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BRIEF REPORT

Cloze probability does not only affect N400 amplitude: The case of complex prepositions

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Abstract

Cloze-probability levels are inversely correlated with N400 amplitude, indicating an easier integration for expected words in semantic-pragmatic contexts. Here we exploited the prespecified standard order of complex prepositions and measured the ERPs time-locked to the last preposition in sentences in which complex prepositions were presented in their standard form or with the last preposition changed. The expected preposition elicited an N280 followed by an N400–700, two ERP components previously associated to the processing of closed-class words. The unexpected preposition elicited only an N280, and the N400–700 was reduced. These results reflect the specificity of the contextual constraints linked to the complex preposition word sequence.

Descriptors: ERPs, Sentence comprehension, N400–700, Cloze probability, Vocabulary class

The ERP literature on language processing has extensively shown that an unexpected constituent elicits a large N400 (e.g., Kutas & Hillyard, 1984) and that the N400 amplitude inversely correlates with cloze-probability levels. The role of cloze probability, operationalized in terms of a constituent predictability in a sentence, has been mainly investigated through violations of semantic-pragmatic sentential constraints (e.g., Kutas, Van Petten, & Kluender, 2006).

In the present paper we focus on contextual constraints that induce high levels of cloze probability, similarly to semantic-pragmatic sentential constraints, but have a different origin: They in fact derive from the collocational nature of the stimuli. The stimuli are complex prepositions such as "*with respect to*" or "*in relation to*" that belong to the vast family known by linguistics as collocations, that is, sequences of lexical items that habitually cooccur having a typical sequential order and a global meaning. Specifically, complex prepositions are arbitrary combinations of constituents usually formed by a preposition (P_1), a noun (N), and another preposition (P_2). These fixed-order constituents are lexical bundles with a prepositional function (Trawinski, 2003). The fixed nature of complex prepositions makes the last preposition highly predictable given a sufficient fragment (e.g., P_1–N).

Recent studies showed that semantic-pragmatic constraints affect the N400 amplitude also for closed-class words (DeLong, Urbach, & Kutas, 2005; King & Kutas, 1995). The aim of this study was to test whether the specificity of the constraints conveyed by a collocational context might modulate comprehension in a potentially different way with respect to semantic-pragmatic constraints. Hence we investigated the effect of the collocational constraints on the last preposition (P_2), comparing the ERPs elicited by P_2 in sentences that contained the standard complex preposition (see 1a for an example) with those elicited by a different, unexpected, P_2 given the same collocational context (see 1b):

		P_1	N	P_2	
1a.	*Esistono molte prove*	*a*	*sostegno*	*di*	*quella ipotesi.*
	There are many proofs	in	support	of	that hypothesis.
1b.	*Esistono molte prove*	*a*	*sostegno*	*per*	*quella ipotesi.*
	There are many proofs	in	support	for	that hypothesis.

Given the high expectation of P_2 (*di* in 1a) due to the collocational context P_1–N, an unexpected preposition (*per* in 1b) should cause a larger N400, as in DeLong et al. (2005) and King and Kutas (1995). Because the N400 is typically modulated by

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semantic-pragmatic contextual constraints, this result would extend the functional meaning of this component to a different type of contextual constraint.

However, alternative predictions are possible given the functional status of complex prepositions and the status of the target word we manipulated (a closed-class word). Neville, Mills, and Lawson (1992) argued that there are two left anterior negative deflections related to closed-class words: the N280, after the N1–P2 complex, followed by the N400–700. The N280 was considered to reflect the lexical access to the closed-class word (Neville et al., 1992). However, the existence of an electrophysiological marker for the categorical difference between open- and closed-class words has been largely debated. Some researchers did not find a clear distinction between the two vocabulary classes on this early component (Brown, Hagoort, & ter Keurs, 1999; Munte et al., 2001). Other researchers argued that the two negativities are a modulation of the same component shifting in latency on the basis of either lexical frequency (see the notion of Lexical Processing Negativity; King & Kutas, 1998; Kutas, 1997) or of word length (Osterhout, Allen, & McLaughlin, 2002; Osterhout, Bersick, & McKinnon, 1997). Because our aim was not to establish the electrophysiological correlates of word category information, we only assumed a functional distinction between a lexically related negative component (with a peak at around 280 ms for short, high-frequent items) and a negative component sensitive to semantic-pragmatic contextual constraints, that is, the N400 (reported for closed-class words as well; DeLong et al., 2005; King & Kutas, 1998).

