# Information Structure effects on the Processing of Nouns and Verbs: Evidence from Event-Related Brain Potentials

ABSTRACT

Electroencephalographic (EEG) signals can reveal the cost required to deal with information structure mismatches in speech or in text contexts. The present study investigates the costs related to the processing of different associations between the syntactic categories of Noun and Verb and the information categories of Topic and Focus. It is hypothesized that - due to the very nature (respectively, predicative and non-predicative) of verbal and nominal reference - sentences with Topics realized by verbs, and Focuses realized by nouns, should impose greater processing demands, compared to the decoding of nominal Topics and verbal Focuses. Data from event-related potential (ERP) measurements revealed an N400 effect in response to both Nouns encoded as Focus and Verbs packaged as Topic, confirming that the cost associated with information structure processing follows discourse-driven expectations also with respect to the word-class level.

# Information Structure effects on the Processing of Nouns and Verbs: Evidence from Event-Related Brain Potentials[1]

EMANUELA PICIUCCO

*Department of Industrial, Electronics and Mechanical Engineering, Roma Tre University, Rome, Italy*

VIVIANA MASIA

*Department of Foreign Languages, Literatures and Cultures, Roma Tre University, Rome, Italy*

EMANUELE MAIORANA

*Department of Industrial, Electronics and Mechanical Engineering, Roma Tre University, Rome, Italy*

EDOARDO LOMBARDI VALLAURI

*Department of Foreign Languages, Literatures and Cultures, Roma Tre University, Rome, Italy*

PATRIZIO CAMPISI

*Department of Industrial, Electronics and Mechanical Engineering, Roma Tre University, Rome, Italy*

ABSTRACT

Electroencephalographic (EEG) signals can reveal the cost required to deal with information structure mismatches in speech or in text contexts. The present study investigates the costs related to the processing of different associations between the syntactic categories of Noun and Verb and the information categories of Topic and Focus. It is hypothesized that - due to the very nature (respectively, predicative and non-predicative) of verbal and nominal reference - sentences with Topics realized by verbs, and Focuses realized by nouns, should impose

[1] The experiment has been devised and set up by the five authors together; ELV is responsible for section 2; VM is responsible for sections 1, 3, 5.2, 6.1; ELV and VM wrote together sections 4, 5.1, 6.3 and 6.4; EP, EM and PC are responsible for section 5.3, EP and EM are responsible for sections 5.4 and 6.2; Section 7 has been jointly written by the five authors.

greater processing demands, compared to the decoding of nominal Topics and verbal Focuses. Data from event-related potential (ERP) measurements revealed an N400 effect in response to both Nouns encoded as Focus and Verbs packaged as Topic, confirming that the cost associated with information structure processing follows discourse-driven expectations also with respect to the word-class level.

KEYWORDS: Information Structure, Word Classes, Expectations, Event-related potentials.

## 1. Introduction

Thanks to the great temporal resolution that characterizes them, electroencephalographic (EEG) signals have been often analyzed to gain insights into the brain processes which are carried out during language processing tasks. In more detail, investigations on language processing have been performed considering event-related potentials (ERPs) since the early 1980s (Kutas & Hillyard, 1980; Kutas & Federmeier, 2000; Bambini, 2012). ERPs are voltage changes of the electrical activity of the brain and can be induced by sensory or cognitive events (Luck & Kappenman, 2011). Two ERP signatures, N400 and P600, have been found to strongly interact with the brain response to linguistic inputs. Specifically, N400 is a negative component peaking between 300 and 500 ms after stimulus onset, and its elicitation has been associated with difficulties in lexical-semantic retrieval (Kutas & Federmeier, 2000; Lau, Phillips & Poeppel, 2008), semantic integration/unification mechanisms (Hagoort & van Berkum, 2007), the processing of more or less expected information structural patterns (Cowles, Kluender, Kutas & Polinsky, 2007; Masia, Canal, Ricci, Lombardi Vallauri & Bambini, 2017; Wang & Schumacher, 2013), and the decoding of

non-literal meanings (Kutas & Federmeier, 2011; Weiland, Bambini & Schumacher, 2014). P600, a component peaking between 500 and 800 ms, has been originally observed in parsing difficulties caused by syntactic violations or garden path sentences (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992); Kaan & Swaab, 2003), yet its functional role has also been associated to mechanisms of context update (Burkhardt, 2006; Hoeks, Brouwer, & Holtgraves, 2014) and new information decoding (Burkhardt, 2007; Domaneschi, Canal, Masia, Lombardi Vallauri, & Bambini, 2018).

The present paper aims at assessing the contribution of ERPs in exploring how the brain deals with a special type of language interface, namely the one between the information structure and the word class level of a sentence. Notably, variations in the brain response in terms of evoked potentials will be inquired in cases where more or less expected combinations between word classes (mainly noun and verb) and distinct patterns of information structure (i.e. Topic-Focus articulations) are processed.

The paper is organized as follows. In Section 2 a working definition of information structure units is provided, and their relation to noun and verb classes in language use is canvassed. Section 3 reports an overview of the existing literature both on the processing of different utterances' information structures and on the mental representation of the noun-verb distinction. Building on Section 2, the prediction that there should be some sort of "processing preference" for topical nouns over focal nouns, and for focal verbs over topical verbs, is formulated in Section 4. Section 5 describes the experimental design adopted to test our predictions on the neurophysiological response to distinct patterns of associations between noun and verb categories and

information structure units. Results from ERP measurements are then discussed in Section 6, and conclusions are drawn in Section 7.

## 2. Theoretical views: Information Structure and Word Classes

Since its very discovery as an independent level of utterance organization (related to but not subsumed by semantics or syntax), Information Structure was defined in terms of predicativity. The founding remarks by the Second Prague School, beginning at the half of the XX century (Daneš, 1964; Daneš, 1967; Daneš, 1974; Firbas, 1966, Firbas, 1987), led to calling as Theme and Rheme the fundamental units of what was then called an utterance's Functional Sentence Perspective, with the first seen as "what the utterance is about", and the second as "what the utterance actually tells (about the Theme)". Even etymologically, and absolutely not by chance, the Theme is conceived as typically encoding reference to some object or entity, while the Rheme is the predication, the part of the utterance encoding what is actually said.

