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Agreement processing in control and raising structures. Evidence from sentence production in Spanish

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Abstract

We report the results of a study investigating the production of gender and number agreement between head noun and predicative adjective in Spanish using an elicited-error paradigm with preambles that included either Control or Raising verbs. In order to identify if the subjects of the infinitivals selected by these two verb types are syntactically identical (Movement Theory of Control) or distinct (Theory of Control by PRO or anaphora), the following features in the preambles were manipulated: gender of head noun (Feminine–Masculine), gender and number (Singular–Plural) of local noun, and type of verb (Control–Raising). We analyzed the agreement errors and omissions patterns, as well as response times in the production of the target adjective. The error rate was not different across the two syntactic conditions, but the two verb classes were associated with significantly different number of target omissions. Furthermore, omissions in the Control condition were specifically associated with feminine agreeing adjectives. This pattern was also reflected in the adjective production latency. Taken together, these results undermine the Control by Movement explanation and argue for a Control by PRO analysis of Control constructions.

Keywords: Psycholinguistics; Language production; Agreement; Control and Raising structures; Spanish

1. Introduction

The study of empty categories has been an area of long standing debates in both theoretical linguistic and psycholinguistic research. While different theoretical frameworks propose a variety of encoding mechanisms, there is a general consent about a certain typology of empty categories. Thus, most psycholinguistic and theoretical linguistic frameworks (Bresnan, 1978; Chomsky, 1995; Fodor, 1995; Nicol and Swinney, 1989; Pickering and Barry, 1991; Pollard and Sag, 1994; Postal, 1974; Rosenbaum, 1967; Sag and Fodor, 1995; Swinney et al., 1989; Zagona, 2003) distinguish

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between gaps/empty categories which are due to Wh-question formation, relativization or other forms of leftward dislocation (often called A-bar movement) from gaps/empty categories associated with passivation or unaccusative frame formation (aka A-movement). However, there are certain empty categories on whose nature both theoretical and experimental research has not yet converged. One such case is the gap in the subject position of embedded infinitival phrases of Raising (*John seemed to like apples*.) and Control (*John tried to like apples*) verbs. Standard generative theory (Chomsky, 1981; Chomsky and Lasnik, 1993) has postulated two different types of empty categories for these two constructions: NP trace (or copy) in the case of Raising, and a phonologically null pronominal category (PRO) in the case of Control. However, this typology has been challenged by recent Minimalist literature (Boeckx et al., 2010a; Hornstein, 1999, 2001), which proposed to unify the two empty categories (eliminating PRO in favor of NP trace for Control as well). At present, theoretical and experimental research is yet to provide conclusive evidence regarding this question. In this paper we present data from an induced agreement error production experiment in *Rioplatense* (RP) Spanish that was designed to address the issue.

1.1. Control infinitival constructions: theories and experimental evidence

The Control infinitival construction is governed by a specific class of verbs (Control verbs) that select subject-less infinitives as their complement.

Example:
(1) María$_i$ prefiere [EC$_i$ vivir tranquila$_{fem/sg}$]
‘‘Mary prefers to live quietly’’

In subject-Control verbs, the (overt) subject of the main verb controls the reference of the implicit subject of the subordinate sentence, forcing a relation of identity between the two.

It is common to compare Control infinitival constructions to Raising constructions (*María parece vivir tranquila* ‘‘Mary seems to live quietly’’), given that both structures contain an explicit subject (see examples 2 and 3: *Juan*) and a covert infinitival subject (an empty category, EC), which is referentially dependent of the subject of the main clause. The standard generative assumption regarding Control and Raising infinitivals is that in the former, subject position is occupied by the phonologically null pronominal object PRO, while in the latter it is occupied by an NP trace (Rosenbaum, 1967). In most versions of the Standard Theory (and then also in the Government-Binding Model or GB), Control is part of Binding Theory, while Raising is considered an instance of A movement.

