Revista de Estudos da Linguagem, Belo Horizonte, v.25, n.3, p.1537-1566, 2017

The ERP technique in children's sentence processing: a review

A técnica de ERP no processamento de sentenças de crianças: uma revisão

Marília Uchôa Cavalcanti Lott de Moraes Costa
Universidade Federal do Rio de Janeiro, Rio de Janeiro, Rio de Janeiro / Brasil
marilia@letras.ufrj.br

Resumo: A medição da ativação cerebral por meio da técnica de potenciais relacionados a eventos (ERP) tem sido valiosa para lançar luz sobre diversas cognições humanas. A linguagem é uma das cognições que têm sido estudadas com essa técnica de grande resolução temporal entre o estímulo apresentado e a ativação observada decorrente desse estímulo. A área de aquisição da linguagem tem se beneficiado especialmente dessa técnica, dado que é possível investigar relações entre dados linguísticos e a ativação cerebral sem a necessidade de uma resposta explícita, como apertar um botão ou apontar para uma imagem. O objetivo deste artigo é apresentar o estado da arte sobre o processamento de frases em crianças utilizando a técnica de ERP.

Palavras-chave: ERP/EEG; processamento de frases; aquisição da linguagem; N400; P600.

Abstract: The measurement of brain activation through the technique of event related potentials (ERP) has been valuable in shedding light on various human cognitions. Language is one of those cognitions that has been studied using this technique, which allows for a more accurate temporal resolution between the stimulus presented and the time in which we observe an activation resulting from this stimulus. The area of

eISSN: 2237-2083
DOI: 10.17851/2237-2083.25.3.1537-1566

language acquisition has especially benefited from this technique since it is possible to investigate relationships between linguistic data and brain activation without the need for an explicit response. The purpose of this article is to present the state of the art in children's sentence processing captured by the ERP technique.

Keywords: EEG/ERP; sentence processing; language acquisition; N400; P600.

Received on December 10, 2016.

Accepted on April 4, 2016.

The purpose of this article is to review the literature that measures on event-related potentials captured by an electroencephalogram (EEG/ERP) in the field of sentence processing in children. This technique has been used by different laboratories to capture different modes of brain activation related to cognitive tasks and has already shown important results. This article intends to demonstrate results showing that 18-month-olds are sensitive to word category of words and 24 month-olds are able to distinguish poorly formed sentences from those that are well formed in the language they are acquiring. Studies with children up to 4 years of age are presented in this work, establishing the vast linguistic competence of children in this age group. This article also presents the ERP technique and the main components found in adults, making it possible to perceive the differences and similarities between adult and child processing. This review aims to contribute to the language acquisition and neuroscience of language fields by bringing the state of the art in these two areas to the Brazilian public.

First, it is important to acquaint the reader with the EEG-ERP technique. Electroencephalography (EEG) is an imaging technique that measures the electrical activity generated by brain structures (TEPLAN, 2002) on the surface of the scalp. Scalp voltages directly reflect neuronal activity. This refers to the continuously recorded electrical activity from the surface of the scalp after being picked up by metal electrodes. It is the oldest imaging technique. Hans Berger reported the first recording in 1929 (see Luck, 2005, for a historical background on this technique).

EEG has a millisecond temporal resolution and is a non-invasive procedure that can be used in both adults and children. It is relatively inexpensive when compared to other systems, such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), hemodynamic methods, or magneto-encephalogram (MEG), and does not require specialized medical personnel. Another important aspect when comparing the EEG with hemodynamic methods is that, unlike the latter, the EEG testing environment is silent, which is ideal for language studies that use auditory stimuli.

EEG has a lower spatial resolution, since electric signals are generated inside the skull and cross several barriers, such as different types of brain tissue and cellular barriers, until they reach the scalp. The electrical activity ricochet until reaching the surface, meaning the activation captured in the scalp and the place where it was generated are not analogous, i.e., the source of the electrical activity is not normally located directly beneath the electrode where the measurement is being taken.

The neuronal responses associated with sensory, linguistic, and motor events are embedded in the continuous signal recorded by the EEG – as well as unrelated neural activity and noise (Teplan, 2002). The event-related potentials technique is used to analyze the electrical responses corresponding to a specific event (JOHNSON, 2001; LUCK, 2005). This technique consists of averaging of the brain activity from a series of trials (the item of an experiment) that corresponds to the same experimental condition. This allows researchers to eliminate noise and neuronal activities unrelated to the experiment.[1] When calculating the mean of the signal, it is assumed that the signal of interest occurs consistently throughout the trials, while the noise is random (LUCK, 2005).

However, to ensure the exclusion of only unwanted noise and not the relevant signal, a large number of experimental items are needed to calculate the mean, known as the signal-to-noise ratio (SNR). The higher the signal, the lower the influence of noise. This means that to obtain a

[1] For ease of reading, any activation unrelated to the experiment will be called noise.

reliable ERP waveform in a standard language experiment, the average must be made with at least 20-30 different tokens within the experimental condition. Thus, when one discusses an ERP effect on a specific word in a particular condition, this means the average of the electrophysiological activity in different tokens of the same type (BROWN; HAGOORT; KUTAS, 2000).

The ERP method can directly identify the potential related to the processing of a stimulus. It is widely used in language acquisition studies (OBERECKER *et al*., 2005; OBERECKER; FRIEDERICI, 2006; SILVA-PEREYRA *et al*., 2005a, 2005b; SILVA-PEREYRA *et al*., 2007; BERNAL *et al*., 2010; BRUSINI *et al*., 2016a, 2016b; COSTA, 2015) and language processing in general (KUTAS *et al*., 1980; FRANÇA *et al*., 2004; GOMES; FRANÇA, 2013; GOMES, 2014; GOMES; FRANÇA, 2015). Another advantage of ERPs is that there is no need for participants to perform a task – which makes this technology more attractive to younger populations, who can participate in language studies without receiving instructions (CONBOY *et al*., 2008). In most ERP studies, volunteers are instructed to perform a task simply to keep them alert, but brain activity can be captured without any specific task.

After decades of study, some electrical components have been frequently observed – N170, ELAN, N400, P300, P600 – when participants process specific stimuli (such as speech, faces, etc.). Today, these are considered markers for certain types of processing carried out in the brain. There are restrictions to qualifying a specific brain activity found by an experimental paradigm as an already well-known electrical component. For example, there are well-defined criteria for a given brain activation to be characterized as an N400 or P600. The population of neurons involved in the identified activity needs to be large enough and its activity needs to be synchronized and coherent over a sufficiently long time-window; in this example, the minimum duration would be 200ms. The definition of a potential consists of three dimensions of the recorded activity:

1. Latency (ms): the time at which a potential begins, develops, and disappears;

2. Spatial distribution: the arrangement of the electrodes that exhibit the effect;

3. Voltage: the polarity of the effect (positive or negative).

These components are commonly named taking into account their polarity (N or P) and the number of milliseconds during which the maximum effect is typically observed (e.g.: N400, P600).