Halliday (1985) introduces Thematic Structure as a feature of the clause. In accordance with the Prague School terminology, he defines the Theme as "the element which serves as the point of departure of the message" expressed by the clause, "that with which the clause is concerned". The Rheme, conversely, is defined as "the remainder of the message, the part in which the Theme is developed". A similar definition suggests a strong affinity between the Theme and nominal constituents on the one side, between the Rheme and verbal or in general predicative constituents on the other. Halliday himself remarks that "a Predicator is rarely thematic". In sum, Theme and Rheme seem to present themselves (by definition, and in actual utterances) as two complementary parts of any message encoded by a clause, which is made of an entity ("what the message is about", the Theme) and a predication ("what is told", the

Rheme), exactly as the clause is made - syntactically - of a nominal and a verbal part. What is thematic has the nature of an entity, what is rhematic that of a process.

Currently, the terms Theme and Rheme have been replaced in most of the literature by Topic and Focus respectively, but the concepts remain essentially the same. Emanuela Cresti's pathbreaking work (Cresti & Moneglia, 2010) has shown that Topics have their typical (mainly ascending-descending) "Topic-contours", while Focuses are produced under the various contours which describe the utterances' illocutions. In an assertion, the Topic will be prosodically produced as a Topic, and the Focus will carry an assertive contour. In a question, the Topic will again have its Topic contour, but the Focus will carry an interrogative (ascending) contour. The same for an illocutionary act of command, protest and so on. In other words, prosody crucially shows that while the Topic of the utterance only encodes the entity to which the illocutionary act will apply, the Focus is responsible for the illocution, that is, for the particular kind of predication encoded by the utterance.

Among others, Cresti & Moneglia (2010) have shown pretty well, on huge amounts of data belonging to corpora of spontaneous speech, that an information unit carrying the function of a Topic can actually be made of any kind of syntactic constituent, and the same holds for a Focus. Therefore, information structure is largely independent from syntax. Considering for example the following sentences:

(1) A. Is John in town?

B. John went to China.

(2) A. Who is representing us in China now?

B. JOHN went to China.

The clauses contained in the "B" utterances in (1) and (2) are actually different, despite the apparent syntactic identity. In fact, in (1) the utterance is about John, and it

predicates that he went to China. Hence, *John* is the Topic of the message, and *went to China* is the Focus. In (2), conversely, the utterance is about going to China, and it predicates that it is John who did it. In other words, *went to China* is the Topic of the message, and *John* is the Focus. Now, the case represented by (2) is possible and even frequent, but (1) is the default case. It is more expected and straightforward for nominal constituents to realize the nomination of entities, and for verbal constituents to realize the predication of the message. In the mentioned examples, this can be seen from the fact that language is organized to express the first case by means of the unmarked, default construction, while the second case requires marked, contrastive prosody.

In more detail, it has been shown from vast corpora of spontaneous speech that nominals are more frequently associated to Topics, while verbal constituents more frequently realize Focuses.

For example, Mittmann (2012) has shown that in the C-ORAL-BRASIL Brazilian Portuguese corpus, nominal Topics are more than twice as frequent as verbal Topics, while the ratio found by Cavalcante (2015) in a vast American English corpus was 7:1. These figures are extracted by Mittman's and Cavalcante's data by considering utterances whose information structure does not involve more than one clause. They do not consider those cases where, in a complex sentence, the Topic of the utterance can be an entire clause, possibly made of both nominal and verbal constituents.

Cresti & Moneglia (2010) report that, in a representative corpus of Italian spontaneous speech, Topic units are filled nearly 60% by noun phrases and nearly 40% by other constituents, including adverbial phrases, adjectival phrases, prepositional phrases, and subordinate as well as main clauses. By the same token, Focus units (called "Comment" in their terminology) are filled nearly 62% by verb phrases

and nearly 38% by adverbial phrases, adjectival phrases, prepositional phrases and noun phrases.

These observations lead us to formulate the prediction that the associations between the syntactic categories of Noun and Verb and the information categories of Topic and Focus, though in principle free, may not be completely inter-independent, but oriented. More precisely, the processing of nominal Topics and verbal Focuses should be cognitively less costly in terms of required brain processing, being the most frequent and more "homogeneous" option: Nouns are already made for denoting entities and Verbs are already made for predicating about entities. On the contrary, the processing of verbal Topics and nominal Focuses should be cognitively more costly, being the less frequent and less "homogeneous" option. Verbs must change their primary function in order for them to denote an entity, and nouns must change their primary function if they are to express a predication.

It is worth remarking that, in principle, different processing efforts could be simply due to the fact that infrequent structures may generate a more "surprising" response. Still, it can be observed that, although Focal Nouns and Topical Verbs have lower frequencies as compared to Topical Nouns and Focal Verbs, nonetheless none of them is rare. As a consequence, a "surprising" response should be highly unlikely for both of them. What makes them really different is the relative nature of their components, in that Nouns, being non-predicative, have more semantic/pragmatic affinity to Topical information status, while Verbs, being predicative, have more semantic/pragmatic affinity to Focal information status. This difference in semantic/pragmatic "homogeneity" may well cause different effort, thus being the best candidate to explain possible brain processing effects.

The aim of the present paper consists in verifying the plausibility of such predictions, analyzing the cognitive effort when processing sentences with different kinds of associations between the syntactic categories of Noun and Verb and the information categories of Topic and Focus. Specifically, electroencephalographic (EEG) signals, giving information on the electrical activity of the brain, are exploited to perform such analysis. EEG event-related potentials (ERPs), that is, time- and phase-locked brain responses measured as the direct result of specific cognitive events, are used as descriptors of the brain workload in the considered scenarios.

## 3. Literature Overview

The literature regarding noun and verb processing is illustrated in Section 2.1, while experimental findings on Information Structure processing are outlined in 2.2.

### 3.1. Noun and Verb Processing

Brain response to nouns and verbs has been the object of several neurophysiological investigations over the last two decades (Cappa & Perani, 2003; Damasio & Tranel, 1993; Pulvermüller, Lutzenberger & Preissl, 1999). Both fMRI and ERP studies report fairly consistent topographic specializations of these two word classes in the human brain, with nouns mainly activating visual cortical regions, and verbs chiefly involving pre-frontal and frontal motor regions (Cappa & Perani, 2003). Different processing patterns, though, have appeared less consistent and less robust in other works in which grammatical class detection produced a more remarkable response only when extended sentence contexts were adopted in experimental stimuli (Levelt, Roelofs & Meyer, 1999). ERP measurements have also proved useful to unravel how word class processing taps into the construal of other levels of analysis, and earlier and more recent