Examples:
(2) [Juan$_i$ intenta [*PRO*$_i$ besar a María]]
‘‘John tries to kiss Mary’’
(3) [Juan$_i$ parece [t_i besar a María]]
‘‘John seems to kiss Mary’’

In (2) the reference of PRO is controlled by the subject of the infinitival; however PRO can also be Controlled by a matrix object (*Juan ordenó a María limpiar la mesa* ‘‘John ordered Mary to clean the table’’) or appear without an explicit controller (*Tener que hacer algo muchas veces es aburrido* ‘‘Having to do something repeatedly is boring’’). Furthermore, subject-Control constructions are often sub-divided into obligatory and non-obligatory subtypes. Obligatory Control predicates can also be exhaustive when the controller-controllee reference is the same (verbs such as *lograr* ‘‘manage’’: *El jefe logró reunir el comité a las 6* ‘‘The chair managed to gather the committee at 6’’) or partial, when the reference of the controllee is taken as a subset of the reference set of the controller (verbs such as *preferir* ‘‘prefer’’: *El jefe prefirió reunirse a las 6* ‘‘The chair preferred to gather at 6’’) (Landau, 2000, 2003). The focus of the theoretical debate and of the current experiment is the obligatory Control class.

As mentioned above, since the beginning of generative grammar (Rosenbaum, 1967), the empty categories in Control and Raising structures have been considered to be distinct. The theoretical distinction between the infinitival structures at stake here was originally motivated by differences in their thematic properties. Raising verbs have a single argument (the proposition denoted by the embedded clause) with only one thematic role assigned (internal argument), while Control verbs have more than one argument (the matrix subject and the embedded proposition), and two thematic roles assigned (internal and external argument). As a consequence, the matrix subject in Raising has only one thematic role assigned to it (by the verb of the infinitival clause), while in Control it has pre-theoretically two (one assigned by the infinitival verb and one by the Control verb itself).

Following Polinsky (2013), below we summarize some similarities and fundamental differences between Control and Raising structures:

- Both Control and Raising structures keep an interpretive dependency between an explicit element that appears in a clause and a null element that appears in another clause. Thus, both structures create an interpretive dependency between the subject of the embedded clause and the subject of the main clause.
- Both structures selected an infinitive, but different structures may be assigned to these infinitives: for Control, a CP, and for Raising, an IP (within Standard Theory. In Minimalism or HPSG, for example—this difference is not explicit).
- Control structures impose selection restrictions on its arguments, but not Raising structures (see examples in Polinsky, 2013 on expletives or idiom chunks).
- Control predicates require their subjects to be animate, volitional, and the complement should specify an action requiring a volitional subject. Raising predicates are transparent in the selection restrictions of their subordinate predicate.
- With respect to passivization, in Control structures when the predicate of the subordinate is passivized, the meaning changes; however, in Raising structures it is maintained.
- Control structures do not support reconstruction, while Raising structures do.
- Possibilities to nominalise also differ. While Control structures allow to nominalise freely, Raising structures never allow it.

With regard to the analysis of structures, the relationship between the subject of the infinitival and the matrix subject in Raising structures has been (and still is) standardly analyzed as an A-movement chain, similar to the movement in passive or Raising-to-object constructions. The NP receives its thematic role inside the infinitival construction and raises (moves) to the matrix subject position to receive case (and be pronounced). Therefore, in Raising, the identity requirement between the implicit infinitival subject and the matrix subject follows from their syntactic identity. Given that, according to standard generative theory, a single NP can only receive a single thematic role (Chomsky, 1981), an analogous movement account for Control was not tenable. Instead, it was proposed that in infinitivals embedded by Control verbs the subject position is occupied by PRO, an empty category which receives the thematic role from the infinitival construction but is referentially controlled by the matrix subject (Chomsky, 1981; Chomsky and Lasnik, 1993; Landau, 2000, 2003).