The literature on linguistic aspects in the brain already has a considerable number of studies, and there are many hypotheses about how linguistic processes work . Poeppel and Embick (2005) and Marantz (2005) express the difficulties and importance of the intersection between Linguistics and Neuroscience (POEPPEL; EMBICK, 2005; MARANTZ, 2005). Poeppel and Embick draw attention to important challenges that they name as *incompatibility of granularity* and *ontological incommensurability*. The first concept is related to the fact that there is incongruity between the representational elements of the two disciplines. In general, linguistics works with well-detailed elements, distinctive features, morpheme, phrases, among others, whereas in neuroscientific approaches, the terms are seen more broadly, dendrites, neurons, cortical columns. The second concept is related to the fact that these elements of linguistic theories cannot be directly compared with the units observed by Neuroscience. The authors point out that these problems are not specific to language, but are "interface problems" common to cognition studies" (POEPPEL; EMBICK, 2005).

Although the possibility of discovering the mechanisms underlying linguistic processing is exciting, elements that elicit or affect some ERP component are not equal to a neurocognitive function. For the time being, the most direct way to observe an ERP result is to present highly controlled events that differ in only one variable and compare them among many participants. If a difference is found, it must be because the stimuli have some property that the participants' brains "could differentiate."

Each study postulates an explanation that fits the data and possibly a theory, but it is only after a number of similar results that we will be able to better understand what elements described in ERP literature as being distinct components mean with respect to the underlying mechanisms. With each new study, more is understood about language, the brain, and the technique. Many years after the first ERP study in language, the debate is still open as to what the various ERP components found in language mean for language and how to integrate those studies with the massive body of existing work on psycholinguistics to reach the best models on language processing. As Pylkkänen and colleagues state:

> In this endeavor, a cognitive model is crucial as without it, the cognitive neuroscientist does not know what to look for in the brain, what the nature of the relevant representations might be, or how the different components of a process might interact with each other." (PYLKKÄNEN; BRENNAN; BEMIS, 2011)

Components commonly found in sentence processing experiments in adults

Much has already been learned about the fact that linguistic anomalies at the semantic, morphological, and syntactic levels elicit a series of ERP responses with different characteristics. Studies with syntactic and morphological anomalies, for example, have demonstrated qualitatively different ERP responses to different types of violations. These types of components are reviewed below.

As already mentioned, ERP components are usually named according to their polarity and latency. However, some components can be named in respect to topography. LAN (Left Anterior Negativity) and ELAN (Early Left Anterior Negativity) are two examples in the language field. The two waveforms appear early and, according to the literature, are elicited by syntactic violations. As the name suggests, LAN and ELAN are negative waveforms captured to the left in the anterior areas of the brain. Analyzed as being identical, the two waveforms differ only in their latency. The ELAN is very precocious and appears between 150 and 200 milliseconds after the beginning of the critical element, whereas the

LAN develops between 300 and 500 milliseconds. Studies have reported that LAN and ELAN contrasted neutral sentences, i.e. grammatical, with sentences containing syntactic violations: morphosyntax was not appropriate (agreement or repeated case marker) or sentences containing a combination of inappropriate words (e.g., a word or group of words appeared in a context in which words of a different syntactic category were expected – HAGOORT; LEVELT, 2009; HWANG; STEINHAUER, 2011).

O N400

In the late 1970s, Martha Kutas and Steven Hillyard investigated the influence of the sentential context on word recognition. They initially thought that manipulating the degree of predictability at the end of sentences would lead them to observe the P3 component, which is usually related to the probability of a certain stimulus appearing. The authors manipulated the end of sentences, ranging from congruent to uninterruptable, but, instead of a positive anterior form, they found a negative form. In fact, the only manipulation that triggered a P3 was the use of congruent endings, but with different fonts,capital letters, in the last word. This new waveform was called the N400 because of its polarity and the fact that its peak is observed around 400ms (KUTAS; HILLYARD, 1980). In 1980, the first article on N400 was published. A couple of examples of this work were *"I like my coffee with cream and sugar."* versus *"I like my coffee with cream and socks."*[2] The second type of sentence would lead to a negative waveform 400 ms after the critical element, which in this case is the final word (sugar or socks). This seminal work was conducted with visual stimuli, written words. At that time, the authors interpreted the waveform as a result of a semantic violation. A large number of papers replicated this effect by extending the findings to other modalities (HOLCOMB; COFFEY; NEVILLE, 1992) and other linguistic contexts, including pairs of words and broader discursive contexts, as well as sentences (OSTERHOUT; HOLCOMB, 1992; BERKUM; HAGOORT; BROWN, 1999; FRANÇA, 2002; FRANÇA *et al*., 2004; HÄNEL-FAULHABER *et al*., 2014).

Today, the N400 is described as a wide negative deflection of the ERP that begins 200-300 ms after a word or in the case of sign languages the case of sign languages, presented auditorily or visually and peaks after approximately 400ms in the centro-parietal electrodes (cf. KUTAS; FEDERMEIER, 2011; LAU; PHILLIPS; POEPPEL, 2008). Researchers have observed the N400 in a variety of tasks, ranging from word priming and message-level processing to the role of attention and awareness in language comprehension, activation differences between hemispheres activated by semantic memory, and vocabulary building when learning a language (OSTERHOUT; MCLAUGHLIN, 2006; KOTZ; HOLCOMB; OSTERHOUT, 2008). It has also been used to compare differences between populations, e.g., young people vs. the elderly, healthy vs. schizophrenic patients (KUPERBERG *et al*., 2006).

> In general then, the N400 is thought to reflect the degree of ease or difficulty in retrieving stored knowledge associated with a potentially meaningful item from semantic memory, contingent upon both the characteristics of the stored item itself, as well as the contextual cues available. (KUTAS; DELONG, 2008, p. 157).

Although an N400 response is mostly associated with semantic anomaly, it has also been elicited by most significant stimuli – spoken, written or signed words; pronounceable non-words; and known acronyms, but also for non-human sounds, faces, gestures, and scenes. Ever since the first waveform was reported, researchers have attempted to explain the underlying mechanisms related to the N400. The component has been studied from different angles and fields of investigation; however, there are still many aspects that are still not fully understood today. According to Kutas and Federmeier (2011), a crucial point in the literature on N400 is the compelling panorama of how perception, attention, memory, and language work together in the neuronal events responsible for the N400 (KUTAS; FEDERMEIER, 2011). Although not exclusively elicited in language processing studies, N400 is a tool to investigate issues related to the temporal course of language processing. One point is still under debate: exactly which process(es) does (do) the component reflect?

P600

P600 was first described in 1992 by Osterhout and Holcomb. It is a positive-going waveform that presents its maximum amplitude at around 600 ms after the critical stimulus and is elicited in both visual and auditory modalities. It typically activates centro-parietal electrodes, but some studies have reported this component in frontal electrodes (FRIEDERICI, 2002). P600 is also called Syntactic Positive Shift (SPS) because of its positive nature and the fact that it is elicited by syntactic stimuli (OSTERHOUT; HOLCOMB, 1992; FRIEDERICI; PFEIFER; HAHNE, 1993; HAGOORT; BROWN; GROOTHUSEN, 1993; OSTERHOUT; HOLCOMB; SWINNEY, 1994; GOMES; FRANÇA, 2013; GOMES, 2014; GOMES; FRANÇA, 2015).

