was unlikely to account for the observed group differences in ERPs.

Finally, some concern about the effects of general cognitive abnormalities on the study results may be relevant as the patient group made significantly less accurate semantic judgments than did healthy participants. The inferior performance of patients could be a reflection of such deficits as attention or motivation impeding sentence processing at a deep semantic level. However, this possibility seems unlikely given that patients produced a statistically normal N400 effect to target words in the control condition. The latter finding also rules out any explanation of differences between groups in the experimental condition being due to generally smaller N400s in patients with schizophrenia.

In summary, the most important finding of the present study is that context-irrelevant semantic representations of the words from the discourse inappropriately affected processing of the upcoming words during language comprehension in schizophrenia. This result could be a consequence of inadequate contextual suppression of such representations and/or excessive activation of such representations as they were retrieved from semantic memory. Importantly, patients with schizophrenia appeared to use sentence context normally when materials included no words contextual effects of which could disrupt sentence integration.

REFERENCES

Adams, J., Faux, S. F., Nestor, P. G., Shenton, M., Marcy, B., Smith, S., & McCarley, R. W. (1993). ERP abnormalities during semantic processing in schizophrenia. *Schizophrenia Research*, *10*, 247–257.

Aloia, M. S., Gourovitch, M. L., Missar, D., Pickar, D., Weinberger, D. R., & Goldberg, T. E. (1998). Cognitive substrates of thought disorder, II: Specifying a candidate cognitive mechanism. *American Journal of Psychiatry*, *155*, 1677–1684.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Andreasen, N. C. (1984a). *The scale for the assessment of positive symptoms*. Iowa City, Iowa: The University of Iowa.

Andreasen, N. C. (1984b). *The scale for the assessment of negative symptoms*. Iowa City, Iowa: The University of Iowa.

Andrews, S., Shelley, A. M., Ward, P. B., Fox, A., Catts, S. V., & McConaghy, N. (1993). Event-related potential indices of semantic processing in schizophrenia. *Biological Psychiatry*, *34*, 443–458.

Barch, D. M., Cohen, J. D., Servan-Schreiber, D., Steingard, S., Cohen, J. D., Steinhauer, S. S., & van Kammen, D. P. (1996). Semantic priming in schizophrenia: An examination of spreading activation using word pronunciation and multiple SOAs. *Journal of Abnormal Psychology*, *105*, 592–601.

Benjamin, T. B., & Watt, N. F. (1969). Psychopathology and semantic interpretation of ambiguous words. *Journal of Abnormal Psychology*, *74*, 706–714.

Blaney, P. H. (1974). Two studies of the language behavior of schizophrenics. *Journal of Abnormal Psychology*, *83*, 23–31.

Brown, C., & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience*, *5*, 34–44.

Chapman, L. J., Chapman, J. P., & Miller, G. A. (1964). A theory of verbal behavior in schizophrenia. In B. A. Maher (Ed.), *Progress in experimental personality research* (Vol. 1, pp. 49–77). New York: Academic Press.

Cohen, J. D., Barch, D. M., Carter, C., & Servan-Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology*, *108*, 120–133.

Cohen, J. D., Servan-Schreiber, D. (1992). Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychological Review*, *99*, 45–77.

Condray, R., Steinhauer, S. R., Cohen, J. D., van Kammen, D. P., & Kasparek, A. (1999). Modulation of language processing in schizophrenia: Effects of context and haloperidol on the event-related potential. *Biological Psychiatry*, *45*, 1336–1355.

Ellis, A. W., & Young A. W. (1988). *Human cognitive neuropsychology*. Hove, UK; Hillsdale, USA: Erlbaum.

Flashman, L. A., Flaum, M., Gupta, S., & Andreasen, N. C. (1996). Soft signs and neuropsychological performance in schizophrenia. *American Journal of Psychiatry*, *153*, 526–532.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the state of patients for the clinician. *Journal of Psychiatric Research*, *12*, 189–198.

Geis, M. F., & Winograd, E. (1974). Norms of semantic encoding variability for fifty homographs. *Bulletin of the Psychonomic Society*, *3*, 429–431.

Geisser, S., & Greenhouse, S. (1959). On methods in the analysis of profile data. *Psychometrica*, *24*, 95–112.

