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FULL-LENGTH REPORT

Is the noun ending a cue to grammatical gender processing? An ERP study on sentences in Italian

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Abstract

Gender-to-ending consistency has been shown to influence grammatical gender retrieval in isolated word presentation. Notwithstanding the wealth of evidence, the exact role and the time course of processing of this distributional information remain unclear. This ERP study investigated if and when the brain detects gender-to-ending consistency in sentences containing Italian determiner-noun pairs. Determiners either agreed or disagreed in gender with the nouns whose endings were reliable or misleading cues to gender (transparent and irregular nouns). Transparent nouns elicited an increased frontal negativity and a late posterior positivity compared to irregular nouns (350–950 ms), suggesting that the system is sensitive to gender-to-ending consistency from relatively early stages of processing. Gender agreement violations evoked a similar LAN-P600 pattern for both types of nouns. The present findings provide evidence for an early detection of reliable gender-related endings during sentence reading.

Descriptors: Gender-to-ending consistency, Grammatical gender, Agreement, ERPs, Language processing

The aim of the present study is to investigate the role of the nominal ending in the processing of grammatical gender during sentence comprehension. Linguistic and psycholinguistic models of grammatical gender processing differ in the role attributed to this information and in the mechanisms that are thought to be involved in the processing of agreement dependencies (for an overview, see Mancini, Molinaro, & Carreiras, 2013; Molinaro, Barber, & Carreiras, 2011). As Corbett (1991) argues, gender is a rather puzzling grammatical category that can shed important light on the ways in which the brain stores and processes linguistic information.

Grammatical Gender Retrieval and the Gender-to-Ending Consistency Effect

Gender is an abstract lexical feature of a noun (Cacciari & Cubelli, 2003; Delfitto & Zamparelli, 2009). Together with number and person, it is part of the grammatical features that give rise to agreement relations (Mancini et al., 2013). There is a great variability in the ways in which languages express grammatical gender, with English being a gender-unmarked language and French, Spanish, and Italian being gender-marked languages (Comrie, 1999; Corbett, 1991; Vigliocco, Vinson, Paganelli, & Dworzynski, 2005). Although psycholinguistic studies have given a fair amount of attention to grammatical gender retrieval (Cacciari & Cubelli, 2003; Friederici & Jacobsen, 1999), it is still unclear when and how the processing system takes advantage of gender-to-ending consistency to retrieve grammatical gender within a sentence context.

In Italian, as in most Romance languages, masculine and feminine gender of nouns is always specified, with a conceptual criterion for assigning gender to human beings (based on the biological gender of the referent) and an arbitrary criterion for assigning gender to objects, roles, and abstract entities, as well as some animals (Cacciari & Cubelli, 2003; Cubelli, Lotto, Paolieri, Girelli, & Job, 2005). In addition, nominal endings (*-a* and *–o*) typically map onto a specific gender class. In Italian, the declension classes with the most numerous members are those formed by masculine nouns ending in *–o* (with plural forms ending in *–i*) and by feminine nouns ending in *–a* (with plural forms ending in –e). These constitute approximately 71% and 68% of singular nouns, respectively (Cacciari, 2011; D'Achille & Thornton, 2006). The nominal ending can be a morphological marker for gender in nouns with a biological gender (e.g., *ragazz-a* "girl," *ragazz-o* "boy"), which acts as a paradigm for the morphological realization of the plural form (Di Domenico, 1997; Paolieri, Lotto, Leoncini, Cubelli, & Job, 2010).

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While the *-a* and *-o* endings have a high cue reliability and availability (i.e., the conditional probability of a category given a particular cue; Bates & MacWhinney, 1982; MacWhinney, Bates, & Kliegl, 1984), the gender of singular nouns ending in *-e* cannot be predicted from the word form alone since a similar proportion of masculine and feminine singular nouns end in *–e* (17% and 20%, respectively). Following Bates, Devescovi, Pizzamiglio, D'Amico, and Hernandez (1995), we define the nouns ending in *-e* as gender-opaque and those ending in *-a* and *-o* as gender-transparent (henceforth, opaque and transparent nouns, respectively). There is also a small number of Italian nouns where the typical gender-to-ending correspondence is reversed (4.4% of masculine nouns: *pigiama* "pyjamas," and 0.2% of feminine nouns: *mano* "hand")—henceforth, irregular nouns. In irregular nouns, nominal endings are a misleading cue to grammatical gender (De Martino, Bracco, & Laudanna, 2010; Padovani, Calandra-Buonaura, Cacciari, Benuzzi, & Nichelli, 2005).

The characteristics of the Italian nominal system suggest that grammatical gender information cannot be unequivocally recovered from the word form. For instance, gender-to-ending consistency is based on distributional information that can provide ambiguous (in the case of opaque nouns) or unreliable (in the case of irregular nouns) information about the gender of a noun (Vigliocco & Franck, 1999). One can decide the gender of a noun, or compute gender agreement dependencies, without necessarily relying on morphophonological markers (Badecker, Miozzo, & Zanuttini, 1995; Caramazza & Miozzo, 1997; Vigliocco, Antonini, & Garrett, 1997), since a word-form independent abstract gender representation is associated with each lexical constituent (Delfitto & Zamperelli, 2009).

Although this distributional information conveyed by the word form is not always reliable and can be redundant (Vigliocco & Franck, 1999), behavioral evidence has shown gender-to-ending consistency effects in isolated word presentation. Specifically, it has been observed that participants are typically faster and more accurate when deciding the gender of transparent nouns than opaque/irregular nouns (Bates, Devescovi, Hernandez, & Pizzamiglio, 1996; Bates et al., 1995; Hernandez et al., 2004; Peereman, Dufour, & Burt, 2009; Schiller, Munte, Horemans, & Jansma, 2003; Spalek, Franck, Schriefers, & Frauenfelder, 2008; Taft & Meunier, 1998). Similar findings have been reported in the studies with Italian adult speakers, when explicit decisions about grammatical gender were required (Bates et al., 1995, 1996; De Martino et al., 2010; Miceli et al., 2002; Padovani & Cacciari, 2003; Padovani et al., 2005). However, it should be noted that these gender-to-ending consistency effects are task and modality dependent, generally obtained with explicit, strategic tasks (e.g., gender decision, grammaticality judgment) rather than with implicit, real-time tasks (e.g., word repetition, phoneme monitoring), and are more likely to emerge with visually rather than auditory presented stimuli. Despite this, studies on language acquisition seem to suggest that nominal endings play an important role in gender assignment in second language learners (Bordag, Opitz, & Pechmann, 2006; Bordag & Pechmann, 2007; Chini, 1995) and children (Caselli, Leonard, Volterra, & Campagnoli, 1993; Matthews, 2010; Pérez-Pereira, 1991).

One of the most relevant interpretations of gender-to-ending consistency effects comes from the dual-route model (Gollan & Frost, 2001), according to which there are two sources of gender information: (1) a lexical source based on abstract information stored with the noun (e.g., $tavolo_{\mathrm{MASC}}$ "table"), and (2) a nonlexical, form-based source that relies on phonological/orthographic information (e.g., *-o* is the nominal ending of Italian masculine nouns). These two routes are thought to retrieve gender information differently. The lexical route extracts the abstract information about gender from the lexical representation of the noun, without any influence of gender-correlated formal aspects. In contrast, the nonlexical route derives grammatical gender from its correlation with formal cues. Although the lexical route always provides the correct gender of a noun, the grammatical gender of transparent nouns can also be recovered from the nonlexical route. On the contrary, only the lexical route can be consulted to recover gender information about opaque nouns and irregular nouns.

Although the two-route hypothesis can explain much of the behavioral evidence available to date, some important questions remain unanswered. First, the evidence in favor of this hypothesis comes from studies on nouns and word pairs presented in isolation (Bates et al., 1995, 1996; Gollan & Frost, 2001; Hernandez et al., 2004; Peereman et al., 2009; Spalek et al., 2008; Taft & Meunier, 2008), rather than on sentences that represent a more appropriate test for the role of grammatical gender in comprehension processes. Second, most of the behavioral studies showing the effect of gender-to-ending consistency have used gender-explicit tasks (e.g., gender decision). Deciding gender identity or gender agreement on target words presented in isolation may require strategies that do not normally characterize gender retrieval (Radeau & Van Berkum, 1996). In addition, the comprehension of a complex sequence of words is associated with the processes of integration and reanalysis that may not be required when the system performs metalinguistic tasks on isolated words (Barber & Carreiras, 2005; Caramazza, 1997).

