Electrophysiological responses to argument structure violations in healthy adults and individuals with nonfluent Aphasia

Abstract

Agrammatic individuals show impaired production of verbs with complex argument structure. Whether these participants show argument structure deficits during comprehension, however, is unclear. The present study investigated this issue by examining electrophysiological responses to argument structure violations in agrammatic individuals and healthy adults. Results showed that unlike control participants, who evinced a negative effect followed by a positive shift (N400-P600) in response to argument structure violations, individuals with agrammatic aphasia showed a P600 response only. This suggests impaired real time processing of the thematic requirements of verbs.

Introduction

In recent years, several studies have found that agrammatic individuals show impairments in producing verbs and sentences with complex argument structures, e.g. they show greater difficulty producing 3- than 2-argument verbs, and 2- than 1-argument verbs (De Blesser & Kauschke, 2003; Jonkers & Bastiaanse, 1996; Kim & Thompson, 2000; among others). The nature of this deficit, however, is not clear. Some findings suggest that argument structure representations are preserved in agrammatism. For example, agrammatic individuals show sensitivity to argument structure properties of verbs in grammaticality judgment, picture matching, and true-false decision tasks (Kim & Thompson, 2000; Lee & Thompson, 2004; Thompson, 2003), and normal activation of argument structure information in cross-modal lexical decision tasks (Shapiro, Gordon, Hack, & Killackey, 1993; Shapiro & Levine, 1990). However, some data indicate that argument structure processing may be affected in agrammatic aphasia (e.g. Grodzinsky & Finkel, 1998). It is therefore still under debate whether argument structure deficits in aphasic individuals are constrained to production, or if they also impact sentence comprehension ability.

Previous studies investigating argument structure processing in aphasia have used off-line tasks, thus not providing information about real-time computation. In contrast, on-line measures such as event-related potentials (ERPs) allow observation of language processing as it unfolds in time. ERP studies of argument structure information processing in healthy individuals have shown that violations associated with the number of arguments (e.g. *The cousin dawdled *the violinist*) elicited a biphasic N400-P600 pattern (Friederici & Frisch, 2000; Frisch, Hahne, & Friederici, 2004). The N400 effect was suggested to reflect difficulty in thematic integration when arguments violate verb argument structure requirements, whereas the P600 was argued to reflect an attempt at syntactic reanalysis or repair following thematic integration failure.

The present study investigated online argument structure processing in agrammatic aphasia by examining ERPs in response to argument structure violations in agrammatic individuals, as well as healthy young and older adults. A semantic violation condition was included to investigate possible differences in sensitivity to semantic and argument structure information.

Method

Participants: The study included 15 agrammatic individuals, 15 young healthy adults and 23 older healthy adults, all native English speakers. Aphasic participants were matched with older control participants for age. All aphasic participants suffered left-hemisphere strokes and were in the chronic stage of aphasia. They were classified as agrammatic based on their performance on the WAB (Kertesz, 2007) as well as narrative language samples and other testing. Mean WAB-AQ was 76.1 (range 56.4 – 93).

Materials: 35 obligatorily two-place verbs (e.g. *pull*) and 35 obligatorily one-place verbs (e.g. *sneeze*) were selected. Correct sentences (1a) contained a transitive verb and a semantically congruent object. Argument structure violations (1b) were realized by replacing the transitive verb with an intransitive verb. For semantic violations (1c), the final word of the sentence was semantically inappropriate.

(1)   a. John visited the doctor and the nurse.

        b. John sneezed <u>the</u> <u>doctor</u> and the nurse.

        c. John visited the doctor and the <u>socks</u>.

Each experimental sentence was 6300 ms long (7 words * 900 ms per word). There were 35 sentences in each condition, along with 160 filler sentences.

Procedures: On each trial a fixation cross was displayed on the computer screen, while an auditory sentence was presented over the loudspeakers. Eight hundred milliseconds after the offset of the sentence, a visual cue instructed the participants to perform an acceptability judgment task. The visual cue was presented for 5000 msec or until a response was made. The next trial started 1500 msec after the participant's button press. Order of presentation was randomized across participants.