While the standard generativist approach distinguished Control and Raising structurally, a number of other analyses (e.g. Bach, 1977; Brame, 1976; Bresnan, 1978) proposed that the two syntactic structures were identical, and that the apparent differences came from semantic-interpretive rules. Since the theoretical shift brought about by the Minimalist Program (Chomsky, 1993,1995) has eliminated the conceptual ground that originally motivated PRO (there is no theta filter any longer), a number of authors (Boeckx et al., 2010a,b; Hornstein, 1999, 2001; O'Neil, 1995) have proposed to analyze (obligatory subject) Control as a case of A-movement (on par with Raising). The Movement Theory of Control (MTC; Boeckx and Hornstein, 2003, 2004, 2006a,b; Hornstein, 1999; Polinsky and Potsdam, 2002) assumes that Case generates movement in both Raising and Control. In this sense, Hornstein proposed that theta roles are features that should be checked. Given these assumptions, OC can be reduced to A-movement as in Raising, and PRO may be reanalyzed as NP-trace. According to the MTC, known differences between Control and Raising constructions are to be explained on independent grounds.

However, within a Minimalist framework, some authors still argue for distinct structures for the two constructions. Landau (2000, 2004), for example, defends the existence of an empty category PRO in the subject position of Control infinitivals. The PRO interpretation is given by the operation Agree, which is established between PRO and its controller. In his proposal, PRO enters the derivation with unvalued, but interpretable phi-features, which are valued by Agree with the controller.

The theoretical debate between the MTC and the PRO accounts of OC has been based primarily on typological data and observations regarding grammatical knowledge (elicitations/acceptability judgments). For example, the proponents of the MTC have presented backward Control as a critical test case that argues against PRO (e.g. Boeckx et al., 2010a,b). In languages with backward Control, such as Korean or Tsez (Monahan, 2003; Polinsky and Potsdam, 2002), the subject has been proposed (on the basis of a case and other tests) to be overtly realized within the embedded clause while the matrix clause contains the corresponding 'controlled' null subject. The PRO theory of Control cannot account for such cases since it would mean that the null anaphor is structurally higher and c-commanding its antecedent which runs against the core notion of anaphors in natural language. Under the MTC, combined with the copy theory of movement, backward Control is simply a case of phonological spell-out (or pronunciation) of the lower copy in a movement chain, a well-attested (even if uncommon) phenomenon.

Landau (2007), in defense of PRO, provides arguments that at least certain cases that have been analyzed as backward Control (such as Tsez) should be reconsidered. However, Alexiadou et al. (2010) bring to the fore data supporting the existence of backward Control in Greek and Romanian, which is impervious to Landau's arguments.

On the other hand, Landau, in a series of papers (2000, 2003, 2004, 2007), has provided a number of arguments against the viability of the MTC. One such argument comes from the differences between OC and Raising with respect to Icelandic quirky case distribution. Certain verbs in Icelandic assign to their subjects a dative (quirky) rather than a nominative case. It has been long noted that such subjects preserve the quirky case following A-movement (i.e. passive, Raising, ECM). However, when the matrix verb is an OC verb, the controller surfaces with the case assigned by the matrix verb (accusative in the case of object Control and nominative in subject Control), rather than with the 'original' quirky case. Landau (and Bobaljik and Landau, 2009) argues that these differences reflect the difference in structural properties or in derivational history of the matrix subject. In Raising the subject 'bears the marks' of having been generated inside the embedded infinitive. The matrix antecedent in Control structures does not bear the same marks since it was never part of the embedded infinitival. It is PRO that bears the quirky case (and agrees with the embedded infinitival). Boeckx et al. (2010b), in their reply to Bobaljik and Landau (2009), argue that under specific assumptions concerning the assignment of quirky case (most importantly that it is associated with theta assignment and so is 'over-written' if a DP receives a second theta role as is the case in OC) and in particular if one assumes that A-movement could also be a reflex of agreement and not only Case, the MTC can be made compatible with the Icelandic facts. More recently, Wood (2012) constructs a different form of argument against the MTC based on other facts from Icelandic, namely the compatibility of OC with a ''resumptive'' pronoun that is otherwise a barrier for movement. Wood concludes that for the MTC to be maintained it must be assumed that the locality conditions on the movement in OC are different then for either A or A bar movement.

As things stand, it appears that linguistic typology and grammatical knowledge of speakers do not provide conclusive evidence in favor or against either approach. This is particularly true for languages such as English or Spanish where both approaches can (or were constructed to) account for the OC facts and the differences between OC and Raising. While both approaches can account for the OC data from Spanish, for example, they clearly posit different mechanisms to do so (pronominal anaphora vs. movement). By doing so, they potentially make different predictions regarding the on line processing of these constructions. What can psycholinguistic experimental paradigms contribute to the discussion?