Thus, it remains unclear whether these two routes work and eventually interact at the sentence level with tasks that do not explicitly refer to gender. In addition, it is still a matter of debate when the distributional information conveyed by the word form would be taken into account, and whether formal gender cues would influence the computation of agreement dependencies. Researchers put forward at least two different views concerning this issue: the postlexical checking hypothesis (Bates et al., 1995, 1996; see also Gollan & Frost, 2001; Hofmann, Kotz, Marschhauser, Yves von Cramon, & Friederici, 2007) and the reliable cue hypothesis (Taft & Meunier, 1998; see also Afonso, Domínguez, Álvarez, & Morales, 2003; Grüter, Lew-Williams, & Fernald, 2012). According to the postlexical checking hypothesis, the processing system primarily relies on the lexical route. When conflicting information exists between the gender specified in the noun representation (the lexical route) and the noun ending (the nonlexical route), a postlexical checking procedure controls for gender-marking regularity. Hence, the nonlexical route is thought to intervene at a later stage of analysis to monitor the output of the lexical route (Bates et al., 1995, 1996). In addition, the information about gender-to-ending consistency should not directly enter into agreement computation, and the postlexical checking should be carried out in a similar way for both agreeing and disagreeing word pairs (Bates et al., 1996). In contrast, the reliable cue hypothesis assumes that gender-to-ending correspondence yields to regularity effects detected at an early stage of processing such that gender retrieval may be delayed, if not impaired, when the most reliable gender cue is not available. Hence, this hypothesis does not rule out a possible influence of gender-to-ending consistency on agreement computation.

Behavioral evidence has thus far been rather inconclusive, with some studies lending support to the postlexical checking hypothesis (Bates et al., 1995, 1996; see also Gollan & Frost, 2001; Hofmann

et al., 2007) and others arguing against it (De Martino et al., 2010; Padovani & Cacciari, 2003; Padovani et al., 2005).

ERP Studies on Grammatical Gender Processing

ERP studies have extensively investigated gender retrieval and gender agreement processing (for an overview, see Molinaro et al., 2011), but have devoted much less attention than behavioral studies to gender-to-ending consistency effects and to the role of this information in agreement computation. ERP studies on sentence comprehension have mostly investigated gender retrieval and agreement under conditions of agreement violations differentiating early and late ERP effects associated with the detection and reanalysis of gender violations, as compared to correct forms (Molinaro et al., 2011). Typically, gender agreement violations within a sentential context elicit positive deflections, with larger amplitudes over centroposterior sites, when compared to the condition without gender violations. This greater positivity starts at about 500 ms poststimulus and extends to 800 ms poststimulus (P600). It has been observed in the case of gender violations involving different sentential constituents (determiner-adjective: Barber & Carreiras, 2005; Gunter, Friederici, & Schriefers, 2000; Hagoort, 2003; Hagoort & Brown, 1999; Molinaro, Vespignani, & Job, 2008; O'Rourke & Van Petten, 2011; Wicha, Moreno, & Kutas, 2004; noun-adjective: Bañon, Fiorentino, & Gabriele, 2012; Barber & Carreiras, 2005; Barber, Salillas, & Carreiras, 2004; Guajardo & Wicha, 2014; O'Rourke & Van Petten, 2011; noun-verb: Deutsch & Bentin, 2001) and different languages (Spanish: Bañon et al., 2012; Barber & Carreiras, 2005; Barber et al., 2004; Guajardo & Wicha, 2014; O'Rourke & Van Petten, 2011; Wicha et al., 2004; Italian: Molinaro et al., 2008; Dutch: Hagoort, 2003; Hagoort & Brown, 1999; German: Gunter et al., 2000; Hebrew: Deutsch & Bentin, 2001). These P600 effects have been linked to the attempts of reanalysis and repair (Osterhout & Mobley, 1995; O'Rourke & Van Petten, 2011), nonsyntactic late integration processes (Brouwer, Fitz, & Hoeks, 2012), as well as the costs of structure building, checking, and reprocessing (Van de Meeredonk, Kolk, Chwilla, & Vissers, 2009). Prior to the P600, an increased left anterior negativity (LAN) can emerge between 300 ms and 500 ms poststimulus in response to gender agreement violations, especially with article-noun gender violations in the Romance languages (Barber & Carreiras, 2005; Barber et al., 2004; Gunter et al., 2000; Molinaro et al., 2008; O'Rourke & Van Petten, 2011; but see Wicha et al., 2004). LAN effects have been thought to reflect automatic detection of mismatch between grammatical features (Friederici, 1995; Hagoort, Brown, & Osterhout, 1999), difficulties integrating the disagreeing element in the sentential context (Gunter et al., 2000), or working memory costs (Coulson, King, & Kutas, 1998).

Finally, the ERP studies that looked at word pairs presented in isolation (e.g., article-noun, noun-adjective) have reported a greater negativity at around 400 ms after the target onset in response to gender mismatches as compared to gender matches (Barber & Carreiras, 2003, 2005). Since the topographical distribution of this effect is not restricted to anterior regions, but can involve central-posterior areas, it has been called an N400-type effect thought to reflect syntactic integration processes allowing the detection of morphosyntactic mismatches (Barber & Carreiras, 2003, 2005).

Unfortunately, none of the ERP studies on grammatical gender violations have explicitly tested gender-to-ending consistency effects in sentences. Most studies on gender agreement violations have used transparent nouns (Bañon et al., 2012; Barber & Carreiras, 2005; Barber et al., 2004; Guajardo & Wicha, 2014; O'Rourke & Van Petten, 2011; Wicha et al., 2004), or opaque nouns (Molinaro et al., 2008).

In an ERP study focusing on isolated nouns, Schiller et al. (2003) tested the role of syntactic, semantic, and phonological information in modulating the N200 component when subjects performed a go/no-go task in order to decide the gender of German transparent and opaque nouns carrying semantic or arbitrary grammatical gender. The authors observed a larger N200 difference waves (no-go minus go responses) when the nouns conveying semantic gender had gender-transparent endings compared to gender-opaque ones. The effect was reversed in the nouns with an arbitrary gender with higher amplitudes observed for opaque than transparent nouns. It was concluded that formal gender cues can be detected online during single word processing. Similarly, a recent ERP study using the divided visual field paradigm compared transparent and opaque Spanish nouns preceded by a determiner (Caffarra, Janssen, & Barber, 2014). In the study, the determiner was displayed at the center of the screen and the target noun was presented in a lateralized position (i.e., left or right visual hemifield). Word pairs were presented out of a sentence context and either agreed or disagreed in gender. Participants were asked to judge the grammaticality of the isolated word pairs. An N400-like effect for gender violations was observed for both sides of presentations. However, a main effect of gender-to-ending consistency was observed only when the nouns were presented to the right visual hemifield (which is mainly associated with the left hemisphere processing). Specifically, transparent nouns elicited a greater sustained negativity between 350 and 750 ms, compared to opaque nouns. The authors interpreted this finding as one reflecting the different amount of information sources available during gender processing of transparent and opaque nouns: while in the case of transparent nouns, two different sources can be used (i.e., lexical and form-based), in the case of opaque nouns, only the lexical source can be used to recover gender. Caffarra et al. (2014) concluded that the left hemisphere is more skilled in the use of the form-based route and is better at detecting formal gender cues than the right hemisphere.

In sum, ERP studies on sentence reading have typically showed a greater LAN-P600 pattern in response to gender agreement violations. ERP correlates for gender-to-ending consistency processing have been investigated to a lesser extent. Behavioral and ERP evidence collected on single words and word pairs suggest that the system is sensitive to the distributional information conveyed by the noun ending, especially when an explicit gender task is employed (Bates et al., 1995, 1996; Caffarra et al., 2014; Hernandez et al., 2004; Peereman et al., 2009; Spalek et al., 2008; Taft & Meunier, 1998). It is still unclear, however, whether and when the gender-to-ending consistency information can be detected during sentence reading and what role it plays during agreement processing.

The Present Study

The aim of this ERP study was to investigate whether and when the processing system is sensitive to gender regularity of nominal endings within a sentential context. The high temporal resolution provided by ERPs can be fruitfully used to identify the time course of gender-to-ending consistency processing and to assess the role of this information in gender retrieval during sentence comprehension. To this aim, we conducted an ERP study on sentence comprehension where we manipulated gender-to-ending consistency and

Table 1. *An Example of Sentences in the Four Experimental Conditions*

Transparent nouns		
Agreement	*Mescola con il cucchiaio di legno.*	(S/He) stirs with the$_M$ spoon$_M$ of wood.
Disagreement	*Mescola con la cucchiaio di legno.*	(S/He) stirs with the$_F$ spoon$_M$ of wood.
Irregular nouns		
Agreement	*Regalò il diadema prezioso.*	(S/He) gave the$_M$ diadem$_M$ precious.
Disagreement	*Regalò la diadema prezioso.*	(S/He) gave the$_F$ diadem$_M$ precious.

Note. English translations show Italian word order.

agreement factors. Transparent and irregular Italian nouns were embedded in a sentence context. The target nouns agreed or disagreed with the preceding determiner. Participants performed a comprehension task. ERP responses were recorded during the presentation of the target nouns.

If the processing system is sensitive to gender-to-ending consistency, as the dual route model suggests, then we should find ERP differences between transparent and irregular nouns. The timing of the ERP difference between the two types of nouns should provide us with the information about the time course of the detection of distributional cues conveyed by the nominal ending. According to the postlexical checking hypothesis (Bates et al., 1995, 1996; see also Gollan & Frost, 2001; Hofmann et al., 2007), any effect of gender-to-ending regularity should surface during a postlexical checking that subjects engage in to compute grammatical gender—at later stages of analysis (around 450 ms following the noun presentation; Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006). In contrast, the reliable cue hypothesis predicts that gender-to-ending consistency effects should occur earlier (Taft & Meunier, 1998; see also Afonso et al., 2003; Grüter et al., 2012).

