Object-Clitic Agreement in Croatian: An ERP Study*

Eva Pavlinušić and Marijan Palmović

Abstract: The present experiment was designed to open a discussion on the processing of anaphoric clitics in Croatian. The aim of the experiment was to examine the role of long-distance anaphoric relations and local structural case constraints during pronoun interpretation. On-line processing of cliticized direct-object pronouns embedded in a sentence context was examined using the event-related potential (ERP) technique. Pronominal clitics were either morphologically correct or incorrect. Incorrect pronoun forms contained a gender violation, a case violation, or a violation of both gender and case. Electrophysiological response to each of the violation types was measured at the clitic site and at the sentence-final word and compared to activity in the control condition. The results indicate that, as attested in previous studies in other languages, there are functional and temporal differences between the processing of gender and case violations in pronouns. Whereas gender violations elicit late positivity, i.e., the component related to the processing of syntactic difficulties, case violations elicit a biphasic response in the form of early negativity followed by late positivity. A similar ERP effect is observed with double violations as well, albeit with a different distribution of the early negativity. The appearance of early negativities with case violations confirms previous findings on the rapidity of local syntactic processing as compared to the processing of long-distance anaphoric dependencies. At the end of the sentence, the typical wrap-up effect that reflects final semantic integration is replaced by the component related to syntactic reanalysis and repair.

1. Introduction

Morphological agreement has an important role in parsing and comprehending language. This is especially true for morphologically rich languages in which a relatively free word order allows even mutually dependent sentence constituents, e.g., the verb and its arguments, to be distant from each other and ordered in a way that reflects the information structure of the utterance rather than the underlying syntactic representation of the sentence (Franks 2005). The patterns of morphological marking provide speakers with cues for understanding and producing structurally and semantically acceptable utter-

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ances; they also help them to keep track of referents in the discourse (Corbett 1998).

When it comes to the richness of morphological forms and the relationships they mark, Croatian is no exception among the Slavic languages. For instance, finite verbal forms are marked for person and number agreement with their subjects,[1] whereas members of the noun phrase agree with the head noun in number and gender. Pronouns, in contrast, agree in person and gender with their antecedents (Corbett 1998). Even the shortest and phonologically least salient pronominal forms, i.e., the pronominal clitics, are marked for all the phi-features (person, number, and gender), as well as for case. Clitics differ from strong pronouns in several aspects. According to Despić (2013) clitics have no internal syntactic structure and cannot be focused because they cannot bear phrase accent. Unlike strong pronouns, they can refer to both human and non-human referents, and they can function as bound variables. Clitics must undergo movement, which is not the case with strong pronouns and full NPs (Franks 2005, Despić 2013, Bošković 2015). Pronominal clitics in Croatian are enclitics, i.e., they follow the first accented word in the phrase. When it comes to their syntactic position, they are second-position clitics (Franks 1998, 2005; but see Marušič 2008 for a different view). The existence of second-position clitics in a language has been linked to some more fundamental properties: they are found only in those Slavic languages that have no article, i.e., no DP in general (Despić 2013, Runić 2013, Bošković 2015), and that allow null-subjects (Franks 2005). Consequently, in languages like Croatian, clitics are NPs, not DPs. It is worth mentioning that the very basic assumptions on clitics differ significantly depending on the theoretical framework and language under scrutiny, which is evident from the fact that clitics are sometimes viewed not as words, but as affixes or even distinct morphological categories (for a review, see Gerlach 2002).

In Croatian a pronoun is obligatorily cliticized when it is inserted as direct object, unless its referent is contrastively stressed, as in (3).

(1) Ana voli **Marka**.
Ana$_{F.SG.NOM}$ love$_{3PRES.SG}$ Marko$_{M.SG.ACC}$
'Ana loves **Marko**.'

(2) Ana **ga** voli.
Ana$_{F.SG.NOM}$ CL$_{M.SG.ACC}$ love$_{3PRES.SG}$
'Ana loves **him**.'

[1] In Croatian, finite verbs agree only with their subjects, never with objects.

(3) Ana voli **njega**, ne mene.
Ana$_{F.SG.NOM}$ love$_{3PRES.SG}$ him$_{M.SG.ACC}$ not me$_{1SG.ACC}$
'Ana loves **him**, not me.'

In (1) the full NP *Marka* carries the role of direct object, while in (2) it is replaced by the accusative masculine singular clitic *ga*. In (3) the full pronoun *njega* is used in place of the clitic *ga* because of contrastive focus on the referent of the pronoun.[2]

The form of the object clitic is determined by a twofold mechanism. On the one hand, the verb that governs the pronominal clitic as its internal argument assigns case to the clitic. On the other hand, the clitic inherits phi-features from the NP it is coindexed with, i.e., the antecedent. Both case and phi-features are morphologically marked on the clitic. While the former relationship can be described as a local structural case constraint, the latter is the result of a long-distance dependency that establishes coreference between the pronoun and its antecedent by using various information types: lexical, syntactic, and pragmatic (but also properties that belong to the areas of logical syntax, interpretive systems, informativeness, etc.; Reuland 2003: 17), as well as grammatical cues, i.e., morphological agreement (Corbett 1998).

The present study was designed as a pilot experiment for a study on the processing of anaphoric clitics as verb arguments in Croatian. In this study we focused on morphological information as representative of the long-distance dependencies and on the case constraint as a locally acting principle. The aim of the study was to examine the role of local versus long-distance dependencies during pronoun interpretation and integration using the event-related potential (ERP) technique. Even though there are studies that have investigated the aforementioned processes using event-related potentials, the majority of research has been conducted on Germanic and Romance languages. To the best of our knowledge, no such studies have been conducted on Slavic languages. Language processing in Slavic in general needs to be further explored if the body of knowledge that exists for other language groups is to be attained.