studies in this respect have revealed that semantic and grammatical distinctions between nouns and verbs is bound to emerge even earlier than the canonical N400 time interval (Neville, Nicol, Barss, Forster & Garrett, 1991; Zhao, Dang & Zhang, 2016). For example, Tan & Molfese (2009) noticed that preschoolers' responses to spoken nouns and verbs, either matching or non-matching action or object names presented in a scene, produced P100 and N220 signatures over frontal electrode sites, which suggested a discrimination effort between syntactic classes for both matching and mismatching conditions. In other experiments, verbs have been reported to impose more taxing processing due to their greater morphological and semantic complexity since they designate events, which necessarily involve other participants (Baker, 2003). These findings however appear less systematic when it comes to ambiguous verbs and nouns such as the English *cut*, *kiss*, *head*, etc., which can function either as verbs or nouns depending on their context of occurrence. Indeed, using English words of this kind, Federmeier, Segal, Lombrozo, & Kutas (2000) conducted an ERP study to assess the extent to which manipulation of prior contextual information made the processing of nouns and verbs more or less costly. Notably, presenting short texts with ambiguous nouns and verbs alternatively embedded in verb-predicting and noun-predicting contexts, the authors noticed that more prominent N400 deflections were elicited by both nouns and verbs in less expected contexts (i.e. nouns embedded in verb-predicting contexts and verbs embedded in noun-predicting contexts). They thus concluded that rather than correlating with neatly delimited patterns of neural activation, word class distinctions "emerge in real-time from an interaction of semantic and syntactic properties at both the single-word and the discourse level" (Federmeier et al., 2000). It should be noted that the interplay between word classes and discourse structure – with particular regard to the information structure level - has been less extensively investigated within

the neurophysiological purview. The present paper intends to contribute to this line of research by further developing Federmeier et al.'s premises on the role played by discourse in facilitating word class differentiation.

### 3.2. Information Structure processing

Most of what we know about information structure processing comes from behavioral and EEG studies (Birch & Rayner, 1997; Hruska & Alter (2004a); Schumacher & Hung, 2012; Sturt, Sanford, Stewart & Dawydiak, 2004, among others). In the behavioral domain, the psychological processes underlying the mental encoding of topical vs. focal information have mainly been investigated through reading times and eye movement measures, which yielded overall greater processing demands elicited by focused information, as opposed to topical information (Birch & Rayner, 1997). Possibly due to the adoption of more extensively contextualized stimuli, subsequent neurolinguistic experiments revealed quite deflecting processing trends of information units, in that increasing costs were not only observed in association to information statuses per se, but also - and even more conspicuously - as conditional upon more or less expected syntactic realizations (Burmester, Spalek & Wartenburger, 2014), phonological profiles (Baumann & Schumacher, 2012; Cowles et al., 2007), and activation degrees in discourse (Wang & Schumacher, 2013). In these accounts, topics conveying new information (Wang & Schumacher, 2013) or realized by object dislocation strategies (Burmester et al., 2014) are reported to cost more than topics carrying given information and realized by syntactic subjects. These and other findings on the whole converge on the involvement of both N400 and P600 responses which, as discussed in the mainstream literature, respectively reflect mismatch detection at both the semantic and the discourse level (Kutas & Federmeier, 2000; Masia et al., 2017; Domaneschi et

al., 2018) as well as difficulties in context updating (Burkhardt, 2007). Phonological, syntactic or context-dependency features inconsistently matching with information statuses generally elicited greater N400 responses, sometimes accompanied by subsequent positive deflections. In a recent study, Bañón & Martin (2019), tested the brain response to *it*-clefts, either with dislocated given or new information. While the former condition would be more expected, the latter is less common and was therefore predicted to increase the cost required to process the sentence. Indeed, the authors found that the less expected condition yielded more prominent N400 amplitudes with even greater P600 effects.

So, much of what is at play in information structure processing is profoundly contingent on the level of expectations interlocutors entertain on the distribution information receives in an utterance, and on the types of interactions it displays with other levels of sentence representation. In the present paper, the level of expectations we propose to look into concerns the relation between topic and focus units and the syntactic classes of noun and verb in a sentence.

## 4. Predictions

Capitalizing on the assumptions and the findings above discussed, we expect differences between Topic-Noun/Focus-Verb and respectively Topic-Verb/Focus-Noun combinations to emerge in modulations in the N400 signature. A stronger negative response is expected to be elicited by less homogeneous information structure/word class matchings, represented by topical verbs and focused nouns in our experimental design. An N400 response would be consonant with previous accounts on the expectation-related nature of this component (Bambini, Bertini, Schaeken, Stella & Di Russo, 2016; Kutas & Federmeier, 2011) and, particularly, with unmet

predictions on information packaging strategies (Cowles et al., 2007). In the experimental paradigm used, no given-new opposition (Chafe, 1976) has been measured for the critical information, so we should not expect potential P600 effects to be driven by the activation status parameter.

## 5. Methods

The performed experimental tests are described in the following. Specifically, the adopted experimental design is outlined in Section 5.1, the administered stimuli in Section 5.2, the collected data in Section 5.3, and the performed data processing in Section 5.4.

### 5.1. Experimental Design

In order to collect a proper number of brain responses to all the interesting combinations between information structure and word class (Noun and Verb), a set of 60 pairs of texts, each composed of three-sentence passages, namely a two-sentence context followed by a target sentence, has been created. The critical region in the target sentence contains a Noun or a Verb either realized as Topic or as Focus. To avoid potential overlapping with other discourse phenomena, mainly indefinite phrases have been considered for the Noun set, since definite noun phrases would have been interpreted as triggering a presupposition, thus blurring topicalization and focalization effects. As for the Verb set, mainly infinitives have been used, since they can be flexibly moved from topic to focus position without remarkable infelicity effects (at least in Italian, the same would hardly obtain with fully inflected verbs).

As can be seen from the examples in Table 1, texts have been arranged in pairs, so that the same two-sentence context can be followed by two different target sentences, with a

Noun (or a Verb) in either Focus or Topic condition[2]. To test the predictions outlined in Section 4, the design has been constructed so as to assess the interaction between the two main independent variables of the study, i.e. Type (Noun, Focus) and Condition (Topic, Verb), and how such interaction is reflected in the ERP measurements.

**PLEASE PLACE TABLE 1 HERE**

**5.2. Stimuli**

To isolate the effects of information packaging and word class variation from those related to the discourse availability (givenness vs. newness, Chafe (1976)) of contents, which strongly modulates sentence processing (Basar-Eroglu, Basar, Demiralp, & Schürmann, 1992; Burkhardt, 2006), we have chosen to keep all regions of interest equally new. Therefore, the critical Nouns or Verbs, in Topic or in Focus condition, always convey novel information. Differently from other studies such as those from Baumann & Schumacher (2012), La Rocca et al. (2016), and Hruska & Alter (2004), where expectations on information structure processing have been measured relative to the degree of activation of the contents carried by topical or focal units, in this study we are mainly interested in brain responses to topicalizations and focalizations as realized by different word classes which, to us, makes the unvaried information status parameter even more compelling.