In addition, as in previous ERP studies, we expect gender violations to elicit a P600 preceded by a LAN (Barber & Carreiras, 2005; Barber et al., 2004; Gunter et al., 2000; Molinaro et al., 2008). The reliable cue hypothesis predicts a possible influence of gender-to-ending consistency on agreement computation, while the postlexical checking hypothesis predicts that gender-to-ending consistency should be similarly computed for agreeing and disagreeing elements (Bates et al., 1996).

Method

Participants

Twenty-two native speakers of Italian (12 women), all students at the University of Modena and Reggio Emilia, participated in the experiment for either course credit or a gift reward (€ 15). Age ranged from 19 to 30 years (mean = 22.7, *SD* = 2.6). All participants were right-handed and reported normal or corrected-to-normal vision. No participant had a history of neurological disorders. The research was carried out fulfilling ethical requirements in accordance with the standard procedures at the University of Modena and Reggio Emilia.

Materials

A list of 80 Italian nouns was selected: masculine nouns ended in *-o*, the typical Italian word ending for masculine gender (e.g., *cucchiaio* "spoon$_M$"), and feminine nouns ended in *-a*, the typical feminine gender final vowel (e.g., *bibita* "drink$_F$") (transparent nouns). Further, a list of 80 nouns was created where the noun ending was a misleading predictor of grammatical gender (irregular nouns). Irregular nouns reverse the regular gender-to-ending correspondence having *-o* in the final position for feminine gender (e.g., *mano* "hand$_F$"), and *-a* for masculine gender (e.g., *diadema* "diadem$_M$").

The length (i.e., mean number of characters) for transparent (7.2, *SD*: 2.2, range: 4–12) and irregular nouns (7.2, *SD*: 2.3, range: 4–13) did not significantly differ, $t(79) < 1$; the frequency was also found to be similar (Baroni et al., 2004; mean log-transformed frequency for transparent nouns: 2.8, *SD*: 0.9, range: 0.7–5.2; mean log-transformed frequency for irregular nouns: 2.8, *SD*: 1.0, range: 0.8–5.1; $t(79) < 1$). The two groups of nouns were kept as similar as possible both semantically (e.g., we used a similar number of words for animals in both groups) and orthographically (e.g., we used a similar number of compound nouns; the use of compounds could not be avoided since most Italian irregular nouns are compound nouns). Given that concreteness ratings for the selected words in Italian do not exist, we compared the concreteness ratings for the corresponding English translations (which are highly correlated with the ratings of a subset of Italian words; Della Rosa, Catricala, Vigliocco, & Cappa, 2010); the ratings did not differ (transparent: 4.1, *SD*: 0.9; irregular: 3.9, *SD*: 1.0; $t(79) = 1.51$, $p = .14$; Brysbaert, Warriner, & Kuperman, 2014). Due to a small number of irregular feminine nouns in Italian, a different number of feminine and masculine nouns was used. Given that only 12 irregular feminine nouns could be selected, the same proportion of feminine words was used for transparent nouns. Altogether, we had 12 feminine nouns and 68 masculine nouns for both groups of nouns (irregular and transparent). During the stimulus selection procedure, nouns referring to entities with a biological gender (e.g., professions or animals) were excluded to avoid any possible interaction between the grammatical gender information and the conceptual information concerning the sex of the referent (Vigliocco & Frank, 1999; see supporting information Appendix S1 for the list of experimental materials).

Each noun was paired with a determiner that either agreed (e.g., *il cucchiaio* "the$_M$ spoon$_M$") or disagreed with the noun (e.g., *la cucchiaio* "the$_F$ spoon$_M$"). To enhance ecological validity, different types of determiners were used, such as definite articles (e.g., *il* "the$_M$"), indefinite articles (e.g., *un* "a$_M$"), and prepositions (e.g., *nel* "in the$_M$," *del* "of the$_M$," etc.). The resulting 160 word pairs were embedded in short sentences with a mean length of five words (*SD* = 0.7 words). The word pairs appeared in different sentential positions but never in the sentence final position (at least one word appeared following the target noun in order to avoid wrap-up effects). In addition, when the word pair was in the middle of a sentence, it was always preceded by sentential constituents not inflected for grammatical gender (e.g., simple tense verbs, adverbs, prepositions, conjunctions) to avoid gender computations prior to the target noun presentation.

The experimental manipulations of gender-to-ending consistency and gender agreement resulted in four conditions of 40 trials each. Table 1 provides examples of experimental sentences.

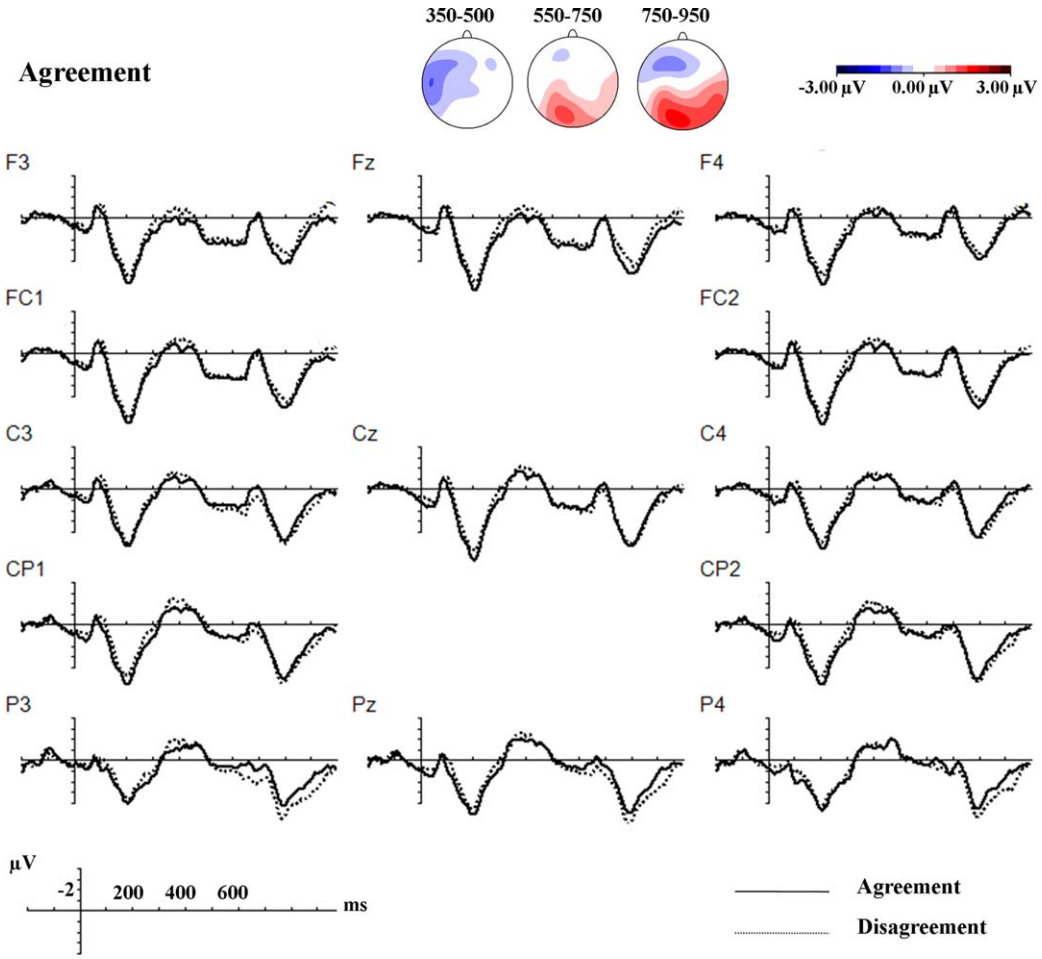

Figure 1. ERP grand-average waveforms for the agreement (solid line) and disagreement condition (dotted line). Negativity is plotted upwards. Topographical maps (on the top) were computed by subtracting the agreement condition from the disagreement condition.

Sentences were counterbalanced across the conditions, so that no participant saw the same version of a sentence repeated in different experimental conditions. In addition, a list of 100 well-formed filler sentences was used (mean length eight words). To prevent participants from focusing solely on transparent and irregular singular nouns, fillers included singular opaque nouns (noun ending in *-e*, a vowel uninformative of the grammatical gender) and other types of plural nouns. Overall, participants read 260 sentences, and the ERP session lasted about an hour.

Procedure

Participants were seated in a dimly lit, soundproof room. To ensure the participants were paying attention to the stimuli, yes/no comprehension questions were presented following 25% of the sentences (always filler sentences). E-Prime software was used for stimuli presentation.

