Review

Mapping sentence form onto meaning: The syntax–semantic interface

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\textbf{A R T I C L E   I N F O}

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Abbreviations:
ERP, event related brain potential
LAN, left anterior negativity
ELAN, early left anterior negativity
N400, negativity around 400 ms
P600, positivity around 600 ms

\textbf{A B S T R A C T}

The understanding of sentences involves not only the retrieval of the meaning of single words, but the identification of the relation between a verb and its arguments. The way the brain manages to process word meaning and syntactic relations during language comprehension on-line still is a matter of debate. Here we review the different views discussed in the literature and report data from crucial experiments investigating the temporal and neurotopological parameters of different information types encoded in verbs, i.e. word category information, the verb's argument structure information, the verb's selectional restriction and the morphosyntactic information encoded in the verb's inflection. The neurophysiological indices of the processes dealing with these different information types suggest an initial independence of the processing of word category information from other information types as the basis of local phrase structure building, and a later processing stage during which different information types interact. The relative ordering of the subprocesses appears to be universal, whereas the absolute timing of when during later phrases interaction takes places varies as a function of when the relevant information becomes available. Moreover, the neurophysiological indices for non-local dependency relations vary as a function of the morphological richness of the language.

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\textbf{1. Introduction}

The comprehension of language in everyday communication involves more than the retrieval of the meaning of single words. Although the latter is a necessary pre-condition for comprehension, the syntactic relation between the verb and its arguments is crucial for the understanding of the message encoded in a sentence. During normal on-line comprehension, several aspects of each upcoming element must be checked to allow the element's integration into the prior context, and, ultimately, to allow the sentence to be interpreted. The processing system needs to retrieve the syntactic and semantic information encoded in each element. As the relevant syntactic information is encountered, the system must check the element's word category (e.g., determiner, noun, verb etc.) to allow the build up of a local phrase structure. For a verb, its argument structure must be checked (e.g., transitive, intransitive) in order to know how many arguments the particular verb takes. As relevant semantic information is encountered, the processing system has to check whether the verb's arguments fulfil the selectional restrictions of the verb (e.g., animacy and other

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semantic features). Last but not least, the system has to process the morphosyntactic information encoded in the verb’s inflection in order to identify the grammatical relation between the verb and its argument (e.g., subject-verb agreement).

Different psycholinguistic theories agree that all these information types must be retrieved and used to guarantee normal comprehension, but there is still some debate over the time course of these processes and the nature of the interplay between lexical-semantic and syntactic information. The interactive approach holds that each information type interacts with each other at every point in time (Marslen-Wilson and Tyler, 1980; MacDonald et al., 1992, 1994a,b; McClelland et al., 1989; Trueswell and Tanenhaus, 1994). The serial approach maintains that local phrase structure building precedes the processing of other information types (DeVincenzi, 1991; Frazier, 1978, 1987a,b; Gorrell, 1995, 1998).

Within the serial approach, researchers have argued that the input first undergoes a syntactic analysis before lexical-semantic information is taken into account (Frazier, 1978; Frazier and Fodor, 1978). Although interaction between syntactic and lexical-semantic information is assumed to take place during a later processing stage, the initial phase is modeled to take only word category information into consideration for the basis of which an initial phrase structure is built. Overviews concerning the behavioral evidence for each of these views are given in Mitchell (1994); Tanenhaus and Trueswell (1995); Frazier and Clifton (1996) and in different articles published in the texts edited by Garfield (1987); Tanenhaus and Carlson (1989); Altmann (1990); Balota et al. (1990); Simpson (1991), Clifton et al., (1994); Hemforth and Konieczny (2000). Each different model is supported by empirical data from behavioral experiments, thus disallowing a final conclusion with respect to the ultimate cognitive architecture of sentence processing. Rather than reiterate the behavioral results in support of the one or the other view, the present article will discuss recent neurophysiological data against the background of a neurocognitive model of language processing (Friederici, 1995, 2002).

The neurocognitive model assumes an initial phase (Phase 1) during which local phrase structure building based on word category information takes places, preceding the processing of other information types during on-line sentence comprehension. Thus, word category information is needed to license further integration processes. In the next processing stage (Phase 2), further syntactic and semantic processes take place in parallel revealing the syntactic and the thematic relations as well as the semantic relations between words. The output of these parallel processes serves as the input to a final stage of integration (Phase 3) where the different information types interact to achieve a final interpretation (Friederici, 2002, compare Table 1).