A number of psycholinguistic studies have explored the processing of both Raising and Control verbs (Betancort et al., 2004, 2006; Bever and Sanz, 1997; Boland et al., 1990; Demestre et al., 1999; García-Albea and Meltzer, 1996; Mauner and Koenig, 2000; Mauner et al., 1995); however, to our knowledge, only a few studies addressed specifically the differences and similarities in the processing of these two classes (Featherston et al., 2000; Michel and Cowles, 2009; Walenski, 2002).

Priming protocols, both sentence-finally and (cross-modally) at the position of the implicit infinitival subject, have been used to study Raising and Control in English (Bever and Sanz, 1997; Nicol and Swinney, 1989; Osterhout and Swinney, 1993; MacDonald, 1989), but only Walenski (2002) has reported differences between the two constructions. Walenski found a priming effect by the matrix subject at the pre-infinitival position in both Raising and Control sentences (contrary to Nicol and Swinney, 1989; Osterhout and Swinney, 1993). This finding argues that some form of reactivation of the matrix subject takes place at the pre-infinitival position, supporting an empty-category analysis of these two constructions. Furthermore, priming occurred in an earlier time window in Raising compared to Control. Nevertheless, though this difference in time course could be due to a structural difference (NP trace vs. PRO), it could also be the result of predictability differences. While Raising verbs always select an embedded infinitival (or small clause) containing a co-referential implicit subject, Control verbs do so only optionally (*John tried to leave* vs. *John tried the cheese*).

Featherston et al. (2000) made use of ERP to compare processing of Control and Raising in German during comprehension. They found an increased positivity (P600) in Raising compared to Control during the presentation of the accusatively marked object of the infinitival verb (since in German the verb appears final in the infinitive clause, it is the object NP that most closely coincides with the empty position of the subject). They interpreted this difference as the additional cost of the processing of a syntactic A-chain in Raising but not in Control (thus favoring PRO-theory of the MTC). However, as argued by Polinsky and Potsdam (2006), the increased activation in the Raising condition could be due to predictability differences, similarly to the results of Walenski (2002). In German, the Raising verb s*cheinen* ''seem'' has more complementation options than the Control comparison producing greater ambiguity that is only resolved when the accusatively marked NP is encountered. Hence, even if some data point to a different processing pattern for the two constructions, explanations are not straightforward and the debate remains open.

To summarize, very little is known yet regarding processing differences between Control and Raising sentences and it is not clear to what extent the observed differences are due to differences in the nature of the empty category involved. Furthermore, to our knowledge, no study has compared Raising and Control in Spanish. Finally, while comprehension of infinitival complementation has been studied with a variety of methodologies such as priming, ERP, reading time and eye movement, the production of these constructions and in particular the interaction with online agreement mechanisms have not been studied. Our study compared Raising and Control in Spanish in sentence production and investigated the interaction of these structures with online agreement mechanisms.

Agreement is of particular interest since the differences between the two approaches (MTC and PRO) have direct implications to the underlying mechanisms of the long distance morphological agreement between the matrix subject and

a target within the embedded clause, in particular for agreement rich languages such as Spanish (Bobaljik and Landau, 2009; Bobaljik and Zocca, 2010). While MTC allows for a local agreement valuation within the embedded clause given the presence of a (silent) copy of the subject, any PRO-based analysis would require either a long distance agreement valuation or a 2-step agreement process (matrix subject-PRO and PRO-embedded clause target). The Raising construction can be taken as a baseline since for both approaches it should allow for local agreement (with the silent copy at the position of infinitival subject). In the study presented here we used agreement error elicitation to find out whether agreement error patterns are different between OC and Raising in RP Spanish. While MTC analysis of OC predicts the two to show similar error pattern, PRO predicts different error patterns since agreement in Control is more costly or error-prone given the long-distance nature of the agreement relation and the mix between NP–predicate agreement and pronoun–antecedent agreement, not present in Raising.