Each trial began with the presentation of a fixation cross at the center of the screen, which disappeared when the participant pressed the space bar. A 300-ms blank interval was presented and followed by a second fixation cross for 200 ms. Then, sentences were presented word by word in light gray letters against a black background. Each word stayed on the screen for 300 ms and was followed by a blank screen for another 300 ms. The final word was always displayed with a full stop. Following 25% of the sentences (see above), a comprehension question appeared on the screen; participants had 5,000 ms to respond by pressing one of the two response buttons (yes or no). The following trial appeared after an interval of 600 ms. The sentence order was randomized, and the button positions were counterbalanced across participants.

Prior to each trial, participants were advised to blink and move their eyes when the first fixation cross appeared on the screen in order to reduce the probability of eye movements in the critical epochs. The experimental session was divided into four blocks of 15 min each and was preceded by a brief practice session (four trials) to familiarize participants with the task.

Electrophysiological recording and analyses. EEG activity was amplified and recorded with the BioSemi ActiveTwo System via 32 active electrodes placed in an elastic cap: Fp1, Fp2, AF3, AF4, F3, F4, F7, F8, FC1, FC2, FC5, FC6, C3, C4, T7, T8, CP1, CP2, CP5, CP6, P3, P4, P7, P8, O1, O2, PO3, PO4, Fz, Cz, Pz, Oz. Two external electrodes were placed on mastoids (A1, A2). Vertical eye movements and blinks were monitored by means of two electrodes placed above and below the left eye (Fp1, Ve1). Horizontal eye movements were monitored by two electrodes at the external ocular canthi (He1, He2). Two electrodes were also placed close to Cz, the common mode sense (CMS) active electrode and the driven right leg (DRL) passive electrode and used to form the feedback

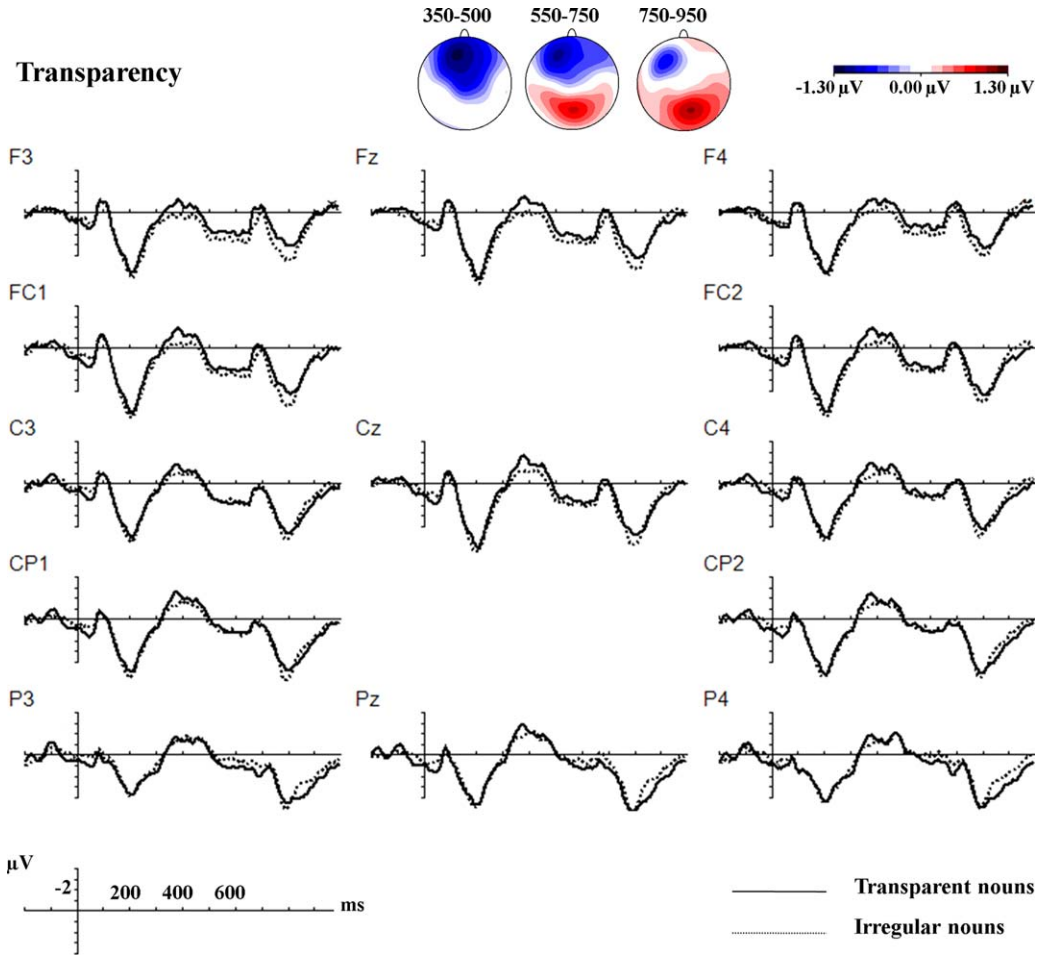

Figure 2. ERP grand-average waveforms for transparent nouns (solid line) and irregular nouns (dotted line). Negativity is plotted upwards. Topographical maps (on the top) were computed by subtracting the irregular condition from the transparent condition.

loop that drives the average potential of the participant as close to the AD-box (analog-to-digital converter) reference potential as possible (Metting van Rijn, Peper, & Grimbergen, 1990). Data were amplified and digitized at a sampling rate of 512 Hz with an antialiasing filter with a cut-off frequency of 104 Hz (fifth order sinc filter); no high-pass filter was applied online. Brain Vision Analyzer was used for data analysis. EEG recordings were rereferenced offline to the average activity of the two mastoids and filtered with a band-pass of 0.1–30 Hz.

Artifacts due to eye movements were rejected by means of a visual inspection. Artifacts due to muscle activity exceeding $\pm$ 100 μV in amplitude were also rejected. On average, 9% of trials were excluded from further analysis due to ERP artifacts; there were no differences in the number of rejections between the conditions, $F(3,84) < 1$. For each target noun, an epoch of 1,200 ms was obtained including a 200-ms prestimulus baseline. Average ERP waveforms were computed time-locked to the onset of the target noun.

Statistical analyses were carried out on three time windows: 350–500 ms, 550–750 ms, and 750–950 ms. ERP effects were evaluated taking into account nine clusters of electrodes. Each cluster represented the mean amplitude of three electrodes in proximate positions: left anterior (F3, F7, FC5), left central (C3, T7, CP5), left posterior (P3, P7, PO3), medial anterior (AF3, AF4, Fz), medial central (FC1, FC2, Cz), medial posterior (CP1, CP2, Pz), right anterior (F4, F8, FC6), right central (C4, T8, CP6), right posterior (P4, P8, PO4). These clusters were included in the statistical analyses as different levels of two topographical factors: longitude (anterior, central, and posterior) and latitude (right, medial, and left). For each time window, a repeated measures analysis of variance (ANOVA) was performed with the two experimental variables as within-subject factors (gender-to-ending consistency and agreement) and two additional topographical factors (longitude and latitude). Effects related to the topographical factors are reported only in the case of significant interactions with the experimental manipulations. The Greenhouse-Geisser procedure was applied on every within-subject effect where the sphericity assumption was violated.

Results

Behavioral Results

The mean of correct responses to the comprehension questions was 96% ($SD = 7.8$), confirming that participants read the sentences for comprehension.

ERP Results

Figures 1 and 2 show ERP waveforms averaged across the factors of agreement and gender-to-ending consistency. The maps show

the topographical distribution of averaged potentials for each of the three time windows. Visual inspection of Figure 1 revealed differences in the responses to the agreement condition with respect to the disagreement condition. Specifically, the disagreement condition appears to have elicited greater negativity around 400 ms and greater positivity after 550 ms, compared to the agreement condition.

Visual inspection of Figure 2 revealed differences between transparent and irregular nouns. Specifically, transparent nouns appear to have elicited greater negativity than irregular nouns at central and anterior areas. The difference starts at around 350 ms after stimulus onset and is maintained throughout the next time window. In addition, greater positivity is present around 550 ms for transparent nouns compared to irregular ones across posterior sites.

Statistical analyses were conducted on three time windows identified by means of the visual inspection: 350–500 ms, 550–750 ms, and 750–950 ms. These windows are also compatible with those analyzed in previous ERP studies on gender violations (Barber & Carreiras, 2005; Gunter et al., 2000; Molinaro et al., 2008).

350–500 ms. A repeated measures ANOVA revealed a significant interaction between agreement and latitude, $F(2,42) = 4.09$, $p < .05$, $\eta_p^2 = .163$. Follow-up t tests showed that this effect was left lateralized (left: $t(21) = 2.46$; $p < .05$; medial: $t(21) = 1.34$; $p = .10$; right: $t(21) < 1$). Thus, the disagreement condition elicited greater negativities over left regions, compared to the agreement condition (see Figure 1).

