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Presupposition of new information as a pragmatic garden path: Evidence from Event-Related Brain Potentials

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ABSTRACT

This study investigates the processing of presupposition in discourse through the Event-Related Brain Potential technique. While theoretical linguistics has largely described the phenomenon of presupposition, there is little empirical investigation, mainly from behavioural studies. Here we employed the Event Related Potential (ERP) technique to search for the brain signature of presupposition as opposed to assertion in discourse. Based on theoretical accounts, we hypothesized that presupposing new information should elicit higher efforts due to the mismatch between the information packaging and the actual knowledge, and to the need of accommodating the presupposed content in the mental model of discourse. We also hypothesized that these efforts could reflect in enhanced N400, similarly to other mechanisms operating at the discourse-context level. Twenty-seven participants were presented with passages containing new information packaged either as presupposition or as assertion. Two types of presupposition triggers were selected: definite descriptions and temporal subordinate clauses. Results evidenced a difference between the processing of presuppositions and that of assertions, reflected in a more enhanced N400 for the former. Results also showed that the temporal development of the presupposition effect is earlier for subordinate clauses than for definite descriptions. Differently from some behavioural studies on presupposition, but consistently with the theoretical literature and with other ERP studies on discourse processing, our data offer the first neurophysiological evidence that presupposition is more costly than assertion when new information is presented, with differences in the time development of the effect across trigger types. We proposed to account for the N400 effect induced by new presuppositions as stemming from a pragmatic "garden path" effect, in that, being presented with a new presupposition, the receiver is led down a mismatch between information packaging and discourse representation.

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1. Introduction

1.1. Presupposition vs. assertion

In the philosophical tradition (since Frege, 1892), presuppositions have drawn attention mainly for their peculiar contribution to truth values. The famous example in (1) (Russell, 1905) presupposes (in the opinion of many)[1] the existence of a present King of France, rather than asserting it:

(1) The present King of France is bald

As a consequence, according to Strawson, when France is a republic or in any case when "the present King of France" cannot refer to any actual (unique) individual, the utterance in (1) is not in a condition to be either true or false, because it does not assert that there exists a King of France: rather, his existence is a pre-condition for the assessment of the truth value of (1). In Strawson (1964), the content of a definite description is regarded as attributed to some *shared knowledge* holding between the participants to the communicative act. Moreover, this knowledge is an *identifying knowledge* of that referent, i.e. one that allows the addressee to match the linguistic expression (a definite description) with some precise portion of reality.

The use of a definite noun phrase implies that: "(a) the speaker believes that there is an object to which the noun phrase refers, (b) the speaker believes that the hearer believes that there is an object to which the noun phrase refers, and (c) the speaker believes that the hearer knows which object is referred to (Kempson, 1975, p. 17). The recourse to the concept of belief is not unproblematic. Some scholars (e.g. Stalnaker, 2002) contend that belief is not the relevant notion for presuppositions, and propose *common ground* in its stead. Common ground, in Stalnaker's definition, is made not only by the common beliefs of the participants, but also by all the notions which participants *treat as if* they were true, for any communicative/pragmatic reason. In other words, common ground is "the set of propositions that are mutually believed as accepted as true". We regard this second definition as probably more comprehensive, and derived from the first. In other words we think, with Strawson and Kempson, that the most basic function of presuppositions is to suggest a shared knowledge, and that only when this is not the case does the second function arise (i.e. acceptance to treat that info *as if* it was shared). Stalnaker, though extending the definition of presupposition to both functions, does not explicitly take any position on whether one may be more basic than the other. More generally, we follow Stalnaker (2002, p. 701) in describing presupposition as follows:

"Speaker presupposition is a propositional attitude of the speaker. […] To presuppose something is to take it for granted, or at least to act as if one takes it for granted, as background information — as *common ground* among the participants in the conversation."

Importantly, presuppositions are triggered not only by definite descriptions, but also by many other linguistic items, lexical or syntactic in nature (Lombardi Vallauri, 2009), such as factive predicates (Kiparsky & Kiparsky, 1971), defining relative clauses (Fox & Thompson, 1990), adverbial clauses (Lombardi Vallauri, 2000), verbs expressing change of state, judging etc. (Fillmore, 1971), and others.

It has also been proposed that presuppositions may require different processing mechanisms as compared with assertions, corresponding to different ways in which assertion and presupposition relate their contents to the *ongoing discourse model* (Johnson-Laird & Garnham, 1980). In other words, assertions and presuppositions allow to make different assumptions on the state their contents have in the memory of the participants: while assertion presents information as something the addressee does not know yet, presupposition presents its content as to be treated as something either already stocked in the addressee's long-term memory (which is often described in discourse analysis as the "encyclopaedic" component of the discourse model), or presently active in his working memory (which is often described as the "contextual" component of the discourse model). While assertion instructs the addressee to *build a new mental slot* for the information it encodes, presupposition basically instructs him to *recognize* its referent among the concepts already in his possession. For example in (2), whose content is completely asserted, the addressee is told that he must introduce a new neighbour of the speaker into his mental model of discourse:

(2) Yesterday a new neighbour arrived

On the contrary in (3), where the existence of the neighbour is presupposed by means of a definite description, the addressee is instructed to look for him and recognize him among the things he already knows about, i.e. among the things that already belong to the discourse model he shares with the source:

(3) Yesterday the new neighbour gave me a cake

[1] The example in (1) presupposes the existence of a present King of France in the opinion of many, though not Bertrand Russel's himself. This notwithstanding, we quote this example here because it is largely diffuse and especially famous for having catalysed the discussion between Bertrand Russell and Gottlob Frege. Frege's position was subsequently adopted by Peter Frederick Strawson and many others. As can be seen from our text, we follow this position, which is prevalent in linguistic pragmatics.

If (3) is directed to an addressee who actually has the speaker's neighbour in his discourse model, he will match the description with his previous knowledge, thus *resolving* the presupposition. But it may also be the case that the addressee does not know about an entity that is presented by the speaker as presupposed. For instance, the speaker may disregard the addressee's being not informed about his having a cousin, and directly tell him what this cousin has done:

(4) You know, I am very excited, because yesterday my cousin won a gold medal at the Olympics

In this case, which at least since Frege (1892) is called *presupposition failure*,[2] the addressee could react by *exposing* (or, put another way, *challenging*, see Givón, 1982) the presupposition, for instance by saying: "Wait a minute: I didn't know you had a cousin!" (Von Fintel, 2004); but he may also cooperate, and *accommodate* the presupposition (Lewis, 1979), i.e. do as if he already knew about the fact stated, and accept that chunk of information exactly as if it had been introduced by way of assertion, ultimately creating a new slot for the speaker's cousin in his mental model of discourse.

1.2. Theory-driven predictions

In this work, we will focus on the difference between assertion and accommodated presupposition when the introduced content is new to the addressee, leaving aside the cases when presupposition occurs for contents which are already known to him. This will allow us to focus the investigation on how different information packaging affects the processing of new information. By "packaging" we mean here the linguistic presentation of some content by means of constructions that determine specific information statuses. For example, some information can be packaged as asserted by means of an asserting main clause, or as presupposed by means of a temporal subordinate clause or a restrictive relative clause with a definite head (Lombardi Vallauri, 1994; Thompson, 1971).

We regard the processing of presupposition of new information as a sort of "pragmatic garden path", caused by a mismatch involving the pragmatic level (Lombardi Vallauri, 2016), rather than the syntactic level as in the classic garden path effect (Altmann, 2013; Bever, 1970). As is known, syntactic garden paths arise when some linguistic element initially suggests an interpretation which subsequently proves wrong, leading the addressee(s) to "go back" and take another path of interpretation (as in *The horse raced past the barn fell*). Similar effects can arise also with linguistic elements suggesting pragmatic (informational) interpretations.[3] This is the case of presupposing information that is not supported by the context. When some content is asserted in a message, it goes with the instruction to process it as new, and to build it *ex novo* in one's mental model of discourse. When, on the contrary, some content is linguistically packaged as presupposed, it goes with the instruction to process it as already known and identifiable, looking for its previous traces in one's discourse model. Now, with new information this attempt will fail, and the addressee will realize that he has no such traces in his memory, thus perceiving a mismatch (as in any garden path) between the interpretation he had first derived from linguistic packaging and the discourse representation he has subsequently formed. As a consequence, he will be obliged to revise his expectations, accept that the considered content is not as known as its linguistic packaging suggested, and accommodate the presupposition by adding that information to his stock.

This leads to the following general and theory-driven prediction: accommodating a presupposition should be more costly than processing the simple assertion of new content. Looking for a concept in one's memory (i.e. in one's discourse model), realizing that it is not there, accepting the mismatch between linguistic packaging and actual knowledge, and finally building a new concept in memory, should require more complex processing and more effort than straightforwardly receiving the instruction to build a new concept in the discourse model, and complying with it.

One may wonder, however, if all presuppositions should produce the same mismatch, because not all presuppositions may have the same *strength*.[4] In principle, this could mean that (i) not all linguistic triggers may effect presuppositions with the same *likeliness*, going from presuppositions which hold in virtually any communicative context to presuppositions that only hold in very favourable conditions; and (ii) not all linguistic triggers effect presupposition to the same *degree*, going from triggers presenting a content as fully shared and completely belonging to the common ground, to triggers presenting a content as only in part so.