2. Electrophysiological Studies on Morphosyntactic Processing

Event-related potential (ERP) has become the method of choice for psycholinguistic research, particularly for dissociating various processes. This is possible because a complex ERP response is comprised of several characteristic waves or components. Previous research has shown each wave to have an interpretation. For example, a LAN (left-anterior negativity)-P600 pattern has

[2] A parallel pattern exists for indirect objects, meaning that the full NP inserted as indirect object can also be replaced by a clitic or a full pronoun.

been associated in many experiments with grammatical violations (Coulson, King, and Kutas 1998; Friederici, Hahne, and Saddy 2002; Barber and Carreiras 2005), where LAN has been interpreted as the electrophysiological signature of the violation and P600 has been related to syntactic reinterpretation or repair processes (Mueller, Hirotani, and Friederici 2007; Mancini, Molinaro, and Carreiras 2013). However, the interpretation of ERP effects is seldom straightforward, since the same components seem to appear as a response to diverse experimental manipulations. For example, LAN has been obtained for linguistic stimuli that were correct, but demanding in terms of working memory resources, whereas the P600 has also been known to appear in syntactically correct sentences with a semantic violation that can be repaired if the assignment of thematic roles is changed (Kuperberg et al. 2003; van Herten, Kolk, and Chwilla 2005). After being observed in response to various types of mismatch—be they orthographic, lexical, and semantic (see Kuperberg 2007 and Bornkessel-Shlesewsky and Schlesewsky 2009)—the P600 was interpreted as reflecting a "late stage of reanalysis that could operate on qualitatively different sources of information" (Molinaro, Barber, and Carreiras 2011: 916).

Putting aside the matter of the precise functional definition of ERP components, we turn to the results of the electrophysiological studies on agreement processing. Violations in both phrase-internal agreement (e.g., article-noun) and clause-internal agreement (e.g., subject-verb) have been shown to elicit the LAN-P600 pattern (Coulson, King, and Kutas 1998; Barber and Carreiras 2005; for a review, see Molinaro, Barber, and Carreiras 2011). The early (LAN) and late (P600) ERP components reflect the early and late stage of syntactic processing. While the appearance of LAN is interpreted as a response to the detection of morphosyntactic anomaly or to the inability to perform automatic syntactic integration, the P600 probably reflects attempts to reanalyze the structure and build the syntactic representation of the sentence (Hagoort, Wassenaar, and Brown 2003; Friederici and Kotz 2003; Barber and Carreiras 2005).

However, other patterns of ERP response have also been observed. In a study on the processing of gender or case violations on pronouns in German and Dutch, Lamers et al. (2006) obtained no LAN, only P600, in sentences with violations. What the authors did obtain in the 300–500 ms time window was an N400 effect. The N400 is an ERP component that reflects difficulties in semantic, lexical, or pragmatic processing (Kutas and Hillyard 1983; Brown and Hagoort 1993; Kutas and Federmeier 2000; Friederici, Hahne, and Saddy 2002; Anderson and Holcomb 2005; among others). It was most pronounced with incongruent gender, probably because the antecedent NP's biological and grammatical gender were both violated by inserting a gender-inappropriate pronoun. The authors assume that the participants relied on semantic information to establish coreference between the pronoun and its antecedent. As to the lack of LAN, the authors suggest that interlanguage variability might account for this result, since the majority of the studies in which LAN

was observed were conducted in English. However, LAN was reported as an indicator of morphosyntactic violations in languages other than English (for a review, see Molinaro, Barber, and Carreiras 2011). In a study on the processing of subject-verb agreement in number and person in Spanish, Silva-Pereyra and Carreiras (2007) obtained AN (anterior negativity) in violation conditions. AN is a component that resembles LAN in latency and polarity but has a more medial and right distribution. It was observed with disagreement in both number and person and was consistently followed by a P600.

In several studies that examined the processing of pronouns, only P600 was observed for violations involving phi-features. Osterhout and Mobley (1995) examined the processing of gender and number violations with reflexive pronouns in English and obtained the P600. Molinaro et al. (2008) also obtained P600 at the reflexive pronoun that disagreed in number with the antecedent or with the verb, and no early negativities. Silva-Pereyra, Carreiras, and Gutiérrez-Sigut (2012) obtained P600 for gender violations on pronouns in sentence contexts in Spanish; they obtained an N400-P600 pattern only when the pronoun form was actually ambiguous between an article and a pronoun. The P600 was observed in Hagoort and Brown's (1999) study in Dutch for gender agreement mismatches between articles and nouns.[3] The violations with interphrase relations have also been shown to elicit only P600: Nevins et al. (2007) obtained the P600 for violations of subject-verb agreement in Hindi, both for violations with a single phi-feature and for violations with two phi-features combined.

Case violations are thought to be processed at the level of argument structure, i.e., as violations of theta-role assignment. Various types of violations with verbal argument structure have been reported to elicit the P600 (Osterhout, McLaughlin, and Bersick 1997; Friederici, Hahne, and Saddy 2002; Kuperberg et al. 2003; van Berkum et al. 2007). In experiments where argument structure is violated by imposing an incorrect case form on one of the arguments, P600 is preceded by N400 (Frisch and Schlesewsky 2001; Mueller, Hirotani, and Friederici 2007). In addition to this, a LAN-P600 pattern has been observed for case violations on syntactic objects of verbs (Friederici and Frisch 2000).

3. The Present Study

In the present study, the processing of long-distance and local relations in Croatian was investigated using ERP. We chose to look at on-line pronoun resolution to see which linguistic levels play the most important roles in the process and what their relationship is in terms of temporal characteristics.

[3] They obtained N400 + P600 pattern at the final word of the sentence.

The anaphoric relationship that has to be established between a pronoun and its antecedent relies heavily on morphosyntactic agreement marking, since only NPs with an identical set of phi-features are candidates for the antecedent. When a pronoun is inserted as an object, its form is also determined by the case the verb assigns. Pronouns inserted as direct objects are assigned accusative case in Croatian and therefore have to take the accusative form. In order to examine the interaction between the long-distance anaphoric dependencies and the local case constraint, we compared ERP responses to the correct pronoun form with ERP responses to each of three violation types: long-distance dependency violations in the form of a gender violation, case violations as an anomaly of the local structural constraint, and joint violations of both gender and case. In other words, there were four experimental conditions:

(i) Congruent Gender, Correct Case (control condition)
(ii) Incongruent Gender, Correct Case
(iii) Congruent Gender, Incorrect Case
(iv) Double Violation: Incongruent Gender, Incorrect Case

The design of the experiment is similar to that in Lamers et al. 2006 with a few differences. The syntactic role of the pronoun in the present experiment is the direct object of the verb, whereas in Lamers et al. 2006 the pronoun was inserted as the object of a PP. Moreover, in Croatian the pronoun is cliticized in the verb-object construction, whereas in German and Dutch the pronoun in the PP remains in its full form. The antecedents of the pronouns in our study are all inanimate, which means that the gender of the pronoun is not semantically motivated, unlike in Lamers et al. 2006. Finally, while ERPs were measured only at the pronoun site in Lamers et al. 2006, in the present study they were measured both at the pronoun site and at the end of the sentence in order to examine whether the parser resolves all violation types immediately upon encountering an error. Several studies have demonstrated that violations within the sentence affect processing of the overall meaning of the utterance, as evidenced by the appearance of a so-called wrap-up effect (the semantics-related N400 effect) at the sentence-final word (Molinaro, Vespignani, and Job 2008; Hagoort and Brown 1999).