The present version of the proposal assumes that the timing relation of these three processes is fixed, but that the time window for each stage can vary as a function of the particular stimulus material or language, the stimulus presentation parameters as well as the experimental paradigm and task.

Here, findings from recent event-related brain potential (ERP) studies that focused on the time course of syntactic and lexical-semantic processes in different languages and paradigms will be reviewed. We restrict our discussion to those sentence processing studies that have worked with a violation paradigm including the following different violation types: phrase structure violation, subject-verb agreement violation, verb argument violation and violation of a verb’s selectional restrictions. All of these studies center around the processing of verbs and the information encoded therein. The central role of verb information for language processing has been acknowledged by linguistic theory (Fillmore, 1968; Jackendoff, 2002) as well as psycholinguistic modeling (Mitchell, 1994; Tanenhaus et al., 1991). We will see that seemingly equivocal neurophysiological data may ‘fall into place’ once the relation between the verb and its language-specific arguments is considered.

ERP studies conducted over the past two decades have identified different ERP components which have been interpreted to relate to different functions during language comprehension. A centro-parietally distributed negativity, label N400, has been found in relation to difficulties of both semantic integration (e.g., Kutas and Hillyard, 1980; Kutas and Van Petten, 1994, Brown and Hagoort, 1993; Chwilla et al., 1995 from Hahne and Friederici, 2002) and the processing of thematic information (e.g., Friederici and Frisch, 2000; Frisch and Schlesewsky, 2001; Frisch et al., 2004). Syntactic processes have been discussed with respect to left anterior negativities (ELAN/LAN) and to late centro-parietal positivities (P600) (for overviews, see Hagoort et al., 1999; Friederici, 2002). More recently, P600 effects were also reported for the processing of semantic/thematic violation in sentence context (for an overview, see Kuperberg, 2007). The present discussion, however, will primarily focus on the syntax-related effects.

A major issue in the discussion of syntax-related effects concerns the presence and absence of ELAN/LAN effects, their latency (early vs. late), as well as their topography (left

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* Presence/absence depending on the degree to which syntactic relations are assigned on the basis of inflectional morphology in a given language.

b Within one language (e.g., German) depending on the violation realization, i.e. incorrect number of arguments or incorrect argument case marking and between languages depending on whether realized in a scrambling language (e.g., German) or in a fixed word order language (e.g., English).
lateralized vs. bilateral). The ultimate solution for the variance across different studies in the literature is not simple as the studies have used different violation types, languages and modalities. All these parameters may influence the appearance of the ELAN effects. Here we will mainly consider the parameters of violation types and languages.

Linguistic theories would predict differences between violations of word category information, relevant for the local phrase structure, and subject–verb agreement violation, relevant for the structural dependency between the NPs (arguments) and the verb in a sentence. While processes concerning violations of word category may be similar across languages, processes involved in subject–verb agreement may differ as a function of language because languages differ in how much the assignment of grammatical roles depends on morphology, i.e. person, number and case marking. We will take up these two issues and the relevant ERP data in turn.

2. Computing local phrase structure

The computation of a local phrase is based on word category information retrieved from the word as it is available. A number of ERP studies investigating word category violations have reported an ELAN in different languages (for English, see Neville et al. (1991) for ‘Max’s of proof/Max’s proof; Münte et al. (1993) for ‘your write/you write; Kubota et al. (2004) for 7a ‘I believe him is a spy/I believe he is a spy). In German, ELAN effects were reported in studies investigating word category violations in sentences containing prepositional phrases requiring a noun for their completion, but in which a verb was presented instead for example ‘die Pizza wurde im gegessen/the pizza was in-the eaten/die Pizza wurde gegessen/the pizza was eaten (Friederici et al., 1993; Hahne and Friederici, 1999, 2002 in EEG studies and in MEG studies Knösche et al., 1999; Friederici et al., 2000). The syntax-related negativity was present early, i.e. about 150 ms post word onset when word category information was signaled by the prefix (see references above), but late with respect to word onset when word category was provided by the suffix (Friederici et al., 1996, 2004; Hagoort et al., 2003). This means that the effect was early with respect to the word category decision point. The studies seem to show an early left anterior negativity, i.e. an ELAN, when time-locked to the word category decision point.

The word category decision point is also relevant in the interpretation of the results from experiments conducted by Van den Brink and Hagoort (2004). In their study, Dutch sentence material was used in which the word category verb was signaled by a suffix -de as in kliedered/messd. As the first part of the crucial word klieder/mess can be read as a noun, one would predict that the word klieder -de in a noun context only elicits a left anterior negativity after the onset of the suffix -de. And this is exactly what was found.