1.2. Agreement errors in sentence production

Agreement errors in language production, both naturally occurring and induced, have been used extensively in the literature to inform speech production models (Bock and Cutting, 1992; Bock and Miller, 1991; Bock and Eberhard, 1993; Bock and Levelt, 1994; Bock et al., 2001; Eberhard et al., 2005; Franck et al., 2006, 2008, 2010; Gillespie and Pearlmutter, 2011; Levelt, 1989; Vigliocco et al., 1995, 1996; Vigliocco and Hartsuiker, 2002, inter alia). Such errors have also been used to study differences between L1 and L2 (e.g. Clahsen and Felser, 2006; Hoshino et al., 2010; Tanner et al., 2012). Less often, researchers have made use of agreement errors to investigate the nature of the syntactic representations themselves (Franck et al., 2002, 2006; Vigliocco and Nicol, 1998). In this paper we present data from an induced agreement error experiment in RP Spanish that was designed to address the long standing debate in the linguistic literature regarding the proper analysis of Control and Raising infinitival constructions. In order to induce such errors, we made use of the attraction paradigm (Quirk et al., 1972), where subject–verb agreement errors occur due to an interfering (or local) noun that appears (with different agreement values) between the head noun of the subject and the verb. In (4) the plural *cabinets* inside the singular subject NP headed by the singular *key* ''attracts'' erroneous plural morphology on the verb:

(4) * *The key to the cabinets are on the table*.

Different studies have empirically addressed the study of agreement in different languages by analyzing these errors both in language production (Bock et al., 2012; Hartsuiker et al., 2003; Vigliocco et al., 1995, 1996) and comprehension (Acuña-Fariña et al., 2014; Barber et al., 2004; Martin et al., 2014; Molinaro et al., 2011; Nicol et al., 1997; Pearlmutter et al., 1999; Wagers et al., 2009). Studies have focused primarily on subject–verb agreement, but there are also reports of this phenomenon in subject–predicate gender agreement (Badecker and Kuminiak, 2007; Vigliocco and Franck, 1999, 2001; Vigliocco and Zilli, 1999), and pronoun–antecedent gender and number agreement (Bock et al., 1999, 2004; Meyer and Bock, 1999).

One of the characteristics of attraction errors, for both number and gender, is the asymmetry found between different agreement values. For the languages studied so far (Spanish, Italian, French, English, German, Dutch, Russian, Czech, Slovene), the most frequent errors are erroneous plural agreement (instead of singular in the case of number) and feminine agreement (instead of masculine for gender) in the presence of a plural and/or feminine attractor. The reverse pattern is highly unusual (Franck et al., 2002). While it has been shown that conceptual (semantic) and phonological factors might also play a role in this particular error pattern (Bock and Eberhard, 1993; Bock et al., 2001; Eberhard, 1997; Foote and Bock, 2011; Franck et al., 2002, 2008; Gillespie and Pearlmutter, 2011; Haskell and MacDonald, 2003; Vigliocco et al., 1995, 1996), attraction is triggered also by the morphological (or syntactic) features involved (Antón-Méndez et al., 2002; Bock and Miller, 1991; Fayol et al., 1994; Franck et al., 2002, 2006, 2008; Hartsuiker et al., 2003; Vigliocco and Nicol, 1998).

Sentence production models differ in their explanations for this phenomenon. Certain models assume that it occurs during the grammatical encoding of the subject noun phrase (Bock et al., 2001, 2004; Eberhard et al., 2005), while others propose that it occurs during the copying or retrieval of the appropriate agreement values at the verb or adjective (Badecker and Kuminiak, 2007; Bock and Levelt, 1994). As proposed by Staub (2010), both types of mechanisms might actually be at play in the general class of attraction errors. Despite differences in implementation, multiple models propose that the asymmetry in the error patterns is a consequence of the relative markedness of plural and feminine gender relative to the singular and masculine values.