3.1. Methods

3.1.1. Participants

Twenty-one undergraduate students (17 women, 4 men) participated in the experiment. They were all native Croatian speakers, right handed, with no his-

tory of neurological or psychiatric disorders, and with normal or corrected-to-normal vision. Their ages ranged from 19 to 23 (mean = 20,8). They received a course credit for their participation.

3.1.2. Material

The object pronominal clitics were presented in the sentence context. Each experimental sentence began with an adverbial phrase containing time reference (e.g., 'every morning', 'every two weeks') and continued with a transitive verb followed by a direct object clitic,[4] after which another adverbial phrase was inserted that specified the place of the action ('in the garden', 'at the cafe') or the company ('with his neighbor', 'with her friends'). Each experimental sentence was preceded by an introductory sentence in which the antecedent of the pronoun was introduced. All the antecedents were inanimate NPs inserted as direct objects in postverbal position and marked for accusative case, so that the participants could rely on pragmatic information such as parallelism (since both the antecedent and the pronominal clitic are inserted postverbally as direct object) in pronoun interpretation in the absence of agreement marking, i.e., in violation conditions. In this way the pragmatic level of processing was held constant and was not expected to interfere with the other linguistic information necessary for pronoun resolution. Half of the NPs introduced as antecedents were masculine nouns, and the other half were feminine. None of the nouns had biologically motivated gender, since none of them designated an animate entity.

In the violation conditions the agreement marking and/or structural constraint was violated by inserting the inappropriate pronoun form. Thus, if the antecedent was a masculine noun, in the experimental sentences it was replaced by (i) a masculine singular accusative pronoun in the control condition, (ii) a **feminine** singular accusative pronoun in gender-violation condition, (iii) a masculine singular **dative** pronoun in case-violation condition, and (iv) a **feminine** singular **dative** pronoun in double-violation condition. Examples of the experimental stimuli can be found in (4).

[4] The object clitic in the experimental sentences is placed in the second position of the phonological phrase. In that way the case violation is detectable at the clitic, whereas if the clitic was placed in the second position of the utterance, it would not have been detectable until the verb was encountered. However, it should be noted that this placement is not unusual in the Croatian written language, and native Croatian speakers do not find it awkward or incorrect. The placement of the special clitics in Croatian has already been recognized as a far more complex matter than was assumed under the standard "second-place" approach, since the clitics appear in every possible position in the utterance, except at the beginning (and even there in the spoken language), in both written and spoken language (for an analysis, see Peti-Stantić 2013).

(4) a. Congruent Gender, Correct Case

Branko izrađuje drveni stolac.
Branko$_{M.SG.NOM}$ make$_{3PRES.SG}$ wooden$_{M.SG.ACC}$ chair$_{M.SG.ACC}$

Već pola sata brusi **ga**
already half hour$_{M.SG.GEN}$ sand$_{3PRES.SG}$ CL$_{M.SG.ACC}$

u radionici.
in workshop$_{F.SG.LOC}$

'Branko is making a wooden chair. He has already been sanding it for half an hour in the workshop.'

b. Incongruent Gender, Correct Case

Mislav pije crni čaj.
Mislav$_{M.SG.NOM}$ drink$_{3PRES.SG}$ black$_{M.SG.ACC}$ tea $_{M.SG.ACC}$

Svakog jutra priprema ***ju**
every$_{M.SG.GEN}$ morning$_{M.SG.GEN}$ prepare$_{3PRES.SG}$ CL$_{F.SG.ACC}$

u velikoj šalici.
in large$_{F.SG.LOC}$ cup$_{F.SG.LOC}$

'Mislav drinks black tea. Every morning he prepares *her in a large cup.'

c. Congruent Gender, Incorrect Case

Anton uređuje svoju garažu.
Anton$_{M.SG.NOM}$ decorate$_{3PRES.SG}$ REFL$_{ACC.SG}$ garage$_{F.SG.ACC}$

Već dva tjedna čisti ***joj** s
already two week$_{M.PL.ACC}$ clean$_{3PRES.SG}$ CL$_{F.SG.DAT}$ with

prijateljima.
friend$_{M.PL.INST}$

'Anton is decorating his garage. He has been cleaning *[to her] for two weeks already.'

d. Incongruent Gender, Incorrect Case

Jana je kupila modni
Jana$_{F.SG.NOM}$ AUX$_{3SG}$ buy$_{3PERF.SG}$ fashion$_{M.SG.ACC}$

časopis. Prije spavanja čita
magazine$_{M.SG.ACC}$ before sleeping$_{N.SG.GEN}$ read$_{3PRES.SG}$

***joj** u krevetu.
CL$_{F.SG.DAT}$ in bed$_{M.SG.LOC}$

'Jana bought a fashion magazine. Before sleeping she reads *[to her] in bed.'

A list of 120 sentence pairs was created, with 30 experimental sentences for each condition. Four versions of every experimental sentence were created for each condition, which made it possible to generate four lists of stimulus sentence pairs.

3.1.3. Procedure

Experimental stimuli were visually presented in a randomized order. Four sentence lists were distributed among the participants, so that each participant saw each sentence only once. The entire introductory sentence appeared on the screen for three seconds, after which the experimental sentence was presented phrase by phrase with the exception of the verb and the critical word (the pronominal clitic), which were presented as single words. Each phrase, as well as the verb and the pronominal clitic, was presented for 500 ms. One-fifth of the sentence pairs were followed by a simple comprehension question. After the last word of the experimental sentence a fixation point appeared in the center of the screen for two seconds and was followed either by the next introductory sentence or by the comprehension question. The participants' task was to read the sentences carefully and answer the question by pressing the button on the response box (the right one for YES, the left one for NO).

3.1.4. Data Acquisition and Analysis

An elastic cap (ActiCap) with 32 electrodes placed according to the international 10–10 system was used to record the continuous EEG signal. Eye movements were monitored by placing the VEOG and HEOG electrodes above and beneath the right eye for vertical movements and in temple areas on each side of the face for horizontal eye movements. The continuous EEG signal was recorded with a sampling rate of 250 Hz and the average reference (the only option for the Brain Products G.m.b.H. Quick Amp amplifier). Off-line the signal was rereferenced to the linked mastoids. It was filtered with a bandpass filter of 0.01–20 Hz, and corrected for eye blink artifacts using an ICA algorithm built in the Brain Products Analyser 2 software. Other artifacts (e.g., muscle artifacts) were removed manually. The signal was then segmented and averaged in the interval of –100 to 1000 ms around the onset of the critical word, i.e., the object clitic (trigger 1) and the final word of the experimental sentence (trigger 2). Baseline correction was performed according to the 200 ms pre-stimulus interval.