Gernsbacher, M. A., & Faust, M. (1990). The role of suppression in sentence comprehension. In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 97–128). Amsterdam: North Holland.

Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *16*, 430–445.

Goldberg, T. E., Aloia, M. S., Gourovitch, M. L., Missar, D., Pickar, D., & Weinberger, D. R. (1998). Cognitive substrates of thought disorder, I: The semantic system. *American Journal of Psychiatry*, *155*, 1671–1676.

Gorfein, D. S., Viviani, J. M., & Leddo, J. (1982). Norms as a tool for the study of homography. *Memory & Cognition*, *10*, 503–509.

Grillon, C., Ameli, R., & Glazer, W. M. (1991). N400 and semantic categorization in schizophrenia. *Biological Psychiatry*, *29*, 467–480.

Hogaboam, T. W., & Perfetti, C. A. (1975). Lexical ambiguity and sentence comprehension. *Journal of Verbal Learning & Verbal Behavior*, *14*, 265–274.

Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of the N400 in language processing. *Psychophysiology*, *30*, 47–61.

Hollingshead, A. B. (1965). *Two-factor index of social position*. New Haven, CT: Yale Station.

Kausler, D. H., & Kollasch, S. F. (1970). Word associations to homographs. *Journal of Verbal Learning & Verbal Behavior*, *9*, 444–449.

Kerns, J. G., Berenbaum, H., Barch, D. M., Banich, M. T., & Stolar, N. (1999). Word production in schizophrenia and its relationship to positive symptoms. *Psychiatry Research*, *87*, 29–37.

Kounios, J., & Holcomb, P. J. (1992). Structure and process in semantic memory: Evidence from event-related brain potentials and reaction times. *Journal of Experimental Psychology: General*, *121*, 459–479.

Koyama, S., Hokama, H., Miyatani, M., Ogura, C., Nageishi, Y., & Shimokochi, M. (1994). ERPs in schizophrenic patients during word recognition task and reaction times. *Electroencephalography and Clinical Neurophysiology*, *92*, 546–554.

Kuperberg, G. R., McGuire, P. K., & David, A. S. (1998). Reduced sensitivity to linguistic context in schizophrenic thought disorder: Evidence from on-line monitoring for words in linguistically anomalous sentences. *Abnormal Psychology*, *107*, 423–434.

Kutas, M., & Hillyard, S. A. (1980). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychiatry*, *11*, 99–116.

Kwapil, T. R., Hegley, D. C., Chapman, L. J., & Chapman, J. P. (1990). Facilitation of word recognition by semantic priming in schizophrenia. *Journal of Abnormal Psychology*, *99*, 215–221.

MacKay, D. G. (1987). Asymmetries in the relationship between speech perception and production. In H. Heuer & A. F. Sanders (Eds.), *Perspectives on perception and action* (pp. 301–333). Hillsdale, NJ: Lawrence Erlbaum Associates.

Maher, B. A. (1983). A tentative theory of schizophrenic utterance. In B. A. Maher & W. B. Maher (Eds.), *Progress in Experimental Personality Research* (Vol. 11, pp. 1–51). San Diego, CA: Academic Press.

Maher, B. A., Manschreck, T. C., & Rucklos, M. E. (1980). Contextual constraint and the recall of verbal material in schizophrenia: The effect of thought disorder. *British Journal of Psychiatry*, *137*, 69–73.

Manschreck, T. C., Maher, B. A., Milavetz, J. J., Ames, D., Weisstein, C. C., & Schneyer, M. L. (1988). Semantic priming in thought disordered schizophrenic patients. *Schizophrenia Research*, *1*, 61–66.

Nelson, D. L., McEvoy, C. L., Walling, J. R., & Wheeler, J. W. (1980). The university of South Florida homograph norms. *Behavior Research Methods & Instrumentation*, *12*, 16–37.

Nestor, P. G., Akdag, S. J., O'Donnell, B. F., Niznikiewicz, M., Law, S., Shenton, M. E., & McCarley, R. W. (1998). Word recall in schizophrenia: A connectionist model. *American Journal of Psychiatry*, *155*, 1685–1690.