In particular, definite descriptions, since they contain no verbs, are syntactically less cognate to assertion than adverbial clauses. In Lehmann's (1988) terms, they are more *downgraded* structures, featuring less traits of a complete, independent utterance (such as overt verbal predication, finite agreement for person, etc.). In other words, they are *less predicative* and, as a consequence, they may be *less assertive*. This raises the hypothesis that the same content may be more strongly presupposed

[2] It is the same phenomenon that affects example (1), namely the fact that some linguistic trigger activates a presupposition which is not supported by the context in which it appears. The context, in this sense, is defective.

[3] For other instances of garden path effects at the pragmatic level, see the case of jokes (Coulson, 2015), humour (Dynel, 2009), and incoherent discourse (Ferstl, 2007).

[4] This represents one of the most debated points in the current literature in semantics. Cf. For instance Abbott (2000), Abusch (2002), Glanzberg (2003; 2005). We tackle here only one aspect of the issue, and in a slightly different way, which has been sketched by Lombardi Vallauri (2009: 37–42), to which we refer. In this view, parameters such as morphosyntactic explicitness, semantic plausibility and informational status are proposed as factors that can strengthen or weaken the effect of a presuppositional trigger.

(i.e. presented as more known and identifiable) if packaged by means of a definite description as in (5), than if included in a temporal subordinate clause as in (6):

(5) I read *Tom's letter* with great pleasure
(6) *When Tom wrote me a letter*, I read it with great pleasure

The different levels of strength we are considering here are quite different from those dealt with for instance by Glanzberg (2003; 2005) or Domaneschi, Carrea, Penco, and Greco (2014). That is to say that both definite descriptions and adverbial subordinate clauses trigger presuppositions belonging to what Glanzberg calls *strong presuppositions*, which, in case of failure, *oblige* addressees to repair the context, i.e. to include the content of the presupposition into their representation of the world where the communication takes place.[5] The difference we are considering here is thus a minor one: that Tom's having written a letter is more strongly presented as already shared between the participants in (5) than in (6), cannot be demonstrated beyond any doubt within linguistic analysis. It can just be contended that (6) is more natural than (5) in contexts where Tom's having written a letter is not already shared information:

(Uttered out of the blue, to someone who knows Tom but doesn't know anything about his having written a letter)

(5′) ?You know, I hadn't seen Tom for a while, but I've read *his letter* with great pleasure …

(6′) You know, I hadn't seen Tom for a while, but *when he wrote me a letter*, I read it with great pleasure …

In other words, the subordinate clause is better adapted to performing a predication aimed at introducing new information, as compared with the definite nominal, which is completely devoid of predicativity. Similarly, applying a well-known test for the detection of presuppositions, negative versions of (6) are more likely than negative versions of (5) to receive interpretations where the whole utterance is negated, revealing that the presuppositive effect of the relevant construction may be weak or, under certain contextual circumstances, null:

(5″) It is not true, that I read *Tom's letter* with great pleasure

(6″) It is not true, that *when Tom wrote me a letter*, I read it with great pleasure

It seems that the existence of Tom's letter cannot be negated in (5″) because it is presupposed in any case, while Tom's having written a letter may also be negated in some interpretations of (6″), which would mean that it can be interpreted as non-presupposed. Further evidence for this may come from (5‴) and (6‴):

(5‴) It is not true, that I read *Tom's letter* with great pleasure. ?Actually, Tom never wrote to me.

(6‴) It is not true, that *when Tom wrote me a letter*, I read it with great pleasure. Actually, Tom never wrote to me.

The last clause in (5‴) is hardly acceptable, because the preceding negative statement cannot negate the existence of Tom's letter, encoded by the definite description. On the contrary, the same clause is (more) acceptable in (6‴), because the preceding negative statement can also negate Tom's having written a letter, encoded by the temporal subordinate clause.

Similarly, the scope of *he was lying* in (5⁗) can only include John's having read with pleasure, and not the existence of a letter from Tom. But there are two possible interpretations of (6⁗), namely one in which John's lying is only referred to his having read with pleasure, and the other also including Tom's having written to him:

(5⁗) John said that he read Tom's letter with great pleasure, but he was lying

(6⁗) John said that when Tom wrote him a letter he read it with great pleasure, but he was lying

As we have observed, this may be due to the fact that the subordinate clause is syntactically more similar to a predicative structure, thus being more likely to be interpreted as part of the utterance's predication.[6]

These considerations would draw a difference of strength (as presupposition triggers) between definite descriptions and subordinate clauses: the likeliness and degrees to which these two triggers cause presuppositional interpretations of their contents may be different, and it would be interesting to inquire, if possible, the neural correlates of this difference. Of course the hypothesis of a difference we have advanced here is based, as it often happens with language items, on evidence from introspection. In our view, this is not a reason to avoid testing the validity of the hypothesis by means of neural responses: rather, the opposite. A hypothesis whose theoretical bases are uncertain can find useful confirmation – or disconfirmation – precisely from empirical testing.

[5] Those called *weak presuppositions* by Glanzberg include implicits effected by triggers such as focus particles (*too, even*), which are often also regarded as implicatures.

[6] Similar effects can be observed in the following utterances, where the scope of John's lying admits two interpretations, i.e. also one including the content of the possibly presupposing construction, only in the (b) version: (a) John lied when he said that he had read *Tom's letter* with great pleasure; (b) John lied when he said that *when Tom wrote him a letter*, he read it with great pleasure.

We tried to test the predictions sketched above by setting up an experimental study employing Even-Related Potentials (ERPs), a methodology that explores time-course dynamics of language processing and provides a useful test-ground to consider linguistic hypotheses in the neurolinguistics and neuropragmatics perspective (Bambini, 2010; Schumacher, 2012; Van Berkum, 2009).

1.3. Experimental approaches to presupposition

Early experimental approaches to presupposition processing involved behavioural tests based on information verification paradigms (Hornby, 1974; Langford & Holmes, 1979; Loftus, 1975). These studies showed that false information is more difficult to detect when it is conveyed by means of presupposition as opposed to assertion.

Very few studies explored brain's activity in decoding and comprehension of presupposed information. A pioneering study by Wetzel and Molfese (1992) measured ERPs linked to sentences containing either factive (*noticed*, *revealed*) or non-factive predicates (*maintained*, *supposed*), with the former projecting presupposed information. They could differentiate the ERPs to these two types of verbs with a Principal Component Analysis. However, the use of a special procedure for stimulus presentation (compressed speech), the interest in the auditory modality, and the analysis of epochs comprising the whole presentation of the sentences do not allow to identify specific ERP components linked to presupposition as compared with assertion, and thus do not help in drawing precise hypotheses for the present study.

More recently, Hertrich et al. (2015) used magnetoencephalography (MEG) to measure brain response to presuppositions triggered by German definite determiners compared with indefinite ones, in an auditory, two-sentence paradigm. The first sentence presented a context in which a singular referent or multiple referents (or simply non existing referents) were introduced. Depending on the type of entity introduced, the definite or indefinite determiners in the second sentence could encode referents matching with the introduced context or not. The authors found that the cross-correlations between speech signal and MEG fields had a different time development in the two conditions. The latency of the M50c was slightly delayed and the amplitude of the M200c was larger in context mismatching conditions compared with the context matching condition. These effects suggest that the disruption of discourse coherence may interrupt highly automatic processes devoted to speech perception (M50c) and also inhibit phonological/lexical processes (M200c). Finally, a biphasic alpha suppression was observed for discourse incoherent passages, which was interpreted as reflecting the reduction of expectation opportunities in case of discourse incoherence. The differences in methodology (MEG), modality (auditory), and data analysis procedure (cross-correlations with the speech envelope) do not allow drawing specific ERP predictions for our study. However, taking Hertrich et al.' conclusions liberally, we can expect that a mismatch due to presupposition (e.g., when new information is presented as presupposed) should generate increased amplitude in those components that reflect workload at the level of discourse-based expectations.

In the last years, presupposition has become a topic of interest within the domain of experimental pragmatics, as a test ground to explore its processing underpinnings relative to conventional or scalar implicatures (Cory, Romoli, Schwarz, & Crain, 2016), on the one hand, and to asserted information, on the other (Schwarz & Tiemann, 2016; Schwarz, 2015; Tiemann et al., 2011). A number of experimental investigations have been conducted in this direction: Tiemann et al. (2011) tested the processing of the focalizing adverb *again* through a self-paced reading paradigm, while Schwarz (2015) tested eye movements linked to focal adverbs and change-of-state predicates through a Visual World paradigm, where participants' eye movements relative to a visual scene are tracked while they are listening to auditory linguistic stimuli. Overall, these findings showed that subjects' responses are usually faster when they were presented with presupposed contents, as opposed to asserted ones. According to these studies, thus, presupposition induces a less effortful processing of information, as compared with assertion, the latter being bound to correlate with more taxing mental processes.

However, recent experimental evidence points to a more complex scenario. Through self-paced paradigms using the presupposition triggers *the* and *too*, Singh, Fedorenko, Mahowald, and Gibson (2016) showed that accommodation costs are sensitive to the plausibility of a presupposition in a specific discourse context: accommodating a presupposition is more costly than processing assertion, but only when the presupposed information is implausible. As a further aspect, a new research line hints at the different processing costs that might be associated with different presupposition triggers. Using auditorily presented texts – followed by a series of selection tasks – Domaneschi et al. (2014) showed that definite descriptions and factive predicates were fully processed in the majority of cases, while the presuppositions deriving from focus-sensitive operators and iterative adverbs were not always processed. Processing costs might also vary based on how cognitively loaded a subject is: when the receiver is highly cognitively loaded, he/she is less bound to process a conditional presupposition (Domaneschi, Carrea, Penco, & Greco, 2016).