An ELAN was also found for word category violations in non-Indo-European languages, e.g., in so-called BA constructions in Chinese, which requires that the following element be a noun instead of a verb, in sentences such as ‘the stylist BA cut/ the stylist BA the cloth cut (Ye et al., 2006). The ELAN has also been found for word category violations in Japanese sentence processing (Mueller et al., 2005).

Interestingly, those studies in English and Dutch that have not found an ELAN used syntactically legal but less frequent syntactic structures and not outright violations (e.g., in Dutch, Hagoort et al., 1993). Ainsworth-Darnell et al. (1998) report an absence of an ELAN for the following sentences: Jill entrusted the recipe to friends before.../Jill entrusted the recipe friends before, at their critical word friends. The absence of an ELAN, however, is not surprising as the word friends is a possible grammatically correct continuation in a sentence: Jill entrusted the recipe friends like most. This means that a noun after the first sentence part is correct under certain conditions; therefore, no ELAN is observed.

From the combined studies, we may conclude that an ELAN is observed whenever an incoming item’s word category violates the local syntactic prediction and that the latency as measured from the word onset varies, but is always early when measured from the word category decision point.

The data at hand are in support of a model that predicts ELAN effects as a reflection of an initial phase of local phrase structure building. More recently, there are data suggesting that the amplitude of the ELAN may vary depending on whether ungrammaticality can be decided on the basis of the immediately preceding context alone or whether non-local preceding context has to be taken into account (Lau et al., 2006).

3. Computing dependency relations

3.1. Processing inflectional morphology of verbs

When retrieving meaning from sentences, the information encoded in the verb inflection, in particular, the information of number and person, is most relevant and in some languages it is essential for the assignment of grammatical roles (subject vs. object) in sentences. While in languages with a fixed word order this information may be unnecessary for the sentence’s interpretation, it is crucial for languages with free word order. Although Osterhout and Mobley (1995) found a LAN in a subject–verb disagreement in English, a language with a fixed word order, in simple declarative sentences, subject–verb agreement errors (plural vs. singular) often do not elicit a LAN (Kutas and Hillyard, 1983). On the other hand, languages in which grammatical relations more heavily rely on morphosyntactic information, LAN effects can be observed (Penke et al., 1997; Angrilli et al., 2002; Silva-Pereyra and Carreiras, 2006).

Across different languages, a variety of morphosyntactic violation types have been investigated. Two violation types
have been examined in at least more than one language, namely subject–verb agreement and determiner–noun agreement. Those studies that focused on gender agreement between nouns and their corresponding determiner or their adjective do not always report LAN effects. It may not be surprising that gender agreement violations elicit less stable ERP effects because gender information is part of the lexical entry and in some languages is phonologically constrained by the lexical form of the noun (in Spanish) while in others this is largely not the case (in French). In Spanish, LANs (Carreiras et al., 2004) or P600s (Barber et al., 2004) were observed, whereas in Dutch (Hagoort and Brown, 1999; Van Berkum et al., 2000) and in French (Foucart and French-Mestre, 2004) P600s were found.

For subject–verb agreement violations, stable ERP effects across different languages with strong inflectional morphology have been reported. Violations of number agreement between subject–noun and verb elicited a LAN in German (Penke et al., 1997) and in Italian (Angrilli et al., 2002; DeVincenzi et al., 2003). In another German study in which no LAN effect was found (Münte et al., 1997), the crucial sentences did not contain outright violations but were obscured by a lexical ambiguity of the subject pronoun (Sie which is ambiguous in number she/they). Therefore, these findings do not challenge the argument that, in languages in which inflectional morphology (i.e. subject–verb agreement) is relevant for the assignment of grammatical roles, a LAN is observed. The latter view is corroborated by a study conducted in Hebrew, a language with noun–verb agreement in which noun gender agreement is relevant for the assignment of grammatical roles (Deutsch and Bentin, 2001). In this study, as expected based on relevance of this information for grammatical role assignment, a clear LAN effect was found for gender agreement violation between the noun and the verb.

Thus, LAN effects appear observable in languages in which the identification of grammatical relations depends upon the subject–verb agreement as signaled either by number, person and/or gender features.