The position of the target word has been carefully determined for both the Condition and the Type factors. Particularly, for the Topic condition, the average position of critical nouns in the target sentence is 5 (SD= 1), whereas for verbs it is 4.5 (SD = 1.7). In the Focus condition, the position of nouns is approximately fixed at 10 (SD = 1.8), while for verbs it is 9 (SD = 2.3). Overall, the distribution of critical nouns and verbs is

[2] The full set of stimuli is available at https://biomedia4n6.uniroma3.it/research/Linguistic_InformationStructure_WordClass/Linguistic_InformationStructure_WordClass_Stimuli.zip

fairly homogeneous within and between the Topic and Focus conditions, meaning that the effects of Topic vs. Focus packaging should not be distorted by unsystematic positional oscillations of the target words. As a result, the syntactic encoding of critical words as Topic or Focus, at least in terms of sentential position, is expected to be more comparable between the Noun and the Verb set. In the target sentences, the mean length of critical words did not significantly differ for the chosen Noun and Verb sets, nor did their overall frequency in common language uses, as the resulting mean values show (Noun = 25,85; Verb = 20,83). Furthermore, in compliance with standard normalizing measures in experiments utilizing context-target pairs as stimuli, the naturalness of all texts has been judged on a 5-point Likert scale by another group of subjects in an offline questionnaire. A two-away ANOVA on the collected responses showed no significant interaction ($F(1,35)= 1.2$; $p= 0.6$) between the Type (Noun, Verb) and Condition (Topic, Focus) parameters. This suggests that any effect to be foreseen at the electrophysiological level should not be put down to unnatural or implausible features of the stimuli.

The employed stimuli have been submitted as audio tracks. Since they have been recorded and presented at normal speech rate, the timing between the offset of a region of interest and the beginning of the next word could be quite short. Specifically, the inter-word means and standard deviations for each combination of Type and Condition are {mean = 151ms, SD = 49ms} for Noun/Topic, {mean = 166ms, SD = 62ms} for Verb/ Topic, {mean = 182ms, SD = 121ms} for Noun/Focus, {mean = 209ms, SD = 105ms} for Verb/Focus. The aforementioned inter-word intervals are quite similar for all the considered Type x Condition combinations, with differences due to the natural way the considered Types and Conditions are verbally performed to pack information within sentences. Moreover, an ANOVA test could not find any

significant effect regarding possible (information structure) x (word class) interactions on the collected timing values (*p-value* =0.71).

It is worth observing that, having used stimuli with such inter-word timings to reproduce natural conditions, the EEG responses to consecutive words could overlap, making it hard to record clean and artifact-free potentials, and affecting the feasibility of detecting differences in the behaviors observed for distinct combinations of Type and Condition. This is especially valid for comparisons of Noun and Verb usages in Topic, due to the typically shorter subsequent silence period with respect to Focus conditions. Nevertheless, as it will be shown in Section 6.2, significant effects on the cognitive cost of processing more or less expected combinations of information structure and word class have been indeed found in the performed tests, testifying that the employed stimuli have been properly designed to highlight significant interaction effects. In particular, as it will be seen, although the average length of the inter-word interval after a Focus is (quite naturally) longer than after a Topic, the effects were found both for Topic/Verb and for Focus/Noun, suggesting that the effect is due to the cognitive factors proposed in the paper, rather than to minor vs. major overlapping of EEG signals.

### 5.3. Data Collection

Thirty-five students (7 men, mean age = 22.8, SD = 3.5) from Roma Tre University have taken part in the experiment. All subjects were right-handed (mean laterality = 0.81, SD = 0.16, cf. Oldfield (1971), native Italian speakers, with normal or corrected-to-normal vision. None of them reported history of neurological or psychiatric disorders. Informed consent was obtained from all subjects prior to each experimental session.

During the experiment, participants sat in a dimly lit, sound-attenuated room. Subjects were asked to look at a fixation cross in the center of a computer screen while listening to the provided stimuli.

The 60 pairs of texts have been arranged into two randomized lists according to a Latin Square design, so that each participant was presented with only one occurrence of the two-sentence context whose target sentence contained either a Noun or a Verb in Topic or in Focus condition. Both lists also contained further 30 fillers, randomly interspersed between the experimental trials, with no marked topicalizing or focalizing constructions.

In order to make sure that the investigated Type × Condition interactions had no significant effect on the comprehensibility of the designed texts, all experimental stimuli were accompanied by two verification questions presented visually on the computer screen. After reading each question, subjects had to press a TRUE/FALSE button on the keyboard.

During the presentation of the stimuli, EEG signals of the participants have been acquired using a 19-channels system GALILEO Be Light Amplifier, with an original sampling rate of $S_r$ = 256 Hz. The electrodes were placed on the scalp according to the 10-20 standard montage, and the electrical impedance was kept under 10 kΩ using conductive gel at the beginning of each acquisition. The EEG measures are referenced to the AFz position, and represented as potentials $v^{(c)}[t]$ between the $c$-th electrode and the reference electrode, with $c = 1, \ldots, C = 19$. EEG recordings have been time-locked to the presentation of the target words, represented by the head noun of the indefinite phrase for the Noun set (see Table 1), and by the infinitive verb for the Verb set. The obtained synchronization signal has been used to lock the raw EEG traces to the occurrence of the words of interest.

### 5.4. Data Processing

A spatial common average referencing (CAR) filter (McFarland, McCane, David, & Wolpaw, 1997) is first applied to the acquired data in order to improve their signal-to-noise ratio (SNR), and make them as much independent as possible on the employed reference, by subtracting from each raw EEG signal $v^{(c)}[t]$, $c = 1. . .$, C, the mean voltage sensed over the entire scalp. The obtained signals are then band-pass filtered through the application of a band-pass filter in order to retain spectral components in the range [0.5 − 40] Hz, containing the main EEG rhythms of interest for the present study. Subsequently, EEG signals are segmented into epochs time-locked to the words under analysis, considering time intervals lasting from $T_{preS}$ = 50 ms before the stimulus end, to $T_{postS}$ = 1000 ms after it. The result of the aforementioned process is a set of $N_T$ = 60 epochs $v_n^{(c)}[t]$, $n = 1, . . ., N_T$, for each participant. After the application of independent component analysis (ICA), artifacts are automatically labeled and removed (Pion-Tonachini, Makeig, & Kreutz-Delgado, 2017). The post-stimulus signals are then normalized with respect to the pre-stimulus baselines, obtaining the set of epochs $\tilde{v}_n^{(c)}[t]$, $n = 1, . . ., N_T$ and $c = 1, . . ., C$ from which ERP descriptors are derived as follows.