There is instead a higher consensus on the N400–700 as a stable vocabulary marker for closed-class words (Brown et al., 1999; Kutas et al., 2006; Munte et al., 2001). Van Petten and Kutas (1991) first described this N400–700 component as part of the family of contingent negative variation (CNV). The CNV typically increases when participants are expecting a relevant event to occur. Accordingly, closed-class items would act as syntactic signals to the reader that a new phrase head constituent is imminent with an electrophysiological correlate represented by the N400–700. Brown et al. (1999), however, argued that in the N400–700 time window the system might prepare for a generic content word and not necessarily for the syntactic head of a prepositional phrase. In any case, for both hypotheses this expectation is reflected in a CNV-like component that develops contingent upon the processing of a closed-class word.

In our study, we expect the P_2 in the standard complex preposition to elicit an early negative peak (at around 280 ms) and an N400–700. Because we balanced the length and frequency of P_2 in the standard and modified conditions, we did not expect any modulation on the earlier component. In contrast, a P_2 that is unexpected, given the previous collocational context P_1–N, should affect either the N400–700 or the N400. If the P_1–N–P_2 sequence is processed as a single functional element that prepares the processing system for a content word, an unexpected P_2 might disrupt the functional role to be assigned to the following content word, reducing the N400–700. On the other side, if cloze probability affects the waveforms irrespective from the semantic-pragmatic or collocational origin, a larger N400 might be expected.

Method

Participants

Fifty undergraduate students from the University of Modena took part in the experiment for course credit after giving informed consent (26 female; age range: 19–24 years). They were all right-handed native Italian speakers with normal or corrected-to-normal vision without any history of neurological disorders.

Material

Sixty Italian complex prepositions with a literal meaning constituted by a preposition (P_1), a noun (N), and a final preposition (P_2) were selected and inserted in well-formed sentences (Standard condition, see 1a). We then derived a corresponding set of sentences in which the final preposition (P_2) was substituted with another preposition in the same position (Modified condition, see 1b). The standard collocations were quite frequent in a corpus of written Italian (http://dev.sslmit.unibo.it/corpora) (907.4 occurrences over 3 million words), whereas the modified complex prepositions were almost absent (97.4 occurrences). The length and frequency (Laudanna, Thornton, Brown, Burani, & Marconi, 1995) of P_2 in the two conditions were balanced (length: Standard: $M = 3.35$ letters, $SD = 1.16$; Modified: $M = 3.2$ letters, $SD = 1.07$, $t[59] = 1.43$, *n.s.*; log-frequency: Standard: $M = 3.72$, $SD = 0.5$; Modified: $M = 3.62$, $SD = 0.48$, $t < 1$). The cloze probability of P_2 was assessed using a written completion test administered to 36 participants: The sentence fragments containing P_1–N were continued in 89% of the cases with P_2 and in 0.7% of the cases with the substituted preposition. Twenty-two participants rated the naturalness of all the sentences on a 7-point scale from 1 (*unnatural sentence*) to 7 (*fully natural sentence*). The two conditions significantly differed (Standard: $M = 4.8$, $SD = 0.86$; Modified: $M = 3.7$, $SD = 0.94$, $t_1[21] = 7.82$, $p < .001$, $t_2[59] = 7.505$, $p < .001$). The mean naturalness rating of the Modified condition, very close to the middle point of the scale, suggests that the sentences were perceived as less natural than in the Standard condition but not as semantically ill formed.