3.2. Processing information of argument nouns

The grammatical relations between a verb and its arguments in languages with free word order, such as German or Japanese, are not only marked by the verb’s inflection but moreover by the noun phrase’s inflection in the form of case marking.

When reviewing the relevant literature, it seems that violations of the verb’s argument structure and its arguments either lead to a LAN or to an N400 depending on the language, and within a given language depending on the type of violation between the verb and its arguments in a sentence. When considering a verb’s argument structure, it is important to recognize that there are two ways it can be violated. A violation can be realized as a mismatch between the number of available arguments and those required by the verb or as a mismatch between the case marking of a given argument and that required by the verb.

For German verb argument structure violations, such as Der Mann wurde geowied/The man was cried, in which an intransitive verb was presented in a passive structure requiring a transitive verb, a LAN was seen at the verb (Rösler et al., 1993). A LAN/P600 was found at the sentence’s final verb when the case of the actual object-argument (accusative) violated the verb’s argument structure (requiring a dative marked object argument), but an N400/P600 pattern was found when thematic assignment was impossible due to a mismatch between the already encountered number of arguments (three) and the number of arguments required by the verb (two) (Friederici and Frisch, 2000). These different patterns were taken to reflect different aspects of verb argument structure. The N400/P600 pattern, in particular, was related to the fact that given the mismatch between the already perceived number of arguments (three) and the number of arguments the verb allowed (two) not only the grammatical roles, but also the thematic/semantic roles of the arguments could not be assigned. In a German study in which the two arguments of a verb carried nominative case (Frisch and Schlesewsky 2001), rendering the assignment of thematic roles impossible, an N400 followed by a P600 was also observed.

In English, a language with fixed word order, case marking violations such as The plane took we to paradise/The plane took us to paradise in which there is a mismatch between the case of the pronoun we, i.e. nominative, reserved to subjects, and its postverbal position which in a non-interrogative clause is reserved for objects, and object case, elicited a LAN (Coulson et al., 1998). Notice that in German, a free word order language, a P600 was found for a double subject structure (Frisch and Schlesewsky, 2001).

A recent model by Schlesewsky and Bornkessel (2004) pays credit to these findings in that it assumes two parallel processing routes during Phase 2 of language processing: a thematic route which considers case and when marked unambiguously can map thematic roles directly and a syntactic route which is used for ambiguously marked arguments considering syntactic information (e.g., word order or subject–verb agreement) instead. This latter route is generally used for languages without case marking.

3.3. Processing verbs’ selectional restriction information

The processing of the selectional restriction violation of verbs has been studied in numerous studies across different languages. The violation of a verb’s selectional restriction elicits an N400 effect (e.g., Friederici et al., 1993). Because the N400 as a reflex of a semantic mismatch between the verb and
its arguments is well established in the literature, we will take this as a given for the further discussion (Kutas and Hillyard, 1983; Kutas and Federmeier, 2000). Most recently, it was shown that the amplitude of the N400 varies systematically as a function of the number of semantic features violating the relation between the verb and its object (Li et al., in press).

3.4. Assigning thematic and semantic relations

The neurocognitive model presented in the introduction (Friederici, 2002; Friederici and Kotz, 2003) assumes that word category based processes (Phase 1) precede processes assigning semantic relations and thematic relations (Phase 2). In this model, these two latter processes are assumed to be realized in two parallel processing streams, one dealing with semantic relations, such as selectional restrictions, and one dealing with thematic role assignment on the basis of morphosyntactic information, such as the verb’s inflection (subject–verb agreement) and the noun’s case (case marking of the verb’s arguments).

The assumption of two parallel working processing streams during Phase 2 is based on data from experiments which varied both semantic and syntactic factors during sentence processing. Independence of the two factors was found in a study by Gunter et al. (2000), but an interaction was reported by Hagoort (2003). Thus, the data available do not unequivocally support the notion of parallel, independent processing streams during Phase 2. It appears that under certain conditions the two processing streams may interact. A crucial difference between those studies supporting interactive processes and those supporting parallel processes again may be the type of violation investigated. Hagoort (2003) examined semantic and syntactic violations within a noun phrase, i.e. between the determiner’s gender (the, neuter gender) and the noun’s gender (umbrella, common gender) on the one hand and between the adjective (honest) and the noun (umbrella) on the other, and observed an N400 effect for the pure semantic violation which was increased by the additional gender violation. This interaction effect may be due to the fact that gender information is lexically based and thus not totally independent of lexical–semantic processes. Gunter et al. (2000) manipulated anomalies across phrases in German and evoked a violation that included gender and case information. In doing so, they observed a LAN for the syntactic violation (*die bereiste den Land/she travels the (masculine) Land (neuter)/die bereiste das (neuter) Land (neuter)) and an N400 for the semantic anomaly between the noun and the prior verb (*die befährt das Land/she drives-through the land) and found no interaction in this time window, but a LAN plus an N400 for the combined violation followed by a P600 whose amplitude varied as a function of both the syntactic and the semantic anomaly (*die befährt den Land/she drives-through the (masculine) land (neuter)) (Gunter et al., 2000). Thus, in this study, an interaction was found for the P600, that is in Phase 3 of the neurocognitive model.