Most of the research on agreement up to now has analyzed errors, yet few studies have also included an analysis of response times (RT). Notably, two studies have explored this approach. Haskell and MacDonald (2003) were the first to conduct a study using the error elicitation paradigm that took into consideration both errors and RT. The participant read a

subject phrase (e.g., *the key to the cabinets*) and an adjective (e.g., *rusty*), and was required to produce a question about whether the subject had the property in question (e.g., *Was the key to the cabinets rusty*?). The results indicated that when a local plural noun appeared, latency voice onset increased when participants produced a singular auxiliary in answering a question (Vigliocco and Nicol, 1998). Namely, the response latencies increased if there was a mismatch between the head noun and the local noun. Staub (2009) designed a series of experiments in which he manipulated the grammaticality of sentences with errors matching number and measured response times (RT). The author investigated how the latency of the right options can be modulated by the presence of an attractor number. The results confirmed that the presence of an attractor increased the correct number agreement RT. These results seem to support models, such as the one presented here, in which the interference of a number attractor makes the process of calculating the correct morphological agreement value more difficult in general (cf. also Eberhard et al., 2005).

1.3. Modeling agreement production and attraction errors

As has been argued by Marantz (2005), it is quite complicated to investigate simultaneously competence (or representational) and performance (or procedural) dimensions of linguistic behaviors. Mostly, studies tend to make specific assumptions regarding one of the dimensions in order to study the other. Since the goal of the current study is to explore the differences between two syntactic constructions and not to investigate or argue for a specific model for speech production, we will make few assumptions regarding the performance model. It is important to bear in mind that these assumptions are made in order to be able to spell out specific predictions by the competing syntactic theories and interpret accordingly the eventual results. As we will briefly revisit in the discussion, this experiment was not designed to test or choose among competing production/processing models.

We will adopt the general lines of Badecker and Kuminiak (2007)'s ''Working Memory Retrieval Model'' for agreement production, which is based on Lewis and Vasishth (2005)'s parsing model. This family of models inherits from Optimality Theory the notion of violable constraints (Bresnan, 2000, 2001; McCarthy, 2002; Prince and Smolensky, 2004). We will combine this general architecture with specific assumptions regarding under-specification and markedness that derive the observed asymmetry in attraction errors for both number and gender agreement.

1.3.1. The Working Memory Retrieval Model (WMrm)

Once a noun phrase (or more generally any Φ-feature marked item) has been produced/retrieved, it (or at least its associated features) remains active in Working Memory (WM). The model assumes that the lexical units are maintained in this workspace and that each lexical unit has its own morphosyntactic information, i.e. information about their combinatorial properties to bind to structural and functional roles. Following Lewis and Vasishth (2005), we assume that the level of activation of these features decreases with time (or equivalently for our purposes, with the amount of other linguistic materials that has been produced or retrieved during that time). Once an item requiring a selection of a morphologically agreeing form (i.e. a verb or an adjective) is retrieved for production, a search is executed in WM for the relevant antecedent. Fayol et al. (1994) have demonstrated the role of WM in agreement and agreement errors. Badecker and Kuminiak (2007) extend Lewis and Vasishth (2005)'s architecture to agreement production and demonstrate how such a model captures known and novel error data.

Antecedent re-activation. Once a ''moved'' linguistic item (a filler) has been re-activated in the corresponding gap, the activation level of its associated features is boosted (Fayol et al., 1994; Hartsuiker et al., 2003; Hartsuiker and Barkhuysen, 2006; Schriefers and van Kampen, 1993; Stowe, 1986). Furthermore, Franck et al. (2010) have demonstrated that reactivation of an NP in (at least a certain kind of) a gap can produce attraction errors.

1.3.2. Markedness

In a number of influential agreement production models the markedness of the plural and feminine is encoded via under-specification of the corresponding singular and masculine features (Bock and Eberhard, 1993; Franck et al., 2002; Vigliocco et al., 1995, 1996). The asymmetry in the processing of the value of gender and number features has been experimentally tested for Romance languages (Antón-Méndez et al., 2002; Correa et al., 2004; Picallo, 2008). Here we will follow this approach. In the terms of the WM model discussed earlier, adjective agreement defaults to the masculine/singular if, following search, no feminine/plural Φ-feature is associated with the appropriate antecedent in WM. Thus masculine/singular agreement is not triggered by the presence of certain features in WM but via the absence of such features.