Two counterbalanced lists were created, each of which contained 30 sentences per condition and 150 filler sentences containing the target prepositions (P_2) but not in multiword configurations. Each participant saw only one of the two lists. The assignment of the stimuli to the Standard or to the Modified condition in each list was random.

Procedure

Participants were tested individually in a silent room. The sentences were visually presented word by word (maximum visual angle: 5°) after the presentation of a fixation cross at the center of the screen. Each word was presented for 300 ms followed by a 300-ms blank screen. The final word of each sentence was presented with a period followed by a 1500-ms intertrial interval. Every 10 sentences on average, participants were asked to answer a true–false question by pressing the corresponding button. The questions were equally distributed across the two conditions. The experiment lasted approximately 35 min.

Electroencephalograph (EEG) Recordings and Analysis

EEG was amplified and recorded with a BioSemi ActiveTwo system from 30 Ag/AgCl active electrodes (http://www.biosemi.com) mounted on a cap and placed on the scalp according to the International 10–20 System (AF3, AF4, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, CP5, CP1, Cz, CP2, CP6, P7, P3, Pz, P4, P8, PO3, Oz, PO4) plus two sites below the eyes for eye movement monitoring. Two additional electrodes placed close to Cz, the Common Mode Sense [CMS] active electrode and the Driven

Right Leg [DRL] passive electrode, were used to form the feedback loop that drives the average potential of the participant as close as possible to the AD-box reference potential (Metting van Rijn, Peper, & Grimbergen, 1990). Skin–electrode contact, obtained using electro-conductive gel, was monitored, keeping voltage offset from the CMS below 25 mV for each measurement site.

All the signals were (DC) amplified and digitalized continuously with a sampling rate of 512 Hz with a anti-aliasing filter with -3 dB point at 104 Hz (fifth order sinc filter); no high-pass filtering was applied online. The triggering signals to each word onset were recorded on additional digital channels.

EEG data were off-line re-referenced to the average activity of the two mastoids and band-pass filtered (0.2–30 Hz, 12 dB/octave) plus a notch filter at 50 Hz, given that for some subjects the low-pass filter was not effective in completely removing the 50-Hz artifact. Epochs containing the ERPs elicited by the target word (P_2) were extracted in the interval from -200 ms to 700 ms.

Segments including artifacts exceeding ± 80 μV amplitude were rejected; 6 participants, given the high number of rejected epochs ($>25\%$), were excluded from the following analyses. In the remaining participants, rejections rates did not statistically differ across conditions (mean rejection rate of 7% for the Standard condition and 6% for the Modified condition; $t<1$).

Single subject waveforms for each condition were obtained averaging single epochs after a prestimulus baseline correction (– 200 ms) and used for the extraction of grand-average waveforms and the computation of mean voltages in different time windows.

Mean voltage values at the midline and lateralized electrodes were treated separately. At the midline, two-way analyses of variance (ANOVAs) with repeated measures on Condition (Standard, Modified) and Electrode (Fz, Cz, Pz, Oz) were performed. We grouped the remaining electrodes in four regions of five electrodes each for evaluating topographical differences: Left Frontal (AF3, F7, F3, FC1, FC5), Right Frontal (AF4, F4, F8, FC2, FC6), Left Posterior (CP1, CP5, P3, P7, PO3), and Right Posterior (CP2, CP6, P4, P8, PO4). ANOVAs were performed on these regions with different levels for the Longitude factor (Anterior, Posterior), Hemisphere factor (Left, Right), and Condition factor (Standard, Modified). Greenhouse–Geisser correction was applied to F values when appropriate.

Results

Participants answered the comprehensions questions with an overall accuracy of 93% (without any between-condition difference, $t<1$).