Noteworthy, in pointing to faster responses for presupposition, studies in experimental pragmatics seem in contrast with the available neurophysiological evidence, which, albeit limited, points to higher costs for presuppositions. A possible reason for this discrepancy might lie in the different experimental paradigms employed. For instance, while the MEG study (Hertrich et al., 2015) tested sentences in a discourse context, behavioural studies often used poorly contextualised materials, i.e. isolated sentences with no previous discourse context or sentences with minimal discourse context. Likely, in the absence of a sufficiently rich discourse context, no expectations can be formulated on the activation state and packaging statuses of upcoming contents. So, in order to ensure efficiency in processing, information decoding capitalizes on the cues provided by packaging, with presupposition instructing to a less costly processing because it is received as backgrounded information, while assertion induces a more effortful processing, as it presents some information as foregrounded and therefore more

relevant in the sentence. Conversely, when a discourse context is available, it influences the processing of subsequent sentences, either on the level of truth-conditional values or on that of information structure. Moreover, it is also possible that the different techniques used reveal different aspects of the comprehension mechanisms, and that processing costs, as they are assessed through neurophysiological techniques, may not be thoroughly captured by behavioural measures.

1.4. Study rationale and experimental predictions

The aim of this study is to identify the brain signature for presupposition processing. Specifically, we aimed at unravelling the brain response to processing presuppositions of new information as compared with assertions on the basis of ERP measurements, by testing whether the distinction between presupposition and assertion as described in the theoretical linguistics literature finds empirical evidence in the neurophysiological response. To our knowledge, this is the first study directly targeted at assessing the underlying neurophysiological activity associated with contextually new information when presupposed and when asserted.

As a second goal, we aimed at inquiring potential differences between presupposition triggers, which is a largely unexplored issue in both neurolinguistics and psycholinguistics literature. To this purpose, in the experimental set we included presuppositions conveyed both by definite descriptions (e.g. *The girl*) and temporal subordinate clauses (e.g. *When you went away* …), compared with assertion counterparts (*There was a girl* and *You went away*). The reason of selecting these two types of triggers was two-fold. This choice was motivated by the different strength of the two presupposition triggers, namely the difference in likeliness and degree of conveying shared contents, as evidenced in theoretical research presented in section 1.2. The difference in strength is likely to be due to the structural, syntactic differences between the two types of triggers, with definite descriptions more downgraded thus more cognate to presupposition than temporal subordinate clauses. Second, from the practical point of view, the constructions associated with these two types of triggers easily allowed us to maintain the content unaltered when building the assertion counterparts, and to avoid unbalanced presupposition/assertion pairs.

A further innovative aspect of our research is the ecological validity of the experimental stimuli. Instead of using poorly contextualised sentences, stimuli were presented as utterances belonging to discourse passages. Moreover, these passages were taken from actual newspapers and magazines, and only slightly modified (in order to normalize them for the experimental purposes). In this way, stimuli included the amount of context that usually accompanies linguistic utterances in natural communication, and such contexts were as natural as possible. To our view, this aspect is fundamental when designing experiments that target phenomena at the level of discourse context and discourse memory such as presupposition, as in the frame of electrophysiology of discourse and conversation (Hoeks & Brouwer, 2014; Van Berkum, 2012) and in experimental pragmatics and neuropragmatics research (Bambini & Bara, 2012; Schumacher, 2012; Van Berkum, 2009).

As part of the study rationale, we tried to translate our theory-driven predictions in terms of neurophysiological response and ERP components. Based on the linguistic literature, we formulated the general prediction that accommodating a new presupposition should cost more than processing a new assertion because, in the former case, the receiver is given the instruction to search for a missing antecedent in prior discourse, and is subsequently obliged to realize that it must be *ex novo* created. Differently, with assertion, the creation of a mental slot for the newly introduced referent takes place straightaway, which eventuates in no additional processing costs for the processor. The prediction of additional costs for new presupposition finds support in previous EEG evidence of a brain signature for presuppositions (Wetzel & Molfese, 1992) and in previous MEG evidence of higher costs for context-mismatching presuppositions (Hertrich et al., 2015), although information about the specific ERP components associated with such costs is not clear from these studies.

Of potential interest for our study is a bulk of literature addressing the temporal dynamics of context and discourse processing, within the domain of neuropragmatics (Van Berkum, 2009). This literature showed that a more prominent elicitation of the N400 component is observed when the linguistic input is difficult to integrate because inconsistent with different aspects of context, including individual's world knowledge (e.g., Hagoort, Hald, Bastiaansen, & Petersson, 2004), individual beliefs (e.g., Van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009), and the information we know about the speaker (e.g., Van Berkum, Van den Brink, Tesink, Kos, & Hagoort, 2008). Other studies showed that also the discourse context affects the N400, which is higher when discourse-based expectations are violated (Nieuwland & Van Berkum, 2006; Van Berkum, 2010). A nice example of the effect of context on the N400 is seen on metaphor and metonymies, where a richer context can suppress the N400 effect that is triggered by metaphorical (Bambini, Bertini, Schaeken, Stella, & Di Russo, 2016) and metonymic (Schumacher, 2014) uses of words in a less supportive context. In all, it seems that the N400 indexes dynamically configured representations of context, where people routinely use their knowledge of discourse and the world to predict upcoming information (Van Berkum, 2012).

Other studies that may provide background for the present investigation addressed the processing of referential expressions and different information structural patterns in discourse (Burkhardt & Roehm, 2007; Schumacher & Hung, 2012; Wang & Schumacher, 2013). The authors showed that, in two-sentence passages, the presentation of a new referent being packaged as topic, or of a given referent being presented as focus elicited a more prominent N400 component as compared with cases displaying more expected and aligned configurations between activation states and information packaging (i.e. when a new referent was presented as focus, and a given referent as topic in the target sentence) (Wang & Schumacher, 2013). In addition, this negativity pattern was followed by a Late Positivity component after 500 ms. It was also shown that these two components are independent: for instance, in sentence-initial position, the comparison between given and inferred entities elicited only an N400 effect (Schumacher & Hung, 2012). By contrast, the comparison between new referents conveyed

through definite NPs presented in different contextual fit conditions affected the P600 component (Burkhardt, 2007). On this basis, a model of referential processing was proposed, with (i) the N400 indexing Discourse Linking, i.e. the process that computes various cues to reflect the expectation of an upcoming referent and the initial attempts to link it with discourse, and (ii) the Late Positivity indexing Discourse Updating, i.e. discourse-internal reorganization (Wang & Schumacher, 2013). Relevant for our research, these studies suggest that new or inferred discourse entities are more costly when they receive an unexpected packaging, since this packaging instructs to look for a missing antecedent in discourse, thus accruing linking costs, i.e. the attempt of connecting some information to what has been uttered before in a coherent manner.

The evidence from discourse and information structure processing described above offers a solid basis to formulate hypotheses on the ERP response for new presuppositions, pointing in the direction of the N400. Specifically, the higher costs associated with new presuppositions, as opposed to new assertions, could be indexed in terms of enhanced negativity in the N400 time window. Since presupposition activates the search for information in the mental representation of the ongoing discourse, the brain is likely to respond by manifesting the typical N400 signature associated with processing discourse and with linking less expected information packages into the discourse model (as shown in Wang & Schumacher, 2013).

Along these lines, when translating our theory-driven prediction of different strength across presupposition triggers into experimental terms, we assumed that the N400 response may as well be modulated by the type of trigger. Specifically, our experimental prediction was that, relative to assertions, presuppositions conveyed by definite descriptions should exhibit a more negative N400 than presuppositions conveyed by subordinate clauses, due to the higher strength of the trigger in terms of degree of conveying shared information, subtracting it to complete assertion. In other words, we expected the N400 response to be more enhanced in the case of definite description triggers, as the downgraded structure of the construction should accrue the strength of the presupposition and, accordingly, the costs for linking a new referent into the discourse model.

Alternatively, one could assume that processing a new presupposition requires a revision of the sentence, indexed in late positive effects, in line with what happens for a syntactic garden path. In a seminal paper, Osterhout, Holcomb, and Swinney (1994) showed that unpreferred interpretations of syntactic garden path sentences are associated with effects on the P600 component, which has often been taken as indexing structural re-analysis (e.g., Friederici, 2002) triggered by different types of (morpho)syntactic difficulties, such as agreement violations (for review see Molinaro, Barber, & Carreiras, 2011) or degrees of syntactic complexity (Friederici, Hahne, & Saddy, 2002). However, despite some similarities between syntactic and pragmatic garden path in terms of unexpected configurations, we do not believe that processing these two types of garden paths should hinge on the very same brain mechanisms. In the case of presuppositions, readers should process presupposed information as already given, but have no previous trace in the discourse representation. Difficulties arise from realizing this lack of antecedents, thus accommodating the presupposition in discourse memory. In other words, the task revolves around the information status of notional contents in one's world representation. In the case of syntactic garden path, difficulties arise when the parser realizes that the default structural analysis turns out to be wrong and needs a revision. In other words, the task revolves around variations in the structural pattern of the linguistic input.

