Electrophysiological Features of Late-Stage Language Processing in Patients with Schizophrenia

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Abstract. Language deficits are a prominent feature of schizophrenia. The Event-Related Potentials (ERPs) is a technique used to investigate neural mechanisms of language processing. Most studies suggest ERPs components of late-stage language processing are abnormal in patients with schizophrenia. This study systematically reviews the electrophysiological features of late-stage language processing in patients with schizophrenia. The N400 amplitude in patients with schizophrenia is usually lower than that of normal individuals, and they are unable to effectively integrate semantics. At the same time, the P600/LPC waveforms of the relevant patients show a situation similar to that of the N400. Both reduced amplitudes of the N400, P600, and LPC components and delayed latencies of the N400 and LPC are abnormally delayed in patients with schizophrenia suggest that patients with schizophrenia exhibit systematic impairments in late-stage language processing. This review provides a theoretical basis for further exploration of the EEG characteristics of language processing in patients with schizophrenia.

Keywords: Schizophrenia, ERPs, Semantic processing.

1. Introduction

Cognitive impairment, including language processing ability, is a prominent feature of schizophrenia [1,2]. Neurocognitive studies have documented robust behavioral and electrophysiological evidence of language processing abnormalities during acute phases of schizophrenia [3].

The ERPs technique can non-invasively and dynamically monitor activity status of brain when processing language [4]: in studies of schizophrenia, it is helpful to understand brain's neural dynamics and aberrant networks by analyzing relative components [3]; in research for language processing, ERPs can reflect the functional connectivity of understanding, processing and expressing language [5].

The N400 is a negative-going ERP component peaking around 400 ms post-stimulus [4], reflecting the understanding of semantic information of words [6–8], semantic priming effect and contextual processing ability [9,10]. Also, the 600ms positive peak is named P600. It reflects the processes underlying syntactic processing and enhances in response to syntactic violations. Some studies consider P600 as a part of LPC, because it occurred within the time window of LPC, and N400 even extends into the LPC time window [10,11]. Given that the P600 often overlaps with the late positive complex (LPC) in timing and purportedly shares functional similarities in syntactic and semantic reanalysis, this review groups findings reporting either component under the combined label "P600/LPC" [10,12,13].

Numerous studies have demonstrated that N400, P600/LPC components in schizophrenic patients are significantly different from healthy people. Prior studies revealed that the N400, P600 and LPC components, relating to the late language processing, wholly reduced amplitude [12]. What's more, N400 and LPC delayed latency but P600's latency is similar to health [14,15]. N400, P600 and LPC are classified as mid-to-late components. It's important to understand pathogenesis of schizophrenia and the neural mechanisms of language processing in humans. This study aims to explore electrophysiological features of late-Stage language processing in patients with schizophrenia and try to demonstrate that the deficit of post-lexical processing and syntactic use is common in schizophrenia.

2. Literature Review

Browsed all studies on N400, it is definite that the majority of studies have focused on semantic processing, contextual integration, or both. Based on the existing studies, the whole N400 studies will be divided into two categories in this research: “semantic comprehension” and “contextual integration”. However, the quality of P600/LPC studies is not large enough to be classified.

2.1. N400 in schizophrenia

2.1.1 Semantic Comprehension

Bobes et al. found, in patients with schizophrenia, an abnormal reduction in N400 component with a higher behavioral error rate in long stimulus onset asynchrony (SOA) paradigm [16]. The authors believed this abnormality is attributable to impaired specific semantic processing while also providing evidence against the "hyper-association" hypothesis. Niznikiewicz et al. aimed to research early stages of semantic network activation through short SOA paradigm [17]. As same as other studies, the study found in comparison to health, schizophrenia had the absence of semantic priming effects. Furthermore, the study found a reduced inhibitory control in semantic spreading activation and a lower N400 amplitude in the unrelated semantic condition compared to the control group. These findings indicate that language processing in individuals with schizophrenia is impaired in inhibitory control. Condray et al. reported N400 primping effect is abnormally reduced and both automatic activation and controlled attention mechanisms during semantic memory access are disrupted in patients [10]. In addition, the study thought automatic activation is more consistent with Parallel Distributed Processing (PDP) model through comparing the haloperidol-treated group with the placebo group. Kostova et al. observed patient group showed a reduction in N400 and found related words elicited a larger N400 amplitude [13]. Iakimova et al. found patients with schizophrenia, in contexts with rich sentential cues, utilize enhanced semantic processing strategies, and their behavioral response times correspond to the canonical latency patterns of the N400 and LPC [12]. The authors believed that it showed a slowing of semantic search, and that language impairment arises from a deficit in contextual information integration, which indicates impaired processing of global semantic information.