#### 5.4.1. Event-Related Potentials

For each user and for each possible combination of Type × Condition, the selected samples are averaged in order to generate a single ERP signal. In more detail, as laid out in Section 4, we focus our analysis on the behavior of the N400 and P600 components, isolated considering time windows starting $T_{N400Start}$ = 300 ms and $T_{P600Start}$ = 500 ms after the stimulus end, respectively, and lasting 200 ms. Within this time lapse, three distinct features are extracted and taken into account as indicator of the

cost of processing the different sentences, namely the mean and the peak value within the considered time windows, and the latency of the obtained ERP peaks. Such characteristics, separately evaluated for each of the *C* considered channels, are employed in the statistical analysis outlined in Section 6.

## 6. Results

The obtained results are here reported, together with a discussion on the observed ERPs in response to different patterns of associations between information units and the two word classes considered in the present study.

In order to verify the hypotheses stated in Section 4, several statistical testing procedures have been carried out. In more detail, Section 6.1 first reports the results obtained from norming questionnaires performed in order to address whether the usage of different Type × Condition combinations may affect the understandability of the experimental texts. Sections 6.2 and 6.3 respectively illustrate the outcomes from the tests performed on the ERP samples to evaluate the effects of different Type × Condition interactions on brain processing. The gathered results are then discussed in Section 6.4.

### 6.1. Understandability analysis

A preliminary analysis of subjects' responses to verification questions yielded an overall accuracy of 95% (SD= 0.07) which suggests that all texts have been carefully read by the subjects. A two-way ANOVA crossing Condition (Topic, Focus) and Type (Noun, Verb) with verification accuracy displayed no significant interactions ($F<1$), indicating that neither the topical/focus packaging level nor the word class one interfered with the comprehension of the texts and that all stimuli have been understood equally well. Another two-way ANOVA has been performed on the

interaction between the two factors for the subjects' response times to verification questions, showing again no statistically significant result ($F(1,35) = 0.19$; $p=0.7$), implying that subjects took more or less the same amount of time to answer verification questions, irrespective of the Condition or Type manipulations carried out in the target sentences. Text complexity has also been evaluated by measuring the length of the submitted texts, designed with a mean range between 33.3 and 36 (SD = 5) words. A two-way ANOVA run on the Condition × Type interaction has shown no significant result ($F(1,56) = 3.6$, $p=0.06$), suggesting that all texts displayed on the whole the same length, and that the length parameter did not overall affect the brain response to the experimental passages listened to by the subjects. In other works, text complexity has also been gauged by calculating readability indexes (see Gulpease index for Italian written texts in Piemontese (1996)) which, given the auditory presentation modality of our stimuli, we have preferred not to consider for the present study.

**6.2. ERP Results**

The ERP features mentioned in Section 5.4.1, that is, mean, peak, and latency, are considered as dependent variables in two-way Type (Noun, Verb) × Condition (Topic, Focus) ANOVA tests, performed to evaluate the existence of an interaction between the considered categories of information structure and the two word classes. The *p-values* obtained when considering both N400 and P600 ERPs are reported in Table 2. Values reported in bold display significant interactions, having considered a level of significance at 0.05, and a Bonferroni correction depending on the number of employed channels, i.e., 19, for each ERP. As expected, the N400 signature has emerged as the most prominent characteristic to reveal the interaction between the employed information structure and the considered word classes, with significant

results observed in centro-parietal areas. The mean value over the N400 interval is the descriptor providing the most relevant information.

**PLEASE PLACE TABLE 2 HERE**

To provide a visual representation of the obtained results, the brain regions where significant interactions have emerged from the analysis of the mean of the N400 ERPs are reported in Figure 1, which include both the location of the most relevant channels, as well as a topographic map of the obtained *p-values* obtained using interpolation on a fine cartesian grid. Furthermore, Figure 2 reports a set of topographic maps to describe the temporal behavior of *p-values* computed through ANOVA tests conducted on consecutive time windows, each lasting 50 ms. Significant values start to appear in the centro-parietal area for time intervals coherent with N400 responses.

**PLEASE PLACE FIGURE 1 AND FIGURE 2 HERE**

It is worth specifying that, since the number of electrodes employed for our EEG acquisitions is quite limited, in the performed statistical tests we have opted to rely on the Bonferroni correction to handle the family-wise error rate (FWER) in our multiple-comparison scenario, instead of resorting to non-parametric statistical tests such as Threshold-Free Cluster Enhancement (TFCE) analysis (Smith and Nichols, 2009), which could benefit from high-density montages to improve the computed statistics. Actually, we have found significant effects even following the employed parametric testing approach, which is typically much more conservative than non-parametric alternatives.

In order to gain further insights on the effects of using different combinations of Type and Condition categories, several statistical *t*-tests have also been performed, each

evaluating the effects on N400 and P600 of adopting different word class Types in a specific Condition of information structure.

In more detail, the *p-values* obtained when considering the processing of nouns and verbs occurring in Focus condition are given in Table 3, with significant differences reported in bold, for the same significance level and the same correction adopted in the performed ANOVA tests. In order to give a visual representation of the observed behaviors, ERPs referred to Focus conditions are reported for selected channels in Figure 3, where it is shown that the processing of focused nouns produces greater N400 deflections than the decoding of focused verbs. The reported results confirm what has already been observed with the ANOVA tests, showing that the most significant differences are linked to the mean and peak values of the N400.

**PLEASE PLACE TABLE 3 AND FIGURE 3 HERE**

The results related to the ERP responses to nominal and verbal Topics are shown in Table 4. A comparative analysis highlights that the Focus condition induces most of the effects on cognitive processing. ERPs extracted from responses recorded in correspondence to nominal and verbal Topics are provided in Figure 4.

**PLEASE PLACE TABLE 4 AND FIGURE 4 HERE**

Similarly, statistics regarding the same class type but different conditions have been performed. Specifically, the *p-values* obtained when taking into account verbs occurring both in Focus and Topic conditions are reported in Table 5. Again, the achieved results show that the differences can be observed in the mean and peak values of the N400 time window. Table 6 instead, reports the results related to the ERP responses to nominal Topics and Foci. The analysis performed considering the processing of nouns results in statistically significant effects in the mean and the peak amplitudes of the N400 responses, mainly in parietal brain areas.