2. Materials and methods

2.1. Participants

Twenty-nine university students (8 men, mean age = 23, SD = 4) took part in the experiment and were paid for their participation. Data from two participants were excluded because of excessive number of artifacts (>30%). All subjects were right-handed (as attested by the Edinburgh Handedness questionnaire: mean laterality = 0.89; Oldfield, 1971) native speakers of Italian, with normal or corrected to normal vision, no history of neurological or psychiatric disorders. All of them signed a written informed consent. The experimental protocol was approved by the local Ethics Committee (Comitato Etico Area Vasta Nord Ovest, Azienda Ospedaliero-Universitaria Pisana).

2.2. Experimental design

In order to test the predictions of the study, we devised a two-factor experimental design, with *Status* (Presupposition, Assertion) and *Trigger* (Definite Description, Subordinate Clause) as independent variables, both varied within subjects. Status was varied within items and Trigger was varied between items. The dependent variables were accuracy for the behavioural task and the average amplitude of single subjects' ERPs recorded from each electrode during the time-window of interest. We expected the difference between Presupposition and Assertion to manifest as a main effect of the Status factor, with more negative amplitude for presuppositions. Moreover, we expected the trigger types to affect the difference between Presupposition and Assertion, with presuppositions triggered by subordinate clause less different from assertions than presuppositions triggered by definite descriptions. In other words, we expected the difference between trigger types to yield an interaction between the Status and the Trigger factors.

2.3. Stimuli

Stimuli consisted of 80 pairs of three-sentence passages. Each passage in the pair was formed by a two-sentence context followed by a target sentence in which the experimental manipulation was carried out, thus displaying either a

presuppositional or an assertive construction (within-items Status factor). Two sets were created, one containing presuppositions conveyed through definite descriptions and their assertive counterparts, and one containing presuppositions conveyed through subordinate clauses and their assertive counterparts (between-items Trigger factor).

Materials were constructed out of authentic written sources such as Italian newspaper articles (from *La Repubblica*, *Il Messaggero* and monthly scientific magazines), public ads and excerpts of narratives or essays. Constructions containing presuppositions were extracted from the authentic text and their assertive counterparts were created *ad hoc* by leaving the content unaltered as much as possible. For the Definite Description set, we singled out [defART + noun] patterns and derived their assertive counterparts by means of presentative constructions (e.g. "La ragazza" [*The girl*] vs. "C'è una ragazza" [*There is a girl*]). We occasionally used definite phrases containing possessive adjectives preceding the critical noun (e.g. "Il mio gatto" [*My cat*]) or demonstrative adjectives (e.g. "Questo libro" [*This book*]). For the Subordinate Clause set, we singled out adverbial clauses introduced by the temporal marker "quando" (*when*) and derived their assertive counterparts by converting the dependent clause into a main one (e.g. "Quando ho visto tua madre" [*When I saw your mother*] vs. "Ho visto tua madre" [*I saw your mother*]). Occasionally, slight modifications of the original texts proved necessary in order to ensure comparable lengths of the contexts and target sentences across conditions and trigger types. Manipulations mainly consisted in the addition or deletion of a few words.

An important aspect of the stimulus construction is that passages in all conditions were selected so as to have all target sentences convey new information. Notably, the choice of focusing on new information (and thus on accommodating rather than resolving presuppositions) was a necessary element to balance the two sets with respect to the amount of discourse knowledge and to focus on the differences between accommodating a new presupposition vs. processing a new assertion: for already known information, assertions would indeed result in pragmatically infelicitous constructions.

Table 1 illustrates examples of the experimental stimuli for both constructions and types of triggers.

In selecting the materials, we tried to control for the position of the critical word across conditions, balancing the syntactic constraints posed by the different constructions and the ecological source of the stimuli. In the Definite Description set, for presuppositions the critical word was set on the noun triggering the definite description, and on the very same noun in the presentative construction for assertions. In the Subordinate Clause set, for presuppositions the critical word was set on the end of the predicate (either a noun or a verb) in the dependent clause and on the very same word in the main clause for assertions. For the Definite Description set, the position of the critical word oscillated between 2 and 3 in the presupposition condition (mean = 2.4, SD = 0.5) and between 2 and 4 in the assertion condition (mean = 3.6, SD = 1.0). Expectably, this slight variation is due to the different syntactic constructions involved in the presupposition/assertion comparison. Similarly, for the Subordinate Clause set, the position of the critical word ranged between 2 and 7 (mean = 4.8, SD = 1.2) in the presupposition condition, and between 2 and 6 (mean = 3.9, SD = 1.2) in the assertion condition.

2.4. Measures on materials

Stimuli were controlled for a number of potential confound variables, to ensure that the ecological sources did not produce unbalanced materials.

Table 1
Examples of the experimental stimuli. The target words are bold typed. English translation is provided between brackets.

	Presupposition	Assertion
Definite Description set	*Context* È ormai dato certo che la specie umana non è pura. In effetti, il nostro DNA contiene informazioni genetiche proprie dei Neanderthal, che molto presto popolarono l'Europa. [Eng. It is by now well established that the humankind is not pure. In fact, our DNA contains genetic information belonging to Neanderthals, who soon peopled Europe.] *Target sentence* La **migrazione** è stata confermata da un recentissimo articolo di alcuni ricercatori, italiani e stranieri. [Eng. The **migration** was confirmed by a very recent article published by Italian and foreign researchers.	*Context* È ormai dato certo che la specie umana non è pura. In effetti, il nostro DNA contiene informazioni genetiche proprie dei Neanderthal, che molto presto popolarono l'Europa. [Eng. It is by now well established that the humankind is not pure. In fact, our DNA contains genetic information belonging to Neanderthals, who soon peopled Europe.] *Target sentence* Ci fu una **migrazione**, confermata da un recentissimo articolo di alcuni ricercatori, italiani e stranieri. [Eng. There was a **migration**, confirmed by a very recent article published by Italian and foreign researchers.]
Subordinate Clause set	*Context* Da 12 anni Ye Weibin, in arte Antonio, vive in Italia. Dopo aver svolto diversi lavori, ora gestisce un bar in periferia. [Eng. Ye Weibin, in art Antonio, has been living in Italy for 12 years. After several jobs, he now runs a bar in the suburb.] *Target sentence* Quando è diventato **papà**, portava sempre la figlioletta nel suo locale, tenendola con sé tutto il giorno. [Eng. When he became a **father**, he used to bring his little daughter to the bar keeping her with him all day.]	*Context* Da 12 anni Ye Weibin, in arte Antonio, vive in Italia. Dopo aver svolto diversi lavori, ora gestisce un bar in periferia. [Eng. Ye Weibin, in art Antonio, has been living in Italy for 12 years. After several jobs, he now runs a bar in the suburb.] *Target sentence* È diventato **papà** e porta sempre la figlioletta nel suo locale, tenendola con sé tutto il giorno. [Eng. He has become a **father** and now he always brings his little daughter to the bar, and keeps her with him all day.]

2.4.1. Naturalness

First, the *naturalness* of the target sentences with respect to the provided contexts was pre-tested in order to ensure that the ecological items and the created ones were equally felicitous in discourse (for similar measure, see "good continuation" in Burkhardt, 2007; and "acceptability" in Wang & Schumacher, 2013). Since our paradigm focused on the difference between presupposition and assertion as two information packaging strategies, and given that context was equal in the two conditions, naturalness seemed more appropriate than other measures that manipulate the amount of discourse knowledge and the activation state of the presupposed content. One hundred participants (20 male), matched for age and education with the participants of the EEG study, were presented with all passages divided in two lists and were asked to judge the naturalness of the target sentence with respect to the preceding context on a 5-point Likert scale. Participants who rated less than 25% of the items were excluded from the dataset. The final sample included 67 participants.

Conditions obtained an average level of naturalness ranging between 3.40 and 3.46 (see Table 2). The subject-based ANOVA showed no effect for Trigger ($F(1,66) = 0.58$, $p = 0.44$) nor for Status ($F(1,66) = 0.03$, $p = 0.86$). The interaction was not significant (Trigger X Status $F(1,66) = 1.34$, $p = 0.25$). Also the item-based ANOVA showed no significant effects, nor for Trigger ($F(1,78) = 0.01$, $p = 0.91$) or Status ($F(1,78) = 0.22$, $p = 0.64$) or the interaction (Trigger X Status $F(1,78) = 0.61$, $p = 0.43$). The lack of statistically significant effects suggests that any foreseeable electrophysiological difference between conditions and/or trigger types should be put down to a stronger influence of information packaging variations rather than to degrees of naturalness of the experimental items.

2.4.2. Readability and length

For each passage we also estimated the readability based on the Gulpease index. As reported in other studies on Italian (Bambini, Resta, & Grimaldi, 2014), the Gulpease index provides a measurement of the relative ease or difficulty of a text and considers two main variables: the length of words and the length of sentences in a text. Resulting values range from 0 (lowest readability) to 100 (highest readability). Average Gulpease level was in the range 52–60 for all conditions (see Table 2), thus falling into the range of easy independent reading level for subjects with a high school degree (Piemontese, 1996).

Finally, we calculated the length of each passage, in terms of number of words. Conditions had an average length varying from 41.92 to 45.17 words (Table 2). The ANOVA showed no significant effect for Trigger ($F(1,78) = 2.55$, $p = 0.11$) or Status ($F(1,78) = 0.01$, $p = 0.64$). The interaction was not significant (Trigger X Status $F(1,78) = 3.42$, $p = 0.07$), suggesting that length should not affect the ERP response.