2.1.2 Contextual Integration

Kostova et al. focused on text structuring and found text structuring didn't contribute to improving patients’ contextual integration as expected through monitoring N400 component [13]. This result suggests that basic semantic integration impairment has cross-contextual stability. Moreover, Kostova believed that reduced semantic priming effects and N400 abnormalities did not affect all individuals with schizophrenia, but were largely confined to the subtype characterized by formal thought disorder. Iakimova et al. found patients with schizophrenia exhibit no significant difference in the processing of metaphors and literal sentences, implying a deficit in interpreting figurative language [12].

2.2. P600/LPC in Schizophrenia

Lee et al. found that patients with schizophrenia showed that in a comparative study with bipolar manic patients and healthy controls, individuals with schizophrenia not only performed worst in syntactic processing, but also exhibited abnormally reduced P600 amplitudes in response to syntactic violations[15]. And the study confirms that there is no significant difference in P600 latency between individuals with schizophrenia and healthy controls. By manipulating the level of text structuring, Kostova et al. found that the LPC differentiation between related and unrelated words was absent in patients with schizophrenia, but only in highly structured tasks[13]. In contrast to healthy controls, patients exhibited reduced LPC amplitudes specifically for unrelated words. Iakimova et al. reported the finding of globally attenuated LPC responses, coupled with an absence of differential processing across metaphorical, literal, and incongruent sentences, indicates disrupted semantic integration in schizophrenia[12]

Table. 1 Studies on N400 in ERPs of Patients with Schizophrenia

Author	Language	Experimental Focus	Experimental Mode	ERPs Result	Conclusions from ERPs
Andrews et al.[11]	English	Semantic Comprehension	Sentence completion semantic congruency judgment task	N400 amplitude was larger for congruous than incongruous words, with no difference between incongruous types; latency was similar overall but shorter for unrelated than related incongruous items; Patients exhibited earlier ERP differentiation for related incongruous stimuli, but failed to show early differentiation for unrelated incongruous stimuli.	Preserved semantic priming in schizophrenia suggests intact semantic memory, with verbal deficits arising at the performance level. Attenuated N400 amplitudes emerge only under task demands requiring semantic categorization and response selection — not from general semantic insensitivity. N400 sensitivity to congruency is normal, indicating that prior reports of N400 reduction reflect decision-making demands, not impaired semantic processing
Bobes et al.[16]	Chinese & Spanish	Semantic Comprehension	Picture-word semantic matching task (long SOA)	N400 amplitude is attenuated during long-SOA priming, and the N400 effect is larger (more negative) for unrelated than related words	The N400 deficit in schizophrenia reflects a specific impairment in contextual integration — rather than enhanced semantic associations — challenging the longstanding "loosened associations" hypothesis.

Niznikiewicz et al.[17]	English	Semantic Comprehension & Contextual Integration	Lexical semantic judgment task(short SOA & direct priming paradigm)	Under unrelated conditions, patients with schizophrenia exhibited more negative N400 amplitudes than healthy controls, whereas no significant difference was observed under related conditions. Within-group analysis revealed a lack of priming effect in patients, and their N400 latency was significantly prolonged compared to controls.	ERP analyses reveal a dysfunction in the semantic network of patients with schizophrenia, reflecting a pure neural abnormality unconfounded by behavioral response complexity — with the core deficit lying in impaired inhibitory control during early language processing.
Matsuoka et al.[18]	Japanese	Semantic Comprehension	Lexical semantic judgment task	Semantic processing effects on ERPs were observed in both groups during the 200–298 ms and 300–598 ms time windows, but only in patients did these effects persist into the 600–698 ms window; The delayed repetition effect was nearly absent in patients with schizophrenia.	These findings suggest that aberrant semantic activation in schizophrenia — including the paradoxical increase in N400 amplitude to congruent or semantically related words — stems from a failure to use preceding contextual information to generate accurate semantic predictions, thereby rendering even expected stimuli as unexpected.