ERP data recording and analysis: EEG data was acquired using a high impedance physiological measurement system (ANT: Advanced NeuroTechnology). ERPs were recorded from 32 scalp sites. ERPs were time-locked to the onset of the critical word in each sentence (for semantic violations - the sentence final noun; for argument structure violations – both the determiner immediately following the verb and the noun following it). Three latency windows were defined for statistical analyses: 300-500, 500-700 and 700-800 msec post word-onset.

Results

Behavioral results: Agrammatic participants were significantly less accurate in responding to sentences with argument structure violations (Mean accuracy – 59.7%) than grammatically correct sentences *(*Mean accuracy – 84.3%*, F* (1, 14) = 10.34, *p* < .01), and sentences with semantic anomalies (Mean accuracy – 81.4%*, F* (1, 14) = 19.49, *p* < .01). However, there was no significant difference in accuracy between grammatical sentences and sentences with semantic violations (*F* < 1). Additionally, agrammatic participants had significantly prolonged response latencies, compared to both control groups (all *p*s < .01, corrected for multiple comparisons), in all conditions.

ERP results: In the argument structure violation condition, young control participants showed a biphasic effect, with early negativity (N400) followed by a positive shift at the position of the post-verbal determiner (see Figure 1). Older controls showed a late centro-parietal positivity at the determiner; at the critical noun, they displayed a broadly distributed early negativity, followed by posterior positivity (P600) (see Figure 2). Agrammatic participants did not show an N400-like effect on either the determiner or the noun, but a small positivity was observed at the position of the determiner (see Figure 3).

In the semantic violation condition, all three participant groups showed an N400 effect, but the negativity was reduced in the agrammatic group compared to the two control groups (see Figure 4).

Discussion

In this study, we investigated argument structure processing in individuals with agrammatic aphasia, using a grammaticality judgment task and ERP recordings. Results showed that the agrammatic participants were impaired on grammaticality judgments of sentences including argument structure violations, to an extent exceeding the deficits reported in previous studies (Grodzinsky & Finkel, 1998; Kim & Thompson, 2000).

Online, agrammatic participants displayed different electrophysiological responses to argument structure violations than control participants. Both control groups displayed an N400-P600 pattern (though this effect appeared on the determiner for the young group and on the noun for the older group). In contrast, argument structure violations elicited only an attenuated P600 effect in participants with aphasia, and no early negativity was observed. The P600 component has been found to be sensitive to a variety of syntactic violations, including phrase structure deviations (Neville, Nicol, Barss, Foster, & Garrett, 1991) and agreement or inflection errors (Coulson, King, & Kutas, 1998, Osterhout & Nicol, 1999). It also has been associated with grammatical but syntactically nonpreferred constructions (Osterhout & Holcomb, 1992, 1993).

In contrast to argument structure violations, the agrammatic participants' response to semantic violations was not qualitatively different from control participants'.

The present results show that agrammatic individuals do not demonstrate normal real-time sensitivity to mismatches between the argument structure requirements of a verb and the incoming linguistic information accompanying it. While these participants are aware of semantic incongruity in real time, the same does not hold for verb-argument incongruity, as evidenced by the lack of an N400 component, as well as by their grammaticality judgments. The P600 effect may reflect a later attempt of the agrammatic participants to integrate the surplus incoming material with the preceding sentence context.

