

## Processing of temporary syntactic ambiguity in Italian “who”-questions: a study with event-related potentials

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### Abstract

This study investigated the processing of direct Italian “who”-questions, containing a temporary ambiguity of the syntactic role (subject/object) of the initial pronoun. To this aim we measured event-related potentials (ERPs) evoked by the disambiguating verbal agreement word and by the following ones. Results showed two positive deflections, corresponding to a P300 and to a P600, only at the target verb of the object-first extraction, the condition which has been demonstrated to be less preferred by speakers. The functional meaning of this positive complex, similar to patterns already reported for German subject/object ambiguous relative clauses, was discussed with reference both to results obtained in other languages using similar sentences and to psycholinguistic parsing models.

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Over the last two decades the understanding of language mechanisms has been greatly improved following the application of the event-related potentials (ERPs) to paradigms which have used different kinds of linguistic violations (semantic or syntactic ones) within sentences. In such a way, in a number of different languages, at least three specific ERP signatures have been identified and associated to specific processes of linguistic comprehension. A centro-parietal negative component, called N400, is evoked when a stimulus does not fit into the phrasal semantic context [1,5,16]. A late centro-parietal positive component, called P600 or syntactic positive shift (SPS), is related to difficulty of syntactic integration caused by different types of grammatical violations [1,5,14,17]. Finally, a left anterior negative component, called LAN or Early LAN (ELAN) on the basis of its latency, occurs in correspondence of syntactic anomalies and

is associated with syntactic structural processing complexity [1,5,19]. In addition to linguistic violation, linguistic ambiguity has proved itself to be a key-tool for investigating features and mechanisms of language comprehension. In particular, the study of permanent or temporary syntactic ambiguities, in the so-called garden-path sentences, plays a fundamental role in the debate among different parsing models. Most of studies have outlined, in fact, a parser, which immediately tends to attribute a syntactic structure to the ongoing ambiguous word string, even though this could cause the cost of a reprocessing in the case of a mismatch between the on-line constructed representation and the actual input. Behaviourally, this way of analysing sentences is reflected by longer reading times and worst accuracy during the processing of the condition considered to be less preferred by the parser [8], and electrophysiologically by the finding (at the same disambiguating word level) of the P600 component, normally evoked by outright syntactically violated stimuli. Whereas for syntactic violations such component was more posterior, in the case of ambiguities it was more distributed on anterior locations [21]. In particular, the analysis of the preferred choices made

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by the parser during sentence interpretation has suggested that it entertains only one analysis at a time for a given input string; namely, **it tends to assign the simplest syntactic structure compatible with the input.**

In the present study, we examined a particular kind of ambiguous sentences: **Italian direct “who”-questions, which present the temporary ambiguity of the pronoun grammatical role.** The pronoun “who”, indeed, could be the subject or the object of the sentence and the clarification of its role is **provided by its agreement with verb number.** The ambiguity of such pronoun is solved in different ways across different languages: by marking the pronoun case (like sometimes in German, i.e., *Thomas fragt sich, wer (subj.) den (obj.) Doktor verständigt hat* [Thomas asks himself, who has called the doctor]: Subj.; *Thomas fragt sich, wen (obj.) der (subj.) Doktor verständigt hat* [Thomas asks himself, who the doctor has called]: Obj.), through the order of phrasal elements (like in English, i.e., *Thomas asks himself, who (subj.) has called the doctor* (obj.): Subj.; *Thomas asks himself, who (obj.) the doctor (subj.) has called*: Obj.), or through the number agreement of sentence constituents (exemplified in Italian: *Thomas si chiede chi (subj./obj.) chiamò il dottore (obj./subj.)* [Thomas asks himself, who has called the doctor/who the doctor has called]: Subj. or Obj.; *Thomas si chiede chi (obj.) chiamarono i dottori (subj.)* [Thomas asks himself, who the doctors have called]: Obj.). Most behavioural studies have demonstrated a **clear preference for the subject-first structure,** as shown by longer reading times and worst performances for the object-first structure [4,8,22]. This result has been obtained in different languages, in particular, a self-paced reading study performed in Italian, side by side to the present, with exactly the same stimuli used here, has found reading times significantly longer at the disambiguating verb of the object structure, compared with the subject one [6]. We expected such a result, as it is in line with the parsing strategy of constructing the simplest syntactical structure compatible with the input. Specifically, for the filler-gap dependencies, like the ambiguous “who”-questions we used, this way of analysing sentences is reflected in the “Active Filler Strategy” [7,8] or, in the nearly equivalent, “Minimal Chain Principle” [2,4]. According to these, the syntactic processor assigns the moved constituent, also called filler (here the pronoun “who”), to the first possible gap position within the sentence, which is the subject gap. Nevertheless, in spite of a general agreement about these behavioural results and their underlying explanatory principles, the components evoked by the disambiguating word of the less preferred extraction have been less consistent across the literature. The use of ambiguous structures with the subject/object-first extraction, indeed, has produced nearly always a P600-like component for the unpreferred object structure [12,15,18,23], but this deflection was sometimes in isolation [15,18,23], sometimes accompanied by other positivities [12]. In addition, the presence of this positive component has been detected sometimes only for particular subgroups of subjects (i.e., high span readers or fast comprehenders) and its latency has been found to