In Figure 1 we report the grand averages for the two experimental conditions at each electrode. A negative peak around 280 ms is evident after the N1–P2 complex, maximal in the left frontal sites for both conditions. This N280 peak is followed by a slow negative deflection on frontal sites that starts at about 350 ms and returns to baseline at 600 ms, when the following noun appears, consistently with the time course and shape of the N400–700 described in the literature (Brown et al., 1999; Van Petten & Kutas, 1991). The N400–700 component is left lateralized for the Standard condition and is larger than the one elicited by the Modified condition.[1]

[1]No effects were evident at the following word and at the end of the sentence.

The two components were statistically evaluated using the mean voltages as dependent variables in two time windows: 200–350 ms for the N280 and 350–650 ms for the N400–700.

The ANOVA on the midline electrodes in the 200–350-ms time windows showed only a main effect of Longitude, $F(3,129)=17.56$, $p<.001$, whereas the ANOVA on the four lateralized regions showed main effects of Longitude, $F(1,43)=57.40$, $p<.001$, and Hemisphere, $F(1,43)=56.02$, $p<.001$. The main effects of the spatial factors (Longitude and Hemisphere) are due to the left and frontal distribution of the N280.

The midline electrodes ANOVA on the 350–650-ms time window showed a main effect of Longitude, $F(3,129)=29.48$, $p<.001$. The analyses on the four lateralized regions revealed main effects of Longitude, $F(1,43)=58.21$, $p<.001$, Hemisphere, $F(1,43)=47.07$, $p<.001$, and Condition, $F(1,43)=4.03$, $p<.05$, and a Hemisphere × Condition interaction, $F(1,43)=12.37$, $p<.001$. Post hoc analyses comparing the two conditions in each electrodes region revealed an effect only in the left-anterior region, $t(43)=-2.739$, $p<.01$. These results suggest a left lateralization of the N400–700 for the Standard condition (e.g., F7/F8 and FC5/FC6) and a marked reduction on left-anterior sites of the N400–700 for the Modified condition.

Discussion

This study investigated the electrophysiological correlates of the processing of a specific type of closed-class items whose final constituent has a high cloze probability. Complex prepositions are in fact constructed by combining two propositions and a noun in a fixed prespecified sequence. We hypothesized that the contextual expectation for P_2, given P_1–N, might be different from that typically at work in semantic-pragmatic contexts (Kutas et al., 2006) being due to the collocational nature of complex prepositions. And in fact our results showed a functional dissociation of the two components, the N280 and the N400–700, previously associated to closed-class word processing.

The N280, more evident on the left sites of the scalp, did not differ in the Standard versus Modified conditions. The lack of modulation of this component, considered to index the lexical processing of the critical closed-class word (King & Kutas, 1998; Neville et al., 1992), suggests that the collocational context P_1–N did not influence the lexical access to the target preposition P_2. The second relevant component, the N400–700, was affected by the change of the expected preposition: When the complex preposition was presented in its standard configuration, a left-lateralized N400–700 emerged. In contrast, in the Modified condition a marked reduction of the N400–700 on the left hemisphere was recorded. This component (typically elicited by closed-class words in sentential context) has been considered to reflect the system expectation for either a content word (Brown et al., 1999) or, more specifically, a syntactic head (Van Petten & Kutas, 1991). Consistent with both hypotheses, our results suggest that the standard form of the complex preposition indeed played this role indexed by a large and left lateralized N400–700. However, when the standard configuration was changed (as in 1b), the contextual expectations for a collocational prespecified P_2 were not satisfied. This led to a weakening of the functional role of the modified complex preposition and to a potential loss of its syntactic signaling function. This process is mirrored by the reduced N400–700. The high off-line cloze-probability values of P_2 suggest that,