Niznikiewicz et al.[19]	English	Semantic Comprehension	Syllable judgment task(short SOA)	N400 amplitude was attenuated in unrelated conditions relative to healthy controls, with a lack of semantic priming and a significant inhibitory effect observed.	The aberrant language process observed in schizophrenia reflects a dominance of inhibitory mechanisms over impaired semantic activation — rather than a primary deficit in activation.
Salisbury et al.[20]	English	Semantic Comprehension	Sentence meaning judgment task	Patients with schizophrenia exhibited significantly larger N400 amplitudes to all sentence endings, regardless of semantic congruency, whereas healthy controls showed N400 enhancement only to incongruent endings. Furthermore, N400 peak latency was significantly prolonged in patients relative to controls.	The N400 pattern supports the "semantic activation maintenance deficit" model: initial semantic activation may be intact, but the ability to sustain activation in working memory is impaired.

Mathalon et al.[21]	English	Semantic Comprehension & Contextual Integration	Picture-word verification task(short SOA)	In the primed/unprimed word comparison, patients with schizophrenia exhibited slower overall responses, yet their behavioral priming effect was comparable to that of healthy controls. N400 latency at Pz was unaffected by group. Behavioral priming was not significantly associated with thought disorder or unusual thought content, but showed a significant negative correlation with hallucinatory behavior.	The normal N400 response to primed words indicates intact utilization of semantic context — neither deficient nor exaggerated priming — suggesting preserved capacity for contextual and semantic integration. The attenuated N400 to unprimed words reveals reduced sensitivity to subtle semantic inconsistencies, providing direct evidence for a diffuse semantic activation profile. Critically, under short SOA conditions, the absence of N400 latency delay in patients confirms that this deficit originates in purely automatic, pre-attentive processing stages, independent of strategic or attentional modulation.

Kostova et al.[13]	French	Contextual Integration & Semantic Comprehension	Lexical semantic judgment task(weakly associated words & short SOA)	N400 abnormalities in schizophrenia were not modulated by contextual structure; semantically related words elicited more positive amplitudes than unrelated words and amplitude in related-words were significantly enhanced compared with healthy controls.	Patients with schizophrenia exhibit a fundamental deficit in semantic integration that impairs their ability of semantic associations — challenging the hypothesis that high-structure contexts can fully compensate for this impairment and demonstrating its cross-contextual stability.
Condray et al.[10]	English	Semantic Comprehension	Lexical decision task (word/nonword)	Patients with schizophrenia showed reduced N400 priming, but haloperidol-treated patients exhibited a significant effect only at Fz electrode — particularly under automatic semantic activation.	Both automatic activation and controlled attention mechanisms during semantic memory access are impaired in schizophrenia, with the pattern of automatic activation best accounted for by a parallel distributed processing model.
Iakimova et al.[12]	French	Semantic Comprehension & Contextual Integration	Metaphor judgment task	N400 amplitude at midline electrodes was significantly more negative for incongruent endings than congruent ones; metaphorical endings elicited more attenuated N400 responses than literal endings; and literal endings elicited more negative N400 amplitudes than those in healthy controls.	N400 effect showed that slowed semantic search, reflects a core deficit in contextual integration that underlies their broader language impairment, and show profound difficulty in processing metaphorical contexts — suggesting a breakdown in the brain's ability to use situational context to constrain and refine semantic access.

Best & Bowie[22]	English	Semantic Comprehension	Semantic matching task	In the 300–500 ms window, phonologically similar and novel endings elicited larger N400 amplitudes than typical endings — an effect stronger in diagnosis-blinded participants. In the 600–900 ms window, central-parietal amplitudes exceeded right and left parietal amplitudes, with right > left; and novel endings showed earlier onset at central-parietal sites than at either lateral parietal site.	The modulation of N400 amplitude by diagnostic awareness provides neurophysiological evidence that the observed semantic anomaly reflects an expectancy effect — wherein unexpected stimuli elicit amplified neural responses due to violated predictions.