Originally, the P600 was interpreted as reflecting of syntactic processes. It was observed in response to different syntactic violations, including violations in phrase structures (OSTERHOUT; HOLCOMB, 1992; HAGOORT; BROWN; GROOTHUSEN, 1993); subcategorization violations (OSTERHOUT; HOLCOMB, 1992; OSTERHOUT; HOLCOMB; SWINNEY, 1994); violations of number, tense, gender, and case agreement (COULSON, KING, KUTAS, 1998, NEVINS *et al*., 2007); and violations of constraints on long-distance dependence (PHILLIPS; KAZANINA; ABADA, 2005). Because of the variety of circumstances in which the P600 had been observed, it was interpreted as reflecting syntactic repair (OSTERHOUT; HOLCOMB, 1992; FRIEDERICI, 1995) and structural reanalysis, or syntactic integration (GIBSON, 1998; KAN *et al*., 2000, HERTEN, KOLK, CHWILLA, 2005). However, in the past ten years, the interpretation that P600 is specifically related to syntactic processing has been questioned (KUPERBERG; SITNIKOVA, 2003; KOLK *et al*., 2003; KIM; OSTERHOUT, 2005). P600 is already being discussed as a component that can reflect both the syntactic and semantic components (BORNKESSEL-SCHLESEWSKY; SCHLESEWSKY, 2008; HOEKS; STOWE; DOEDENS, 2004; KUPERBERG, 2007).

Gouvea *et al*. (2010) studied all commonly described “P600 stimuli” in order to have a better understanding of the nature of this waveform. They used a within-subject experimental design with the maximum of similar stimuli for three types of structural configurations that had been discussed in the literature as “P600 elicitors” –

ungrammatical sentences, garden paths, and completion of long-distance dependencies. The result was that the topography for syntactic garden paths, grammaticality violations, and the completion of long-distance dependencies was quite similar, but the wh-dependency had a different distribution, initially more anterior. The wh-dependency elicited a P600 of smaller amplitude, and in garden path sentences and ungrammatical condition researchers found an additional negativity and "the posterior P600 had a later onset latency in the ungrammatical conditions (500-700 ms) than in the garden path condition (300-500 ms)" (GOUVEA *et al*., 2010).

Gouvea *et al*. (2010) suggest that the P600 may reflect a common set of processes that begin as soon as sufficient information has been accumulated to initiate them. From this point of view, even when the P600 occurs in distinct latencies, it still reflects the same underlying processes; the latency difference would more or less reflect the time needed to complete the processes that trigger the P600.

Since positivity that peaks at 600 ms is caused by different types of stimuli, it naturally raises the question of whether it reflects a single underlying mechanism or several different processes. For the time being, some researchers have discussed possible ways to explain the P600 as reflecting differences in the computations performed by a single underlying process, but it may still be possible that small differences in topography, voltage, and peak time are indices of different underlying mechanisms.

ERP language studies on sentence processing in young children

Few ERP studies have tested sentence processing in children for several reasons: (i) movement artifacts, (ii) difficulty in placing the EEG/electrodes cap, (iii) participation of parents or caretakers, and (iv) duration of the experiments and difficulty in finding attractive stimuli. As explained earlier, one of the main difficulties for quality recording is movement. Adult participants are requested not to move and refrain from blinking during critical parts of the test. In contrast, a young child cannot be asked to be quiet, especially when they are between 14 and 36 months old – the exact age when the beginning of sentence processing needs to be studied. It is very tiring for them to remain still for a long time. The last barrier is the duration of the experiments: although EEG is the optimal technique for studying children, as it is silent and children do not have to give open answers, ERP requires averaging of multiple trials in each condition, which generally makes the experiments too long for children (20-30 minutes). If a child does not participate in the experiment for a sufficient amount of time, the number of trials will be too low to obtain stable averages. To encourage children to stay in the experiment long enough, the stimuli need to be very appealing to them. All of these barriers may explain why there are so few studies with young children in the ERP literature.

A final difficulty with children is that a developing brain does not have the same properties as a fully developed brain (PUJOL *et al*., 2006). It is not uncommon for children's ERP components to be different temporally, topographically, or in terms of polarity. Therefore, it is difficult to use the knowledge we have on adult literature to extrapolate what is to be found in young populations (COCH, MITRA, GEORGE, 2012). Differences may occur in latency, duration, and amplitude.

Although there are many obstacles in ERP developmental research, there are still some groups around the world that carry out this endeavor. We find ERP studies in different cognitive domains and age groups (KOVELMAN, 2012). In the study of language, most studies are done in English, French, or German. There are also many studies in prosody and phonology (MILLS *et al*., 2004). Evidence shows that children can discriminate between sound categories, stress patterns (FRIEDERICI; FRIEDRICH; CHRISTOPHE, 2007), and prosodic units, for example. Phonology studies are usually done with very small infants who do not mind wearing the caps; in many cases, studies can be done even when the baby is inattentive to the task (for example, distracted by soap bubbles while listening to syllables or words) and sometimes even while sleeping (DEHAENE-LAMBERTZ; PENA, 2001).

There are also studies on speech segmentation. A study performed with children up to 7 months of age presented significant evidence of speech segmentation, as participants showed a positive polarity (KOOIJMAN *et al*., 2013). Studies are also conducted with the ERP technique to investigate lexical access. Researchers have developed an appropriate paradigm for adults and children in which the participant sees an image of an object and, at the same time, hears an auditory stimulus that is a word that may or may not correspond to the object's reference, or is a pseudonym that is phonetically good or ill-formed – in Portuguese, examples like 'baluga' and 'btinica', respectively. Using this paradigm, Friedrich and Friederici (2004) observed a change in development between the ages of 12 and 19 months. ERP effects in 19-month-olds were reported as being quite similar to those of adults, i.e., an N400 effect for incongruous words and phonetically possible pseudowords, but not for phonetically illegal words (FRIEDRICH, FRIEDERICI, 2004). However, they did not find a negativity in 400 ms in 12-month-olds. Different from the results found with 12-month-olds, in another study carried out in 2010, the authors observed an N400 priming effect at 12 months of age. The activation was related to the level of word production babies displayed. Participants were divided into two groups: one with high early word production and the other with low early word production. Only the first group had what Friedrich and Friederici interpreted as a N400 (FRIEDRICH; FRIEDERICI, 2010).

According to Silva-Pereyra *et al*. (2005b), most children display two unique developmental moments after the first year of life. The first is an acceleration in the speed of vocabulary growth from 16 and 20 months of age (SILVA-PEREYRA *et al*., 2005b). At 20 months of age, ERP differences between known and unknown words become lateralized and more differentiated over the temporal and parietal regions of the left hemisphere, possibly reflecting the increased specialization of these areas for language processing (cf. Debra Mills for a review of these results). The second is in the development of the morpho-syntax of children between 24 and 30 months of age. This second moment is particularly relevant to this study, given the relationship with sentence processing.

Oberecker *et al*. (2005) and Oberecker and Friederici (2006) worked on sentence processing in 2-year-olds, 28-month-olds, and 24-month-olds, respectively. The study was conducted in German. They tested whether children at that age were sensitive to the syntactic structures of their language, as exemplified in (1), (2), and (3):

(1) Der Löwe brüllt

The lion roars (or is roaring)

(2) Der Löwe im Zoo brüllt

The lion at the zoo roaring

(3) Der Löwe im brüllt

The lion in roaring

The sentences were presented to children in three conditions – two grammatical conditions and one ungrammatical. The grammatical sentences had either DP (VP) structure as in (1) or DP [PP VP] structure as in (2). The ungrammatical condition had sentences with case mismatch; the case was marked by a preposition that took a noun or adjective, but the sentences contained a verb instead, as in (3). The results presented in Oberecker, Friedrich, Friederici (2005) demonstrated that participants at 2.8 years of age exhibited what the authors called ELAN and P600, whereas those at 2 years of age exhibited only a P600 (OBERECKER; FRIEDERICI, 2006) . The pattern found in the older group was in line with the adult control group, which also exhibited an ELAN and P600. The authors interpreted these findings as suggesting that principles of syntax are established early in development, since P600 was present in the younger group, at least for simple sentences.