vary in relation to the difficulty of the repair processes involved in the rebuilding of the syntactic structure initially assigned [12,18,23]. The investigation of these ambiguous sentences by means of event-related potentials (ERPs) is still missing in Italian. Therefore, with the present work we aimed to identify the electrophysiological pattern evoked by the two processes we suppose to be involved in the comprehension of our Italian ambiguous sentences: **the detection of this specific kind of syntactic anomaly, created by the object-first extraction, and the following stage of syntactic representation reconstruction.** In particular, as the more consistent result in other languages is a P600-like, we expected to find a similar component, whose latency, distribution, and possible association with other deflections, could provide important information about the complexity of the processes involved in Italian “who”-question comprehension. The overlapping of the elicited components with those already found, or, on the contrary, the discovery of a completely different pattern could give, in such a way, useful directions about the way in which Italian language solves the ambiguity with respect to languages in which the phenomenon has been studied so far.

The experimental material consisted of 60 pairs of temporarily ambiguous subject–object direct “who”-questions, derived by De Vincenzi’s “Test for Subject/Object Italian Interrogative Sentence Comprehension” [3] or constructed in a similar fashion. All sentences consisted of six words. The transitive verb required a direct accusative object. In order to minimize plausibility effects, verbs did not semantically bias towards one extraction rather than the other one. For each pair of questions, the interrogative pronoun “chi” was necessarily singular, the second noun was always plural, whereas the verb was singular in one sentence (subject-first reading) and plural in the other (object-first reading). Thus, the verbs represented the disambiguating word of the sentence. To illustrate: *Chi (subj.) bacia i nonni (obj.) con affetto?* (*Who kisses the grandparents with affection?*) for the subject-first extraction, and *Chi (obj.) baciano i nonni (subj.) con affetto?* (literally: *Who kiss the grandparents with affection?* in English: *Who do the grandparents kiss with affection?*) for the object-first one. Each participant saw only one version of each pair. The 30 sentences with the object-first and the 30 with the subject-first extraction were intermixed, in the experimental list, with 120 filler sentences with different structure (well-formed or containing some kind of anomaly). Participants were randomly assigned to the two equivalent lists and did read overall 180 sentences. Each sentence was presented word-by-word, in the centre of the screen, for 300 ms. The inter-stimulus interval was 300 ms. Twenty-five university students (13 females, 12 males; mean age: 23.12 years, S.D.: 1.92) took part in the experiment, after informed consent for their participation. All of them were right-handed according to the Edinburgh Handedness Inventory [20], native Italian speakers, and with normal or corrected to normal vision. They were asked to read silently the stimuli and to answer to randomly presented questions (approximately 1 every 10 sentences), used to insure participants paid attention during the task. The evoked po-

tentials were recorded from 19 tin electrodes, mounted on an ElectroCap and placed according to the International 10–20 System. Linked mastoids were used as reference. In addition, four electrodes were placed around the orbital region to detect eye movements. Electrophysiological data were continuously recorded by means of a SynAmp system and Scan 4.1 software (NeuroSoft), in dc mode, with low-pass filter set to 100 Hz, sampling rate of 500 Hz, and resolution of  $0.168 \mu\text{V}/\text{bin}$ . The recorded waveforms were divided into epochs around the target word (the verb), from 200 ms before its onset until 3600 ms after its appearance, and further processed off-line. Analyses were performed separately on the target word (w1) and on each one of the following words until the end of the sentence (w2/w5), on the mean voltage computed within two time windows following every word onset: 300–400 ms and 450–550 ms. The two intervals were selected on the basis of both the grandaverage waveform inspection of the target word (see Fig. 1), and the time windows previously chosen in other studies that used a similar sentence paradigms [12,18]. In each interval we conducted an analysis on four quadrants: left anterior (mean of F3, F7, T3), right anterior (mean of F4, F8, T4), left posterior (mean of T5, P3, O1), and right posterior (mean of T6, P4, O2), by means of a three-way