The visual representation of the reported comparisons, which take into account the same word class but different packaging conditions, are reported in Figure 5 and Figure 6. More in detail, Figure 5 shows examples of the grand average ERPs related to the electrodes displaying more prominent N400 responses in the comparisons between verbal Topics and verbal Foci, while Figure 6 depicts the comparisons between grand average ERP responses to nominal Topics and nominal Foci.

**PLEASE PLACE TABLE 5 AND FIGURE 5 HERE**

**PLEASE PLACE TABLE 6 AND FIGURE 6 HERE**

**6.3. Discussion**

The results obtained from the ERP analysis confirm the expectations about the N400 component, and, notably, those associated with the processing of less expected information structural patterns (Cowles et al. 2003; Wang & Schumacher, 2013; Masia et al. 2017). In our study, the less expected patterns are represented by the Focus-Noun and Topic-Verb conditions.

As shown in both the grand averages and the statistical measures, the N400 effects observed in centro-parietal regions are mainly prominent when considering two comparisons, that is, in response to focused nouns compared to focused verbs (Table 3, Figure 3), and for focused nouns as opposed to topical nouns (Table 6, Figure 6). As already hinted at, this trend appears to go quite remarkably in the direction of an expectation-based processing of information structure and, particularly, towards a realization of information units that is on the whole consistent with both the functions Topic and Focus generally perform in an utterance and with the cognitive contribution associated with the mental encoding of different word classes. More particularly, since Focus has an essentially predicative nature, it is safe to assume that its most expected

association is with verbs or, more generally, with predicative segments of sentences. Instead, its association with the nominal category, although anyway frequent in spoken discourse – especially when it comes to narrow focalizations – is functionally less homogeneous, due to the fact that nouns (even those characterized by an eventive meaning such as *construction*, *demonstration*, *raising*, etc.) are less predicative in nature. Also, since focused constituents are expected to "say something" about topical entities, what is said about these entities in non-marked syntactic orders is more likely to coincide with verbal and, more generally, predicative syntactic units, and the topic with nominal syntactic units. Decoding a nominal syntactic unit in focal packaging thus requires dealing with a mismatching combination between a part of speech and its presentation in terms of discourse status which, in the case of focused nouns, entails assigning the function of "predicating something about the topic" to a syntactic unit which is not predicative itself.

A further aspect to underline is that in the Topic condition (cf. Table 4, Figure 4), the difference registered between verb and noun is not as strong as that noticed in the Focus condition. A possible and plausible explanation to this result is that, contrary to Focus, information packaged as Topic is generally presented as communicatively less salient and therefore as somewhat taken for granted on the processing level (Birch & Rayner 1997; Sturt et al 2004, among others). As a consequence, a less expected matching between word class and information packaging strategy may be expected to come with a weaker cognitive impact in topical than in focal realization.

Regarding word class types, the stronger negativity observed for topical verbs as compared to verbs in focus – although less prominent than that observed for nouns in topical vs. focal packaging - is indicative of a counter-expectation effect elicited by assigning topical packaging – which is more typical of nominal, time-stable lexical

categories – to more predicative syntactic units. The slightly less prominent N400 deflections registered for this condition, compared to focal verbs, reflects an increasing processing demand owing to the central brain area's dealing with a less homogeneous information packaging - word class matching, and therefore with the effort required to "solve" a discursive mismatch caused by mentally representing predicative content (i.e. a verb) as a unit to say something about. This thus involves an overall restructuring of the linguistic context with a subsequent revision of expectations on the communicative dynamism of the ongoing discourse.

As already hinted at in the foregoing, differences between focal and topical packaging are more robust in the noun condition than in the verb condition, the costs imposed by focal nouns being considerably greater than those associated with the processing of topical nouns. On balance, our data seem to extend to information structure processing the results on expectation-based processing of word classes suggested by Federmeier, McLennan, De Ochoa, & Kutas (2002), on which this study also capitalized on, who found modulations in the N400 signature during the online processing of English nouns and verbs in more or less predictable syntactic positions or discourse functions. In our research we sought to demonstrate that, besides interactions with the prosodic level (Cowles et al., 2007; Hruska & Alter, 2004) and with degrees of activation of information in the receiver's short-term memory (La Rocca et al. 2016; Masia et al., 2017), the processing of information structure is also sensitive to expectations associated with the word class being selected by the speaker to package some information as Topic or Focus of the sentence.

Other electrophysiological studies on unexpected information packaging criteria (Masia et al., 2017) reported N400 effects in response to novel information packaged as presupposition, as compared to the same item of information packaged as assertion,

which confirm the connection of this component with less expected strategies of information packaging. These trends were interpreted as stemming from costs of *discourse linking* mechanisms (Masia et al. 2017), that is difficulties in linking some information to the foregoing discourse.

In our study, costlier cognitive operations were elicited by focal nouns, meaning that the mental operations required to perform a predication (i.e. focusing) by means of a noun are more taxing than those required to perform it by means of a verb. The fairly strong N400 effect observed in response to focal nouns, compared to focal verbs (cf. Table 3, Figure 3), can therefore be explained as reflecting a cognitive overload required to mentally construe a nominal type of information in focus function (which is typically associated with predicates and, more particularly, with verbs). For the topic condition, this scenario appears reversed, though with less significant values, in that topical verbs seem to be correlated with greater amplitudes in the N400 component, as compared to topical nouns. In other words, the negative deflections elicited by topical verbs is suggestive of costlier processing operations due to mentally representing eventive meanings in a packaging which is more typical of nominal categories.

All in all, the gleaned results do not point to significant trends in the P600 signature. To some extent, this outcome was not to be expected due to the fact that P600 more often correlates with updating efforts when some new information is being processed (Schumacher 2006; Domaneschi et al. 2018) or when parsing difficulties are experienced by the receiver (Gouvea et al. 2010). However, in our experimental design, all regions of interest in the target sentences conveyed new information, which means that no additional updating costs were required to the subjects. Also, the four experimental conditions were not opposed for factors related to the syntactic

complexity or syntactic anomalies of the stimuli. These factors thus possibly made the elicitation of a P600 effect less likely.

To sum up, our results can be said to disconfirm previous data on the major processing demands imposed by verbs, as compared to nouns. The trends observed in the present study rather substantiate Federmeier et al.'s view that word class processing is contingent on their discourse profile and that verbs can be costlier than nouns, or viceversa, only to the extent that their discourse status – and, notably, their information structural status – is less or more compliant with the receiver's expectations on the current representation of the discourse contents.

