What makes syntactic processing of subject–verb agreement complex? The effects of distance and additional agreement features

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A B S T R A C T

This study investigates two types of factors potentially affecting the level of complexity of processing subject–verb agreement: (i) distance between the subject and the critical verb (0, 1 or 2 constituents) and (ii) type of intervening constituent between the subject and the verb (adverb versus an NP within a PP). NPs, but not adverbs, include additional number features that potentially increase complexity of processing the agreement relationship between the number features of the subject NP and the verb. Event-related potentials (ERPs) were measured to investigate the neural correlates of agreement processing. Eighteen native Spanish speaking participants read grammatical sentences as well as ungrammatical sentences violating subject–verb agreement. The ungrammatical sentences elicited posterior negativities in the 350–500 ms time window. No effects of distance or type of constituents were found in this time window. A typical P600 effect was also observed in response to the agreement violations. The linear distance between the subject and the verb influenced the P600 effect; the sentences containing two constituents elicited more positive going waveforms compared to sentences without intervening constituents. The type of constituent did not play a role. The results fit psycholinguistic accounts assuming that integration of additional linguistic elements makes it more complex to process the subject–verb agreement relationship at the verb, regardless of the presence of additional number features.

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1. Introduction

In many languages, the relation between the subject and the verb is expressed by inflecting the verb for agreement features that match with those of the subject noun. The inflected form of the verb depends on the features of the subject. Compare for example the sentences: 'the girl reads a book' versus 'the girls read books'. In order for successful processing of the dependency agreement relationship, the features of the subject noun need to be tracked and temporarily stored until the critical verb has been comprehended or produced (see Pearlmutter, 2000; Kaan, 2002). In the current study, we investigated the complexity of processing subject–verb agreement within an ERP-paradigm. We investigated whether agreement processing is influenced by the number of constituents between the subject and the verb and by the properties of these

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constituents. In the following sections we will first describe Spanish subject–verb agreement followed by a discussion of previous studies on the complexity of subject–verb agreement processing. Then an overview of the neurophysiological signature of agreement processing will be given. Our experimental study will then be presented followed by our results and discussion.

1.1. Morphosyntactic agreement processing in Spanish

In Spanish, correspondence between the number features of the subject NP and the verb is required. The grammatical number of the subject is expressed by two forms: singular and plural. The noun and its corresponding verb coincide in number through suffixing, like in this simple sentence: *los perros están en la casa* ('The dogs are in the house'). In this sentence both the subject (*perros* 'dogs') and verb (*están* 'are') are plural, generating agreement between features. In longer, more complex sentences intervening material can be present between the noun and the verb. An example is a PP containing an NP following the subject NP: 'The dog of the boys is in the house'. The singular features of the head noun are maintained, even though the number features of the second NP are plural. In Spanish, other phrasal constituents can be placed between the subject NP and the verb. In this sentence the subject NP is followed by an adjectival phrase: *El gato gordo camina en la calle* (lit: the cat fat walks in the street; 'the fat cat walks in the street') or an adverbial phrase (AdvP): *El gato típicamente camina en la calle* ('the cat usually walks in the street').

1.2. Complexity in agreement processing

Earlier studies reported that linguistic elements intervening between the subject NP and the critical verb affect processing the agreement relationship, resulting for example in production errors (e.g. Bock and Miller, 1991; Wagers et al., 2009). Production of sentences that contain an additional noun after the subject NP with mismatching number features which is placed before the verb, often elicit subject–verb agreement errors (Bock and Miller, 1991). Specifically the condition in which the subject NP is singular and the second NP is plural triggers the agreement error of inflecting the verb for plural number agreement instead of singular (Bock and Miller, 1991; Franck et al., 2002; Hartsuiker and Barkhuysen, 2006). This effect has been explained by assuming that plurality is more marked than singularity. The plural form attracts the agreement on the verb resulting in errors when the subject NP is singular (Wagers et al., 2009). Thus, asymmetry in markedness between singular/plural number features of the subject explains the occurrence of errors of the kind NP1 [sing] NP2 [plur] V [plur], and the absence of production errors of the kind NP1 [plur] NP2 [sing] V [sing].

In a comprehension task, Nicol et al. (1997) showed that sentence contexts that elicit agreement errors in production (singular subject NP, plural NP2) were read more slowly compared to sentences with matching number features, or with a plural subject NP (all sentences were grammatical). Pearlmutter (2000) conducted a self-paced reading experiment in which participants read sentences with a subject NP followed by two PPs containing NPs (singular/plural, for example *the lamp near the painting(s) of the house(s) was damaged in the flood*). Grammatical sentences containing singular subject NPs were read faster than sentences that contained at least one plural NP, indicating that plurality is indeed marked (Pearlmutter, 2000). Wagers et al. (2009) found that participants accepted ungrammatical sentences as grammatical in 55% of the instances when the sentence contained a plural 'agreement attractor' (for example: *the key to the cells were rusty from many years of disuse*). These sentence contexts trigger so-called 'illusory' subject–verb agreement.

In the literature several psycholinguistic models have been formulated that account for agreement errors. The hierarchical account of agreement processing assumes that feature information from heads percolate up to maximal projections within a hierarchical tree structure. Errors in feature matching can arise when interfering feature numbers (those of an additional noun adjacent to the subject noun and verb) accidentally override the target number features (Pearlmutter, 2000). The Dependency Locality Theory (DLT) in sentence comprehension also predicts effects of intervening constituents between the subject and the verb (Gibson, 2000). At the base of the DLT is the idea that the mechanisms involved in sentence parsing require at least two computational resources. Sentence comprehension depends on structural integration (i.e. incorporating a new word into the existing information) and keeping the sentence structure, including grammatical features, in memory. This account hypothesizes that the greater the distance between an incoming word and the most local head or dependent to which it attaches, the greater the integration cost is, specifically in the cases where a new discourse referent is introduced (Gibson, 1998, 2000). Thus, this account predicts that inserting linguistic elements between the subject and the verb, even though these elements may not have number features, will impact on processing subject–verb agreement.

1.3. ERP signature of agreement processing

Recording ERPs has proven to be a useful tool for studying subject–verb agreement. The time-course of the ERPs in response (in milliseconds) to the stimulus and its properties reveal insight into detecting and processing subject–verb mismatches. Morphosyntactic processing is associated with two ERP components: the left anterior negativity (LAN) and the syntactic positive shift, also known as the P600. In multiple studies (see for a review Molinaro et al., 2011) a bi-phasic pattern, characterized as a LAN followed by a P600 is described in response to morphosyntactic agreement violations. In Spanish, the language under investigation, this bi-phasic pattern has also been observed (see Barber and Carreiras, 2005; Mancini et al., 2011). The LAN component is a negative-going deflection typically appearing as a response to detection of morphosyntactic