3.2. Results

The results show a complex pattern of ERP responses to different types of violations. Both negative and positive waves can be observed on both points of averaging: at the clitic site and at the end of the sentence (last word). However, Figure 1 on page 170, which represents the waveforms in all conditions averaged on these two points, does not reveal more than the existence of the effects in the late latencies. Topographic maps for the averages measured at the clitic site (Figures 2–4 on pages 171–72) and at the sentence-final position (Figures 5–7 on pages 172–73) provide better insight into the pattern of the results in the relevant latencies.

This pattern can vaguely be described as a negative-positive wave related both to incongruent gender and incorrect case (or both), with different amplitudes in different conditions.

3.2.1. The Effects Obtained at the Clitic Site

The effects obtained at the clitic position turned out to be the most important for the interpretation of the results. Generally, it seems that the negative wave around 400 ms is related to incorrect case (at least to a greater extent) and that

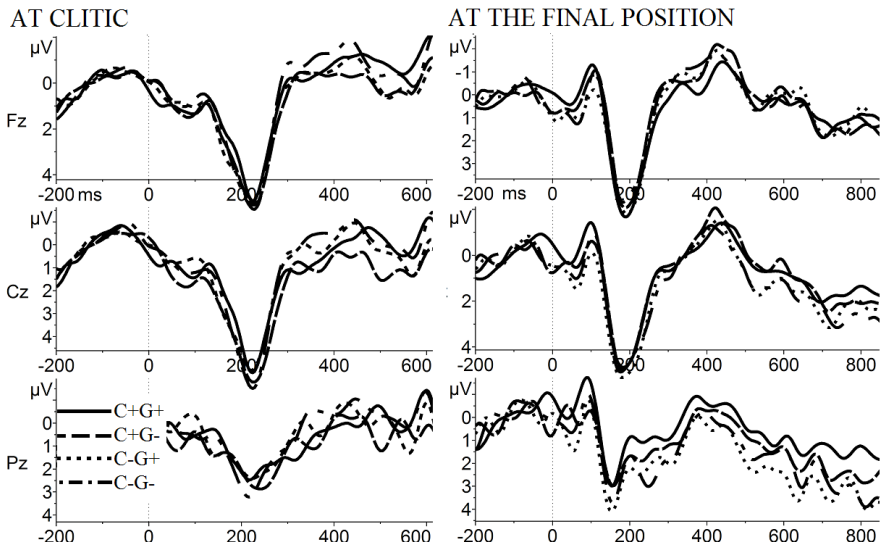

Figure 1. The ERP waveforms for all conditions obtained at the clitic site and at the sentence-final position on the central electrodes (frontal, central, and parietal). Negativity is plotted upwards.

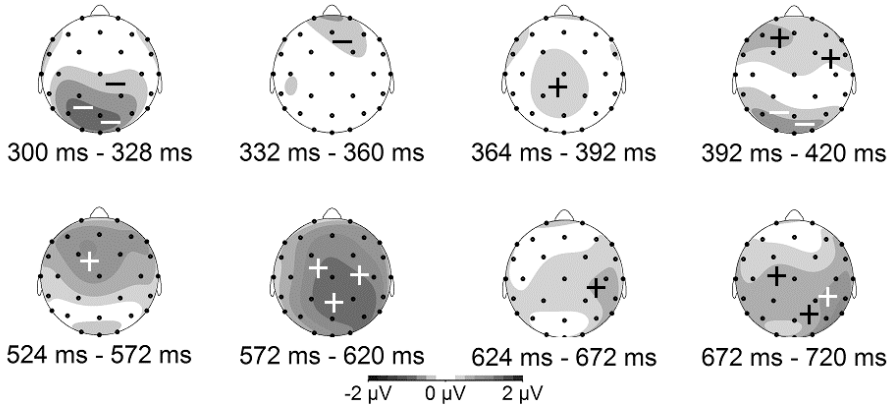

Figure 2. Topographic map based on the computation of difference waves between the control condition and the gender-incongruent condition at the clitic site

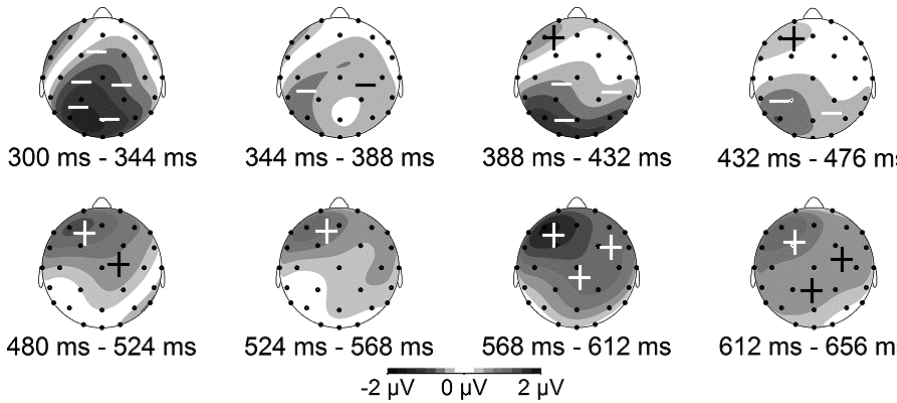

Figure 3. Topographic map based on the computation of difference waves between the control condition and the case-incorrect condition at the clitic site

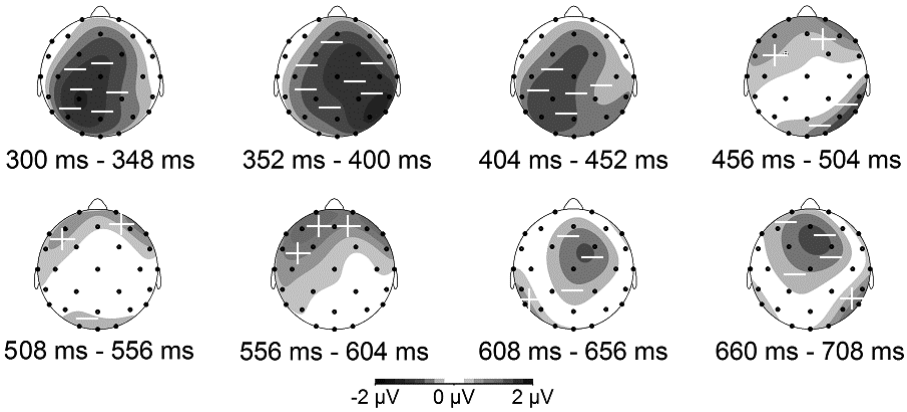

Figure 4. Topographic map based on the computation of difference waves between the control condition and a double-violation (case + gender) condition at the clitic