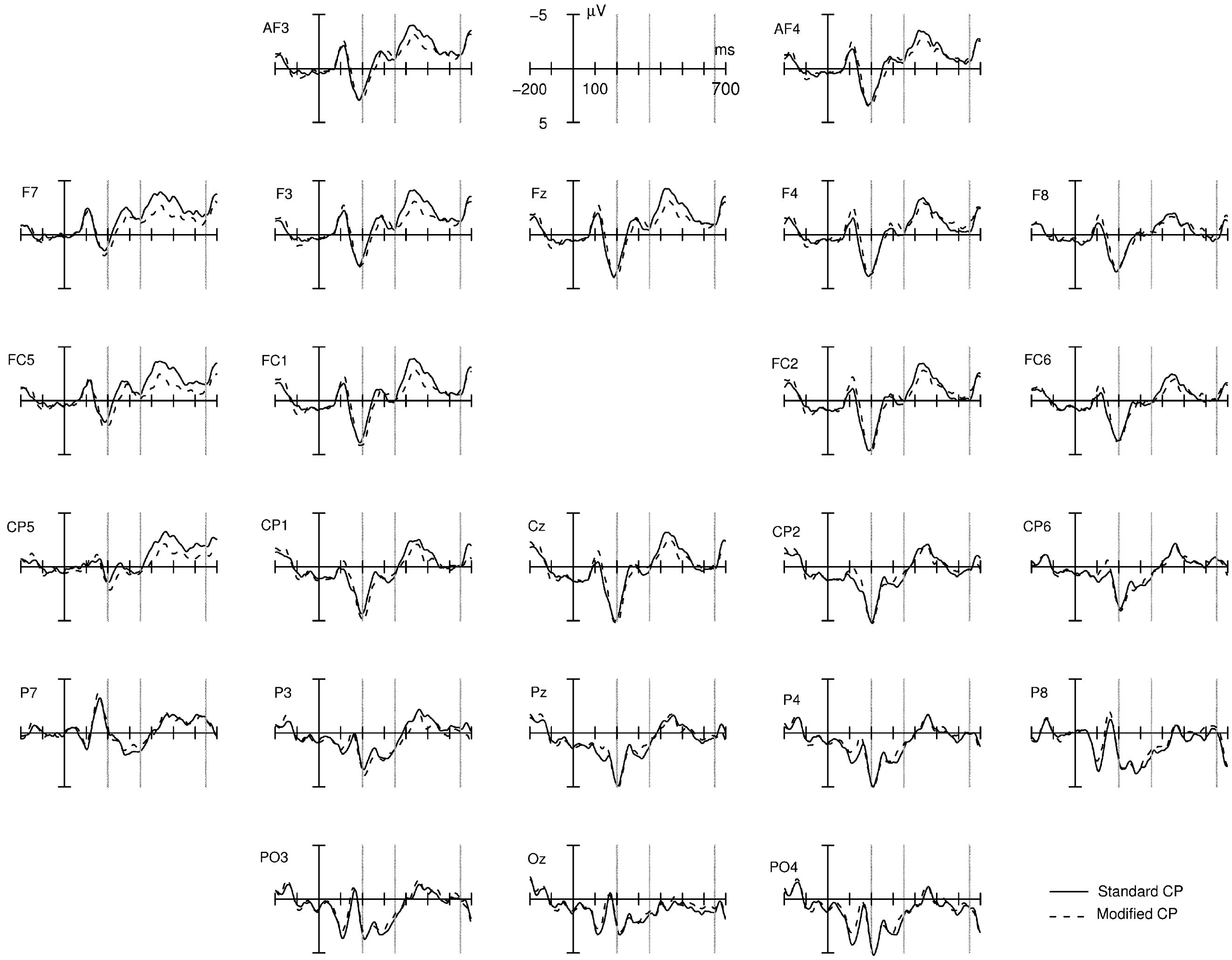

Figure 1. Grand-averaged ERPs time-locked to P_2 for the Standard condition and the Modified condition at each electrode considered in the analysis.

just after they read P_1–N, readers recognized the complex preposition and hence expected a given P_2. When this expectation was not met and a different P_2 arrived, the input no longer corresponded to the standard complex preposition and this might have disrupted the syntactic role associated to the P_1–N–P_2 string.