> According to this interpretation the presence of a P600 effect in 2-year- olds would mean that late integration processes are already at work at this age even though highly automatic syntactic processes reflected in the ELAN are not yet effective. The biphasic ELAN-P600 pattern observed in 2.8-year-olds indicates that local phrase structure building processes are already established by that age in addition to late integration processes at least for the processing of simple active sentences. A similar developmental shift from a P600-only to a biphasic ELAN-P600 pattern was reported for the processing of phrase structure violations in passive sentences between the age of 6 and 7 years (Hahne, Eckstein, and Friederici, 2004). (FRIEDERICI; THIERRY, 2008, p. 227).

In 2010, Bernal and colleagues studied whether children built online expectations in relation to the syntactic category of the next word in a sentence. The researchers presented children with sentences that had nouns in place of verbs and vice-versa. The results showed different brain responses for grammatical and ungrammatical sentences, suggesting that at 24 months of age, children construct online expectations about the category of words. Another interesting finding was that the topography of the brain response was different for nouns and verbs, suggesting that the processing of nouns and verbs in young children could already be driven by different underlying mechanisms (as found in adults).

In 2012, the same group reported similar results with novel words (BRUSINI, 2012). They taught the children new nouns and verbs created for the French phonotatic test, *touse* as in (4), one week before the test – never with the target structure – and on the day of the test, as in Bernal *et al*. (2010), They presented these in grammatical sentences as in (5) or ungrammatical sentences in which the nouns taught the previous week were now inserted in the verb structure, as in (6), and vice-versa.

(4) Oh regarde, un touse!

Look, a touise touse!

(5) L'indien pousse le $[\text{touse}]_N$

The Indian pushes the touse.

(6) *Alors, elle le $[\text{touse}]_V$ de joie.

So, she touses with joy.

The researchers also found different responses to grammatical and ungrammatical sentences, although with a different topography and time-window than those of the 2010 study. This thesis was developed in a number of articles published in 2016 (BRUSINI *et al*., 2016a, 2016b).

Still in relation to the syntactic processing, and more specifically to verbs and morphosyntax, two articles from the same group of researchers were published in 2005 (cf. SILVA-PEREYRA *et al*., 2005a; SILVA-PEREYRA *et al*., 2005b). A study with older children was published first, and then a younger group was also tested, the results of which were published separately. This means that, once the authors had observed the potentials obtained by manipulating morphosyntactic and semantic properties, they were confident that such activation could be found in younger children. It is common in the development ERP literature to first look for the phenomena in one age group and then try to determine how early the phenomenon can be observed. Silva-Pereyra *et al*. (2005b) discussed the time course of ERPs using syntactic and semantically anomalous sentences to compare with the control, using children of 36 months of age (SILVA-PEREYRA; RIVERA-GAXIOLA; KUHL, 2005b). The objective was to see what kind of brain activation would be observed when syntactically and semantically anomalous sentences were presented to pre-school participants. Silva-Pereyra *et al*. (2005a) also presented the same set of stimuli in a younger population, 30 months of age (SILVA-PEREYRA *et al*., 2005a).

Silva-Pereyra and colleagues studied children of 36 and 48 months of age, manipulating syntactic and semantic elements (SILVA-PEREYRA, RIVERA-GAXIOLA, KUHL, 2005). They added the suffix *-ing* to structures in which it is not licensed, as in (7), and altered the internal argument of verbs by making them ungrammatical, as in (8).

(7) My uncle will watching a movie.
1POS tio FUT assistir-ASP DET filme
Meu tio irá assistindo um filme.

(8) My uncle will blow the movie.
1POS tio FUT soprar DET filme
Meu tio vai soprar um filme.

With this manipulation, the authors demonstrated that children of 36 and 48 months of age presented different ERP effects for syntactic and semantic processing (even without explicit attention to the sentences) and that their responses changed between 3 and 4 years of age. The activations were located earlier at 3 years than at 4 years of age. The same pattern was replicated in 2.5-year-old children.

These authors found a significantly positive change in the waveform during the processing of syntactically anomalous sentences as compared to non-anomalous sentences. This effect consisted only of a long-lasting positive effect that was largest on the anterior regions of the scalp from 500 to 1500 ms. The interpretation was that the effect was consistent with the P600 results from adults during syntactic processing. Adult P600, under the same type of manipulation, are presented in parietal midline electrodes (HAGOORT; BROWN; OSTERHOUT, 1999). However, the syntactic effect on preschoolers had an anterior distribution. A possible conclusion after examining these results is that children have the ability to analyze the syntax at an early age. They use different processes when parsing grammatical and non-grammatical sentences. In general, the evoked potential was a late positivity waveform. This result was interpreted as similar to the adult P600, but the preschoolers had a more distributed response in the anterior electrodes. The same pattern was present in 2.5-year-old children (SILVA-PEREYRA *et al*., 2005a). The general conclusion was that young children have neural signatures of sentence processing early in their language development.

In another study by the same authors (SILVA-PEREYRA *et al*., 2005b), the activations of children at 36 and 48 months of age in sentences with morphosyntactic and semantic violations were compared. This study demonstrated that children at 36 months and 48 months of age demonstrate different ERP effects for syntactic and semantic processing without explicit attention to sentences and that their responses change between 3 and 4 years of age for syntactic violations. A positive wave was observed in the syntactically anomalous sentences in 36 month-olds with a peak of activation at 800 ms, as well as two positive waves in the 48 month-olds: one with a peak at 400 ms and one at 800 ms. These activations were reported as P400 and P800. The authors also reported a difference in topography, which demonstrated stronger activations in the fronto-central regions. Concerning sentences with semantic anomalies, three negative activations were reported as N400, N600, and N800 in both groups.

The importance of syntactic and semantic cues is another area of research in the literature of linguistics and sentence processing. This important question has also been investigated in children. To observe whether semantic suggestions are more salient than sentence structure, Silva-Pereyra and colleagues presented 36-month-old children with sentences in English and in jabberwocky,[2] without semantic content, i.e., using only sentence structure with words that have no meaning (SILVA-PEREYRA *et al*., 2007). They tested 16 children. Half of the sentences were ungrammatical. The sentences had transitive verbs, as in (9). In the example, the internal argument (the cat) is a DP. The researchers replaced the correct type of internal argument, a DP, with a prepositional phrase, as in (10). This is a violation of the structure of the verb "touch." In jabberwocky sentences, the position of functional words is respected in grammatical sentences, as in (11) and (12), but lexical words are replaced by possible, but non-existent, words in the language.

(9) My dolly touched the cat with her hand.

'Minha bonequinha tocou o gato com a mão dela.'

(10) My dolly touched with the cat her hand.

'Minha bonequinha tocou com o gato a mão dela.'

(11) My cholly daunched the glat with her shond.

'Minha tonequinha docou o clato com a prão dela.'