For English, Kuperberg et al. (2003, 2005) also provide compelling evidence that the P600 is modulated both by syntactic and semantic information. These latter studies also varied the crucial information types for elements across phrases. It is possible that the two processing streams assumed for Phase 2 work indeed in parallel, and that semantic and syntactic factors mainly interact during Phase 3 when integrating syntactic and semantic representations.

4. Word category information meets other information types

The model presented in the beginning (Friederici, 1995, 2002; Friederici and Kotz, 2003) and sketched out in Table 1 makes clear predictions with respect to the independence of initial phrase structure building from processes dealing with semantic information, with verb argument structure and with subject–verb agreement. In the following section, evidence for this prediction will be reviewed.

4.1. Word category and semantic information

The most straightforward issue, given the discussion above, may be the possible interplay of word category information and semantic information.

Studies in German revealed that combined word category and selectional restriction violations lead to an ERP pattern similar to that seen for syntactic violations only, namely an ELAN/P600 pattern (Hahne and Friederici, 2002; Friederici et al., 2004) under a grammaticality judgment task. When subjects were required to ignore the syntactic violation and to judge for semantic coherence, an early syntactic negativity and an N400 were found (Hahne and Friederici, 2002). These results indicate that the processing of word category information is independent of semantic information, but that word category information can influence semantic processes. It appears that, during normal on-line processing, semantic integration does not take place for words which are not syntactically licensed (have wrong word category) independent of whether the word category information is available before semantic information (in the word’s prefix) (Hahne and Friederici, 2002) or after the semantic information (in the word’s suffix) (Friederici et al., 2004). Semantic integration can be forced by instruction, but early syntactic processes cannot be altered by instruction (Hahne and Friederici, 2002).

A study in Chinese, a language with little morphosyntactic elements but with a high number of lexical elements which are ambiguous both with respect to meaning and word category, also investigated combined violations of word category and semantic relations (Ye et al., 2006). Even in Chinese, a language in which disambiguation is mainly carried out by contextual semantics, word category information processes appeared prior to and independent of semantic processes. Word category information, however, was found to interact with word meaning already between 250 and 400 ms, which is earlier than observed in other languages. It was speculated that this early interaction may be due to the fact that Chinese has a large number of ambiguous words and semantic information often is the only information that allows disambiguation and that, therefore, semantic information is used early during on-line speech comprehension. Thus, the relative timing of
processes of Phase 1 and Phase 2 appears to be universal across languages of different types, although the absolute time course can vary as a function of language type.

4.2. Word category and verb argument structure

The possible interplay between word category information based processes and verb argument structure information was investigated in the visual and auditory modality in German (Frisch et al., 2004). Word category violations (*Im Garten wurde am gearbeitet/in the garden was on-the worked*) in the auditory domain elicited an ELAN/P600 and in the visual domain a P600, whereas argument structure violations (*Der Garten wurde oft gearbeitet/the garden was often worked*) evoked an N400/P600 in both domains. When the two violation types were combined, no N400, but an ELAN/P600, was observed. This again provides support for the assumption that Phase 1 processes are independent of Phase 2 processes, but that Phase 2 processes can be influenced by Phase 1, such that lexical integration of an element into the context depends on being syntactically licensed.

4.3. Word category and subject-verb agreement

Another study in German examined the possible interplay between word category information and morphosyntactic information signaling subject-verb agreement (Rossi et al., 2005). The critical word in the sentence either had the incorrect word category (a verb in context obligatorily requiring a noun), an incorrect inflection (2. Person Singular) in a context obligatorily requiring another person (3. Person Singular) or both. Agreement violations elicited a LAN (450–650 ms) followed by a P600. Both the word category violation and the word category/agreement combined violation evoked an ELAN (100–200 ms) followed by a P600. The absence of the LAN effect in the combined condition can be taken as evidence for a functional primacy of phrase structure building processes based on word category information (Phase 1) over agreement processes (Phase 2).