ANOVA with the following within-group factors: Sentence Type (two levels: subject-first extraction versus object-first extraction), Antero-Posterior Gradient (two levels: anterior versus posterior), Lateralization (two levels: left versus right). In the same intervals we also conducted an analysis on the midline, through a two-way ANOVA with the following factors: Sentence Type (two levels: subject-first extraction versus object-first extraction), Electrode (three levels: Fz, Cz, Pz). In addition, as a control for effects of word length, systematically covarying with the factor Sentence Type in Italian language (as the subject-extraction verb is always singular, and so two letters shorter, than the plural object-extraction verb), a further ANOVA has been done for singular (short) and plural (long) verbs of the well-formed filler sentences, whose verbs did not covary with any particular phrasal construction type.

The object-first extraction, when compared to the subject-first one, elicited two positive components on the target word (grey line in Fig. 1).

The first component showed a latency around 300 ms and was located in anterior sites, more markedly in the left side; the second component peaked around 500 ms and was more spread on the scalp. In line with these observations, in the

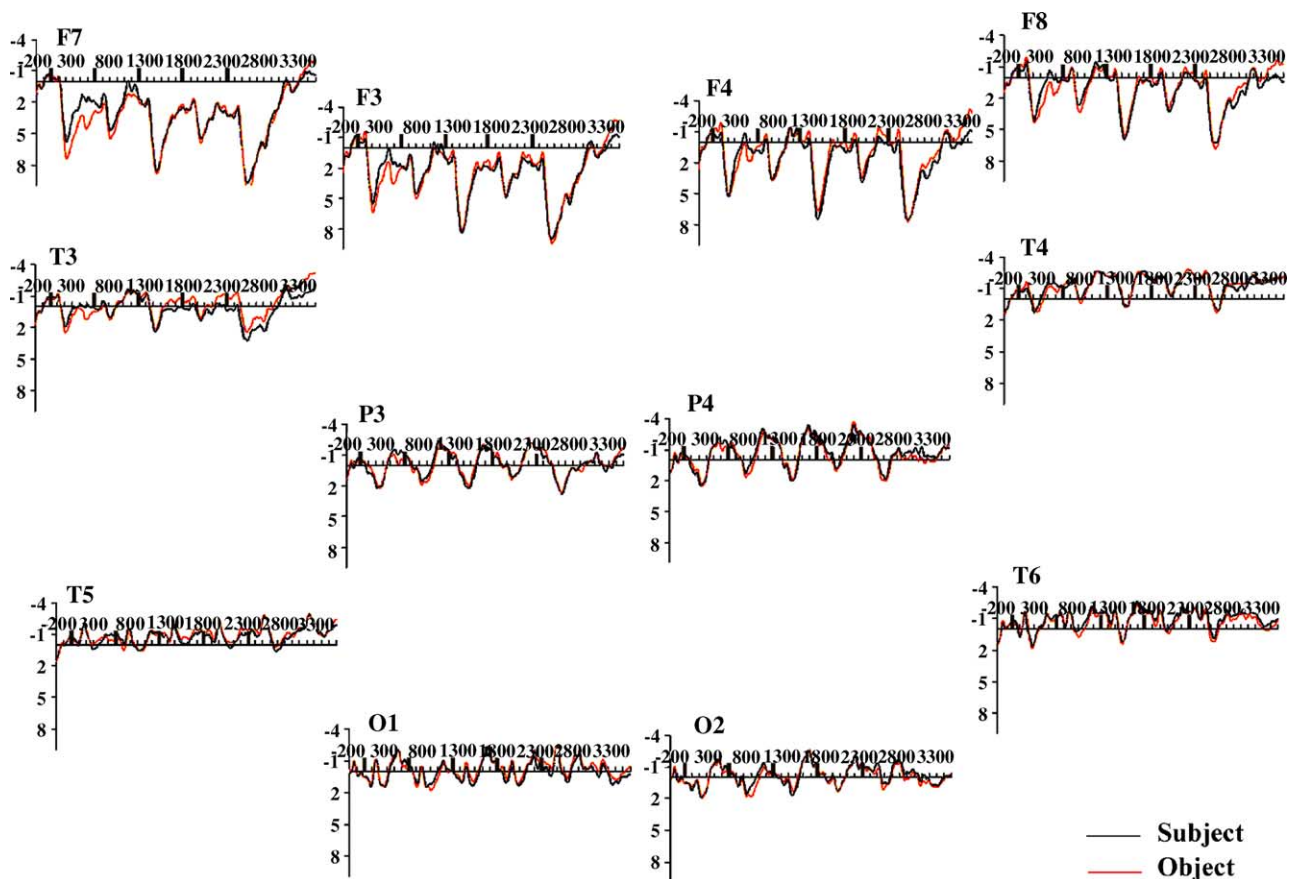


Fig. 1. Grand average waveforms representing 3600 ms of potentials evoked by the sentences, starting from the disambiguating word and recorded over the electrodes selected for quadrant analysis. The dark waveform indicates the object-first structure, the light coloured waveform represents the subject-first one. The bars along the time scale indicate the onset of each word, from w1: target to w5: final (stimulus presentation = 300 ms, stimulus onset asynchrony = 600 ms).

300–400 ms interval after the target word, quadrant analyses revealed a significant interaction of the factors Sentence Type and Antero-Posterior Gradient ( $F_{1,24} = 6.03$ ,  $P < 0.05$ ). Post hoc comparisons (Newman–Keuls) confirmed that **object-first extraction was more positive at frontal sites with respect to subject-first one**. No significant differences between the two kinds of extraction were found in the midline electrodes. For the other words (w2: word following the target/w5: final word), statistical analyses failed to reveal any significant effect. Quadrant analyses in the second time window (450–550 ms) showed, for the target word, both a significant main effect of Sentence Type ( $F_{1,24} = 5.2$ ,  $P < 0.05$ ), and a three-way interaction of the factors Sentence