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Figure 1. Upper: Grand-average ERPs for young controls elicited by correct sentences and argument structure violations at the position of the post-verbal determiner. Lower: Topographical distribution of ERP effects across the scalp based on difference waveforms (violation-correct) at the 300-500, 500-700, and 700-800 msec time intervals.
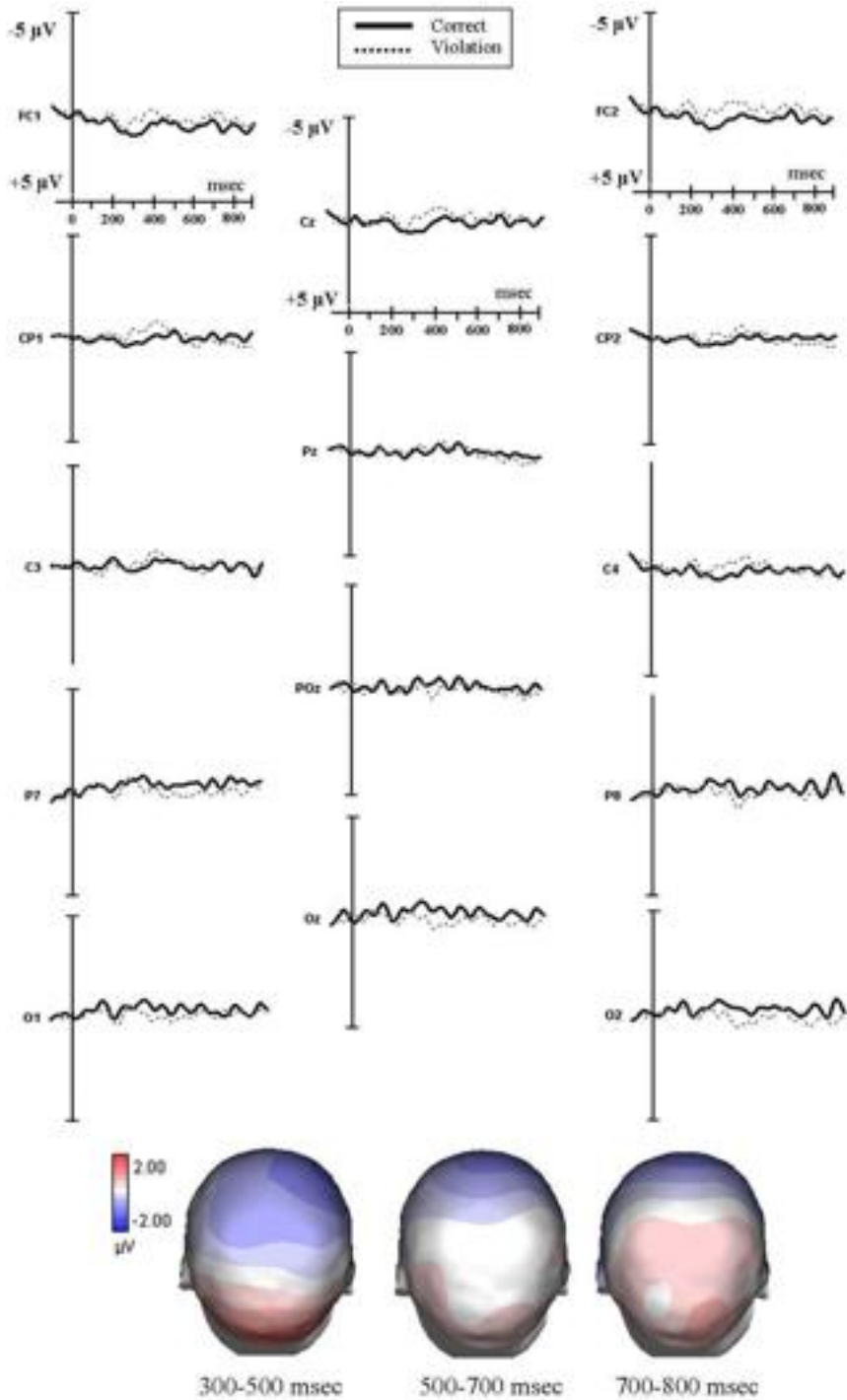
Figure 2. Upper: Grand-average ERPs for older controls elicited by correct sentences and argument structure violations at the position of the critical noun. Lower: Topographical distribution of ERP effects across the scalp based on difference waveforms (violation-correct) at the 300-500, 500-700, and 700-800 msec time intervals.
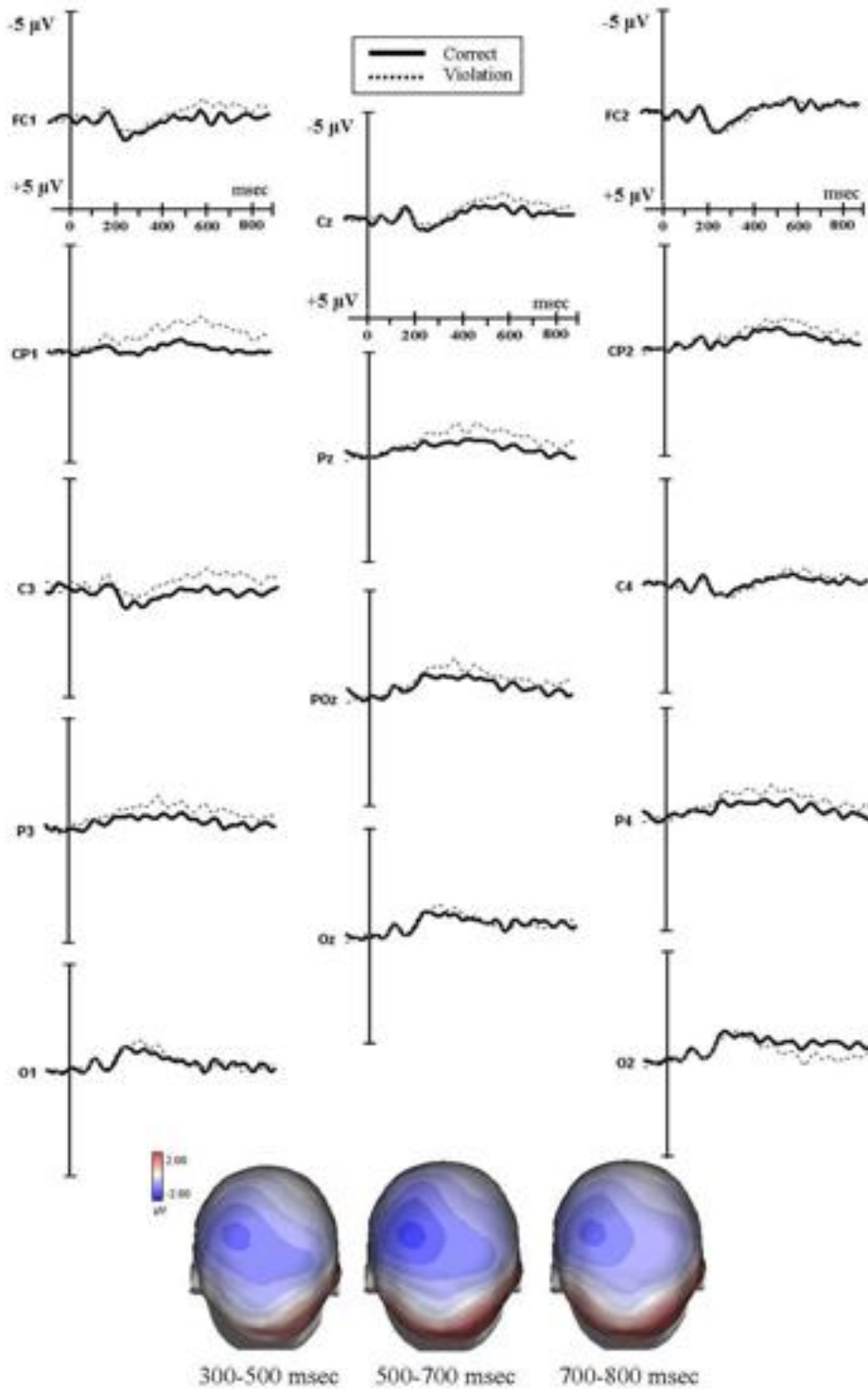

