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Time course of gender agreement violations containing emotional words

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ABSTRACT

Previous studies have provided evidence of the brain's sensitivity to gender agreement violations using the technique of event-related brain potentials (ERPs). Other studies have explored ERP patterns evoked by emotional words in isolation. This study investigates the time course of the processing of emotional words embedded in a sentence context using a gender agreement violation task. Overall, the results show an early component (N1) elicited by pleasant words, a left anterior negativity (LAN) evoked by gender agreement violations, and a late positivity (P600) which was sensitive to the emotionality of words and to the grammaticality of the sentence, with no interaction between these two factors. Such findings provide evidence on the temporal course of syntactic anomalies and affective word properties in the context of the sentence.

1. Introduction

The ability to adequately perceive and comprehend words and sentences is essential in the process by which human beings convey and share ideas. However, not all the ideas or events that we may want to 'shape in each other's brains' (Pinker, 1994, p. 15) are of the same caliber. A priori, it would appear to be of greater usefulness to fully appreciate the healthiness of a meal than, say, to know about the shape of the table. Phylogenetically, emotions are experiences connected to behavior which is both conducive to survival and socially relevant. Their correct identification and decoding is therefore essential in order to establish an adaptive behavioral response (Pourtois, Schettino, & Vuilleumier, 2013). Thus, when language is used to express and evoke emotions, linguistic and emotional processes share a common goal: namely, the correct transmission of an idea with a certain motivational value (Lang & Bradley, 2010).

With this in mind, it is surprising that in the field of neuroscience much less attention has been paid to the study of emotions as manifested through language than to the study of other cognitive domains, such as the processing of pictures

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(Olofsson, Nordin, Sequeira, & Polich, 2008) or faces (Adolphs, 2002). Although recent work has indeed looked at emotional words in isolation (see Citron, 2012; Fischler & Bradley, 2006; Kissler, Assadollahi, & Herbert, 2006 for reviews), research into how such words are processed into their natural habitat, the sentence, is still very limited.

The main aim of the present study is to contribute to a deeper knowledge of the processing of sentences containing emotional words. Towards this end, we have used the methodology of event-related potentials (ERPs), as this allows us to study the on-line detection and processing of grammatical errors in a sentence on the one hand, and the emotional words contained in that sentence on the other.

1.1. Sentence comprehension, agreement and event-related brain potentials

It has frequently been noted that the process of understanding sentences goes well beyond the ability to assign lexical meaning to individual linguistic signs (Fodor, 1995, p. 209), in that sentences express ideas that are a great deal more complex than the mere addition of one lexical meaning to another. In order to capture these ideas, then, humans need skills and knowledge distinct from the meaning of words, such skills involving the ability to connect the different parts of the sentence in a rule-governed fashion. The difference between *the lion killed the tiger* and *the tiger killed the lion*, or between *the hunter killed the lion* and *the lion was killed by the hunter* or *was it the lion that the hunter killed*? is not primarily in the words themselves, but in determinate rules of grammar. Even though parsing sentences (analyzing and understanding them) is both fast and usually effortless, it involves the establishment and resolution of a complex set of syntactic and semantic processes all aimed at the final goal of building a conceptual representation. It is precisely the temporal dimension of all these processes that makes ERPs a valuable tool for the study of sentence comprehension, in that this methodology allows for excellent temporal resolution. A rich body of ERP-based work over the past two decades has contributed considerably to our knowledge on sentence processing, in particular the identification of a series of psychophysiological traces of the different syntactic processes that eventuate in the final interpretation of sentence structure (Hagoort, Brown, & Groothusen, 1993; Münte, Matzke, & Johannes, 1997; Osterhout, Holcomb, & Swinney, 1994).

As for syntactic processing, and specifically the syntax determining the agreement between different parts of the sentence (which will concern us here), various researchers have tried to identify distinct components associated with the establishment of ties based on the co-occurrence of morphological cues of gender, number and person (generally refered to as phi-features in the linguistics literature; see Molinaro, Barber, & Carreiras, 2011; for a review of ERP research). In particular, 80% of studies on gender agreement (which is characteristic, for example, in Romance languages like Spanish or Italian, where noun phrases often have determiners, premodifying adjectives, head nouns and postmodifying dependents, all redundantly coding the same gender and number mark) report an ERP pattern that is formed by two components, a *left anterior negativity* (LAN) followed by a positive shift peaking at about 600 ms (P600/SPS) distributed across centro-parietal electrodes (Molinaro et al., 2011).

LAN is a negative deflection which peaks over left-frontal electrodes in the 300–450 ms range in the presence of morphosyntactic violations (Barber & Carreiras, 2005; Deutsch & Bentin, 2001; Gunter, Friederici, & Schriefers, 2000; Martín-Loeches, Nigbur, Casado, Hohlfeld, & Sommer, 2006; Schacht et al., 2010), even when pseudo-words are being used (Münte et al., 1997). The standard assumption has been that LAN reflects early and basic syntactic processes related to the automatic detection of a morphosyntactic violation between trigger and target items (Molinaro et al., 2011).

In most gender agreement studies, LAN is followed by a positive wave form known as the P600 or *Syntactic Positive Shift* (Hagoort et al., 1993). A large number of studies (Hagoort et al., 1993; Martín-Loeches et al., 2006; Molinaro et al., 2011; Molinaro, Vespignani, & Job, 2008; Osterhout & Mobley, 1995; Wicha, Moreno, & Kutas, 2004) have reported an increase in the amplitude of this component starting at around 500 ms and with a centro-parietal distribution in the case of syntactic violations or lack of congruency. Although in studies on agreement this effect has usually being interpreted as an index of violation processing that takes place during a stage devoted to syntactic reanalysis (Wicha et al., 2004), given the fairly diverse set of P600/SPS triggers attested, a general impression has emerged in which this effect is best associated with a reanalysis cost caused by different sources of information (Molinaro et al., 2011).

1.2. Emotional words and the two dimensional models of emotion: behavioral and electrophysiological studies

Over the past few years, bidimensional models that focus on emotions have contributed to an increased interest in the study of the processing of emotional stimuli by providing a paradigm which allows us to classify and select such stimuli along fairly specific dimensions. Based on work by Osgood (Osgood, Suci, & Tanenbaum, 1957), the entire range of human emotions can thus be arranged systematically (Barrett & Russell, 1999; Bradley & Lang, 2007; Lang, 1979; Russell, 1980, 2003). The two primary dimensions are valence (which ranges from pleasant to unpleasant) and arousal (which ranges from calm to excited). The distribution of emotional stimuli in the affective space defined by these two dimensions tends to show a typical boomerang shape, since unpleasant and pleasant stimuli are usually rated as having higher arousal than neutral ones (Bradley & Lang, 1999; Citron, Weekes, & Ferstl, 2014b; Kissler et al., 2006). Thus, bidimensional models provide us with a way of cataloging and measuring stimuli on the two most important dimensions that define emotions. This has made it possible to create rigorous databases, such as the *Affective norms for English words* (ANEW, Bradley & Lang, 1999). The ratings in these databases have made it clear that valence and arousal are highly correlated (e.g. Citron et al., 2014b; Redondo, Fraga, Padrón, & Comesaña, 2007).