2.5. Procedure and task

The experimental procedure was the following: the two context sentences were presented as a whole in the centre of the computer screen. Participants read the first context sentence and then moved on to the second in a self-paced manner by pressing the space bar. After having read the second context, they pressed the space bar again to be presented with the target sentence that was displayed word-by-word in the centre of the screen (400 ms followed by 200 ms blank). ERPs were time-locked to the presentation of the target word in the target sentence.

For the behavioural task, 1/3 of the stimuli were followed by a semantic association task in which the subjects were presented with two words and were asked to select the word that was more closely related to the previous passages by pressing one of two buttons on the keyboard. See the procedure in Fig. 1.

The 80 pairs were organized into two lists according to a Latin square design so that each participant was presented with only one passage in the pair, ending either with assertion or presupposition. Each list included also 80 fillers with a similar construction, i.e. three-sentence passages, with no presupposition triggers.

2.6. EEG recordings and analysis

EEG was recorded continuously from 60 electrodes placed on the scalp according to the 10–20 International System (Fp1, Fpz, Fp2, AF7, AF3, AF4, AF8, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FT7, FC5, FC3, FC1, FC2, FC4, FC6, FT8, T7, C5, C3, C1, Cz, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, POz, PO4, PO8, O1, Oz, M1, M2). The signal was acquired with a sampling rate of 512 Hz using a Brain Amp® (Brain Products GmbH, Gilching, DE) system, which amplified, recorded and stored the EEG signal in the local hard-drive of the acquisition computer. Two additional electrodes placed below and above the left eye, and two more electrodes at the outer canthi of both eyes were used to monitor eye

Table 2
Means and standard deviations of naturalness, Gulpease index and length.

Conditions	Mean naturalness (SD)	Mean Gulpease (SD)	Mean length (SD) – n. words
Definite Description set			
Presupposition	3.45 (0.64)	60.95 (5.67)	41.92 (5.33)
Assertion	3.44 (0.57)	52.72 (10.16)	43.57 (5.76)
Subordinate Clause set			
Presupposition	3.40 (0.62)	60.80 (5.51)	45.17 (6.23)
Assertion	3.46 (0.71)	60.85 (6.62)	43.67 (6.75)

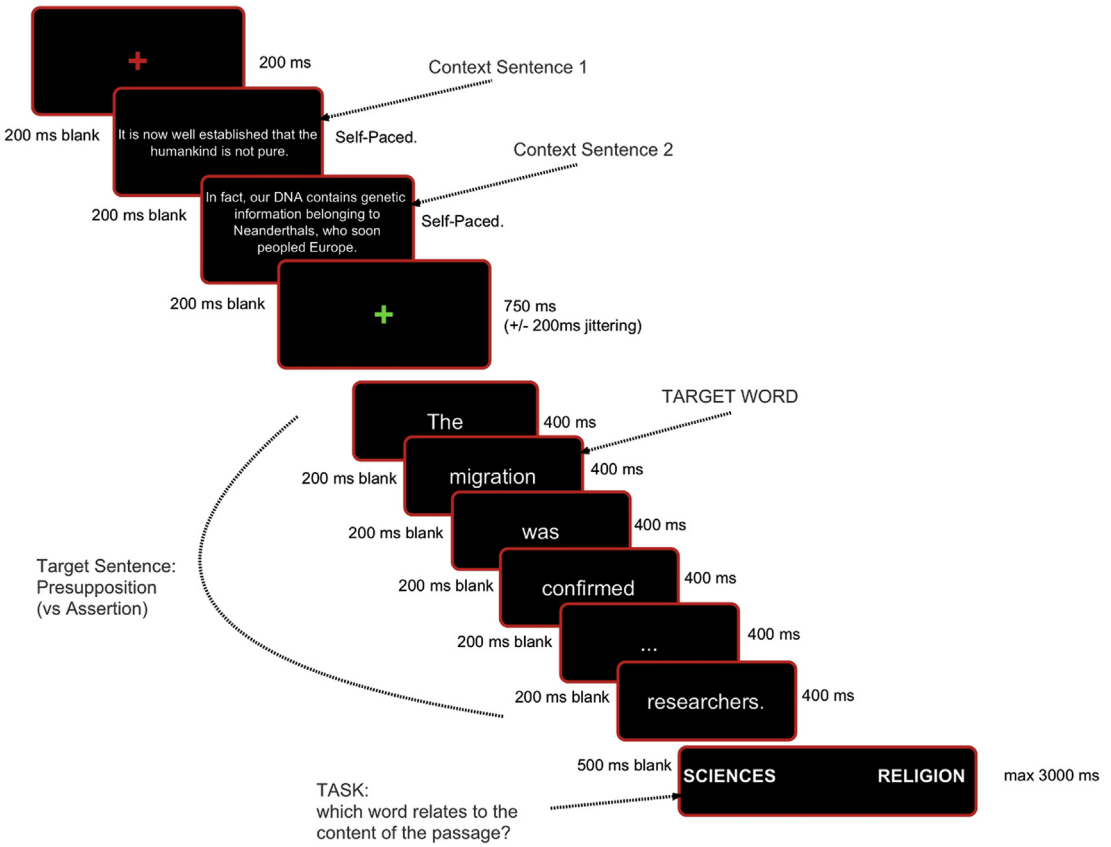

Fig. 1. Presentation procedure of the experimental stimuli.

movements. The EEG signal was online referenced to an electrode close to the Vertex and offline re-referenced to the average activity recorded from the left and right mastoid.

Preprocessing was carried out using Matlab® (The MathWorks, Inc, Natick, US) toolboxes (EEGLAB, Delorme & Makeig, 2004; FieldTrip, Oostenveld, Fries, Maris & Schoffelen, 2010). The EEG was segmented in ERP epochs around the presentation of the critical word (from −350 to 1000 ms) and filtered using a conservative band pass filter from 0.1 to 40 Hz (Tanner, Morgan-Short, & Luck, 2015). Prior to averaging, eye-related activity was corrected using ICA decomposition (e.g., Mennes, Wouters, Vanrumste, Lagae, & Stiers, 2010). Artifact rejection was carried out using a fixed threshold criterion (the maximum amplitude allowed within each epoch was ±150 μV), and manually, using visual inspection to reject the remaining epochs contaminated by artifacts. The overall rejection rate was 13.6%, with no differences between conditions in the number of epochs included (Presupposition = 33.7; Assertion = 33.6; $t < 1$). Baseline correction was carried out subtracting the average activity in the 200 ms pre-stimulus interval from the activity recorded post-stimulus.

Single subject averages from 27 participants were then exported in R (R Core Team, 2015) for statistical analysis. We first investigated the scalp topography of the effects organizing 30 of the 60 electrodes in one topographical factor, i.e., Anteriority with three levels (Anterior, Central, Posterior) constituted by an equal number of electrodes ($n = 10$). To investigate the effects of the experimental manipulation and the differences in scalp topographies, a three-way within-subjects ANOVA was carried out with Trigger (Definite Description, Subordinate Clause), Status (Presupposition, Assertion), and Anteriority (Anterior, Central, Posterior) as within-subjects factors. After visual inspection, the time window of interest for testing the N400 was set from 300 to 550 ms. To better describe the effects of the experimental manipulation, we subsequently restricted our analysis to a number of central and parietal electrodes (C1, Cz, C2, CP1, Cpz, CP2, P1, Pz, P2) where the N400 component is usually distributed (parietally maximal scalp distribution, see Kutas & Federmeier, 2011). On this pool of electrodes, we first performed a two-way within-subjects ANOVA (with Trigger and Status as within-subjects factors) to confirm the reliability of the effect, and then performed a latency analysis (Vespignani, Canal, Molinaro, Fonda, & Cacciari, 2010) to investigate the temporal development of the effect of Status (Presupposition minus Assertion) within different levels of Trigger. The latency analysis can aid visual inspection in describing the ERP pattern.

We adopted Greenhouse-Geisser correction against violations of sphericity (corrected p value and uncorrected degrees of freedom are reported). Effect size is reported using generalized eta square (see Lakens, 2013), and 95% confidence intervals (Morey, 2008) are displayed for the latency analysis.

3. Results

3.1. Behavioural results

The semantic association task following 1/3 of the experimental trials yielded an overall accuracy mean of 98% (SD = 2.43), with all participants scoring over 92%, suggesting that they all paid attention to the stimuli.

3.2. ERP results

From the visual inspection of the Grand Averages (in Figs. 2 and 3) it is possible to observe the N1-P2 pattern typically associated with the visual presentation of words, followed by the N400 component. Differences between conditions are visible as early as 100 ms and seem consistent during the N400 time-window. Differences related to Status involve the N400 component, with more negative ERPs for Presupposition compared with Assertion: differences emerge around 300 ms and are consistent up to 700 ms.

3.2.1. N400 analysis

We first analysed the effect of the experimental factors on the N400 component with one ANOVA on the single subjects average amplitude recorded during the time-window ranging from 300 to 550 (Table 3). Results showed two significant two-ways interactions involving Trigger X Anteriority [$F(2,52) = 10.46$, $p < 0.001$] and Status X Anteriority [$F(2,52) = 4.23$, $p < 0.05$], but no evidence of a significant interaction between the two linguistic variables (Trigger and Status). We followed up these interactions with separate ANOVAs on each level of Anteriority. No reliable effect occurred over Anterior scalp locations. The effect of Status was focused in Central [$F(1,26) = 5.27$, $p < 0.05$] and Posterior [$F(1,26) = 5.30$, $p < 0.05$] locations, while the effect of Trigger was more narrowly distributed over Posterior [$F(1,26) = 10.56$, $p < 0.01$] electrodes.

