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Brain response to Information Structure misalignments in linguistic contexts



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ABSTRACT

The paper inquires, through the analysis of electroencephalographic (EEG) recordings, the processing costs associated to misalignments between the information status (Given/New) of discourse contents and their linguistic packaging as Topic or Focus in discourse. The way information is packaged within utterances, that is, their Information Structure, guides language comprehension. Sentences are typically organized into Topic and Focus units, commonly conveying Given (already active in working memory) and New (not active) information, respectively. Nonetheless, for precise purposes, novel information can be presented in Topic, and known information in Focus. The paper accounts for the efficiency of brain processing in response to such “violations” of Information Structure, through both EEG spectral analysis and whole-brain functional connectivity patterns. The main contribution of the present work is the analysis of brain responses in natural contexts, i.e. when processing whole texts of more sentences, instead of isolated (couples of) utterances as is the case of a number of experimental paradigms pursued in the psycholinguistic domain. EEG signals recorded from a population of 54 subjects highlight the presence of rhythmic changes in different frequency bands, depending on aligned and misaligned Information Structures.

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1. Introduction

The role and relevance of linguistic context in brain processing for both sentence understanding and knowledge updating have been investigated in some recent neurolinguistic studies [1]. Specifically, it is widely agreed that interlocutors continuously make predictions about the contents a speaker is about to convey next, on the basis of information already available in the foregoing discourse [2]. Moreover, participants build expectations that forthcoming contents are presented in ways coherent with their having been already introduced or not, and with their relevance to the communicative task at hand [3]. Anticipation is in fact one of the key strategies used by the brain to ease automation in language understanding: knowing in advance when and how a

specific piece of information will be provided may allow to process it with less waste of cognitive resources, thus avoiding working memory overload [4].

On the other hand, it is commonly assumed that a greater effort is required to the brain when contextually unexpected contents are encountered, due to a mismatch between the input and the performed predictions. Several syntactic, morphological and semantic linguistic phenomena have been analyzed with the aim of unveiling the neural underpinnings of such states of affairs [5–9].

The aim of the present paper is to investigate, by means of the analysis of electroencephalographic (EEG) recordings, the brain processing cost associated to misalignments with respect to the way information is expected to be organized within utterances, that is, their *Information Structure* [10,11]. Any information provided in a sentence can be distinguished as being *Given* or *New*, referring to its activation state within the current discourse and in the conscious attention of its recipient [12,13]. Given, in this sense, is information recently introduced in discourse and therefore active in the addressee's short-term memory: something participants are currently thinking of. New designates information with no recent introduction in prior discourse or situation, and

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therefore inactive in the addressee's short-term memory. Language is sensitive to whether information is in one or the other of these conditions. After saying:

(1) Jane showed up at my home yesterday
it is possible to continue by saying:

(2) She has found a new job

The reason why the addressee will understand that Jane is the person referred to by “she” is that the idea of Jane is presently active in his working memory. But (2) cannot be uttered out of the blue, because in this case the addressee would find no referent for the pronominal subject, no suitable entity being currently “lit up” in his attention. If Jane is not Given in the utterance context, (3) must be uttered instead of (2):

(3) Jane has found a new job

At the same time, discourse actually develops through *Topic* and *Focus* (or *Topic* and *Comment*) units, which differently contribute to the illocutionary level of utterances, that is, the level in which cues to the interpretation of the intended communicative purpose are provided [13–15]. In oral communication, their detection is mainly triggered by prosody. The Focus of a sentence conveys information proposed by the speaker as his main contribution to the ongoing interaction, thus expressing the illocutionary force of the utterance [16]. The Topic instead provides the semantic background that makes the Focus understandable, and links focal information to the foregoing discourse. Consequently, only what is presented as Focus remains activated for anaphoric reference in the subsequent discourse:

(4) [She drinks]_{T,(1)} [in front of the children]_{F,(2)}, and this₍₂₎ is bad.
(5) [In front of the children]_{T,(1)} [she drinks]_{F,(2)}, and this₍₂₎ is bad.
(6) [She DRINKS]_{F,(1)} [in front of the children]_{T,(2)}, and this₍₁₎ is bad.¹