In addition, the interactions between gender-to-ending consistency and the two topographical factors were found significant (Consistency × Longitude: $F(2,42) = 3.79$; $p < .05$, $\eta_p^2 = .153$; Consistency × Latitude: $F(2,42) = 3.63$; $p < .05$, $\eta_p^2 = .147$). ERP response to transparent and irregular nouns was different over anterior (anterior: $t(21) = 2.08$; $p < .05$; central: $t(21) = 1.14$; $p = .13$; posterior: $t(21) < 1$) and medial areas (left: $t(21) < 1$; medial: $t(21) = 2.00$; $p < .05$; right: $t(21) = 1.06$; $p = .15$, see Figure 2).

Crucially, no significant interaction emerged between gender-to-ending consistency and agreement, $F(1,21) < 1$. In order to check whether the effects of consistency and agreement were differently distributed, as suggested by visual inspection, an additional ANOVA was performed on the amplitude of the difference waves calculated for both agreement and consistency effects (i.e., subtraction between agreement and disagreement waves, and between transparent and irregular waves, respectively). The within-subject factor of manipulation type (two levels: consistency, agreement) and the factors of longitude and latitude (as defined above) were used. Results showed a significant interaction between manipulation type and latitude, $F(2,42) = 5.28$, $p < .05$, $\eta_p^2 = .201$, showing that the topographical distribution of the two effects differed significantly across electrode clusters. Specifically, while agreement reached its greater effect size over left sites (left: −.70 μV; central: −.49 μV; right: −.25 μV), consistency showed greater effect size over medial sites (left: −.22 μV; central: −.77 μV; right: −.35 μV).

550–750 ms. Results showed a significant interaction between agreement and longitude (Agreement × Longitude: $F(2,42) = 5.55$; $p < .01$, $\eta_p^2 = .209$). However, follow-up t tests comparing the agreement and disagreement conditions for each level of the longitude factor did not show any significant differences (all ps > .05).

The interaction between gender-to-ending consistency and longitude was also significant, $F(2,42) = 7.38$; $p < .01$, $\eta_p^2 = .260$). Follow-up comparisons between the transparent and irregular condition showed marginally significant differences over the frontal areas (anterior: $t(21) = 1.51$; $p = .07$; central: $t(21) < 1$; posterior: $t(21) = 1.26$; $p = .10$).

Again, no interaction between agreement and gender-to-ending consistency was found, $F(1,21) < 1$.

750–950 ms. Significant interactions between agreement and topographical factors were observed (Agreement × Longitude: $F(2,42) = 19.93$; $p < .001$, $\eta_p^2 = .487$; Agreement × Latitude: $F(2,42) = 5.55$; $p < .01$, $\eta_p^2 = .209$; Agreement × Longitude × Latitude: $F(4,84) = 3.52$; $p < .05$, $\eta_p^2 = .143$). Separate two-way ANOVAs were performed across each level of the longitude factor in order to localize the topographical distribution. No significant effects were found in the anterior regions. A significant interaction between agreement and latitude was found over central, $F(2,42) = 9.16$; $p < .001$, $\eta_p^2 = .304$, and posterior areas, $F(2,42) = 3.63$; $p < .05$, $\eta_p^2 = .147$. Follow-up comparisons showed significant differences between the agreement and the disagreement condition in the left and right posterior regions (left: $t(21) = 2.40$; $p < .05$; right: $t(21) = 1.95$; $p < .05$). Thus, the disagreement condition elicited more positive response than the agreement condition, and this effect was mainly distributed over posterior regions (see Figure 1).

In addition, the gender-to-ending consistency factor significantly interacted with longitude, $F(2,42) = 6.83$; $p < .01$, $\eta_p^2 = .245$. Significant differences between transparent and irregular conditions were observed at posterior sites (anterior and central: $t(21) < 1$; posterior: $t(21) = 1.66$; $p < .05$, see Figure 2).

No significant interaction between agreement and gender-to-ending consistency was observed, $F(1,21) < 1$. In line with the analyses for the 350–500 ms time window, an ANOVA was performed on the amplitude wave differences calculated for both agreement and consistency effects, including manipulation type (consistency, agreement), longitude and latitude as within-subject factors. No significant effect including the factor manipulation type reached significance (all ps > .05), suggesting that the effect of agreement and consistency did not significantly differ in the effect size or in the topographical distribution.

Discussion

The present study investigated if and when the system takes advantage of gender-to-ending regularity to retrieve grammatical gender information within a sentence context. To this aim, Italian gender-agreeing and disagreeing determiner-noun pairs were embedded in sentences. Nominal endings provided reliable (transparent nouns) or misleading (irregular nouns) cues to grammatical gender.

The ERPs in response to the target nouns showed two distinct effects between 350 ms and 950 ms: the gender-to-ending consistency effect and the agreement effect. These two main effects did not interact in the three subsequent time windows. Specifically, during the first and second time windows (350–500 ms, 550–750 ms), transparent nouns elicited a larger frontal negativity than irregular nouns. In the third time window (750–950 ms), a more positive response for transparent nouns was observed across posterior sites. The disagreement condition elicited different responses compared to the agreement condition. Specifically, between 350 ms and 500 ms, disagreement waves were found to be more negative than those of the agreement condition. This left lateralized negative effect in the 350–500 ms time window fits well with the LAN (Molinaro et al., 2011). Following this negativity, larger positivity was observed for the disagreement condition than for the

agreement condition. This effect did not reach a clear statistical significance between 550 and 750 ms but it did between 750 and 950 ms after stimulus onset, showing a posterior distribution. Although this positive effect was not statistically strong in the 550–750 time window, it can be reasonably interpreted as a P600 effect on the basis of its polarity and the nature of the syntactic violation under investigation. This biphasic ERP response is consistent with previous ERP studies on gender agreement processing in sentences (Barber & Carreiras, 2005; Barber et al., 2004; Gunter et al., 2000; Molinaro et al., 2008; O'Rourke & Van Petten, 2011).

The ERP differences between transparent and irregular nouns suggest that the system is sensitive to the presence of reliable formal cues to gender. This finding implies that gender-to-ending consistency can be detected not only when people need to make an explicit decision on gender of isolated nouns, but also when they are reading sentences for comprehension. The high temporal resolution of the ERP technique allowed us to identify the temporal onset of the gender-regularity effect. Specifically, gender-to-ending consistency started to influence ERP brain response from 350 ms poststimulus onset.[1] This relatively early ERP effect of gender-to-ending consistency rules out the possibility of formal cues to gender being detected and used only at final postlexical stages of gender processing to monitor the output of the lexical route, as proposed by the postlexical checking hypothesis (Bates et al., 1995, 1996; see also Gollan & Frost, 2001; Hofmann et al., 2007). Rather, this finding is more consistent with the reliable cue hypothesis according to which the distributional information conveyed by the nominal ending is detected as early as possible (Taft & Meunier, 1998; see also Afonso et al., 2003; Grüter et al., 2012). Interestingly, the ERP difference between transparent and irregular nouns observed within a sentence context was maintained until 950 ms poststimulus. Similar to the agreement effect, the manipulation of consistency evoked a biphasic response, with a negative effect followed by a late posterior positivity. Although the two phases of the electrophysiological response appear to be similar in terms of polarity and latency, the topographical distribution of the negativity elicited by transparent nouns with respect to irregular nouns differs in the first time window from that of the previously discussed LAN elicited by agreement mismatches. Indeed, the analysis on the difference waves showed that the LAN for agreement violation is maximal over left sites (in line with previous findings of article-noun agreement, see Molinaro et al., 2011) while the negativity for consistency is maximal over medial sites. This latter effect is hard to reconcile with a LAN. In addition, its topography is akin to that found in other ERP studies comparing different degrees of gender-to-ending consistency (Caffarra et al., 2014; Schiller et al. 2003). These studies have reported modulations of an initial ERP negative effect with a similar topography, and in some cases a long-lasting duration. In the present study, the comparison between a LAN elicited by a grammatical violation and the negativity for gender-to-ending consistency showed that these effects have different topography, implying different neural generators and thus being possibly related to distinct cognitive processes. We will now try to better characterize the gender-to-ending consistency effect on the basis of previous ERP literature.

Long-lasting ERP differences have been previously reported in the context of different amounts of cognitive demands and working memory loads (Monfort & Pouthas, 2003; Ruchkin, Canoune, Johnson, & Ritter, 1995; Ruchkin, Johnson, Canoune, & Ritter, 1990; Ruchkin, Johnson, Mahaffey, & Sutton, 1988). Specifically, slow shifts over the frontal cortex have been related to short-term retention of verbal or visual-spatial stimuli (Johnson, 1995; Ruchkin et al. 1990; Ruchkin, Johnson, Grafman, Canoune, & Ritter, 1992). This shift usually starts around 300 ms following stimulus onset and lasts until the end of the retention interval (Johnson, 1995). The polarity of these shifts is not always consistent in the literature, but negative shifts are more frequently reported (Johnson, 1995; but see King & Kutas, 1995). In addition, a polarity reversal can sometimes be observed from anterior to posterior regions (Ruchkin et al., 1988). This is due to the fact that positive or negative polarity of a given ERP component at a given electrode site is related to the orientation of the equivalent current dipole with respect to the electrode. Each current dipole always produces both positive and negative voltages, and the specific distribution of positive and negative voltages on the scalp depends on the position and orientation of the dipole (Luck & Kappenman, 2011). Finally, it has been shown that the amplitude of the slow wave increases with the amount of information that needs to be held in the working memory (Johnson, 1995).