We then selected a pool of electrodes that represent the typical scalp distribution of the N400 component. A Trigger X Status ANOVA was carried out on the average amplitude recorded from this set of electrodes for each participant (Fig. 3). The

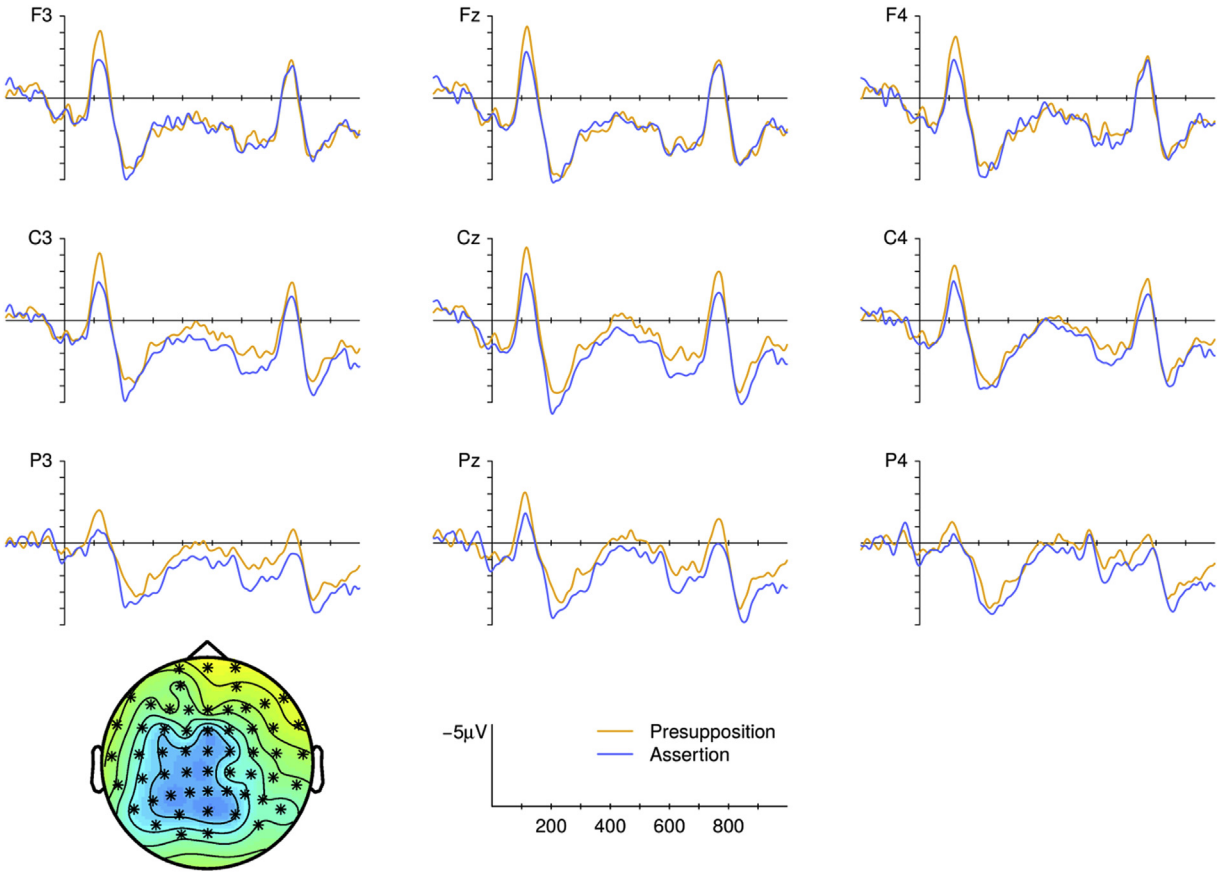

Fig. 2. Effect of Status. Grand average Event-Related Potentials from 27 participants, elicited by the target words in the Presupposition (orange) and Assertion (blue) condition. The ERPs from 9 representative channels are displayed. Negativity is plotted up. The figure shows also the scalp topography of the effect of Status (Assertion minus Presupposition) during the N400 time window (300–550 ms). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

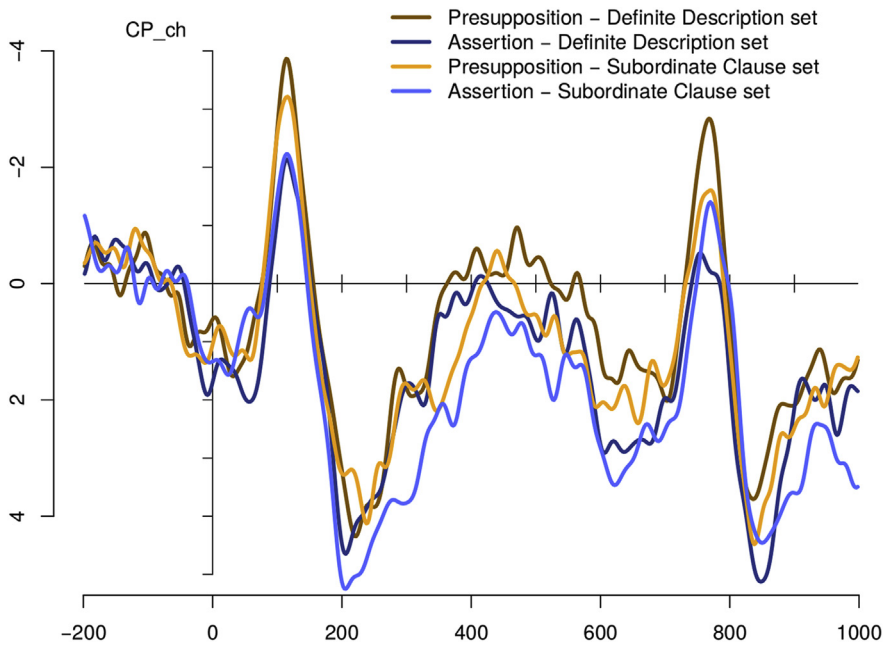

Fig. 3. Grand average Event-Related Potentials from Central-Parietal electrodes. ERPs are displayed with each line representing different levels of Status (Presupposition in orange and Assertion in blue) for both the Definite Description set (darker lines) and the Subordinate Clause set (lighter lines). The time development of the average voltage associated with each condition recorded from nine electrodes (C1, Cz, C2, CP1, Cpz, CP2, P1, Pz, P2) is displayed. Negativity is plotted up. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

analysis confirmed that more negative ERPs were found in Presupposition [+0.47 μV, CI = 0.06,0.88] compared with Assertion [+1.16 μV, CI = 0.75,1.57; $F(1,26) = 6.03$, $p < 0.05$, $\eta^2_G = 0.034$], and more negative voltages were associated with items in the Definite Description set [+0.39 μV, CI = −0.13,0.93] compared with the Subordinate Clause ones [+1.24 μV, CI = 0.71,1.77; $F(1,26) = 5.32$, $p < 0.05$, $\eta^2_G = 0.050$]. Also the absence of a significant interaction between the two factors was confirmed.

These analyses show that Presupposition elicited a larger N400 as compared with Assertion, with a canonical scalp distribution over Central and Posterior electrodes. The effect of Trigger elicited ERP differences occurring during the same time-window, with an N400 effect focused on Posterior electrodes, larger for stimuli in the Definite Description set than for stimuli in the Subordinate Clause set. However, the absence of significant interactions suggests that Status does not differentially affect the ERPs associated with each Trigger type during the tested time-window. In other words, the larger N400 effect associated with presuppositions compared with assertions was not different in the two sets of materials.

3.2.2. Latency analysis

Although the interaction between Trigger and Status is not significant, differences in the time development of presupposition and assertion for the two types of Trigger can be noticed from the visual inspection of Fig. 3. In particular, the effect of Status seems to have an earlier onset in the Subordinate Clause set compared with the Definite Description set. The ANOVAs carried out on the

Table 3
Analysis of Variance on the N400 time window. Results of ANOVAs on the ERP mean amplitude recorded between 300 and 550 ms are reported. Anteriority was used as a factor (with three levels) and interactions involving Anteriority were followed up by different ANOVAs on each level of Anteriority. Generalized eta squared are reported as measure of effect size. (*p < 0.05; **p < 0.01; ***p < 0.001).

Factors	DF	F value	p	η^2_G
Trigger	(1,26)	2.55	0.12	0.017
Status	(1,26)	3.31	0.08	0.014
Trigger X Status	(1,26)	0.51	0.48	0.002
Trigger X Anteriority	(2,52)	10.46	<0.001 ***	0.028
Anterior: Trigger	(1,26)	0.56	0.45	0.005
Central: Trigger	(1,26)	3.14	0.09	0.031
Posterior: Trigger	(1,26)	10.56	0.003 **	0.076
Status X Anteriority	(2,52)	4.23	0.02 *	0.008
Anterior: Status	(1,26)	0.01	0.92	0.000
Central: Status	(1,26)	5.27	0.03 *	0.029
Posterior: Status	(1,26)	5.30	0.03 *	0.035
Trigger X Status X Anteriority	(2,52)	1.22	0.30	0.002

N400 time-window cannot capture such differences in time development. We thus performed a latency analysis (Fig. 4) in which we computed mean and 95% confidence intervals for the effect of Status (subtracting Assertion from Presupposition) for a series of consecutive time-windows (15 ms wide). It is possible to appreciate how the effect of Status affects the ERPs to Subordinate Clause set during the early portion of the N400 time window, from 200 ms to 450 ms; in comparison, when looking at the Definite Description set, the effect is composite, with a very early negative difference occurring during the first 100 ms followed by a later negative effect that is reliable only after 400 ms and carrying over until 700 ms.