(12) My cholly daunched with the glat her shond

'Minha tonequinha docou com o clato a prão dela.'

If children used semantic knowledge rather than syntactic knowledge to determine whether or not a sentence was incongruent, then we would expect the activation effects to be stronger for sentences that were semantically incongruent rather than syntactically incongruent. The authors found greater negative and positive activations for anomalous sentences than for non-anomalous ones. However, the authors' results are difficult to interpret since none of the effects lasted more than 200ms. In fact, the activations were only 150ms, which is quite fast for this kind of phenomenon. Therefore, what the reader takes from the article is the variety of latency and localization that the authors found that were sometimes aligned with other studies; however, some latencies and location were also observed that have not yet been reported.

The last study to be reported concerns an investigation on the argument structure. COSTA (2015) investigated whether two-year-olds unconsciously know that certain verbs enter specific argument structures, as in (13), demonstrating the effect of grammaticality if a known verb enters another structure, as in (14), present in other languages of the world, but not observed in French. Short videos in which a storyteller tells a story while manipulating dolls were shown to the children. Throughout the stories, grammatical sentences, as in (13) and (15), and ungrammatical sentences, as in (14), were heard. The researchers subsequently analyzed the brain activation related to these sentences. The results showed a negative activation between 200ms and 450ms after the child had listened to the verb being manipulated. These results indicated that children are sensitive to argument structure manipulations.

(13) Thomas lui donne une fleur pour lui dire merci.

'Thomas gave him a flower to say thank you.'

(14) * Elle lui donne qu'ils seront toujours amis.

'She gave him that they would always be friends.'

(15) Elle lui crie qu'il faut manger la bonne viande.

'She shouted at him to eat the good meat.'

All of these studies indicate that very young children, who start to produce words and short sentences a few months at the time of testing, already have linguistic intuition about what is and is not possible in their native language when processing sentences. Syntactic and semantic violations elicit different waveforms from those found in well-formed sentences. The results presented here suggest that children of one-and-a-half, two and three years of age are able to process complex syntactic structures online. This leads us to think about what mechanisms are already active at this age and what other types of verbs children are sensitive and when that (these) capacity(-ies) would be available.

Conclusion

The activation observed when children process sentences does not necessarily occur in the same topography and temporal window found in classic ERP components. Some authors have reported activations that occur in windows of 500-1500ms and in earlier positions as P600. This would run in line with what Gouvea (2010) notes in her review of the P600. However, it is not yet known whether all elements reported as P600 in adults will be found in the children and whether they will represent the same underlying processes. It is important to continue this type of research so as to know more about children's syntactic processing with a larger body of data from other languages.

The area of study on ERP language development is still quite recent, and the best ways to test and interpret data are continuously being debated to find the best system. The field is expanding, and each year more research and new groups are formed around the world. Comparison with adults is necessary, but sometimes, when activation does not fit that found in adults, no obvious conclusion can be drawn. The difference may exist due to the level of linguistic maturity or factors related to the child's anatomy. Therefore, to say only that the results are different does not necessarily lead to clear conclusions regarding what processes such activation indicates.

Nevertheless, what is known today about children's processing in ERP is already quite encouraging. Eighteen-month-olds are sensitive to manipulations of categories in day-to-day words and, at 24 months, in words learned in the laboratory. Studies show that, at 24 months, children are sensitive to manipulations regarding case marking and that, at 28 months, activation already shows an adult pattern. At 30 months, children are sensitive to syntactic and semantic manipulations. This same manipulation elicits an activation with more anterior location in three-year-old children than in four-year-old children. Researchers have also found differences in activation in 36-month-olds when jabberwocky sentences were tested vs. standard language sentences.

This article presented the ERP technique, showing the path the field has taken in trying to understand the mechanisms underlying cognition and, specifically, language – the literature on adults is briefly presented, showing its main components and more relevant studies.

Next, the literature was presented on child development using the ERP technique, its challenges, and encouraging results. Lastly, the most important articles on argument structure using the ERP technique were also summarized. The activation observed when children process sentences does not necessarily occur in the same topography and time-window found in classic ERP components. Some authors have reported activations occurring in windows of 500-1500ms and in anterior positions as P600. This would run in line with what Gouvea *et al*. (2010) notes in her review of P600. However, we do not yet know whether or not all reported elements, such as P600 in adults, will be found in the child population and whether or not they will represent the same underlying processes. It is important to continue the research to have a larger body of data from other laboratories, other tasks, and other languages in order to learn more about syntactic processing in children.

Therefore, this field of research faces considerable challenges when attempting to cover different sources of information from different disciplines related to studying language and/or child development. Nonetheless, there is reason to be optimistic that cross-fertilization is possible (POEPPEL, EMBICK, 2005) if phenomena are investigated with due care. However, researchers should not be apprehensive in assuming that cortical activation in children is directly comparable to the results found in adults. Further research is warranted to confirm that the same time and polarity windows mean the same computations for both populations.

Bibliography

BERKUM, J. J. A.; HAGOORT, P.; BROWN, C. M. Semantic Integration in Sentences and Discourse: Evidence from the N400, *Journal of Cognitive Neuroscience*, MIT, v.11, n. 6, p. 657-671, 1999. Doi: https://doi.org/10.1162/089892999563724

BERNAL, S.; DEHAENE-LAMBERTZ, G.; MILLOTTE, S.; CHRISTOPHE, A. Two-year-olds compute syntactic structure on-line. *Developmental Science*, Wiley Online Library, v. 13, n. 1, p. 69-76, Jan. 2010. Doi: 10.1111/j.1467-7687.2009.00865.x.

BORNKESSEL-SCHLESEWSKY, I.; SCHLESEWSKY,M. An Alternative perspective on "semantic P600" effects in language comprehension, *Brain Research Reviews*, Elsevier, v.59, p. 55-73, 2008. Doi: https://doi.org/10.1016/j.brainresrev.2008.05.003

BROWN, C.; HAGOORT, P.; KUTAS, M. Postlexical Integration Processes in Language Comprehension: Evidence from Brain-Imaging Research. In: GAZZANIGA, M. S. (Ed.). *The New Cognitive Neurosciences*. [S.l.]: A Bradford Book; MIT Press, 2000. chap. 61, p. 881-895. ISBN 0-262-07195-9.

BRUSINI, P. *Découvrir les noms et les verbes: Quand les classes sémantiques initialisent les catégories syntaxiques*. 2012. Dissertation (PHD) – École Normale Superieure, France, 2012.

BRUSINI, P.; DEHAENE-LAMBERTZ, G.; van HEUGTEN, M.; CARVALHO, A.; GOFFINET, F.; FIÉVET, A. C.; CHRISTOPHE, A. Ambiguous function words do not prevent 18-month-olds from building accurate syntactic category expectations: an ERP study. *Neuropsychologia*, Elsevier, v. 98, p. 4-12, Apr. 2017. Doi: https://doi.org/10.1016/j.neuropsychologia.2016.08.015.

BRUSINI, P.; DEHAENE-LAMBERTZ, G.; DUTAT, M.; GOFFINET, F.; CHRISTOPHE, A. ERP evidence for on-line syntactic computations in 2-year-olds. *Developmental Cognitive Neuroscience*, Elsevier, v. 19, p. 164-173, 2016a. Doi: https://doi.org/10.1016/j.dcn.2016.02.009.

