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Research Report

Morphological agreement at a distance: Dissociation between early and late components of the event-related brain potential

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ABSTRACT

Syntactic relationships among non-adjacent words are a core aspect of sentence structure. Research on complex sentences with displaced elements has concluded that resolving long-distance dependencies can tax working memory. Here we examine a simpler relationship—morphological agreement between the elements of a noun phrase—across a gradient of distance. Participants read sentences with violations of gender agreement among Spanish nouns, determiners and adjectives. For those explicitly assigned the task of detecting errors, accuracy was uniformly high across the four levels of distance between (dis)agreeing words. A second group performed a comprehension task as ERPs were recorded. Gender agreement errors elicited a left anterior negativity (LAN) regardless of the distance between (dis)agreeing words, indicating that the errors were detected. In contrast, a temporally later component of the ERP (P600) showed decreasing amplitudes as the number of words between (dis)agreeing elements increased. Smaller P600 responses were also associated with slower responses to the comprehension questions. Given other work suggesting that the P600 indexes attempted repair of a problematic sentence structure, the results suggest that the participants became increasingly unwilling to re-visit their initial parse of a sentence as the required effort increased, despite having noted an error. The results are discussed within the context of studies showing that readers often compute inadequate structural representations of sentences. We suggest that P600 amplitude may reflect the costs versus benefits of sentence re-analysis, determined by a combination of sentence structure, task requirements, and the degree to which sentence meaning hinges on a correct structural analysis.

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1. Introduction

Most of the world's languages use morphological agreement to flag relationships among words in sentences. For instance, although the morphology of English is simplified relative to

many languages, it retains a few overt agreement requirements, such as person and number agreement between nouns and verbs (e.g., *the student says* versus *the students say* versus *I say*). Other languages possess richer morphological systems, such that German includes six forms of the indefinite article *ein* ("a"),

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with the correct variant depending on the case, number and gender of the subsequent noun. Morphological agreement helps to identify constituent boundaries and the relationships between constituents (see Bates et al., 1999 and MacWhinney and Bates, 1989 for discussion of the variable importance of morphological agreement versus word order across languages). Overt morphological agreement is especially useful in identifying structural relationships among words that are separated by intervening words (long-distance dependencies), which in turn influence the final interpretation of a sentence. Consider, for example, the ambiguity of the English sentence *The footprint of the suspect found last night was analyzed*—was it the footprint or the suspect that was located last night? The parallel sentence in Spanish contains no such ambiguity because nouns and their modifiers are marked for gender, and the feminine past participle *encontrada* (found), matches only one of the possible antecedents, *huella* (footprint): *La huella_{FEM} del sospechoso_{MASC} encontrada_{FEM} la noche anterior fue analizada_{FEM}.*

Although the potential utility of morphological agreement for sentence parsing is most evident when there are intervening words, successful resolution of long-distance dependencies has long been identified as troublesome for readers and listeners due to the burden placed on working memory. Indeed, it has been argued that readers often fail to use gender agreement information during initial sentence parsing, even when it may prevent ambiguity (Brysbaert and Mitchell, 2000). The current experiment examines the processing of gender agreement in Spanish across a gradient of distance between the words that should agree. Native speakers of Spanish read correct sentences and those with violations of gender agreement as their electrical brain activity was recorded, affording a non-intrusive measure of how and when agreement is processed. Below, we review grammatical gender in Spanish, the difficulty of processing long-distance dependencies, and different components of the event-related brain potential associated with earlier and later syntactic processing.

1.1. Grammatical gender

Grammatical gender is pervasive in Indo-European and other language families and, in most instances, is a purely morphological feature. In Spanish, a small set of animate nouns have masculine and feminine forms corresponding to their natural gender (e.g., *chico/chica*, *boy/girl*). The much larger majority of nouns have no correspondence between their grammatical gender and any real-world notions of masculinity or femininity (even when one might think that an inanimate noun is closely associated with men or women, e.g., *ovario_{MASC}* /ovary and *barba_{FEM}*/beard). Gender is, for the most part, merely a way in which nouns are categorized in a large number of languages, including German, Dutch, French, Italian, Greek, Arabic, Norwegian, Icelandic, etc.

In some languages, such as Dutch and French, the gender of an unknown word is difficult to predict from its pronunciation or spelling (Blom et al., 2008; Franck et al., 2008). In contrast, the two-gender system of Spanish is fairly transparent and regular in the mapping between gender and the phonology/orthography of nouns. It is estimated that for 68% of nouns, endings of “-o” and “-a” indicate masculine and feminine gender, respectively (Moreno-Sandoval and Goñi-Mendoza,

2002). The remainder end with “-e” or with a consonant and are variably masculine or feminine. A very small number of nouns—less than 2%—are inconsistently marked (e.g., *mano_{FEM}*; Teschner and Russell, 1984). Like nouns, a majority of adjectives are consistently inflected with “-o” and “-a” for masculine and feminine gender (estimated as 62% by Moreno-Sandoval and Goñi-Mendoza, 2002).

1.2. Agreement: near and far

Whether or not noun gender is transparently marked, the overt manifestation of grammatical gender is through agreement. In Spanish, all words within a noun phrase (determiner and any adjectives) must agree in gender and number with the head noun, as must any adjectives or participles outside of the noun phrase that modify that head noun. The words involved in the gender agreement structure may thus be adjacent or nonadjacent. In example 1, the masculine noun *piano* selects an immediately adjacent masculine article (*el*), adjacent (*antiquo*) and nonadjacent adjectives (*feo*), and also a more distant masculine adjective (*caro*) after the embedded clause.

1. El piano antiguo y feo que compramos ayer fue caro.
(The ugly antique piano that we bought yesterday was expensive.)

The current experiment examines whether evaluation of agreement becomes less likely or more difficult with increasing distance, by comparing correct and incorrect agreement across a gradient of distance, via sets of sentences like those below.

- 2A. Acabo de llegar y creo que **el (la) piano** está aquí.
(I've just arrived and think that the piano is here.)
- 2B. Llegamos hace poco y vimos **el piano roto (rota)** en la sala.
(We arrived not long ago and saw the broken piano in the room.)
- 2C. Me han dicho que **el piano** está **roto (rota)** y ya no funciona.
(They've told me that the piano is broken and no longer works.)
- 2D. **El piano** que compramos ayer está **roto (rota)** y no funciona.
(The piano that we bought yesterday is broken and doesn't work.)

Examples 2A and 2B contain two agreement structures with immediately adjacent words, a determiner–noun sequence and a noun–adjective sequence, respectively. Although these are equivalent in lacking any intervening words, we hypothesize that the article–noun sequence has a special status for Spanish speakers due to the statistical properties of the language. Determiners are a small set of words, the large majority of which occur in masculine and feminine forms (e.g., *el/la*, *un/una*, *ese/esa*, *este/esta*, *otro/otra*, *aque/ aquella*, exceptions are the personal possessives *mi*, *tu*, *su*, which are gender-invariant). Gender-matching between determiners and nouns is strongly deterministic, such that the gender of a determiner predicts the gender of the subsequent noun with greater than 99% validity. The exceptional case is that feminine nouns beginning with a stressed “a” are not preceded by *la*, so that *el_{MASC} agua_{FEM}* is correct. Because determiners are an obligatory part of a Spanish noun phrase

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