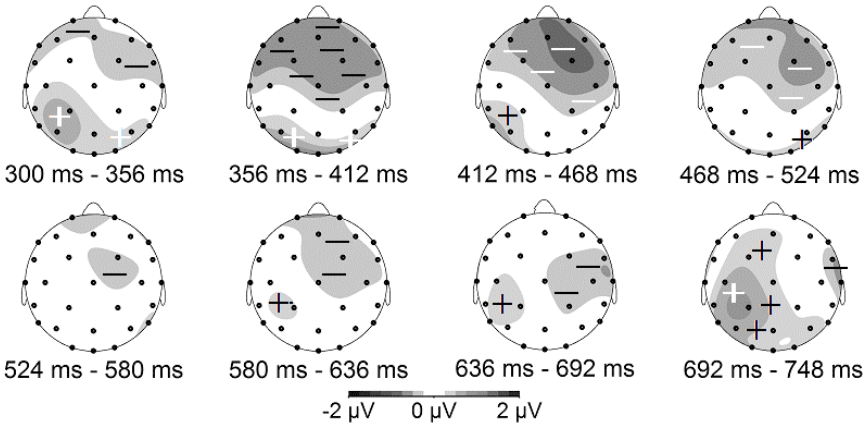

Figure 5. Topographic map based on the computation of difference waves between the control condition and the gender-incongruent condition at the sentence-final position

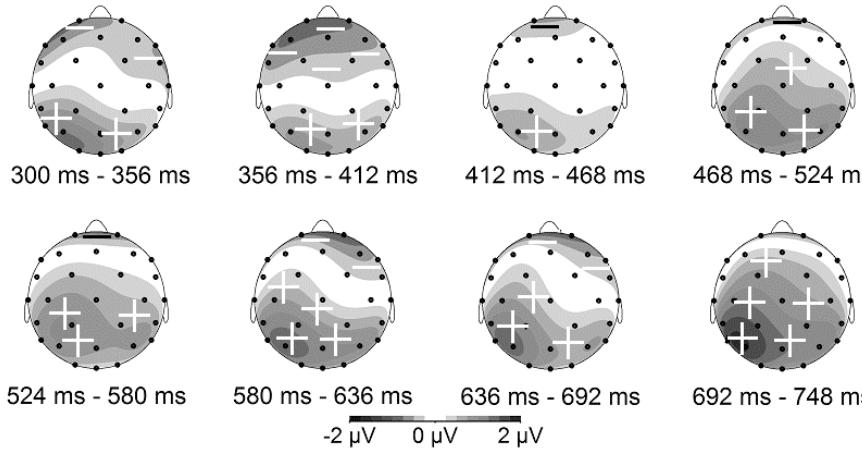

Figure 6. Topographic map based on the computation of difference waves between the control condition and the case-violation condition at the sentence-final position

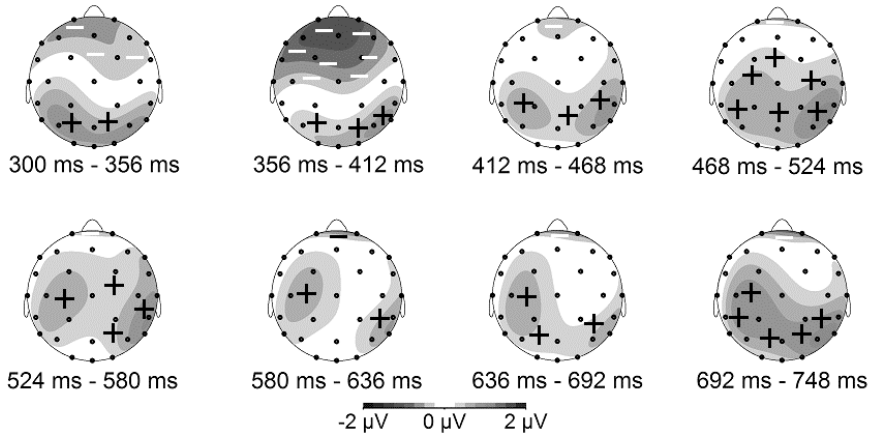

Figure 7. Topographic map based on the computation of difference waves between the control condition and a double-violation (case + gender) condition at the sentence-final position

the later positivity (around 500 ms and later) is related to the gender incongruence. Double violation (violation of both gender and case) seems to produce a negative effect around 400 ms followed by the frontal positive effect around 500 ms and later. However, one-way ANOVA measured for the mean amplitudes on each electrode in the 350–450 ms time interval showed no significant differences, while the post-hoc tests (LSD) give only scarce differences (between gender-incongruent and double-violation condition on FC2 electrode ($p = 0.04$) and between case-incorrect and gender-incongruent condition on P3 electrode ($p < 0.05$)). Similarly, in the later interval (480–580 ms) the results of the one-way ANOVA show no significant differences, with only scarce differences on some electrodes (between the case-incorrect and the gender-incongruent condition on F3 ($p = 0.02$), and between the control condition (no violation) and the gender-incongruent condition on FC1, Cz, and CP2 electrodes (with p-values 0.04, 0.03, and 0.04, respectively)).

3.2.2. The Results Obtained at the Sentence-Final Position

At the sentence-final position the results seem to be the opposite (although the general negativity-positivity is still visible): an anterior negativity elicited by gender incongruence, a posterior positivity elicited by the case violation and, roughly, their sum in the double-violation (case + gender) condition (see Figures 5–7).

Again, the one-way ANOVA shows that there are no statistically significant differences on any particular electrode. Both in the early and late intervals (350–450 ms and 550–650 ms, respectively) the post-hoc test showed no significant differences between experimental conditions. However, the repeated measure ANOVA reveals the factors that can explain the obtained data.