BRUSINI, P. DEHAENE-LAMBERTZ, G.; DUTAT, M.; GOFFINET, F.; CHRISTOPHE, A. ERP evidence for on-line syntactic computations in 2-year-olds, *Developmental Cognitive Neuroscience*, Elsevier, v.19, p. 164-173, jun. 2016b. Doi: https://doi.org/10.1016/j.dcn.2016.02.009.

COCH, D.; MITRA, P.; GEORGE, E. Behavioral and ERP evidence of word and pseudoword superiority effects in 7- and 11-year-olds. *Brain Research,* Elsevier, v. 1486, p. 68-81, Nov. 2012. Doi: 10.1016/j.brainres.2012.09.041.

CONBOY, B. T.; RIVERA-GAXIOLA, M.; SILVA-PEREYRA, J. F.; AND KUHL, P. K. Event-related potential studies of early language processing at the phoneme, word, and sentence levels. In: FRIEDERICI, A. D.; THIERRY, G. (Org.). *Early language development*: bridging brain and behavior, Trends in language acquisition research series. Amsterdam/ The Netherlands: John Benjamins, 2008. v. 5, p. 24-64. Doi: https://doi.org/10.1075/tilar.5.04con.

COSTA, M. U. C. L. M. *Argument Stucture in Language Acquisition*: an ERP Study. 2015. 174f. Dissertation (PHD) – Faculdade de Letras, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2015.

COULSON, S.; KING, J. W.; KUTAS, M. Expect the Unexpected: Event-related Brain Response to Morphosyntactic Violations. *Language and Cognitive Processes*, Taylor & Francis Online, v. 13, n. 1, p. 21-58, 1998. Doi: 10.1080/016909698386582.

DEBOER, T.; SCOTT, L.; NELSON, C. Methods for acquiring and analyzing infant event-related potentials. In: HAAN, M. D. (Org.). *Infant EEG and event-related potentials*. [S.l.]: Psychology Press, 2007. chap. 1, p. 5-38.

DEBRUILLE, J. B. The N400 potential could index a semantic inhibition. *Brain Research Reviews*, Elsevier, v. 56, n. 2, p. 472-427, Dec. 2007. Doi: 10.1016/j.brainresrev.2007.10.001.

DEHAENE-LAMBERTZ, G.; PENA, M. Electrophysiological evidence for automatic phonetic processing in neonates. *Neuroreport*, LWW Journals, v. 12, n. 14, p. 3155-3158, Oct. 2001. ISSN 0959-4965.

FRANCA, A. I. *et al*. Discriminating among different types of verb-complement merge in Brazilian Portuguese: An ERP study of morpho-syntactic sub-processes. *Journal of Neurolinguistics*, Elsevier, v. 17, p. 425-437, 2004. Doi: 10.1016/j.jneuroling.2004.02.001.

FRANÇA, A. I. *Concatenações linguísticas*: estudo de diferentes módulos cognitivos na aquisição e no córtex. 236f. 2002. Dissertation (PHD) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2002.

FRANÇA, A; GOMES, J. Técnica de ERP: investigando a assimetria sujeito-objeto na interface sintaxe-semântica com EEG. *Letras de Hoje*, Porto Alegre, v. 50, n. 3, p. 360-370, Jul.-Sept. 2015. Doi: https://doi.org/10.15448/1984-7726.2015.3.18411.

FRANÇA, A.I.; LEMLE, M; GESUALDI, A.; CAGY, M.; INFANTOSI, A.F.C. A neurofisiologia do acesso lexical: palavras em português. *Revista Veredas*, Juiz de Fora, UFJF, v. 2, p. 34-49, 2008.

FRIEDERICI, A. D. The time course of syntactic activation during language processing: a model based on neuropsychological and neurophysiological data. *Brain and Language*, Elsevier, v. 50, p. 259-281, 1995. Doi: https://doi.org/10.1006/brln.1995.1048.

FRIEDERICI, A. D. Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, Elsevier, v. 6, n. 2, p. 78-84, Feb. 2002. ISSN 1364-6613.

FRIEDERICI, A. D. *et al*. Processing linguistic complexity and grammaticality in the left frontal cortex. *Cerebral Cortex* [New York, N.Y., 1991], Oxford Academic, v. 16, n. 12, p. 1709-1717, Dec. 2006. Doi: 10.1093/cercor/bhj106.

FRIEDERICI, A. D.; FRIEDRICH, M.; CHRISTOPHE, A. Brain responses in 4-month-old infants are already language specific. *Current Biology: CB*, Bethesda, v. 17, n. 14, p. 1208-1211, Jul. 2007. Doi: 10.1016/j.cub.2007.06.011.

FRIEDERICI, A. D.; FRISCH, S. Verb Argument Structure Processing: The Role of Verb Specific and Argument-Specific Information. *Journal of Memory and Language*, Elsevier, v. 43, n. 3, p. 476-507, Oct. 2000. Doi: 10.1006/jmla.2000.2709.

FRIEDERICI, A. D. *et al*. Syntactic parsing preferences and their on-line revisions: A spatio-temporal analysis of event-related brain potentials. *Cognitive Brain Research*, Bethesda, v. 11, p. 305-323, 2001. Doi: https://doi.org/10.1016/S0926-6410(00)00065-3.

FRIEDERICI, A. D.; MEYER, M. The brain knows the difference: two types of grammatical violations. *Brain Research*, v. 1000, n. 1-2, p. 72-77, Mar. 2004. Doi: http://dx.doi.org/10.1016/j.brainres.2003.10.057.

FRIEDERICI, A. D.; PFEIFER, E.; HAHNE, A. Event-related brain potentials during natural speech processing: effects of semantic, morphological and syntactic violations. *Cognitive Brain Research*, Bethesda, v. 1, n. 3, p. 183-192, Oct. 1993. Doi: https://doi.org/10.1016/0926-6410(93)90026-2.

FRIEDERICI, A. D.; THIERRY, G. (Org.). *Early Language Development. Bridging brain and behaviour*. (Trends in Language Acquisition Research) Amsterdam/Philadelphia, John Benjamins Publishing Company, 2008. Doi: https://doi.org/10.1075/tilar.5.

FRIEDERICI, A. D.; WEISSENBORN, J. Mapping sentence form onto meaning: the syntax-semantic interface. *Brain research*, Elsevier, v. 1146, p. 50-58, May 2007. Doi: 10.1016/j.brainres.2006.08.038.

FRIEDRICH, M.; FRIEDERICI, A. N400-like semantic incongruity effect in 19-month-old infants: Processing known words in picture contexts. *Journal of Cognitive Neuroscience*, MIT Press Journals, p. 1465-1477, 2004. Doi: 10.1162/0898929042304705.

FRIEDRICH, M.; FRIEDERICI, A. D. Maturing brain mechanisms and developing behavioral language skills. *Brain and Language*, Elsevier, v. 114, n. 2, p. 66-71, 2010. Doi_ 10.1016/j.bandl.2009.07.004.

FRISCH, S.; HAHNE, A.; FRIEDERICI, A. D. Word category and verb-argument structure information in the dynamics of parsing. *Cognition*, Elsevier, v. 91, n. 3, p. 191-219, Apr. 2004. Doi: 10.1016/j.cognition.2003.09.009.