The N400–700 is clearly different from the N400 typically reported when semantic-pragmatic constraints are manipulated. We in fact observed a reduced N400–700 for the unexpected final preposition of the prepositional collocation whereas DeLong et al. (2005) showed a larger N400 for the unexpected determiner. This difference might originate from the diversity of the contextual constraint that operates on the two types of closed-class words, with semantic-pragmatic constraints operating on the determiner in DeLong et al.'s study (N400) and collocational constraints operating on complex prepositions in our study (N400–700). This explorative hypothesis requires further testing on other types of multiword expression in which the constituents and the word order are typically prespecified. Idiomatic expressions are the most clear case of this sort: They might allow us in fact to verify whether the collocational constraint has the same electrophysiological impact when the strings mostly consist of open-class words and have a figurative interpretation.

REFERENCES

Brown, C. M., Hagoort, P., & ter Keurs, M. (1999). Electrophysiological signatures of visual lexical processing: Open- and closed-class words. *Journal of Cognitive Neuroscience*, *11*, 261–281.

DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, *8*, 1117–1121.

King, W. K., & Kutas, M. (1995). Who did what and when? Using word- and clause related ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience*, *7*, 378–397.

King, W. K., & Kutas, M. (1998). Neural plasticity in the dynamics of human visual word recognition. *Neuroscience Letters*, *244*, 61–64.

Kutas, M. (1997). Views on how the electrical activity that the brain generates reflects the functions of different language structure. *Psychophysiology*, *34*, 383–398.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*, 161–163.

Kutas, M., Van Petten, C., & Kluender, R. (2006). Psycholinguistic electrified II: 1994–2005. In M. Traxler & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics* (2nd ed, pp. 659–724). New York: Elsevier.

Laudanna, A., Thornton, A. M., Brown, G., Burani, C., & Marconi, L. (1995). Un corpus dell'italiano scritto contemporaneo dalla parte del ricevente. In S. Bolasco, L. Lebart, & A. Salem (Eds.), *III Giornate internazionali di Analisi Statistica dei Dati Testuali* (Vol. I, pp. 103–109). Roma: Cisu.

Metting van Rijn, A. C., Peper, A., & Grimbergen, C. A. (1990). High-quality recording of bioelectric events. Part 1. Interference reduction, theory and practice. *Medical and Biological Engineering and Computing*, *28*, 389–397.

Munte, T. F., Wieringa, B. M., Weyerts, H., Szentkuti, A., Matzke, M., & Johannes, S. (2001). Differences in brain potentials to open and closed class words: Class and frequency effects. *Neuropsychologia*, *39*, 91–102.

Neville, H. J., Mills, D. L., & Lawson, D. S. (1992). Fractionating language: Different neural subsystems with different sensitive periods. *Cerebral Cortex*, *2*, 244–258.

Osterhout, L., Allen, M., & McLaughlin, J. (2002). Words in the brain: Lexical determinants of word-induced brain activity. *Journal of Neurolinguistics*, *15*, 171–187.

Osterhout, L., Bersick, M., & McKinnon, R. (1997). Brain potentials elicited by words: Word length and frequency predict the latency of an early negativity. *Biological Psychology*, *46*, 143–168.

Trawinski, B. (2003). Licensing complex prepositions via lexical constraints. In F. Bond, A. Korhonen, D. McCarthy, & A. Villavicencio (Eds.), *Proceedings of the ACL 2003 Workshop on Multiword Expressions: Analysis, Acquisition and Treatment* (pp. 97–104). East Stroudsburg, PA: Association for Computational Linguistics.

Van Petten, C., & Kutas, M. (1991). Influences of semantic and syntactic context on open- and closed-class words. *Memory and Cognition*, *19*, 95–112.

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