3.2.3. The Statistical Analysis

Repeated measure ANOVA was performed on the data with three factors in a 2×2×3 design (CASE×GENDER×POSITION). For the purpose of the analysis the frontal, central, and parietal electrodes were averaged for each condition (F3, Fz, and F4 electrodes for frontal, C3, Cz, and C4 for central and P3, Pz, and P4 for parietal, making the POSITION a three-level factor; see Figure 8, opposite). The averaging across only one dimension (anterior to posterior) and not the other (left–right) was based on the visual inspection of the data and the need to keep the number of factors as low as possible. The analysis was performed for the early (350–450 ms) and the late (550–650 ms) interval at the clitic site and at the sentence-final position. Time intervals for analysis

were determined based on the visual inspection of the data and on previous research.

For the analysis performed on the data obtained at the clitic position in the early interval, a statistically significant main effect of GENDER was found ($F(1, 20) = 6.2$, $p = 0.02$, $\eta_p^2 = 0.24$), as well as the statistically significant main effect of POSITION ($F(1, 20)$ 0 7.7, $p = 0.001$, $\eta_p^2 = 0.28$). There was neither a main effect of CASE ($F(1, 20) = 0.9$, $p = 0.35$, $\eta_p^2 = 0.04$) found, nor any statistically significant interaction. However, the post-hoc analysis (Tukey) reveals significant differences between frontal and parietal positions for gender ($p = 0.004$), case ($p = 0.01$), and a double violation ($p < 0.001$). Also, for GENDER the difference between frontal and central positions were found to be statistically significant ($p = 0.01$), but only when the case was incorrect. The results are graphically represented in Figure 8, revealing the details of the statistical "decomposition" of the results: while the lines representing GENDER are separate, representing the main effect (left), the lines representing CASE are close together for both correct and incorrect conditions (right), but with a slope (again, representing the main effect of GENDER). Only on the frontal electrodes the incorrect CASE elicited negativity that can be observed on the topographic maps (right), but a similar effect was obtained for the gender incongruence. The observed power (partial eta squared, η_p^2) confirms that much of the variance in the early interval can be explained by GENDER, although the negative effect is more pronounced in the case-incorrect condition.

In the later interval only the POSITION turned out to be statistically significant main effect ($F(1, 20) = 49.32$, $p < 0.001$, $\eta_p^2 = 0.17$). Both GENDER and

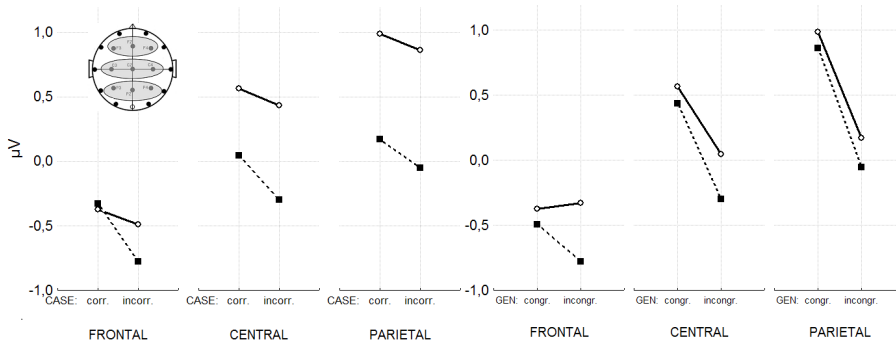

Figure 8. Statistical results for the rmANOVA in the 350–450 ms interval at the clitic site. Left: the lines represent GENDER, full line being congruent, dashed line incongruent gender conditions. Right: the lines represent CASE, full line being correct, dashed line incorrect case conditions.

CASE main effects were not significant ($F(1, 20 = 0.0002$, $p = 0.98$ and $F(1, 20) = 0.032$, $p = 0.86$, respectively). However, a statistically significant interaction of GENDER × CASE was found ($F(1, 20) = 6.05$, $p = 0.02$). The results are graphically shown in Figure 9, opposite.

Graphical representation of the results clearly shows that in the late interval both CASE and GENDER elicit the same effect and, curiously, in the same direction. There is a positive effect of violation in both CASE and GENDER (left ends of all full lines are below the left ends of dotted lines, both left and right). However, when the violations are combined, a negative effect can be observed.

At the sentence-final position the same analysis was performed showing a similar pattern of results (negativity followed by positivity). In the early interval (350–450 ms) no main effects were found (GENDER: $F(1, 20) = 0.25$, $p = 0.6$; CASE: $F(1, 20) = 0.70$, $p = 0.4$). However, a statistically significant interaction POSITION × GENDER ($F(2, 40) = 6.38$, $p = 0.004$) and GENDER × CASE ($F(1, 20) = 6.27$, $p = 0.02$) was found. The results are graphically represented in Figure 10, opposite.

In the late interval (550–650 ms) only the main effect of POSITION was found to be statistically significant ($F(1, 20) = 4.38$, $p = 0.02$). No other main effects reached statistical significance. However, a statistically significant interaction of GENDER × CASE was found ($F(1, 20) = 6.05$, $p = 0.02$). As the tendencies in the results are quite similar, the graph is omitted.

4. Discussion

The gender incongruence between the pronoun and its antecedent failed to elicit negativity in the early time window. Unlike in Lamers et al. 2006, the N400 was not obtained. However, in our study the gender of the antecedent was not biologically motivated, which means that the semantic reanalysis of the antecedent was of no help in interpreting the form of the pronoun. Violation of the gender, which would have also elicited the N400 effect, apparently did not result in additional processing at the pragmatic level either. This indicates that the parser did not commence the search for another antecedent (one with phi-features matching the inserted pronoun), interpreting the form of the clitic as a morphosyntactic error instead.[5] No LAN was observed either,

[5] The discourse-related negativities such as N400 or Nref (van Berkum et al. 2007; Hammer et al. 2008) usually appear if the parser interprets the mismatch in phi-features between the pronoun and its antecedent as an error in the assignment of the antecedent and attempts to find another referent for the pronoun. However, no such negativities were observed in the gender-incongruent condition, which leads us to assume that the reference of the pronoun is not reinterpreted. The reason for certainty in the choice of the referent probably lies in the highly constrained context in which syntactic, semantic, and pragmatic cues were used to ensure that the reference of the

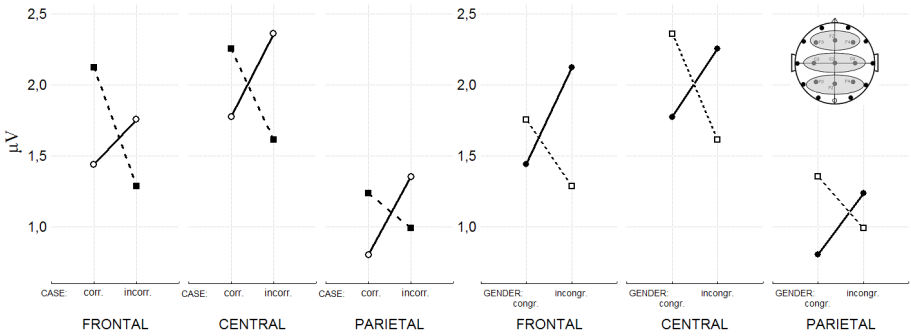

Figure 9. Statistical results of the rmANOVA in the 550–650 ms interval at the clitic site. Left: the lines represent GENDER, full line being congruent, dashed line incongruent gender conditions. Right: the lines represent CASE, full line being correct, dashed line incorrect case conditions.