The timing and the topographical distribution of the ERP effect reported in response to the gender-to-ending manipulation are compatible with those reported in the working memory literature (Johnson, 1995; Ruchkin et al., 1988, 1990, 1992). Given the functional interpretation of the previously reported sustained ERP effects, it is likely that our long-lasting ERP difference between transparent and irregular nouns could reflect the differences in the amount of available information between these two types of nouns. Specifically, while transparent nouns require the activation of two different types of information (lexical and form-based), irregular nouns rely only on the use of the lexical source. According to this interpretation, transparent nouns elicit an initial greater negativity (followed by a greater posterior positivity) compared to irregular nouns, since transparent nouns involve a larger amount of information sources (due to the availability of reliable formal cues) compared to irregular nouns (for a similar interpretation, see Caffarra et al., 2014). This interpretation seems to be difficult to reconcile with behavioral studies showing that participants are usually faster and more accurate when deciding gender of transparent nouns than that of irregular/opaque nouns (Bates et al., 1995, 1996; Hernandez et al., 2004; Peereman et al., 2009; Spalek et al., 2008; Taft & Meunier, 1998). For instance, the processes requiring high working memory loads are usually less accurate and slower at the behavioral level (Fiebach, Schlesewsky, & Friederici, 2002), although different working memory demands are not always associated with behavioral differences (King & Kutas, 1995). Nonetheless, it should be noted that the behavioral advantage of transparent nouns has been consistently observed when participants had to perform an explicit gender decision task on words presented in isolation. Deciding gender identity of single target words may require strategies that do not typically characterize gender retrieval during sentence reading (Radeau & Van Berkum, 1996). In addition, comprehension of a complex sequence of words is linked to the processes of integration and reanalysis that may not be required when the system needs to perform metalinguistic tasks on isolated words (Barber & Carreiras, 2005).

1. This does not imply that grammatical gender information is not available to the processing system earlier. For instance, in Pulvermüller and Assadollahi, (2007), grammatical gender mismatches elicited a negativity between 100 and 200 ms (magnetic mismatch negativity, MMN). In Caffarra, Pesciarelli and Cacciari (2013), the emergence of the N2pc component was modulated by grammatical gender processing between 170 and 320 ms poststimulus.

Thus, the present study suggests that, at least within a sentence context, the availability of reliable formal gender cues can be detected as early as 350 ms after the noun onset and can be kept available until later stages of analysis (i.e., 950 ms). But why should the system maintain this distributional information for such a long time? Within the domain of the sentence processing literature, sustained ERP effects have been reported when dislocated linguistic information needs to be stored in the working memory in order to be used during the processing of subsequent sentential constituents (e.g., to compute long-distance dependencies: Fiebach et al., 2002; King & Kutas, 1995; Müller, King, & Kutas, 1997; Phillips, Kazanina, & Abada, 2005). Similarly, in the present study, the information about reliable formal gender cues could be held in memory since it is potentially useful for later stages of sentence analysis. Below, we will discuss two possible reasons why formal gender cues could be maintained in memory: (1) detecting and/or repairing agreement dependencies, and (2) computing general integration processes at the end of a sentence.

One possibility is that transparent nouns are held in memory because they can be used in the agreement computation. However, if the gender-related ending of the target noun had been crucial in detecting and/or repairing agreement violations with the preceding determiner, we should have found an interaction between agreement and gender-to-ending consistency factors. The lack of the interaction cannot support the idea that gender-to-ending consistency modulates sensitivity to syntactic anomalies of the target noun either at early or late stages of processing. Specifically, the presence of a LAN effect does not seem to be guaranteed by the availability of reliable formal cues in the agreeing/disagreeing elements (for a similar conclusion, see Bañon et al., 2012; cf. Molinaro et al., 2011). Similarly, gender-to-ending consistency does not seem to play a strong differential role in the late processes of repair and reanalysis of gender violations (which underlies the elicitation of the P600; Friederici, 2002), and the availability of gender-related noun endings does not seem to imply the allocation of extra resources to recover from a violation. This can be due to the characteristics of the Italian nominal categorization system (notably, the presence of opaque and irregular nouns that constitute approximately 29% of masculine and 32% of feminine nouns in the singular form). For instance, the most reliable information about the gender of a noun is located at the lexical level where the gender of the noun is specified. The lexical route may have priority in determining not only the noun's gender but also in establishing agreement dependencies (for a similar interpretation, see Molinaro, Barber, Pérez, Parkkonen, & Carreiras, 2013), especially for nouns in which the final vowel is not a morphological suffix. However, this interpretation needs to be cautious since the lack of interaction between agreement and consistency does not provide clear-cut evidence for the independence of the two effects. And, it is still possible that gender-to-ending consistency would be more influential under different circumstances. In the present study, the presence of irregular and opaque nouns (among the fillers) could have made the abstract gender feature specified in the lexicon the most reliable source of information to compute agreement. In addition, the present study has taken into account the case of short-distance dependencies computed between a determiner and the following noun, where the information about gender-to-ending consistency and the syntactic anomaly need to be computed at the same time and on the same sentential constituent. It remains to be seen whether distributional information carried by the noun ending could affect the processes of detection and/or repair of syntactic anomalies in the subsequent sentential constituents (e.g., past participles, adjectives). The late processes of repair and reanalysis seem to be influenced by the amount of information stored in the working memory, especially when this information is carried over long structural/linear distances (Bañon et al, 2012; O'Rourke & Van Petten, 2011). Further studies are needed to address the question of whether formal gender cues, provided before encountering syntactic errors (e.g., agreement dependencies between a noun and a postnominal adjective), would affect processing of long-distance dependencies. This could be the case in the languages where several sentential constituents can signal a strong gender-to-ending consistency (e.g., Romance languages) and where the same gender-related ending can be repeated in a sentence (e.g., "La scatol<u>a</u> ross<u>a</u> che hai comprato è rott<u>a</u> e va cambiat<u>a</u>," *the*$_{F}$ *red*$_{F}$ *box*$_{F}$ *that you bought is broken*$_{F}$ *and needs to be changed*$_{F}$). In this case, maintaining available transparent gender cues might be useful for processing upcoming words. For instance, a recent self-paced reading study showed increased reading times in sentences where different elements show a partial orthographic-phonological overlap, compared to sentences with no overlap (Acheson & MacDonald, 2011). Interestingly, online data showed that reading time differences arose as soon as the first overlapping word was encountered, and these processing costs were also evident at the final portion of the sentence.

An alternative explanation that could account for the sustained ERP effect of gender-to-ending consistency is that distributional cues conveyed by the noun ending are maintained online as processing unfolds and taken into account at the end of the sentence, when global processes of wrap-up and overall integration of sentential information take place (Acheson & MacDonald, 2011; Hagoort, 2003). Previous studies have suggested that maintaining regular orthographic-phonological cues until the end of a sentence might be useful in keeping track of serial order information (Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979), computing correlations between phonological and syntactic/semantic patterns (Farmer, Monaghan, Misyak, & Christiansen, 2011), checking initial sentence interpretation, and fully interpreting the sentence given different sources of linguistic information (Kennison, 2004; Kennison, Sieck, & Briesch, 2003).

In summary, the present ERP study showed that the processing system can rapidly detect formal cues to gender during online sentence comprehension, as predicted by the reliable cue hypothesis. Although this distributional information remained available until later stages of noun processing, the present findings do not provide evidence for an influence of gender-to-ending consistency on agreement computation.

References

Acheson, D. J., & MacDonald, M. C. (2011). The rhymes that the reader perused confused the meaning: Phonological effects during on-line sentence comprehension. *Journal of Memory and Language*, *65*, 123–123. doi:10.1016/j.jml.2011.04.006

Afonso, O., Domínguez, A., Álvarez, C., & Morales, D. (2003). Sublexical and lexico-syntactic factors in gender access in Spanish. *Journal of Psycholinguistic Research*, *43*, 13–13. doi:10.1007/s10936-012-9236-0

Badecker, W., Miozzo, M., & Zanuttini, R. (1995). The two-stage model of lexical retrieval: Evidence from a case of anomia with selective preservation of grammatical gender. *Cognition*, *57*, 193–193.

Bañon, J. A., Fiorentino, R., & Gabriele, A. (2012). The processing of number and gender agreement in Spanish: An event-related potential investigation of the effects of structural distance. *Brain Research*, *1456*, 49–49. doi:10.1016/j.brainres.2012.03.057

Barber, H., & Carreiras, M. (2003). Integrating gender and number information in Spanish word pairs: An ERP study. *Cortex*, *39*, 465–465. doi:10.1016/S0010-9452(08)70259-4

Barber, H., & Carreiras, M. (2005). Grammatical gender and number agreement in Spanish: An ERP comparison. *Journal of Cognitive Neuroscience*, *17*, 137–137. doi:10.1162/08989290 52880101

Barber, H., Salillas, E., & Carreiras, M. (2004). Gender or genders agreement? In M. Carreiras & C. Clifton (Eds.), *On-line study of sentence comprehension; eye-tracking, ERP and beyond* (pp. 309–328) Brighton, UK: Psychology Press.