Type, Antero-Posterior Gradient and Lateralization ( $F_{1,24} = 5.53$ ,  $P < 0.05$ ). Newman–Keuls post hoc showed that the **object-first extraction was more positive compared to subject-first one, and whereas this effect in the left side was spread both on anterior and posterior sites, in the right side it appeared only on anterior sites**. No other significant effect was found both for the target word in the midline and for the other words (w2/w5) in any of the selected clusters of electrodes. So, although a difference was apparent between the two sentence types at several time points (see Fig. 1), especially for w4 and w5, no significant effects were detected for the analysed locations. Finally, the analyses on singular (short) and plural (long) verbs of the well-formed filler sentences failed to show the two components P300-like and P600-like (in the 300–400 ms interval:  $F_{1,24} < 2$ , n.s. for the quadrants,  $F_{1,24} < 3$ , n.s. for the midline; in the 450–550 ms interval:  $F_{1,24} < 1$ , n.s. for the quadrants,  $F_{1,24} < 1$ , n.s. for the midline). This is in line with the claim that, for the “who”-questions, these components are evoked by factors different from uncontrolled linguistic features like the word length.

In sum, the present study investigated the processes involved in temporarily ambiguous subject-first and object-first Italian “who”-questions by means of ERPs evoked both by the word that makes the structure unambiguous and by the following words in the sentence. **We found two positive deflections, namely a P300-like component and a P600-like one for the disambiguating word of the object-first extraction**. No effects were found on any of the remaining words of the sentence, supporting the claim that this kind of temporary syntactical ambiguity causes just a local, temporary processing disturbance. The results we found are in line with earlier studies, which have pointed out, for the unpreferred disambiguating word of ambiguous filler-gap dependencies, positivities between 300 and 600 ms [12,18,23]. In particular, the pattern of activity more similar to ours has been found for German subject–object ambiguous relative clauses (i.e., *Das ist die Direktorin, die (subj) die Sekretärinnen (obj.) gesucht hat* [This is the director that the secretaries sought has]: Subj.; *Das ist die Direktorin, die (obj) die Sekretärinnen (subj.) gesucht haben* [This is the director that the secretaries sought have]: Obj.) [12]. In that case, the posterior P300-like wave has been interpreted as an early P600, associated to a **fast syntactical structure reanalysis**