Metzler et al.[23]	English	Semantic Comprehension	Self-referential semantic judgment task	The attenuation of the N400 effect was positively correlated with the severity of positive symptoms in patients with schizophrenia; patients showed larger N400 amplitudes to incongruent endings than congruent ones, but the N400 effect was attenuated relative to healthy controls; no significant ERP differences were observed between incongruent and congruent trait adjectives under either self-referential or other-referential conditions.	Patients with schizophrenia exhibit attenuated N400 effects to self-referential semantic violations, and the degree of attenuation was positively correlated with the severity of positive symptoms. The attenuation of the N400 effect may reflect impaired self-referential processing in schizophrenia
Boyd et al.[24]	English	Semantic Comprehension	Lexical semantic relatedness judgment task	Patients exhibited reduced N400 semantic priming effects under comparable SOA conditions, while N400 amplitudes to related and unrelated targets at Fz electrode demonstrated good test-retest reliability.	N400 amplitude shows good test-retest reliability, making it a promising neurophysiological biomarker for schizophrenia.

Wu et al.[25]	Chinese	Semantic Comprehension	Idiom semantic congruency judgment task	Compared with pre-treatment, after 12 weeks of treatment, both risperidone and paliperidone significantly reduced N400 latency and increased N400 amplitude under congruent conditions. Under incongruent conditions, only paliperidone significantly shortened N400 latency, while only risperidone significantly increased N400 amplitude.	No significant association was observed between serum BDNF levels and N400 amplitude or latency, suggesting that BDNF may not mediate the cognitive impairments or cognitive improvements observed in schizophrenia, and that the effects of antipsychotic medication on BDNF and cognition may operate via distinct mechanisms.
Raucher-Chéné et al.[26]	French	Semantic Comprehension	Semantic congruency judgment task	Under homophone (ambiguous) vs. control (unambiguous) conditions, patients with schizophrenia exhibited larger N400 amplitudes to incongruent than congruent targets, and the N400 congruency effect was greater for homophones than for control words.	Patients with schizophrenia and those with bipolar disorder both exhibit semantic processing deficits, yet their neurophysiological signatures — as indexed by ERP patterns — reveal distinct underlying mechanisms.

Table. 2 Studies on P600/LPC in ERPs of Patients with Schizophrenia

Author	Language	Experimental Focus	Experimental Mode	ERPs Results	Conclusions from ERPs
Salisbury et al.[20]	English	Semantic Comprehension	Sentence meaning judgment task	Patients exhibited slightly reduced LPC amplitudes and significantly prolonged peak latencies compared to healthy controls.	These findings suggest impaired fine-grained post-integrative processing and slowed working memory updating, reflecting a general deceleration in high-level semantic and cognitive operations following semantic integration.
Kostova et al[13]	French	Semantic Comprehension & Contextual Integration	Lexical semantic judgment task(weakly associated words & short SOA)	Under highly structured conditions, incongruent words elicited larger LPC amplitudes than congruent ones; whereas under weakly structured conditions, the N400 effect persisted into the LPC time window, with congruent words eliciting larger LPC amplitudes.	Abnormalities in the LPC window suggest impaired working memory updating, reduced sensitivity to semantic conflict, and a deficit in post-lexical semantic integration in schizophrenia.

Iakimova et al.[12]	French	Semantic Comprehension & Contextual Integration	Metaphor judgment task	Incongruent sentence endings elicited more positive LPC responses; metaphorical and literal sentences showed distinct neural signatures; overall LPC amplitude was attenuated; and the central-parietal topography of the LPC was observed only in response to incongruent and metaphorical stimuli.	Patients with schizophrenia exhibit impaired semantic integration, and metaphor processing may engage neural mechanisms overlapping with those underlying semantic conflict resolution.
Lee et al.[15]	Korean	Syntactic processing	Auditory syntactic judgment task	Patients with schizophrenia showed significantly reduced P600 amplitudes to syntactic violations, comparable to those with bipolar disorder; however, P600 latency was normal relative to controls but delayed compared to the bipolar group. Moreover, lateralized P600 responses were observed only in healthy controls.	Patients with schizophrenia exhibit a core deficit in basic syntactic processing, reflecting a primary neurocognitive impairment, whereas individuals with bipolar disorder show neural abnormalities that are behaviorally compensated — preserving syntactic performance despite underlying dysfunction.

3. Methodology

All references cited in this study are taken from PubMed. Using advanced search strategies combined with MeSH terms, this study searched for the keywords “schizophrenia,” “language processing,” “ERPs,” “N400,” “P600,” and “LPC.” Studies were filtered to exclude reviews, case reports, non-ERP studies, and articles focused exclusively on the effects of psychotropic medications.