These findings support the idea that initial structure building processes of Phase 1 of the neurocognitive model are independent from the subsequent Phase 2 during which dependency relations are computed.

5. Discussion

The extraction of meaning from a sentence requires the assignment of grammatical relations between the verb and its arguments. When considering the underlying processes of meaning extraction on-line, we can identify a number of processing steps reflected in different ERP components. Although the data available in the literature on the processing of verb-related semantic and syntactic information during sentence comprehension appear to be more complex than initially thought, a certain systematicity in the data emerges once different syntactic information types and language types are taken into account.

Word category information is relevant for initial phrase structure building (Phase 1). The computation of local phrase structure, such as noun phrase, verb phrase and prepositional phase, is handled by the parser prior to and independent of other information types (for an exception, see Eckstein and Friederici, 2006). This process of initial phrase structure building is based on word category information. As word category information becomes available, the parser builds a local structure (e.g., upon encountering a preposition a prepositional phrase is opened). That is, on the basis of the subcategorization properties of the preposition which determine that only nominal lexical elements, e.g., nouns, pronouns, determiners or adjectives, but not verbal elements, e.g., verbs or adverbs, can immediately follow the preposition, the parser can now make predictions with respect to the syntactic category of the upcoming element. The detection of a mismatch between the phrase structure-based prediction for the word category of the upcoming word and the upcoming word’s actual word category is reflected by the ELAN at the word category decision point. The ERP component is called ELAN as it is an early left anterior negativity which is early with respect to the point at which the word category information becomes available (i.e. in the suffix or the word stem). The topography of this component seems to be more anterior and more left lateralized as a function of modality, with a more anterior (bilateral) distribution in the auditory domain and more left (anterior/temporal) distribution in the visual domain. Further research must determine whether the proposed parameter for the topographic variance of the ELAN holds. Dipole modeling indicates that the ELAN component is generated by four dipoles, two in the left and right inferior frontal gyri (with a stronger dipole in the left hemisphere) and two dipoles in the anterior portion of the superior temporal gyrus (with a stronger dipole in the left hemisphere) (Friederici et al., 2000). Brain imaging studies evaluating local phrase structure violations in German indicate an involvement of the anterior superior temporal gyrus and the frontal operculum in the inferior frontal gyrus as the neural network supporting local phrase structure building (Friederici et al., 2003; for a specification of this network at the level of structural connectivity, see Friederici et al., 2006).

Other information types relevant to computed dependencies across phrases are processed in Phase 2. These are information for the assignment of the grammatical and thematic roles such as subject-verb agreement, case of the verb’s arguments and the verb’s argument structure itself as well as semantic information. The syntactic and the semantic processing streams dealing with the relation between phrases appear to be independent. This independence does not necessarily hold for within-phrase dependencies, e.g., in a noun phrase where lexically encoded gender information and lexical-semantic information meet. Subject-verb agreement violations are mostly found to elicit a LAN, independent of whether agreement is based on person (in German), on number (in German and Italian) or on gender information (in Hebrew). As different languages use different cues to assign grammatical roles, either relying on a noun phrase’s position in the sentence (in English) or on morphosyntactic information at the noun and/or the verb (in scrambling languages such as German or Japanese), it may not be surprising that
ERP findings concerning syntactic role assignment vary between different languages and/or language types.

Phase 3 is conceptualized as a phase during which syntactic and lexical–semantic information processed during the earlier phases is integrated. The phase is reflected in the P600 which varies not only as a function of syntactic complexity (Kaan et al., 2000) and syntactic anomaly (Osterhout and Holcomb, 1993; Friederici et al., 2002), but also as a function of semantic factors (Gunter et al., 2000). This suggests that the different information types do interact during this processing stage. The left posterior superior temporal gyrus and its right homologue have been suggested as brain regions supporting these processes (Grodzinsky and Friederici, 2006). Further research, however, is needed to substantiate this suggestion.

The mapping of a sentence’s form onto grammatical function, and thereby to its meaning, appears to vary from language to language depending on the degree to which the assignment of grammatical roles relies on morphology. Languages which heavily rely on morphological cues are more likely to show a LAN than languages that do not. However, the reported ELAN effects indicate that the basic process which outputs the structure of phrases onto which dependencies between phrases are built appears to be quite similar across languages—at least those investigated up to now.

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