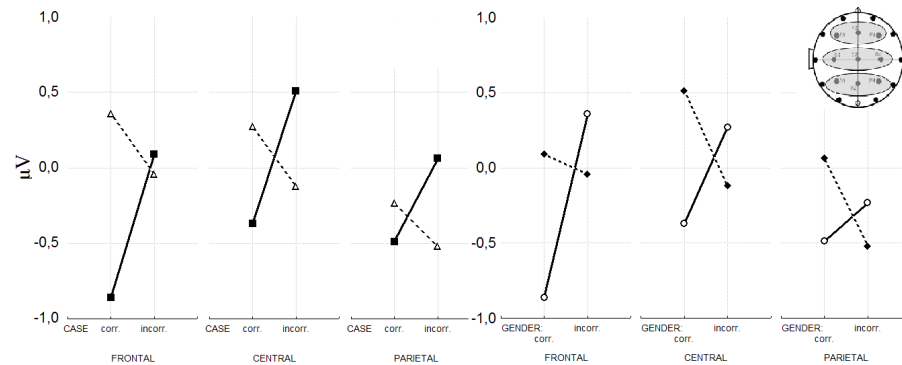

Figure 10. Statistical results of the rmANOVA in the 350–450 ms interval at the sentence-final position. Left: the lines represent GENDER, full line being congruent, dashed line incongruent conditions. Right: the lines represent CASE, full line being correct, dashed line incorrect conditions.

even though it is considered to be a marker of difficulties in morphosyntactic processing especially for agreement violations. However, these results are in line with other studies on processing morphosyntactic violations that have shown that violations in gender (and number) elicit only P600 (Osterhout and Mobley 1995; Hagoort and Brown 1999; Nevins et al. 2007; Molinaro et al. 2008; Silva-Pereyra, Carreiras, and Gutiérrez-Sigut 2012), reflecting the syntactic nature of these features. Moreover, since the parser computes local relationships first (Friederici 2002; Bornkessel-Schlesewsky and Schlesewsky 2009), the gender violation in our study is not immediately perceived as an error because it does not violate the structural demands of the verb phrase: the pronominal clitic is correctly marked for accusative case as demanded by the verb that governs it. Only when attempting to establish the reference relationship between the pronominal clitic and its antecedent will the parser perceive the gender mismatch and attribute the error to the syntactic level, as evidenced by the positivity in the later time window. Late positivity that can be interpreted as P600 was obtained in all violation conditions at the clitic site, albeit with amplitudes and distribution that differ among conditions. The statistical analysis indicates that the effect was the strongest in the gender-incongruent condition, with the maximum around 500 ms PSO (post-stimulus onset) in the centroparietal region of the midline of the scalp. The distribution of the P600 is known to vary depending on the functional processes that underlie its appearance: the P600 with more frontal distribution reflects the processes of error diagnosis or syntactic integration difficulties, whereas the more parietally distributed P600 appears when repair or reanalysis processes take place (Hagoort, Brown, and Osterhout 1999; Friederici, Hahne, and Saddy 2002; Barber and Carreiras 2005; Silva-Pereyra and Carreiras 2007). The results at the clitic site therefore suggest that the parser recognized the gender violation as a syntactic error and initiated the process of repair in order to establish the intended form and integrate the pronoun into the context. This process had finished by the time the end of the sentence was reached, as evidenced by the lack of reliable effects at the end of the sentence (Figure 5).

pronominal clitic was unambiguous. The introductory sentence was structured in a way that maximally constrained the process of reference assignment: the second NP was strongly suggested as the best candidate for the antecedent because it appeared in the same syntactic position as the pronominal clitic in the experimental sentence (as a postverbally inserted direct object). The semantics of the verb in the experimental sentence added to the predictability of the reference of the up-coming element, seen in the examples in (4), as it required a Theme argument, just like the verb in the introductory sentence. The overall meaning of the introductory sentence together with the meaning of the verb used in the experimental sentence created a high degree of expectation for the postverbal NP from the introductory sentence to be referred to in that same position in the experimental sentence.

In the case-incorrect condition a sustained negativity distributed across the central and posterior areas of the scalp were observed in the early time window, followed by anterior positivity in the later time window (approx. 450–650 ms). The case form violations have been demonstrated to elicit negativities in the early time window. Coulson, King, and Kutas (1998) obtained left anterior negativity (LAN) followed by late positivity for pronoun case-form violations for English sentences in which the pronoun was inserted in post-verbal position (*The plane took *we to paradise and back*; Coulson, King, and Kutas 1998: 33), whereas double accusative/double nominative violations on full NPs in Japanese elicited an N400-P600 pattern on the second noun in Mueller, Hirotani, and Friederici 2007. However, the distribution of the early negativity in our study does not correspond to the typical (L)AN or N400 distribution, even though it more resembles the latter. According to Molinaro, Barber, and Carreiras (2011: 923), the early negativities elicited by syntactic violations extend towards the central and posterior areas of the scalp if nonsyntactic information is required to process the violation, e.g., if lexical access is needed, or discourse-level representations are activated. It is possible, therefore, that the dative form of the clitic triggers processing at the discourse-level, i.e., a search for a potential antecedent for the dative pronoun in the previous context, which elicits the negativity. It is also possible that the negativity reflects difficulties in local syntactic processing caused by the unexpected case form, despite the fact that the distribution of the negativity is not typical for LAN. The third possible account of the results is that the negativity represents the variant of the N400 that appears as a response to the violation of the expected theta-structure, as in Mueller, Hirotani, and Friederici 2007. The reason why the negativity does not correspond to any of the aforementioned components most probably stems from the potential structural ambiguity of the dative pronominal clitic. Namely, the dative form that was used in the case-incorrect condition to produce case violations is not disallowed with transitive verbs, since the majority of transitive verbs in Croatian can be used in ditransitive constructions as well, in which the dative clitic precedes the direct object NP, as in (5), or in applicative constructions in which the dative clitic is inserted as an optional argument.[6]

(5) Ivan ima sina. Svakog
Ivan$_{M.SG.NOM}$ have$_{3PRES.SG}$ son$_{M.SG.ACC}$ every$_{N.SG.GEN}$
jutra kupuje mu kolač.
morning$_{N.SG.GEN}$ buy$_{3PRES.SG}$ CL$_{M.SG.DAT}$ cake$_{M.SG.ACC}$
'Ivan has a son. Every morning he buys him a cake.'