Of the 16 included studies, 15 reported N400 findings and 4 reported P600 or LPC effects (with overlap allowed across categories to capture all ERP components examined).

In stage of review, this study divided all studies into N400 and P600/LPC. Articles reporting both N400 and P600/LPC findings were included in both categories to reflect the full scope of ERP component involvement. In each category, this study summarized and compared experimental designs, the features of focusing components, ERPs conclusions.

4. Discussion

SOA is critical for distinguishing the nature of semantic processing abnormalities in schizophrenia: short SOA may unmask hyperpriming, whereas long SOA reveals a deficit in activation maintenance [20,21]. For instance, Mathalon et al. reported intact N400 latency and normal priming under short SOA, contrasting with attenuated effects under long SOA (e.g., Bobes et al. [16]) [21]. Despite apparent discrepancies, these findings converge on a unified model: schizophrenia involves a core deficit in semantic activation maintenance that manifests differently depending on task demands—preserved in brief, automatic contexts but impaired when sustained integration is required.

Among all studies of N400 component, N400 amplitude is reduced in patients with schizophrenia compared with healthy controls. In the semantically unrelated/incongruent condition, N400 amplitude was larger in the semantically unrelated/incongruent condition than in the related/congruent condition; however, it remained significantly attenuated in individuals with schizophrenia compared with healthy controls under the same condition. Some of these studies also reported that N400 priming effect reflected impaired. Within the domain of language behavior research, individuals with schizophrenia demonstrated significant impairments in both semantic and contextual processing. In semantic relatedness tasks, they exhibited reduced ability to comprehend and associate semantic information, along with deficient semantic integration. In context-dependent tasks, most patients failed to effectively utilize contextual cues to guide language comprehension. Consistent with the attenuated N400 response, behavioral data demonstrated significant deficits in semantic integration and context-dependent language use in individuals with schizophrenia, suggesting a shared underlying mechanism of impaired predictive coding during language comprehension. Some researchers found some new association between N400 and schizophrenia. Such as, Metzler et al. reported that patients with schizophrenia who got lower self-concept scores also showed reduced N400 amplitudes, and both measures were positively correlated with symptom severity [23]; Bobes et al. found that late-stage language processing deficits in schizophrenia are consistent across cultures and writing systems (e.g., phonographic vs. logographic scripts), supporting the notion of cross-cultural consistency in the neurocognitive basis of language impairment [16].

Across all studies of P600/LPC component, similar to the N400 effect, the P600 and LPC components both show abnormal reductions in patients with schizophrenia across studies. During syntactic judgment tasks, individuals with schizophrenia exhibit marked difficulties in syntactic comprehension, indicating a core deficit in syntactic processing that is closely associated with attenuated P600 amplitudes.

5. Conclusion

This review synthesizes findings from prior studies to draw the following conclusions: patients with schizophrenia exhibit abnormal reductions in amplitude and delayed latencies in the N400, P600, and LPC components during late-stage language processing, alongside delayed latencies in the N400 and LPC. These ERP abnormalities provide robust neurophysiological evidence for a systemic and pervasive deficit in late-stage language functions — including semantic comprehension, contextual integration, syntactic analysis, and semantic integration — suggesting that language impairment in

schizophrenia reflects a unified, domain-wide neurocognitive disruption rather than isolated processing failures.

This study did not systematically examine subtype-specific differences in schizophrenia, but rather focused on identifying transdiagnostic, core deficits in late-stage language processing that are commonly observed across the disorder. And also, this study did not conduct an in-depth analysis of the relationship between the P600 and LPC components, nor did it include detailed topographic analysis of ERP responses. Furthermore, potential moderating factors — including cultural influences, medication effects, and illness stage — were not systematically investigated, though they were occasionally noted in the included studies.

Future research should investigate subtype-specific ERP profiles in schizophrenia to determine whether distinct clinical subtypes exhibit differential patterns of neural dysfunction during language processing. Additionally, integrating high-resolution neuroimaging techniques — such as Electrocorticography (ECoG) and intracranial EEG (iEEG) — could enhance spatial specificity and provide deeper insights into the neural mechanisms underlying language deficits in schizophrenia.

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