process. This process, as the author have maintained, would consist of two stages, reflected in the same **P300-like component: an immediate diagnosis of the necessity to construct an alternative syntactical structure and the recomputation of such a new structure**. The presence of just one component for both stages is possible, in authors’ opinion, since they have used relative clauses, that is sentences considered easy-to-revise in comparison to other kinds of filler-gap dependencies (i.e., German subject–object ambiguous complement clause: *Er wußte, daß die Sekretärin (subj.) die Direktorinnen (obj.) gesucht hat* [He knew that the secretary the directors sought has]: Subj.; *Er wußte, daß die Sekretärin (obj.) die Direktorinnen (subj.) gesucht haben* [He knew that the secretary the directors sought have]: Obj.). The second component found in that study, the P600-like, has been instead associated with more unspecific and design-dependent re-checking processes. Our attribution of the functional significance to the two components is rather different. With regard to the P300 we found, it showed a frontal distribution compared to the posterior P300 detected in the above-mentioned study and **interpreted as marker of syntactical structure reanalysis process** (that is as an early P600). So it is difficult to attribute our frontal P300 to such a repair procedure. Rather, we propose two possible interpretations of this deflection. **The first views the P300 as a fast detection of the syntactic anomaly caused by the ambiguity, corresponding to the first stage of the sentence reanalysis process**. The fact that it is frontally located is in line with previous researches [21], which found such a distribution for syntactically ambiguous sentences, differently from outright violations, which, instead, seem to elicit positivities more posteriorly distributed. The second interpretation views the P300 as a member of the P3a (also called Novelty-P300) family, **components which generally have been found, nearly in the same time range and anterior locations, for infrequent and unattended stimuli within experimental paradigm** [13]. This statement is supported by a test of indirect subjective frequency estimate of the two extractions (subj./obj. “who”-questions), we performed with different participants ( $n = 31$ ) in an early research phase. This test showed that the object-first extraction was considered significantly less frequent than the subject-first one. With regard to the second component we found, the P600-like, we attribute to it the functional significance of revision of the initial wrong filler-gap assignment, corresponding either to the second stage of the syntactical structure reanalysis [11] or to a more general difficulty of syntactic integration processes [15]. The latency of this component (450–550 ms interval) was shorter, and its amplitude smaller, than the P600 found for more complex garden-path or grammatically violated sentences (500–800 ms interval) [17,21], but its latency was longer with respect to the component, which the already reported studies have interpreted as reanalysis marker (300–400 ms interval) [12,18]. In line with a vast literature which has demonstrated that ERP latency can be a function of the complexity of the required analyses [12,18], we supposed that these latency differences may be due to possible



cross-linguistic features, which may give rise to different levels of processing complexity. In the above-mentioned studies, at the disambiguating verb level, all phrasal constituents are already available for a rebuilding of the initial filler-gap assignment, and there are two elements that need to be reassigned (“Obj.–Subj.–Verb” German structure: *Das ist die Direktorin, die (obj) die Sekretärinnen (subj.) gesucht haben (verb)* [This is the director that the secretaries sought have]). In Italian, even when the parser can detect the construction of an incorrect structure and can start to rebuild a correct index assignment, the last constituent (the subject) is not yet available (“Obj.–Verb–Subj.” Italian “who”-question structure: *Chi (obj.) baciano (verb) i nonni (subj.)?* [literally: Who kiss the grandparents?, in English: *Who do the grandparents kiss?*]) So, even though there is only one constituent that need to be reassigned (the pronoun “chi” as object), the expectation for an incoming input to which assign the subject role (if possible), associated with the maintenance of a not completely structured sentence representation in the working memory could load it more than German relative clause, and therefore cause a delay of syntactic integration processes. Thus, the specificity of the language, in addition to possible differences across the used paradigms, could have caused the observed P600 time shift. Results confirm therefore earlier findings, which stated a clear disadvantage for the object-first extraction [4,8,22]. Indeed, as the P600 has been reported not only for other kind of garden-path sentences, but also for outright syntactical violations, it can be considered to mark, in the filler-gap dependencies, the cost of additional, syntactically guided, revision processes, that are triggered by the perception of an anomaly in the object-first structure. In agreement with behavioural results, this has been taken as proof of an advantage for the subject-first structure, thus supporting the “Active Filler Strategy” [7,8] and the “Minimal Chain Principle” [2,4].

In conclusion, during Italian temporarily ambiguous “who”-questions comprehension, the positive components found for the object-first extraction, and related to its processing difficulty, confirm a model of parser which immediately, word-by-word, constructs a syntactic representation of the incoming sentence. This, even at the cost of a reanalysis, when the built representation reveals itself to be incongruous with the actual input. Results further support the view that the parser assigns a syntactical structure to the incoming stimuli by following the “Active Filler Strategy” [7] or the “Minimal Chain Principle” [2]. In particular, the functional significance we attributed to the components detected for the less preferred syntactical structure is compatible with models that distinguish a two-stages parsing procedure, involving incongruity detection and structural recomputation processes [9,11]. As we found event-related effects quite similar to those detected in previous studies, in spite of large differences not only in the linguistic structure typical of every language, but also in the paradigms used in the literature, the present data support the hypothesis of a parser driven, during sentence analysis, by several principles that can be considered universal [10].

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