Baroni, M., Bernardini, S., Comastri, F., Piccioni, L., Volpi, A., Aston, G., & Mazzoleni, M. (2004). Introducing the "la Repubblica" corpus: A large, annotated, TEI(XML)-compliant corpus of newspaper Italian. *Proceedings of the 4th International Conference on Language Resources and Evaluation, LREC 2004* (pp. 1771–1774). May 26–28, 2004, Lisboa, Portugal.

Bates, E., Devescovi, A., Hernandez, A., & Pizzamiglio, L. (1996). Gender priming in Italian. *Perception & Psychophysics*, *58*, 992–992.

Bates, E., Devescovi, A., Pizzamiglio, L., D'Amico, S., & Hernandez, A. (1995). Gender and lexical access in Italian. *Perception & Psychophysics*, *57*, 847–847.

Bates, E., & MacWhinney, B. (1982). Functionalist approaches to grammar. In E. Wanner & L. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 173–218). New York, NY: Cambridge University Press.

Bordag, D., Opitz, A., & Pechmann, T. (2006). Gender processing in first and second languages. The role of noun termination. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1090–1090. doi:10.1037/0278-7393.32.5.1090

Bordag, D., & Pechmann, T. (2007). Factors influencing L2 gender processing. *Bilingualism: Language and cognition*, *10*, 299–299. doi:10.1017/S1366728907003082

Brouwer, H., Fitz, H., & Hoeks, J. (2012). Getting real about semantic illusions: Rethinking the functional role of the P600 in language comprehension. *Brain Research*, *1446*, 127–127. doi:10.1016/j.brainres.2012.01.055

Brysbaert, M., Warriner, A. B., & Kuperman, V. (2014). Concreteness ratings for 40 thousand generally known English word lemmas. *Behavior Research Methods*, *46*, 904–904. doi:10.3758/s13428-013-0403-5

Cacciari, C. (2011). *Psicologia del linguaggio [Psychology of language]*. Bologna, Italy: Il Mulino.

Cacciari, C., & R. Cubelli (Eds). (2003). A neuropsychology of grammatical gender. An introduction. *Cortex*, *39*, 377–377. doi:10.1016/S0010-9452(08)70254-5

Caffarra, S., Janssen, N., & Barber, H. (2014). Two sides of gender: ERP evidence for the presence of two routes during gender agreement processing. *Neuropsychologia*, *63*, 124–124. doi:10.1016/j.neuropsychologia.2014.08.016

Caffarra, S., Pesciarelli, F., & Cacciari, C. (2013). The interaction between language and visual spatial attention systems in grammatical gender processing. An N2pc study. *Cognitive Neuroscience*, *4*, 217–217. doi:10.1080/17588928.2013.823392

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, *14*, 177–208. doi:10.1080/026432997381664

Caramazza, A., & Miozzo, M. (1997). The relation between syntactic and phonological knowledge in lexical access: Evidence from the 'tip-of-the-tongue' phenomenon. *Cognition*, *64*, 309–343.

Caselli, M. C., Leonard, L., Volterra, V., & Campagnoli, M. G. (1993). Toward mastery of Italian morphology: A cross-sectional study. *Journal of Child Language*, *20*, 377–377. doi:10.1017/S0305000900008333

Chini, M. (1995). *Genere grammaticale e acquisizione. Aspetti della morfologia nominale in italiano L2 [Grammatical gender and acquisition: Aspects of nominal morphology in Italian as L2]*. Milano, Italy: Franco Angeli.

Comrie, B. (1999). Grammatical gender systems: A linguist's assessment. *Journal of Psycholoinguistic Research*, *28*, 457–457.

Corbett, G. (1991). *Gender*. Cambridge, England: Cambridge University Press.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes*, *13*, 21–21. doi:10.1080/016909698386582

Cubelli, R., Lotto, L., Paolieri, D., Girelli, M., & Job, R. (2005). Grammatical gender is selected in bare noun production: Evidence from the picture–word interference paradigm. *Journal of Memory and Language*, *53*, 42–59. doi:10.1016/j.jml.2005.02.007

D'Achille, P., & Thornton, A. M. (2006). I nomi femminili in –o [Feminine nouns ending in –o]. In E. Cresti (Ed.), *Prospettive nello studio del lessico italiano, Atti SILFI* (pp. 473–481). Firenze, Italy: FUP.

Delfitto, D., & Zamparelli, R. (2009). *Le strutture del significato [The structure of the meaning]*. Bologna, Italy: Il Mulino.

Della Rosa, P., Catricalà, E., Vigliocco, G., & Cappa, S. (2010). Beyond the abstract-concrete dichotomy: Mode of acquisition, concreteness, imageability, familiarity, age of acquisition, context availability, and abstractness norms for a set of 417 Italian words. *Behavior Research Methods*, *42*, 1042–1048.

De Martino, M., Bracco, G., & Laudanna, A. (2010). The activation of grammatical gender information in processing Italian nouns. *Language and Cognitive Processes*, *26*, 745–776. doi:10.1080/01690965.2010.491977

Deutsch, A., & Bentin, S. (2001). Syntactic and semantic factors in processing gender agreement in Hebrew: Evidence from ERPs and eye movements. *Journal of Memory and Language*, *45*, 200–224. doi:10.1006/jmla.2000.2768

Di Domenico, E. (1997). *Per una teoria del genere grammatical [A theory of grammatical gender]*. Padova, Italy: Unipress.

Farmer, T. A., Monaghan, P., Misyak, J. B., & Christiansen, M. H. (2011). Phonological typicality influences sentence processing in predictive contexts: Reply to Staub, Grant, Clifton, and Rayner (2009). *Journal of Experimental Psychology: Learning, Memory and Cognition*, *37*, 1318–1318.

Fiebach, C., Schlesewsky, M., & Friederici, A. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: The processing of German wh-questions. *Journal of Memory and Language*, *47*, 250–272. doi:10.1016/S0749-596X(02)00004-9

Friederici, A. D. (1995). The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data. *Brain and Language*, *50*, 259–259. doi:0.1006/brln.1995.1048

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, *6*, 78–78. doi:10.1016/S1364-6613(00)01839-8

Friederici, A. D., & Jacobsen, T. (1999). Processing grammatical gender during language comprehension. *Journal of Psycholinguistic Research*, *28*, 467–467. doi:10.1023/A:1023264209610

Gollan, T., & Frost, R. (2001). Two routes to grammatical gender: Evidence from Hebrew. *Journal of Psycholinguistic Research*, *30*, 627–627. doi:10.1023/A:1014235223566

Grüter, T., Lew-Williams, C., & Fernald, A. (2012). Grammatical gender in L2: A production or a real-time processing problem? *Second Language Research*, *28*, 191–191. doi:10.1177/0267658312437990

Guajardo, L. F., & Wicha, N. Y. Y. (2014). Morphosyntax can modulate the N400 component: Event related potentials to gender-marked post-nominal adjectives. *NeuroImage*, *1*, 262–262. doi:10.1016/j.neuroimage.2013.09.077

Gunter, T. C., Friederici, A. D., & Schriefers, H. (2000). Syntactic gender and semantic expectancy: ERPs reveal early autonomy and late interaction. *Journal of Cognitive Neuroscience*, *12*, 556–568. doi:10.1162/089892900562336

Hagoort, P. (2003). Interplay between syntax and semantics during sentence comprehension: ERP effects of combining syntactic and semantic violations. *Journal of Cognitive Neuroscience*, *15*, 883–883. doi:10.1162/089892903322370807

Hagoort, P., & Brown, C. (1999). Gender electrified: ERP evidence on the syntactic nature of gender processing. *Journal of Psycholinguistic Research*, *28*, 715–728.

Hagoort, P., Brown, C. M., & Osterhout, L. (1999). The neural architecture of syntactic processing. In C. M. Brown & P. Hagoort (Eds.), *Neurocognition of language*. Oxford, UK: Oxford University Press.

Hauk, O., Davis, M. H., Ford, M., Pulvermüller, F., & Marslen-Wilson, W. D. (2006). The time course of visual word recognition as

revealed by linear regression analysis of ERP data. *NeuroImage*, *30*, 1383–1383. doi:10.1016/j.neuroimage.2005.11.048

Hernandez, A. E., Kotz, S. A., Hofmann, J., Valentin, V. V., Dapretto, M., & Bookheimer, S. Y. (2004). The neural correlates of grammatical gender decisions in Spanish. *NeuroReport*, *15*, 863–866. doi: 10.1097/00001756-200404090-00026

Hofmann, J., Kotz, S. A., Marschhauser, A., Yves von Cramon, D., & Friederici, A. D. (2007). Lesion-site affects grammatical gender assignment in German: Perception and production data. *Neuropsychologia*, *45*, 954–954. doi:10.1016/j.neuropsychologia.2006.08.029

Johnson, R. (1995). Event-related potential insights into the neurobiology of memory systems. In F. Boller and J. Grafman (Eds.): *Handbook of Neuropsychology*, (vol.*10*, pp. 135–163). Amsterdam, The Netherlands: Elservier Science.