Nestor, P. G., Kimble, M. O., O'Donnell, B. F., Smith, L., Niznikiewicz, M., Shenton, M. E., & McCarley, R. W. (1997). Aberrant semantic activation in schizophrenia: A neurophysiological study. *American Journal of Psychiatry*, *154*, 640–646.

Niznikiewicz, M. A., O'Donnell, B. F., Nestor, P. G., Smith, L., Law, S., Karapelou, M., Shenton, M. E., & McCarley, R. W. (1997). ERP assessment of visual and auditory language processing in schizophrenia. *Journal of Abnormal Psychology*, *106*, 85–94.

Ohta, K., Uchiyama, M., Matsushima, E., & Toru, M. (1999). An event-related potential study in schizophrenia using Japanese sentences. *Schizophrenia Research*, *40*, 159–170.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburg inventory. *Neuropsychologia*, *9*, 97–113.

Olichney, J. M., Iragui, V. J., Kutas, M., Nowacki, R., & Jeste, D. V. (1997). N400 abnormalities in late life schizophrenia and related psychoses. *Biological Psychiatry*, *42*, 13–23.

Overall, J. E., & Gorham, D. R. (1962). The brief psychiatric rating scale. *Psychological Reports*, *10*, 799–812.

Perfetti, C. A., & Goodman, D. (1970). Semantic constraint on the decoding of ambiguous words. *Journal of Experimental Psychology*, *86*, 420–427.

Perfetti, C. A., & Hart, L. A. (1999). Quality lexical representations (not suppression) are central to reading skill. Poster presented at the 40th Annual Meeting of the Psychonomic Society, Los Angeles, CA, USA.

Salisbury, D. F., O'Donnell, B. F., McCarley, R. W., Nestor, P. G., & Shenton, M. E. (2000). Event-related potentials elicited during a context-free homograph task in normal versus schizophrenic subjects. *Psychophysiology*, *37*, 456–463.

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*, *23*, 695–703.

Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception & Performance*, *11*, 28–39.

Speed, M., Toner, B. B., Shugar, G., & Di Gasbarro, I. (1991). Thought disorder and verbal recall in acutely psychotic patients. *Journal of Clinical Psychology*, *47*, 735–744.

Spitzer, M. (1997). A cognitive neuroscience view of schizophrenic thought disorder. *Schizophrenia Bulletin*, *23*, 29–50.

Spitzer, M., Braun, U., Hermle, L., & Maier, S. (1993). Associative semantic network dysfunction in thought-disordered schizophrenic patients: Direct evidence from indirect semantic priming. *Biological Psychiatry*, *34*, 864–877.

Spitzer, R., Williams, J., Gibbon, M., & First, M. (1990a). *The structured clinical interview for DSM-IIIR (SCID)*. Washington, DC: American Psychiatric Association.

Spitzer, R., Williams, J., Gibbon, M., & First, M. (1990b). *The structured clinical interview for DSM-IIIR—Non-patient edition (SCID-NP)*. Washington, DC: American Psychiatric Association.

Strandburg, R. J., Marsh, J. T., Brown, W. S., Asarnow, R. F., Guthrie, D., Harper, R., Yee, C. M., & Nuechterlein, K. H. (1997). Event-related potential correlates of linguistic information processing in schizophrenics. *Biological Psychiatry*, *42*, 596–608.

Strauss, M. E. (1975). Strong meaning-response bias in schizophrenia. *Journal of Abnormal Psychology*, *84*, 295–298.

Titone, D., Levy, D. L., Holzman, P. S. (2000). Contextual insensitivity in schizophrenic language processing: Evidence from lexical ambiguity. *Journal of Abnormal Psychology*, *109*, 761–767.

Twilley, L. C., Dixon, P., Taylor, D., & Clark, K. (1994). University of Alberta norms of relative meaning frequency for 566 homographs. *Memory & Cognition*, *22*, 111–126.

Vinogradov, S., Ober, B. A., & Shenaut, G. K. (1992). Semantic priming of word pronunciation and lexical decision in schizophrenia. *Schizophrenia Research*, *8*, 171–181.

Wechsler, D. (1981). *Manual for the Wechsler adult intelligence scale—Revised*. New York: Psychological Corporation.

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