[6] We are grateful to an anonymous reviewer for suggesting the applicative as a potential interpretation of the dative clitic.

It is therefore possible that the dative form of the clitic is to some extent (or by some participants) initially interpreted as an additional argument, i.e., a structurally allowed element, even though the expectation on form and reference of the postverbal NP was constrained by the preceding context (referentially identical NPs used as Agent/Theme arguments and inserted in the same syntactic slots in the introductory and experimental sentence, the meaning of the verb in the experimental sentence; see the examples in (4)). The overall structure of both sentences created a high degree of expectation for the postverbal NP from the introductory sentence to be referred to in the same position and in the same case in the experimental sentence. Despite the potential ambiguity of the dative clitic, the appearance of both early negativity and late positivity already at the clitic site suggests that the structural, semantic, and pragmatic cues from the preceding context did bias the expectation regarding the form of the postverbal NP and that the dative form was interpreted as a violation. However, the violation effect was attenuated and influenced by the functional ambiguity of the dative form of the clitic, which affected the early, local syntactic processes, as evidenced by the fact that the obtained negativity is rather weak and does not correspond to the typical distribution of LAN or N400. This line of reasoning is supported by the nature of the following positivity and by the effect at the sentence-final word. In the case-incorrect condition, the P600 at the clitic site was broadly distributed with the maximal amplitudes in the left anterior region (Figure 3). The anterior P600 was related to the processing of the syntactic complexity of the structure and to the difficulties in the integration of the element with the preceding structure (Friederici, Hahne, and Saddy 2002; Barber and Carreiras 2005; Molinaro, Vespignani, and Job 2008; Molinaro, Barber, and Carreiras 2011). Alternatively, the posterior P600 appears if the structure is unambiguously incorrect (Hagoort, Brown, and Osterhout 1999; Silva-Pereyra and Carreiras 2007). At the end of the sentence we find anterior negativity followed by late posterior positivity, which suggests that the case violation has a long-lasting effect, and that it prolongs (or even postpones) the syntactic processes of reanalysis and repair.

Violation of both gender and case at the clitic site elicited negativity with latency and distribution that correspond to the N400 effect. The element encountered (the gender-incongruent dative clitic) violates the morphosyntactic and thematic demands of the structure, since the preceding context announces the Theme argument marked for accusative. Moreover, the phi-features of the clitic do not match those of the most probable antecedent. The double violation is more salient than the gender or case violation, which makes the form of the pronominal clitic easily recognizable as an erroneous structure. The potential functional ambiguity of the dative clitic therefore does not affect the processing of the violation in the way it did in the case-incorrect condition, as indicated by the difference in the ERP effects obtained in the two conditions. The processing of the double violation is reflected in the N400. Lamers et al.

(2006) also obtained an N400-like negativity in the double-violation condition. As already mentioned, the N400 has been observed in several other studies on case-form violations in the sentence context (Frisch and Schlesewsky 2001; Mueller, Hirotani, and Friederici 2007). It has been assumed that the N400 reflects a violation of the thematic structure of the verb. However, it has most frequently been obtained for semantic anomalies (for a review of language-related ERP components, see Osterhout, McLaughlin, and Bersick 1997 and Bornkessel-Schlesewsky and Schlesewsky 2009). It is therefore possible that the double violation renders the clitic semantically opaque and thus elicits the N400. The weak positivity that follows the N400 is distributed in the anterior areas of the scalp, indicating that the parser does not classify the violation as a syntactic error and thus fails to initiate the reanalysis/repair process. At the end of the sentence, anterior negativity followed by late-posterior positivity is observed again. The topographic maps show that this positivity appears later and seems to be weaker than in the case-incorrect condition (Figures 6–7). The lack of the posterior P600 at the clitic site together with the weak effect at the end of the sentence suggests that the violation of both case and gender of the pronominal clitic constitutes an error that is too severe to be repaired, and this blocks syntactic processes, unlike in single-violation conditions where the appearance of the posterior P600 already at the clitic site (gender-incongruent condition) or at the end of the sentence (case-incorrect condition) suggests that the parser reanalyses the structure in order to build a meaningful representation of the utterance. The posterior P600 that appears at the end of the sentence seems to replace the typical wrap-up N400 in the case-violation conditions. Why this is so remains an open question.

5. Conclusion

The results of the present study are in line with previous studies on morphosyntactic processing. They indicate that local and long-distance dependencies are computed in different ways. They engage functionally different mechanisms and follow different time schedules. The violation of anaphoric relations did not elicit a reliable indication of the error recognition in the early time window at the clitic site, whereas the local case violation was recognized as an incorrect form as soon as approximately 300 ms after the onset of the pronominal clitic. If only local relations are processed within the early time window, no difference in ERP effects between the two case-violation conditions is expected. However, the distribution of the early negativity obtained in the case-violation condition differed from the one obtained in the double-violation condition. Moreover, the statistical analysis shows that the gender violation accounts for the majority of the variance in the double-violation condition. Since the double violation was more salient than the case violation, it

is possible that the results reflect the difference in the salience of the violation rather than the difference in the underlying mechanisms.

The difference in processing of the three violation types is not limited to the early time window. Distribution of the late positivity at the clitic site indicates that the parser processes gender mismatch between the pronoun and its antecedent as a syntactic violation, whereas the case violation is locally processed as a syntactically complex or ambiguous structure; the repair/reanalysis process is not initiated until the end of the sentence is reached. Since the pronoun form used in the case-violation condition represents a potential source of confounding in that it cannot be unambiguously classified as erroneous immediately at the clitic site (even though it violates the expectation on the thematic role and case marking of the postverbal NP), the difference between the late positivity in the gender-incongruent and the case-incorrect conditions cannot be viewed as a reliable indication of the functional difference between the processing of these two violation types. Further research is needed to clarify the issue.

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University of Zagreb
Laboratory for Psycholinguistic Research
Zvonimirova 8
10000 Zagreb
Croatia
pavlinusiceva@gmail.com
marijan.palmovic@erf.hr

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