GESUALDI, A. DA R.; FRANÇA, A. I. Event-related brain potentials (ERP): an overview. *Revista LinguiStica*, UFRJ, Rio de Janeiro, v. 7, n. 2, p. 24-42, 2011. 39.

GIBSON, E. Linguistic complexity: locality of syntactic dependencies. *Cognition*, Elsevier, v. 68, p. 1-76, 1998. Doi: DOI: 10.1016/S0010-0277(98)00034-1.

GOMES, J. N. *Investigating the dissociation between n400 and p600 effects on the syntax semantics interface*: an erp study. 183 f. Dissertation (PhD) – Faculdade de Letras da UFRJ, Rio de Janeiro, 2014.

GOMES, J. N.; FRANÇA, A. I. The ample semantic scope of minute language computations: an ERP study of words in Portuguese. *Revista da ANPOLL*, Anpoll, v. 34, p. 309-346, 2013. Available at: <http://anpoll.emnuvens.com.br/revista/article/view/673/698 45>.

GOMES, J.; FRANÇA, A. I. A técnica de ERP: Investigando a assimetria sujeito-objeto na interface sintaxe-semântica com EEG. *Letras de Hoje* (Online), PUCRS, Porto Alegre, v. 4, p. 152-163, 2015. Doi: http://dx.doi.org/10.15448/1984-7726.2015.3.18411.

GOUVEA, A. C. *et al*. The linguistic processes underlying the P600. *Language and Cognitive Processes*, Taylor & Francis Online, v. 25, n. 2, p. 149-188, Fev. 2010. Doi: 10.1080/01690960902965951.

HAGOORT, P. How the brain solves the binding problem for language: a neurocomputational model of syntactic processing. *Neuroimage*, Elsevier, v. 20, p. 18-29, 2003. Doi: https://doi.org/10.1016/j.neuroimage.2003.09.013.

HAGOORT, P. On Broca, brain, and binding: a new framework. *Trends in Cognitive Sciences*, Elsevier, v. 9, n. 9, p. 416-423, Sept. 2005. Doi: 10.1016/j.tics.2005.07.004.

HAGOORT, P.; BROWN, C.; GROOTHUSEN, J. The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*, Taylor & Francis Online, v. 8, n. 4, p. 439-483, 1993. Doi: 10.1080/01690969308407585.

HAGOORT, P.; BROWN, C.; OSTERHOUT, L. The neurocognition of syntactic processing. In: BROWN, C. M.; HAGOORT, P. (Org.). *The neurocognition of language*. Oxford: Oxford University Press, 1999. p.273-317.

HAGOORT, P.; BROWN, C. M. ERP effects of listening to speech compared to reading: the P600 / SPS to syntactic violations in spoken sentences and rapid serial visual presentation. *Neuropsychologia*, Elsevier, v. 38, p. 1531-1549, 2000. Doi: https://doi.org/10.1016/S0028-3932(00)00053-1.

HAGOORT, P.; LEVELT, W. The speaking brain. *Science*, American Association for the Advancement of Science, v. 326, p. 372-373, 2009. Doi: https://doi.org/10.1126/science.1181675.

HÄNEL-FAULHABER, B.; SKOTARA, N.; KÜGOW, M.; SALDEN, U.; BOTTARI, D.; RÖDER, B. ERP correlates of German Sign Language processing in deaf native signers. *BMC Neuroscience*, Springer Nature, v.15, n. 62, p. 1-11, 2014. Doi: https://doi.org/10.1186/1471-2202-15-62.

HERTEN, M. van; KOLK, H. H. J.; CHWILLA, D. J. An ERP study of P600 effects elicited by semantic anomalies. *Brain research. Cognitive Brain Research*, Bethesda, v. 22, n. 2, p. 241-255, Mar. 2005. Doi: http://dx.doi.org/10.1016/j.cogbrainres.2004.09.002.

HOEKS, J. C. J.; STOWE, L. A.; DOEDENS, G. Seeing words in context: the interaction of lexical and sentence level information during reading. *Brain Research. Cognitive Brain Research*, Bethesda, v. 19, n. 1, p. 59-73, Mar. 2004. ISSN 0926-6410.

HOLCOMB, P.; COFFEY, S.; NEVILLE, H. Visual and auditory sentence processing: A developmental analysis using event-related brain potentials. *Developmental Neuropsychology*, Taylor & Francis Online, v. 8, p. 203-312, 1992. Doi: https://doi.org/10.1080/87565649209540525.

HWANG, H.; STEINHAUER, K. Phrase length matters: the interplay between implicit prosody and syntax in Korean "garden path" sentences. *Journal of Cognitive Neuroscience*, MIT Press, v. 23, n. 11, p. 3555-3575, Nov. 2011. Doi: 10.1162/jocn_a_00001.

JOHNSON, M. Functional Brain Development During Infancy. In: BREMMER, G.; FOGEL, A. (Ed.). *Blackwell handbook of infant development.* [S.l.]: Blackwell Publishing, 2001. Chap. 6.

KAAN, E. *et al*. The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*, Taylor & Francis Online, v. 15, n. 2, p. 159-201, Apr. 2000. Doi: 10.1080/016909600386084.

KIM, A.; OSTERHOUT, L. The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language*, Elsevier, v. 52, n. 2, p. 205-225, Feb. 2005. Doi: 10.1016/j.jml.2004.10.002.

KOLK, H. H. J. *et al*. Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain and Language*, Elsevier, v. 85, p. 1-36, 2003. Doi: https://doi.org/10.1016/S0093-934X(02)00548-5.

KOOIJMAN, V. *et al*. Predictive brain signals of linguistic development. *Frontiers in Psychology*, Frontiers Media, v. 4, p. 25, Feb. 2013. Doi: https://doi.org/10.3389/fpsyg.2013.00025.

KOTZ, S. A.; HOLCOMB, P. J.; OSTERHOUT, L. ERPs reveal comparable syntactic sentence processing in native and non-native readers of English. *Acta Psychologica*, Elsevier, v. 128, n. 3, p. 514-527, Jul. 2008. Doi: 10.1016/j.actpsy.2007.10.003.

KOVELMAN, I. Neuroimaging Methods. In: HOFF, E. *Research Methods in Child Language*: A Practical Guide. [S.l.]: Wiley-Blackwell, 2012. Chap. 4, p. 44-59.

KUPERBERG, G.; SITNIKOVA, T. Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research*, Bethesda, v. 17, p. 117-129, 2003. Doi: https://doi.org/10.1016/S0926-6410(03)00086-7.

KUPERBERG, G. R. Neural mechanisms of language comprehension: challenges to syntax. *Brain Research*, Elsevier, v. 1146, p. 23-49, May 2007. Doi: 10.1016/j.brainres.2006.12.063.

KUPERBERG, G. R. *et al*. Building up linguistic context in schizophrenia: evidence from self-paced reading. *Neuropsychology*, Elsevier, v. 20, n. 4, p. 442-452, Jul. 2006. ISSN 0894-4105.

KUTAS, M.; DELONG, K. A Sampler of Event-related brain Potential (ERP) Analyses of Language Processing. *Brain Research in Language*, Springer, v. 1, p. 153-186, 2008. Doi: https://doi.org/10.1007/978-0-387-74980-8_6.

KUTAS, M.; FEDERMEIER, K. D. Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*, Bethesda, v. 62, p. 621-647, Jan. 2011. Doi: 10.1146/annurev.psych.093008.131123.