4. Discussion

The purpose of this study was to investigate, for the first time in the literature, the brain's ERP response related to processing new information when packaged as presupposition or as assertion in discourse. With this view, we chose two of the most commonly discussed presupposition triggers: definite descriptions and temporal subordinate clauses. Also, it was a first attempt to design experimental stimuli in compliance with parameters of ecological validity, being materials constructed out of authentic sources of written language and at the same time balanced with respect to important measures such as naturalness, readability and length. Based on the theoretical literature, we hypothesized that the presupposition of new information should elicit higher cognitive efforts than its assertion, due to the mismatch between the linguistic packaging and the actual discourse representation, in a sort of pragmatic garden path. We also hypothesized that these costs might be higher for presuppositions triggered by definite descriptions than for those triggered by temporal subordinate clauses, due to the higher

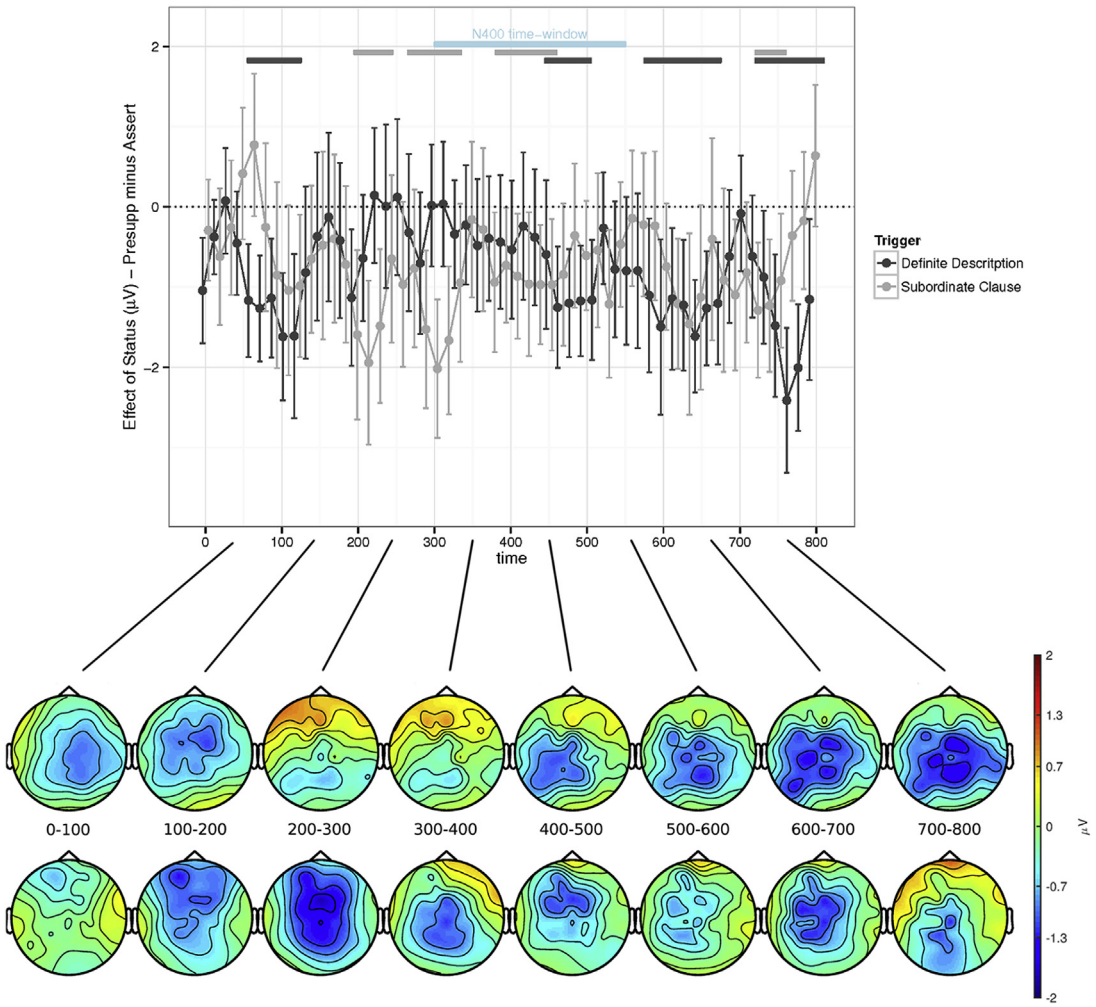

Fig. 4. Latency analysis of the effect of Status across types of Trigger. Above: 95% Confidence Intervals estimation for repeated measures designs within contiguous 15 ms time windows for the difference between Assertion and Presupposition in the Definite Description set (dark grey line and dots) and Subordinate Clause set (grey line and dots). Differences are computed from the mean activity of Central-Parietal electrodes (C1, Cz, C2, CP1, Cpz, CP2, P1, Pz, P2). Horizontal lines at the top of the box represent the time intervals in which differences between Assertion and Presupposition resulted consistent (for at least two consecutive time-windows) for Definite Description (dark grey) and Subordinate Clause (light grey). Below: scalp-maps of the ERP difference between Assertion and Presupposition for the Definite Description set (first row) and the Subordinate Clause set (second row), within contiguous 100 ms time windows.

strength of the former trigger with respect to the latter, possibly related to the syntactic downgrading and consequently the lower predicative force. Based on the experimental literature, we focused the investigation on the N400 component, expecting the costs of presupposition to manifest with the kind of ERP response normally associated to the accrual of discourse processing and discourse linking efforts.

In line with our expectations, the analysis showed a significant difference between presupposition and assertion packaging (what we labelled the Status factor) with more negative voltages observed for presupposition in the N400 time window over central and parietal electrodes, compatible with the description of this component (Kutas & Federmeier, 2011). Second, and slightly different from what we predicted, we observed that the difference between presupposition and assertion has an earlier time development in case of subordinate clause triggers as compared with definite description triggers, with the former being associated with a negativity in the 200–500 time window and the latter being associated with a negativity in the 450–700 time window. We will discuss these two findings separately.

As a first result, the larger N400 effect observed for presupposition as compared with assertion suggests that processing new information when it is packaged as if already taken for granted results in higher processing costs than the simple assertion of new information. Theoretically, this result supports the view that accommodating a new presupposition requires higher costs than simply building a new referent. Empirically, we found that the higher costs are associated with the typical component related to discourse processing. Our N400 result should indeed be considered along with evidence coming from the neuropragmatics literature on context and discourse processing (Van Berkum, 2009). This literature has shown that contents belonging to world knowledge, speaker's characteristics, as well as discourse are processed in the N400 time window, which is especially sensitive to unexpected information. To this literature, we add the case of new presupposition, as one instance of mismatch between information packaging and discourse representation, which requires the accommodation of an unexpected referent in the ongoing discourse model.

Expressly, the fact that new presuppositions are harder to process is indicative of expectation-based mechanisms underpinning the decoding of different information structure patterns (Wang & Schumacher, 2013). More precisely, the mental model of discourse grounds for the anticipation of both activation states and packaging formats of subsequent sentence contents. Our ERP results appear quite consistent with the expectation account, since what we found is a more prominent N400 effect in response to the *less expected* packaging: new presuppositions. Seemingly, this effect can be thought to stem from contravened expectations on the informational structuring of upcoming sentences, as presuppositions are more typically expected to carry given, rather than new, information. When presented with a new presupposition, the receiver is at first induced to interpret it as shared, thus gearing his memory system to search for an antecedent in the mental model of discourse, when he eventually realizes that no antecedent is available and that a new one must be created. To this respect, our results fit into the current debate over the functional role of the N400 and its indexing of prediction mechanisms. Recent accounts assume that information processing occurs incrementally, driven by pre-activated schema or expectations; information that triggers discrepancies with respect to the expectations is processed slowly because the parser must start over restructuring a new contextual representation (Kutas, DeLong, & Smith, 2011). In our case, the N400 might index the search of an antecedent based on the information structure schema that presupposition conveys known information, which fails and forces the speaker to restructure his/her discourse representation.