300-500 msec   500-700 msec   700-800 msec

Figure 3. Upper: Grand-average ERPs for agrammatic participants elicited by correct sentences and argument structure violations at the position of the post-verbal determiner. Lower: Topographical distribution of ERP effects across the scalp based on difference waveforms (violation-correct) at the 300-500, 500-700, and 700-800 msec time intervals.

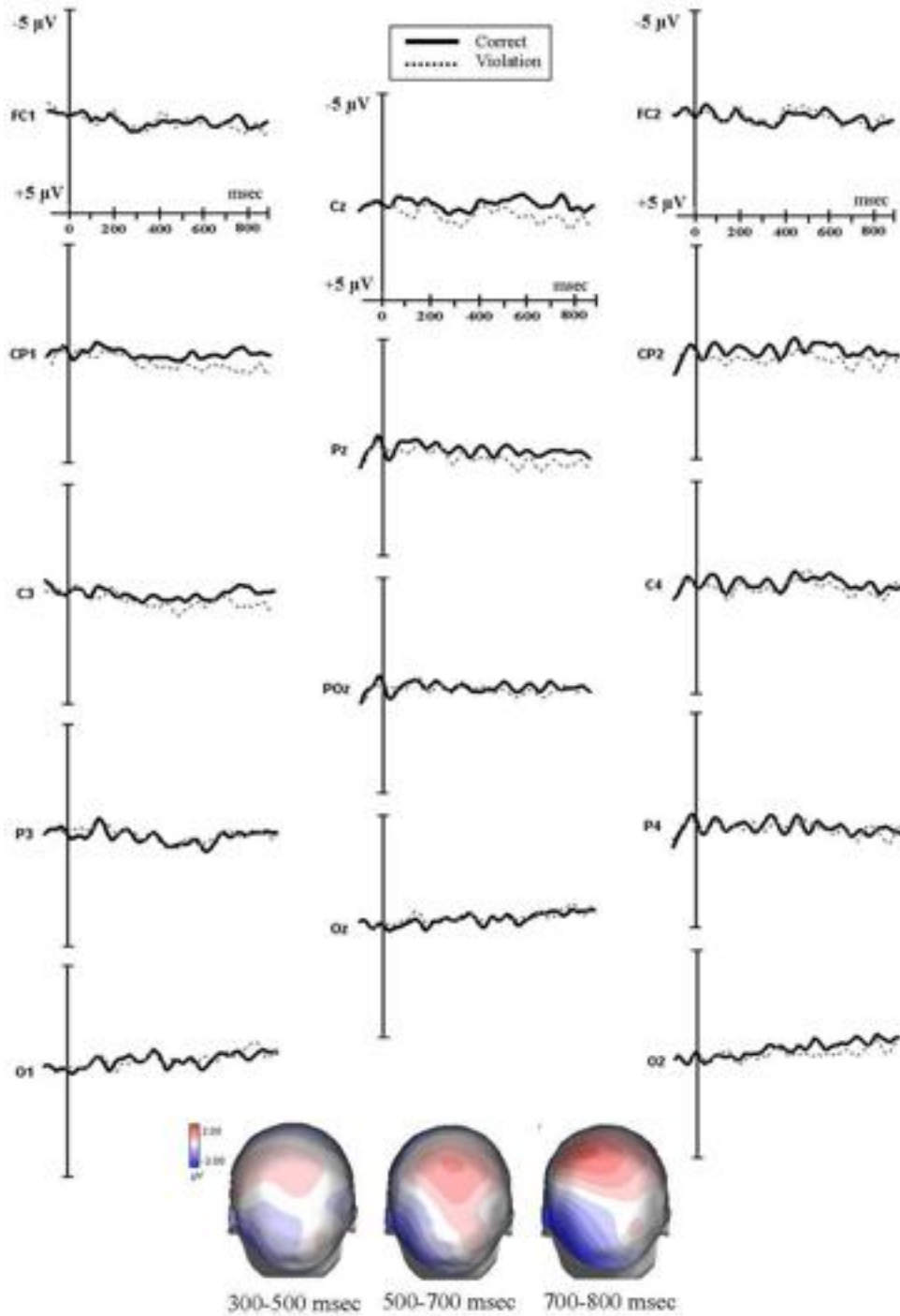
300-500 msec   500-700 msec   700-800 msec

Figure 4. Topographical distribution of ERP effects across the scalp based on difference waveforms (semantic violation-correct) at the 300-500, 500-700, and 700-800 msec time intervals for (a) younger control participants (b) older control participants (c) agrammatic participants