**6.4. Shortcomings and Future Developments**

Although the data gathered in this study are all in all encouraging in the attempt to foster experimental research hypotheses on the interplay between information structure and word classes, the present study is not altogether free from some methodological limitations. One issue concerns the ecological validity of the stimuli which, with a view to achieving a more effective experimental design, have been artificially constructed by the experimenters, as it mostly happens. The norming questionnaires, aimed at assessing the naturalness of the stimuli for native speakers of Italian, have thus provided compelling positive information on the structural soundness and overall perspicuity of the critical items administered as audio tracks. Attempts at obtaining the same relevance of the experimental design to the analyzed linguistic features, but with more ecological stimuli, are an interesting, difficult challenge, and an open path for further research.

Secondly, we have not conducted a prosodic analysis (in terms of presence vs. absence of pitch accent contours) to substantiate the topic/focus status of the critical

regions. Albeit this procedure has sometimes been complied with in previous studies (Schumacher & Baumann 2010; Baumann & Schumacher 2012, among others), we opted for constructional criteria which did not only emphasize the prosodic profile of the critical region but also the overall contribution of the discourse context to the informational status of linguistic units. In fact, as also demonstrated in studies on the phonological correlates of topic and focus (e.g. Frascarelli & Hinterhölzl 2007), intonational prominence may also mark topical constituents based on their discourse role, which is why prosody, without the foregoing linguistic context, risks to be a too partial information structural cue.

A further development of the study would also benefit from gauging the influence of Topic/Focus packaging on the processing of parts of speech other than Nouns and Verbs. For example, it would be interesting to inquire the electrophysiological response (if any) to sentences with topical vs. focal adjectives such as "*Sono belli i gatti di Andrea*" (translated "*Beautiful are Andrea's cats*") vs. "*I gatti di Andrea sono belli*" ("*Andrea's cats are beautiful*").

## 7. Conclusions

In this study, the interplay of utterances' information structure and the word-class level has been inquired looking into their brain correlates through ERP measurements. Data showed that the processing of informational hierarchies is indeed sensitive to the word class selected to realize the Topic or the Focus unit of the sentence. More particularly, a fairly strong N400 effect has been observed in response to Nouns encoded as Focus as opposed to both focused verbs and topical nouns. These findings are in line with two main predictions set forth for the present research: (a) the cost associated with information structure processing follows *discourse-driven expectations* also with respect

to the word-class level, and (b), as put forth by Federmeier et al. (2002), the cognitive cost of mentally representing verbal and nominal classes is not only conditional on the evaluation of category-related features (i.e. that verbs are semantically and structurally more complex than nouns), but follows an expectation-driven path, that is, it responds to the receiver's anticipation of the information packaging properties that a word is expected to exhibit based on the discursive function it is called upon to perform.

**References**

Baker, M. (2003). Lexical categories: Verbs, nouns and adjectives. Cambridge University Press, Cambridge.

Bambini, V. (2012). Neurolinguistics. In Handbook of pragmatics. Amsterdam/Philadelphia, John Benjamins.

Bambini, V., Bertini, C., Schaeken, W., Stella, A., & Di Russo, F. (2016). Disentangling metaphor from context: an ERP study. Frontiers in psychology, 7, 559.

Bambini, V., Resta, D., & Grimaldi, M. (2014). A dataset of metaphors from the Italian literature: exploring psycholinguistic variables and the role of context. PloS one, (9).

Bañón, J.A. & Martin, C. (2019). Anticipating Information Structure: An event-related Potentials Study of focus assignments via the it-cleft. Neuropsychologia, 134, 107203.

Basar-Eroglu, C., Basar, E., Demiralp, T., & Schürmann, M. (1992). P300-response: possible psychophysiological correlates in delta and theta frequency channels. a review. International Journal of Psychophysiology, 13 (2), 161-179.

Bastiaansen, M., Mazaheri, A., & Jensen, O. (2012). Beyond ERPs: oscillatory neuronal dynamics. In The oxford handbook of event-related potential components (pp. 31-50). Oxford University Press.

Baumann, S., & Schumacher, P. B. (2012). (de-) accentuation and the processing of information status: evidence from event-related brain potentials. Language and Speech, 55 (3), 361-381.

Birch, S., & Rayner, K. (1997). Linguistic focus affects eye movements during reading. Memory & Cognition, 25 (5), 653-660.

Burkhardt, P. (2006). Inferential bridging relations reveal distinct neural mechanisms: Evidence from event-related brain potentials. Brain and Language, 98 (2), 159-168.

Burkhardt, P. (2007). The P600 reflects cost of new information in discourse memory. Neuroreport, 18 (17), 1851-1854.

Burmester, J., Spalek, K., & Wartenburger, I. (2014). Context updating during sentence comprehension: The effect of aboutness topic. Brain and language, 137, 62-76.

Cappa, S. F., & Perani, D. (2003). The neural correlates of noun and verb processing. Journal of Neurolinguistics, 16 (2-3), 183-189.

Cavalcante, F. A. (2015). The topic unit in spontaneous american english: a corpus-based study. Universidade Federal de Minas Gerais.

Chafe, W. (1976). Givenness, contrastiveness, definiteness, subjects, topics, and point of view. Subject and topic.

Cowles, H. W., Kluender, R., Kutas, M., & Polinsky, M. (2007). Violations of information structure: An electrophysiological study of answers to wh-questions. Brain and Language, 102 (3), 228-242.

Cresti, E., & Moneglia, M. (2010). Informational patterning theory and the corpus-based description of spoken language: The compositionality issue in the topic-comment pattern. Bootstrapping Information from Corpora in a Cross-Linguistic Perspective, 13-45.

Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. Proceedings of the National Academy of Sciences, 90 (11), 4957-4960.

Daneš, F. (1964). A three-level approach to syntax. Travaux linguistiques de Prague.

Daneš, F. (1967). Order of elements and sentence intonation. To Honor Roman Jakobson, 499-512.

Daneš, F. (1974). Functional sentence perspective and the organization of the text. Papers on functional sentence perspective, 106-128.

Davidson, D. J., & Indefrey, P. (2007). An inverse relation between event-related and time- frequency violation responses in sentence processing. Brain Research, 1158, 81-92.

Domaneschi, F., Canal, P., Masia, V., Lombardi Vallauri, E., & Bambini, V. (2018). N400 and P600 modulation in presupposition accommodation: The effect of different trigger types. Journal of Neurolinguistics, 45, 13-35.

Engel, A. K., & Fries, P. (2010). Beta-band oscillations signalling the status quo? Current opinion in neurobiology, 20 (2), 156-165.

Federmeier, K. D., McLennan, D. B., De Ochoa, E., & Kutas, M. (2002). The impact of semantic memory organization and sentence context information on spoken language processing by younger and older adults: An ERP study. Psychophysiology, 39 (2), 133-146.