Looking more specifically at studies on less expected information structure aspects, our findings are also consistent with previous contributions on processing effects induced by more or less aligned configurations between packaging strategies and activation states of information (Wang & Schumacher, 2013). When unexpected associations between packaging strategies and activation states (e.g. new topics) are presented to the subjects, the N400 amplitude increases. Within this view, the N400 is especially indexing Discourse Linking mechanisms, i.e. the attempts to locate an entity in what has been said previously. The N400 reported for new presuppositions might be accounted for similarly, in that they increase the costs related to linking unexpected information in the discourse model. It should be noted, however, that unexpected information packages often manifest a biphasic N400-Late Positivity patterns, accounted for in terms of Discourse Linking followed by Discourse Updating, i.e. the revision of the discourse model to introduce new referents. The Late Positivity effect is not visible in the brainwaves recorded here. This seems indeed reasonable when we consider that, in our study, all stimuli (i.e. both presuppositions and assertions) conveyed new information, while information structure studies usually compared referents with different activation status. In other words, being information content always new, our stimuli do not differ with respect to the creation of a new slot in the discourse model, while only presupposition initiates a Discourse Linking process. For assertion, no discourse linking occurs, as the configuration straightforwardly instructs the receiver to build a new referent. To further deepen this discussion, it is interesting to compare our findings with the findings from Burkhardt (2007). That study also tested new information, specifically new referents conveyed through definite noun phrases. The experimental manipulation involved contextual fit, with three different conditions ranging from inducible to plausible and necessary context. In other words, all stimuli required the creation of a new slot and presumably equally affected Discourse Linking mechanisms, yet with different degrees of expectancy in terms of update of the discourse model. Consistently, the ERP response did not vary in the N400 but showed a modulation of the P600. Our paradigm is somehow specular, in that all stimuli required an update of the discourse model, and with the same level of contextual fit (as measured in the naturalness rating), but only presuppositions triggered a Discourse Linking process as compared with assertions. This might motivate the absence of the positivity effect and strengthens the interpretation of the N400 as a pragmatic garden path in accommodating new presuppositions. We do not exclude, though, that late positivities might occur when presupposition is considered in a wider range of informational configurations and context fit conditions.

By contrast, our data do not completely support the body of experimental evidence gathered within psycholinguistic and behavioural threads of research, in which presupposition has been reported to facilitate processing and to be available online before asserted content (Schwarz, 2015; Tiemann et al., 2011). To us, there are reasons to believe that the trends observed in these experiments are more strongly conditional upon the paradigms used, often involving isolated sentences with no previous discourse context introducing the critical assertive or presuppositional item. As also suggested elsewhere (Bornkessel-Schlesewsky & Schumacher, 2016; La Rocca, Masia, Maiorana, Lombardi Vallauri, & Campisi, 2016), the lack of context may ground for the adoption of different processing strategies, not guided by discourse-driven expectations, but rather by the formal structure of the stimuli. Therefore, the presence vs. absence of a prior context in the measurement of presupposition processing is a relevant parameter driving the modulation of attentional resources on the contents of upcoming sentences. As already argued in the introduction, the absence of a discourse context might render presupposition a default and more automatic configuration with respect to assertive constructions.

Concerning the ERP differences between presupposition and assertion across levels of the Trigger factor, we showed that no significant interactions emerged during the N400 time window ranging from 300 to 550 ms. This means that different types of triggers are not associated with differences in the size of the N400 effect, contrary to our experimental prediction. However, the latency analysis evidenced differences across types of triggers in the time development of this effect. This seems to confirm our hypothesis at the theoretical level, that there is a difference, possibly in the strength of presupposition, between different kinds of trigger. When considering the Definite Description set, presupposition was associated with more negative voltages compared with assertion in a late time interval ranging from 450 ms to approximately 700 ms; in contrast, when considering the Subordinate Clause set, presupposition was associated with more negative voltages compared with assertion in an early time interval ranging from 200 to 500 ms. The latency analysis thus suggests that the time interval in which the effect is more consistent differs across trigger types, with an earlier onset for presuppositions triggered by subordinate clauses as compared with those triggered by definite descriptions. Previous evidence of early onset for the N400 is reported in studies that compared different types of constraints (Camblin, Gordon, & Swaab, 2007; Molinaro, Conrad, Barber, & Carreiras, 2010), in support of early discourse effects. For instance, Molinaro and colleagues showed that the N400 effect induced by contextual constraints (low > high) has its onset about 100 ms before the N400 effect induced by neighbourhood frequency (high > low). Results were interpreted by assuming that context facilitates word recognition also in early stages of word processing. Camblin and colleagues showed that discourse representations can have an earlier effect on processing than local manipulations. In our case, the effect might be motivated by a combination of discourse-based expectations and strength of the trigger (i.e., likeliness and degrees of conveying presupposed information). It is possible that the discourse-based expectation mechanisms reflected in the N400 become active earlier in new presuppositions triggered by temporal subordinate clauses, as the weaker presupposition trigger and the higher predicative force of the clause facilitate the construction of the discourse model and make the mismatch between the information packaging and the available knowledge immediately available for the speaker. By contrast, in definite descriptions, the strength of the presupposition, i.e. the high probability of conveying shared information, accrued by the downgraded syntactic structure, might delay the recognition of the mismatch and the search for the antecedent. In this view, the earlier effect of Status in the Subordinate Clause set as compared with the Definite Description set might be in line with the idea, put forward in theoretical linguistics, that the strength of a presupposition is lower for the former than for the latter case (Lombardi Vallauri, 2009), and that for stronger triggers the effort of linking a new referent into the discourse model is delayed as less expected in context. While evidence is too limited to draw further conclusions, this finding might offer interesting empirical support to theoretical considerations and, combined with recent behavioural evidence on the differences across trigger types (Domaneschi et al., 2014), might pave the way for a neurotaxonomy of presupposition triggers and how they differently affect discourse processing dynamics.

Another result obtained in the study is the significant difference between the Definite Description set and the Subordinate Clause set (what we labelled the Trigger factor), with more negative voltages observed for the Definite Description set in the N400 time window on posterior sites. We did not have expectations on this effect (rather, we expected an interaction between the Status and the Trigger factors). Considering that the significant difference concerns the comparison between the two sets, i.e., including both presuppositions and assertions, the effect might be due to the structural differences between the two sets. Previous evidence showed that the N400 amplitude is sensitive to the position of the critical word. A strong inverse correlation between sentence position and the amplitude of the N400 component of the ERP was reported (Van Petten & Kutas, 1990), as sentential effects build as successive words add increasing message-level constraints. Given that in the Definite Description set the critical word position was on average 3, while it was 4.35 in the Subordinate Clause set, it is possible that the sentential context of the temporal clauses increased constraints that dissipated the N400 effect.

In sum, the present study represents a first attempt to study presupposition in a naturalistic context. Results allowed us to identify an N400 effect that is likely to be related to the effort of linking antecedentsand that might be seen as the brain signature of new presupposition as compared with new assertions. Although we believe that the evidence for this interpretation is solid, we acknowledge a number of potential limitations of our paradigm and of unanswered questions, which should be taken into account in future research. First, although the contrast between presupposition and assertion clarifies important aspects related to information packaging, it would also be interesting to consider the comparison between presuppositions that are accommodated and presuppositions that are solved based on discourse information. This would allow for a broader understanding of the mechanisms underlying the processing of presupposition. In this perspective, it would also be relevant to consider different activation states of the referent and different contextual constraints, to further understand the impact of discourse context and world knowledge. Here we used all new referents with relatively homogeneous degrees

of salience and relevance in the discourse context. However, the manipulation of these aspects might lead to different processing dynamics. Second, although the comparison between types of triggers led to interesting differences in the neurophysiological response, in the current paradigm we compared constructions associated not only with different strength in conveying presupposed information but also with different syntactic structure (i.e. definite descriptions and temporal clause structures). Paradigms assessing the interplay of discourse and syntactic variables, possibly ruling out the structural differences due, for instance, to word position, would be of great interest for the study of presupposition. To this respect, the early onset of the N400 elicited by presuppositions triggered by subordinate clauses is a result that needs to be explored further. Finally, more refined paradigms should take into account whether presuppositions are actually processed and accommodated by the participants. Recent behavioural studies showed that speakers can avoid processing the presupposition, especially with some kinds of triggers such as change of state or iterative verbs (Domaneschi et al., 2014). In our study, behavioural responses in the association task showed a high accuracy. Although this was not a direct measure of the success of accommodation, the high accuracy rate suggests that participants accurately processed the contents of the passages. Moreover, since the types of triggers employed here are among the easiest to accommodate, it is likely that presuppositions were successfully accommodated. Yet, especially when expanding the investigation to other trigger types, researchers should devise a way of measuring the success of presupposition processing.

5. Conclusion

The present study investigated the brain response to the on-line processing of new presuppositions, as compared with assertions. Results showed more negative voltages for presupposition relative to assertion in the 300–500 ms time interval over central and parietal electrodes. Considering the contextualised stimuli used for the experiment, the elicitation of a N400 effect can be assumed to correlate with expectation-driven processing mechanisms at the discourse level, in that presupposition is usually expected to convey already known information, whereas assertion is more typically associated with new information in discourse. The N400 observed for new presuppositions can therefore be conceived as relating to information packaging variations that can be more or less compliant with the receiver's mental model of discourse.

On the whole, the evidence reported in this work suggests that presupposition processing should be addressed from a discourse-driven perspective rather than nailing down its psychological underpinnings at the sentence level. Studies neglecting the impact of discourse on presupposed meanings might fail to grasp the phenomenon of presupposition in its natural happening, thus deriving distorted interpretations on its cognitive treatment. Conversely, ecological and context-based paradigms in electrophysiology of discourse seem to show that the kind of processing induced by presupposition is not to be measured on the packaging level *per se*, but in closer connection to how expected such packaging is with respect to the mental representation of the ongoing discourse.

Authors' contribution

Study concept: VM; ELV. Experimental design: PC; VB. Data collection: VM; IR. Data analysis and interpretation: PC; VB. Manuscript writing: VM; PC; ELV; VB.

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