KUTAS, M.; HILLYARD, S. Reading senseless sentences: Brain Potentials Reflect Semantic Incongruity. *Science*, American Association for the Advancement of Science, v. 207, n. 4427, p. 203-205, Jan. 1980. Doi: https://doi.org/10.1126/science.7350657.

LAGE, A. C. Aspectos neurofisiológicos de concatenação e idiomaticidade em português do Brasil: um estudo de potenciais bioelétricos relacionados a eventos lingüísticos (ERPs). 2005. Dissertation (PhD) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2005.

LAU, E. F.; PHILLIPS, C.; POEPPEL, D. A cortical network for semantics: (de)constructing the N400. *Nature Reviews. Neuroscience*, Macmillan Publishers, v. 9, n. 12, p. 920-933, Dec. 2008. Doi: 10.1038/nrn2532.

LUCK, S. J. *An Introduction to the Event-Related Potential Technique*. [S.l.]: MIT Press, 2005. ISBN: 9780262122771.

MARANTZ, A. Generative linguistics within the cognitive neuroscience of language. *The Linguistic Review*, De Gruyter, n. 22, p. 429-445, Jan. 2005. Doi: 10.1515/tlir.2005.22.2-4.429

MILLS, D. L. *et al*. Language experience and the organization of brain activity to phonetically similar words: ERP evidence from 14- and 20-month-olds. *Journal of Cognitive Neuroscience*, MIT Press, v. 16, n. 8, p. 1452-1464, Oct. 2004. Doi: 10.1162/0898929042304697.

NELSON, C.; LUCIANA, M. *Handbook of Developmental Cognitive Neuroscience*. 2nd. ed. [S.l.]: MIT Press, 2008. ISBN 9780262141048.

NEVINS, A. *et al*. The role of feature-number and feature-type in processing Hindi verb agreement violations. *Brain Research*, Elsevier, v. 1164, p. 81-94, 2007. Doi: https://doi.org/10.1016/j.brainres.2007.05.058.

OBERECKER, R.; FRIEDERICI, A. D. Syntactic event-related potential components in 24-month-olds' sentence comprehension. *Neuroreport*, LWW Journals, v. 17, n. 10, p. 1017-1021, Jul. 2006. Doi: 10.1097/01.wnr.0000223397.12694.9a.

OBERECKER, R.; FRIEDRICH, M.; FRIEDERICI, A. D. Neural correlates of syntactic processing in two-year-olds. *Journal of Cognitive Neuroscience*, MIT Press, v. 17, n. 10, p. 1667-1678, Oct. 2005. Doi: 10.1162/089892905774597236.

OSTERHOUT, L.; HOLCOMB, P. J. Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, Elsevier, v. 31, n. 6, p. 785-806, Dec. 1992. Doi: 10.1016/0749-596X(92)90039-Z.

OSTERHOUT, L.; HOLCOMB, P. J.; SWINNEY, D. a. Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, Washington, v. 20, n. 4, p. 786-803, Jul. 1994. ISSN 0278-7393.

OSTERHOUT, L.; KIM, A.; KUPERBERG, G. The neurobiology of sentence comprehension. In: SPIVEY, M.; JOANNISSE, M.; MCRAE, K. (Org.). *The Cambridge Handbook of Psycholinguistics*. Cambridge: Cambridge University Press, 2007. p. 1-23.

OSTERHOUT, L.; MCLAUGHLIN, J. Novice Learners, Longitudinal Designs, and Event-Related Potentials: A Means for Exploring the Neurocognition of Second Language Processing. *Language Learning*, Wiley Online Library, v. 56, Supplement 1, p. 4-25, 2006.

PHILLIPS, C.; KAZANINA, N.; ABADA, S. H. ERP effects of the processing of syntactic long distance dependencies. *Brain research. Cognitive Brain Research*, Bethesda, v. 22, n. 3, p. 407-28, Mar. 2005. ISSN 0926-6410.

PICTON, T. W. *et al*. Guidelines for using human event-related potentials to study cognition: recording standards and publication criteria. *Psychophysiology*, Wiley Online Library, v. 37, n. 2, p. 127-152, Mar. 2000. ISSN 0048-5772.

POEPPEL, D.; EMBICK, D. Defining the relation between linguistics and neuroscience. In: CUTLER, A. (Ed.). *Twenty-first century psycholinguistics*: four cornerstones. Mahwah, N. J.: Lawrence Erlbaum, 2005.

POEPPEL, D.; OMAKI, A. Language acquisition and ERP approaches: Prospects and challenges. In: FRIEDERICI, A.; THIERRY, G. *Early language development*: bridging brain and behavior: Amsterdam: John Benjamins, 2008. Doi: https://doi.org/10.1075/tilar.5.12poe.

PUJOL, J. *et al*. Myelination of language-related areas in the developing brain. *Neurology*, American Academy of Neurology, v. 66, n. 3, p. 339-343, Feb. 2006. Doi: 10.1212/01.wnl.0000201049.66073.8d.

PYLKKÄNEN, L.; BRENNAN, J.; BEMIS, D. Grounding the cognitive neuroscience of semantics in linguistic theory. *Language and Cognitive Processes*, Taylor & Francis Online, v. 26, n. 9, p. 1317-1337, 2011. Doi: 10.1080/01690965.2010.527490.

SHAFER, V.; GARRIDO-NAG, K. The neurodevelopmental bases of language. In: HOFF, E.; SHATZ, M. (Org.). *Blackwell handbook of language Development*. Oxford: Blackwel, 2007. chap. 2, p. 21-45. Doi: https://doi.org/10.1002/9780470757833.ch2.

SILVA-PEREYRA, J. *et al*. Grammatical processing without semantics? An event related brain potential study of preschoolers using jabberwocky sentences. *Journal of Cognitive Neuroscience*, MIT Press, v. 19, n. 6, p. 1050-1065, June 2007. Doi: 10.1162/jocn.2007.19.6.1050.

SILVA-PEREYRA, J. F. *et al*. Sentence processing in 30-month-old children: an event-related potential study. *Neuroreport*, LWW Journals, v. 16, n. 6, p. 645-648, Apr. 2005a. ISSN 0959-4965.

SILVA-PEREYRA, J. F.; RIVERA-GAXIOLA, M.; KUHL, P. K. An event-related brain potential study of sentence comprehension in preschoolers: semantic and morphosyntactic processing. *Brain Research. Cognitive Brain Research*, Elsevier, v. 23, n. 2-3, p.247-258, May 2005b. Doi: 10.1016/j.cogbrainres.2004.10.015.

TEPLAN, M. Fundamentals of EEG measurement. *Measurement Science Review*, De Gruyter, Bratislava, Slovakia, v. 2, p. 1-11, 2002.

ZHANG, Y. *et al*. Syntax does not necessarily precede semantics in sentence processing: ERP evidence from Chinese. *Brain and Language*, Elsevier, v. 126, n. 1, p. 8-19, Jul. 2013. Doi: 10.1016/j.bandl.2013.04.001.

YUAN, S.; FISHER, C. Really? She Blicked the Baby? Two-Year-Olds Learn Combinatorial Facts About Verbs. *Psychological Science*, Sage Journals, v. 20, n. 5, p. 619-626, 2009. Doi: 10.1111/j.1467-9280.2009.02341.x.