Federmeier, K. D., Segal, J. B., Lombrozo, T., & Kutas, M. (2000). Brain responses to nouns, verbs and class-ambiguous words in context. Brain, 123 (12), 2552-2566.

Firbas, J. (1966). On defining the theme in functional sentence analysis. Travaux Linguistiques de Prague, 1, 267-280.

Firbas, J. (1987). On the delimitation of the theme in functional sentence perspective. Functionalism in linguistics, 137-156.

Frascarelli, M. & Hinterhölzl, R. (2007). Types of Topics in German and Italian. In Schwabe, K. & Winkler, S. (eds.), On Information Structure, Meaning and Form: Generalization across languages (pp. 87-116). John Benjamins, Amsterdam/Philadelphia.

Gouvea, A. C., Phillips, C., Kazanina, N. & Poeppel, D. (2010). The linguistic processes underlying the P600. *Language and Cognitive Processes*, 25(2), 149-188.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift as an erp measure of syntactic processing. Journal of Cognitive Neuroscience, 8, 337-364151-165.

Hagoort, P., & van Berkum, J. (2007). Beyond the sentence given. Philosophical Transactions of the Royal Society B: Biological Sciences, 362 (1481), 801-811.

Halliday, M. (1985). An introduction to functional grammar (Vol. 1; L. E. Arnold, Ed.).

Hoeks, J., Brouwer, H., & Holtgraves, T. (2014). Electrophysiological research on conversation and discourse. The Oxford Handbook of Language and Social Psychology, 365-386.

Hruska, C., & Alter, K. (2004). Prosody in dialogues and single sentences: How prosody can influence speech perception. Information Structure: Theoretical and Empirical Aspects, 221-226.

Hung, Y.-C., & Schumacher, P. B. (2012). Topicality matters: position-specific demands on Chinese discourse processing. Neuroscience letters, 511 (2), 59-64.

Kaan, E., & Swaab, T. Y. (2003). Repair, revision, and complexity in syntactic analysis: An electrophysiological differentiation. Journal of Cognitive Neuroscience, 15 (1), 98-110.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory perfor mance: a review and analysis. Brain Research Reviews, 29 (2-3), 169-195.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. Trends in Cognitive Sciences, 4 (12), 463-470.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). Annual Review of Psychology, 62 , 621-647.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. Science, 207 (4427), 203-205.

La Rocca, D., Masia, V., Maiorana, E., Lombardi Vallauri, E., & Campisi, P. (2016). Brain response to information structure misalignments in linguistic contexts. Neurocomputing, 199, 1-15.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics:(de) constructing the n400. Nature Reviews Neuroscience, 9 (12), 920-933.

Levelt, W., Roelofs, A., & Meyer, A. (1999). A theory of lexical access in speech production. Behavioral and Brain Sciences, 22, 1-38.

Luck, S. J., & Kappenman, E. S. (2011). The oxford handbook of event-related potential components. Oxford university press.

Masia, V., Canal, P., Ricci, I., Lombardi Vallauri, E., & Bambini, V. (2017). Presupposition of new information as a pragmatic garden path: Evidence from event-related brain potentials. Journal of Neurolinguistics, 42, 31-48.

McFarland, D., McCane, L., David, S., & Wolpaw, J., “Spatial filter selection for EEG-based communication,” Electroencephalography and Clinical Neurophysiology, vol. 103, no. 3, pp. 386–394, Sep. 1997.

Mittmann, M. M. (2012). O c-oral-brasil e o estudo da fala informal: um novo olhar sobre o tópico no português brasileiro.

Neville, H., Nicol, J., Barss, A., Forster, K., & Garrett, M. (1991). Syntactically-based sentence processing classes: Evidence from event-related brain potentials. Journal of Cognitive Neuroscience, 3, 151-165.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia, 9 (1), 97-113.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. Journal of memory and language, 31 (6), 785-806.

Piemontese, M. E. (1996). Capire e farsi capire: teorie e tecniche della scrittura controllata. Tecnodid.

Pion-Tonachini, L., Makeig, S. & Kreutz-Delgado, K. Crowd labeling latent Dirichlet allocation. Knowl Inf Syst 53, 749–765 (2017).

Pulvermüller, F., Lutzenberger, W., & Preissl, H. (1999). Nouns and verbs in the intact brain: evidence from event-related potentials and high-frequency cortical responses. Cerebral cortex, 9 (5), 497-506.

Roehm, D., Bornkessel-Schlesewsky, I., Schlesewsky, M., et al. (2007). The internal structure of the n400: Frequency characteristics of a language related ERP component. Unpublished doctoral dissertation, Nova Science Publishers Incorporated.

Schumacher, P. B. (2006). The P600 reflects cost of new information in discourse memory. *Neuroreport*, 18(17), 1851-1854.

Schumacher, P. B. & Baumann, S. (2010). Pitch accent type affects the N400 during referential processing. NeuroReport, 21(9), 618-622.

Schumacher, P. B., & Hung, Y.-C. (2012). Positional influences on information packaging: Insights from topological fields in German. Journal of Memory and Language, 67 (2), 295-310.

Smith, S. M., & Nichols, T. E. (2009). Threshold-free cluster enhancement: Addressing problems of smoothing, threshold dependence and localisation in cluster inference. Neuroimage, 44, 83–98.

Sturt, P., Sanford, A. J., Stewart, A., & Dawydiak, E. (2004). Linguistic focus and good-enough representations: An application of the change-detection paradigm. Psychonomic bulletin & review, 11 (5), 882-888.

Tan, A.A. & Molfese, D.L. (2009). ERP correlates of noun and verb processing in preschool-age children. Biological Psychology, 80(1), 46-51.

Wang, L., & Schumacher, P. B. (2013). New is not always costly: evidence from online processing of topic and contrast in Japanese. Frontiers in Psychology, 4, 363.

Weiland, H., Bambini, V., & Schumacher, P. B. (2014). The role of literal meaning in figurative language comprehension: Evidence from masked priming ERP. Frontiers in Human Neuroscience, 8, 583.

Weiss, S., & Mueller, H. M. (2003). The contribution of eeg coherence to the investigation of language. Brain and Language, 85 (2), 325-343.

Weiss, S., Mueller, H. M., Schack, B., King, J. W., Kutas, M., & Rappelsberger, P. (2005). Increased neuronal communication accompanying sentence comprehension. International Journal of Psychophysiology, 57 (2), 129-141.

Zhao, B., Dang, J., & Zhang, G. (2016). Investigation of noun-verb dissociation based on EEG source reconstruction. In Asia-pacific signal and information processing association annual summit and conference (APSIPA).