Kennison, S. M. (2004). The effect of phonemic repetition on syntactic ambiguity resolution: Implications for models of working memory. *Journal of Psycholinguist Research*, *33*, 493–516. doi:0.1007/s10936-004-2668-4

Kennison, S. M., Sieck J. P., & Briesch, K. A. (2003). Evidence for a late-occurring effect of phoneme repetition during silent reading. *Journal of Psycholinguistic Research*, *32*, 297–312. doi:10.1023/A:1023543602202

King, J., & Kutas, M. (1995). Who did what and when? Using word- and clause level ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience*, *7*, 376–395. doi:10.1162/jocn.1995.7.3.376

Luck, S. J., & Kappenman, E. S. (2011). *The Oxford handbook of event-related potential components*. Oxford, UK: University Press.

MacWhinney, B., Bates, E., & Kliegl, R. (1984). Cue validity and sentence interpretation in English, German, and Italian. *Journal of Verbal Learning and Verbal Behavior*, *23*, 127–127. doi:10.1016/S0022-5371(84)90093-8

Mancini, S. Molinaro, N., & Carreiras, M. (2013). Anchoring agreement in comprehension. *Language & Linguistics Compass*, *7*, 1–21. doi: 10.1111/lnc3.12008

Matthews, C. (2010). On the nature of phonological cues in the acquisition of French gender categories: Evidence from instance-based learning models. *Lingua*, *120*, 879–879. doi:10.1016/j.lingua.2009.06.007

Metting van Rijn, A. C., Peper, A., & Grimbergen, C. A. (1990). High-quality recording of bioelectric events: Part 1. *Medical and Biological Engineering and Computing*, *28*, 389–397. doi:10.1007/BF02441961

Miceli, G., Turriziani, P., Caltagirone, C., Capasso, R., Tomaiuolo, F., & Caramazza, A. (2002). The neural correlates of grammatical gender: An fMRI investigation. *Journal of Cognitive Neuroscience*, *14*, 618–628. doi:10.1162/08989290260045855

Molinaro, N., Barber, H., & Carreiras, M. (2011). Grammatical agreement processing in reading: ERP findings and future directions. *Cortex*, *47*, 908–908. doi:10.1016/j.cortex.2011.02.019

Molinaro, N., Barber, H., Pérez, A., Parkkonen, L., & Carreiras, M. (2013). Left fronto-temporal dynamics during agreement processing: Evidence for feature-specific computations. *NeuroImage*, *78*, 339–339. doi:10.1016/j.neuroimage.2013.04.025

Molinaro, N., Vespignani, F., & Job, R. A. (2008). A deeper reanalysis of a superficial feature: An ERP study on agreement violations. *Brain Research*, *1228*, 161–161. doi:10.1016/j.brainres.2008.06.064

Monfort, V., & Pouthas, V. (2003). Effects of working memory demands on frontal slow waves in time-interval reproduction tasks in humans. *Neuroscience Letters*, *343*, 195–195. doi:10.1016/S0304-3940(03)00385-9

Müller, H., King, J., & Kutas, M. (1997). Event-related brain potentials to relative clause processing in spoken sentences. *Cognitive Brain Research*, *5*, 193–203.

O'Rourke, P. L., & Van Petten, C. (2011). Morphological agreement at a distance: Dissociation between early and late components of the event-related brain potential. *Brain Research*, *1392*, 62–62. doi: 10.1016/j.brainres.2011.03.071

Osterhout, L., & Mobley, L. A. (1995). Event- related brain potentials elicited by failure to agree. *Journal of Memory and Language*, *340*, 739–739.

Padovani, R., & Cacciari, C. (2003). Il ruolo della trasparenza morfologica nel riconoscimento di parole in Italiano [The role of morphological transparency in recognition of Italian words]. *Giornale Italiano di Psicologia*, *30*, 749– 771.

Padovani, R., Calandra-Buonaura, G., Cacciari, C., Benuzzi, F., & Nichelli, P. (2005). Grammatical gender in the brain: Evidence from an fMRI study on Italian. *Brain Research Bulletin*, *65*, 301–308. doi: 10.1016/j.brainresbull.2004.11.025

Paolieri, D., Lotto, L., Leoncini, D. Cubelli, R., & Job, R. (2010). Differential effects of grammatical gender and gender inflection in bare noun production. *British Journal of Psychology*, *102*, 19–19. doi: 10.1348/000712610X496536

Peereman, R., Dufour, S., & Burt, J. (2009). Orthographic influences in spoken word recognition: The consistency effect in semantic and gender categorization tasks. *Psychonomic Bulletin & Review*, *16*, 363–363. doi:10.3758/PBR.16.2.363

Pérez-Pereira, M. (1991). The acquisition of gender: What Spanish children tell us. *Journal of Child Language*, *18*, 571–571. doi:10.1017/S0305000900011259

Phillips, C., Kazanina, N., & Abada, S. H. (2005). ERP effects of the processing of syntactic long-distance dependencies. *Cognitive Brain Research*, *22*, 407–407. doi:10.1016/j.cogbrainres. 2004.09.012

Pulvermüller, F., & Assadollahi, R. (2007). Grammar or serial order?: Discrete combinatorial brain mechanisms reflected by the syntactic mismatch negativity. *Journal of Cognitive Neuroscience*, *19*, 971–980. doi:10.1162/jocn.2007.19.6.971

Radeau, M., & Van Berkum, J. J. A. (1996). Gender decision. *Language and Cognitive Processes*, *11*, 605–605. doi:10.1080/016909696387006

Ruchkin, D. S., Canoune, H. L., Johnson, R., & Ritter, W. (1995). Working memory and preparation elicit different patterns of slow wave event-related brain potentials. *Psychophysiology*, *32*, 399–399. doi:10.1111/j.1469-8986.1995.tb01223.x

Ruchkin, D. S., Johnson, R., Canoune, H., & Ritter, W. (1990). Short-term memory storage and retention: An event related brain potential study. *Electroencephalography and Clinical Neurophysiology*, *76*, 419–439. doi:10.1016/0013-4694(90)90096-3

Ruchkin, D. S., Johnson, R., Grafman, J., Canoune, H. L., & Ritter, W. (1992). Distinctions and similarities among working memory processes: An event-related potential study. *Cognitive Brain Research*, *1*, 53–53.

Ruchkin, D. S., Johnson, R., Mahaffey, D., & Sutton, S. (1988). Toward a functional categorization of slow waves. *Psychophysiology*, *25*, 393–393. doi:10.1111/j.1469-8986.1988.tb01253.x

Schiller, N. O., Munte, T. F., Horemans, I., & Jansma, B. M. (2003). The influence of semantic and phonological factors on syntactic decisions: An event-related brain potential study. *Psychophysiology*, *40*, 869–869. doi:10.1111/1469-8986.00105

Shankweiler, D., Liberman, I. Y., Mark, L. S., Fowler, C. A., & Fischer, F. W. (1979). The speech code and learning to read. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 531–545.

Spalek, K., Franck, J., Schriefers, H. & Frauenfelder, U. (2008). Phonological regularities and grammatical gender retrieval in spoken word recognition and word production. *Journal of Psycholinguistic Research*, *37*, 419–419. doi:10.1007/s10936-008-9074-2

Taft, M., & Meunier, F. (1998). Lexical representation of gender: A quasiregular domain. *Journal of Psycholinguistic Research*, *27*, 23–45. doi:10.1023/A:1023270723066

Van de Meeredonk, N., Kolk, H. H. J., Chwilla, D. J., & Vissers, C. Th. W. M. (2009). Monitoring in language perception. *Language and Linguistics Compass*, *3*, 1211–1224. doi:10.1111/j.1749-818X.2009.00163.x

Vigliocco, G., Antonini, T., & Garrett, M. F. (1997). Grammatical gender is on the tip of Italian tongues. *Psychological Science*, *8*, 314–314. doi:10.1111/j.1467-9280.1997.tb00444.x

Vigliocco, G., & Franck, J. (1999). When sex and syntax go hand in hand: Gender agreement in language production. *Journal of Memory and Language*, *40*, 455–455. doi:10.1006/jmla.1998.2624

Vigliocco, G., Vinson, D. P., Paganelli, F., & Dworzynski, K. (2005). Grammatical gender effects on cognition: Implications for language learning and language use. *Journal of Experimental Psychology*, *104*, 501–501. doi:10.1037/0096-3445.134.4.501

Wicha, N. Y. Y., Moreno, E., & Kutas, M. (2004). Anticipating words and their gender: An event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. *Journal of Cognitive Neuroscience*, *16*, 1272–1288. doi:10.1162/0898929041920487

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Supporting Information

Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix S1: List of the experimental materials with the corresponding gender.

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