(7) [In front of the CHILDREN]_{F,(1)} [she drinks]_{T,(2)}, and this₍₁₎ is bad. New information is typically presented as the Focus of a sentence, because introducing New contents is typically the speaker's communicative goal, while Given contents are typically encoded as topical, i.e. as background information whose re-sharing is not the purpose of the utterance, though resuming them may be useful to understand the New Focus. For this reason, the Given/New and Topic/Focus pairs have often been treated as coterminous, with Topic referring to Given content, and Focus to New information. Nonetheless, “the distinction between topic and comment is autonomous, in the sense that it cannot be derived from the distinction between ‘Given’ (i.e. the known from the preceding context or situation, contained among the presuppositions) and ‘New’ (not given)” [17]. Indeed, in ordinary communication, novel information may be presented in a Topic unit, while known information can be focalized, as in the following examples:

- (8) A: What are John and Mary going to do over the week end?
B: [Mary]_{T/G} [is going to play tennis]_{F/N}.²
(9) A: What are your friends going to do over the week end?
B: [Mary]_{T/N} [is going to play tennis]_{F/N}.
(10) A: Are John and Mary going to play tennis?
B: Only [MARY]_{F/G}¹ [is going to play tennis]_{T/G}.

Example (8) contains the default alignment between activation states and linguistic packaging, while (9) and (10) contain misaligned configurations, where the expected patterns are reversed, with New and Given contents respectively encoded in the sentence Topic and Focus. In particular, in (10) the focalizing adverb *only* supports prosodic emphasis in producing a *contrastive Focus*,

where already active, Given information is encoded in a way which is different from the most probable expectation of the addressee.

The effects on brain processing of encoding Given/New contents in aligned and misaligned configurations with respect to topical vs. focal packaging are therefore evaluated in this work. Specifically, the literature regarding the analysis of brain reactions to violations of Information Structure is reported in Section 2, together with a description of the limits characterizing the investigations so far carried out on this matter. Section 3 describes the fundamentals of the methodology we propose for inquiring the effects of misaligned Information Structures on brain processing, while Section 4 details the instruments exploited for carrying out the performed analysis. The obtained experimental results are presented and discussed in Section 5, while some relevant conclusions are drawn in Section 6.

2. The experimental literature so far: towards an expectation-based processing model

Earlier psycholinguistic investigations approached the processing of Information Structure units manipulating the syntactic structure of isolated sentences. Indeed, the effects of focality and topicality were measured contrasting sentences like *Jane went to the train station* to cleft versions like *It's Jane who went to the train station*. This paradigm has been used in a number of studies, from Erickson & Mattson's MOSES ILLUSION TEST [18] to later works [19–21] in which the shift from a syntactically unmarked to a syntactically marked sentence was resorted to as the only strategy to encourage the reading of one or the other Information Structure. A methodological implication resulting from this experimental setting was that the critical sentences ended up carrying all New information, since no prior context could allow the treatment of some content as Given or New: “without any preceding information, the listeners [or readers] analyze each sentence as completely new and no information has to be embedded in an already given context” [9]. This obviously led to probe Information Structure processing in conditions far from how human communication really takes place.

In a different tack, later neurolinguistic studies [1,9,10,22–24] have highlighted the role of context-driven strategies in Information Structure processing. More particularly, it has been observed that the costs required to process contents are not only contingent on the topical or focal nature of each content *per se*, but rather on the interplay between packaging strategies and activation degrees of the contents conveyed. Put another way, processing effort depends on precise expectations that prior discourse allows to formulate either on the Given/New status of some information or on the particular packaging it receives in the utterance, based on the goals attained by the speaker in the ongoing interaction. On a general basis, it has been demonstrated that when New information conflates with Focus and Given information with Topic, processing effort appears smaller than it is when Topic-New and Focus-Given combinations are encountered. In these studies, the effects on brain processing of Information Structure misalignments in a specific context have been investigated by typically resorting to texts comprising question–answer and context–target pairs. Such approaches have allowed to precisely locate the temporal reference of utterances eliciting Event-Related Potentials (ERPs), that is, brain responses measured as the direct result of specific cognitive events. Specifically, increases or decreases of processing demands in response to aligned and misaligned informational matchings have been revealed by variations in N400 signatures, with higher deflections elicited by misaligned packagings. The involvement of N400 modulations in such discourse phenomena

¹ Capital letters indicate prosodic emphasis marking the Focus when located to the left.

² T/G=Topic/Given; F/N=Focus/New; T/N=Topic/New; F/G=Focus/Given.

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