1.3.3. Agreement interference/attraction errors

When two NPs are active in WM (N1, the appropriate antecedent, and a competitor N2), the adjective or verb can be incorrectly produced with the Φ-features corresponding to N2. However, this is true only when N2 is associated with the marked value (Plural and/or Feminine) and N1 with the default values (Singular and/or Masculine). This pattern is

expected (and partially motivates) the model presented above. Most errors are the consequence of interference during WM search (retrieval of a feature belonging to the 'wrong' antecedent). Since (only) marked Φ-feature are maintained in WM, attraction errors can only produce the marked value of the feature in place of the unmarked value.

1.4. Overview of the experiment

We have studied the error-pattern for agreement in sentence production of Control and Raising structures in Spanish, by using an elicited-error paradigm (Bock and Miller, 1991). We used an oral sentence-completion task, with preambles that involved the two classes of verbs and studied gender and number agreement between the matrix subject in the preamble and the predicative adjective inside the infinitival which had to be produced by the participants.

Since we assume that Raising is mediated via a copy of the entire matrix subject Determiner Phrase (DP) in the position of the infinitival subject and since it is known that the syntactic representation and its associated morphological features of a filler is reactivated in the gap, we expected Raising to produce the known pattern of attraction errors at the adjective, since N2 is as local to N1 as it was in its pronounced position.

If Control is also derived via a movement operation (as argued for by MTC) then we would predict no differences in the pattern of agreement errors between these two classes. However, if Control is mediated via PRO, differences could be expected. The exact nature of these differences would depend on (and would potentially inform) the details of the PRO theory and how PRO interacts with online agreement mechanisms, an issue which has been largely left unexplored in the literature. A number of possible patterns could be found:

(1) Absence/reduction of intervention errors: Dillon et al. (2013) have shown that morphological agreement of an (overt) reflexive anaphor, unlike verbal agreement, is not sensitive to intervention errors due to a local competitor. If PRO is similar to explicit reflexive anaphors, we would not expect intervention errors in the agreement of PRO with its antecedent. As a consequence, the agreement on the adjective should be less prone to intervention errors (the competitor is no more local to the agreement domain).
(2) If agreement on PRO is sensitive to intervention (contrary to reflexives) or if the adjective does not agree with PRO (given the absence of overt morphological features) but directly with the antecedent noun, we would still expect intervention errors but in addition we would expect overall more errors since, contrary to Raising, the agreement is not local (spec-head) but requires cross-clause search.

2. Experiment

2.1. Method

2.1.1. Participants

Twenty-four native Spanish speakers participated in the experiment. Most of them were students at the University of Buenos Aires, Argentina. The age of the participants ranged from 21 to 40, with a mean of 29.87.

2.1.2. Materials

Items consisted of an adjective presented in its stem form (e.g. *peinad_* ''groomed'') without number or gender features, followed by a complex preamble formed with: Adverb (ending in *–mente* ''-ly'') + main verb + Determiner Phrase + Prepositional Phrase + adverb + Infinitive.

Half of the preambles contained a Raising main verb and the other half a Control main verb.

Examples:
(4) Raising-verb preamble: *Sorprendentemente parecía* (RV) *el cuñado* (N1) *del verdulero* (N2) *anoche estar*... ''Last night, the greengrocer's (N2) brother-in-law (N2) surprisingly seemed to be...''
(5) Control-verb preamble: *Sorprendentemente eligió* (CV) *el cuñado* (N1) *del verdulero* (N2) *anoche estar*... ''Last night, the greengrocer's (N2MascSing) brother-in-law (N1Masc) surprisingly chose to be...''

N1 was the subject's head noun and N2 (the local noun) was inside the modifier of N1. Both had the semantic feature of [+ HUMAN].

The variables manipulated were: (a) gender of the head noun or N1 (Feminine–Masculine), (b) gender (Feminine–Masculine) of local noun or N2, (c) number of N2 (Singular–Plural), and (d) type of verb: Control verb (*elegir* ''to choose'' and *prometer* ''to promise'') and Raising verb (*parecer* ''to seem'' and *resultar* ''to result'') (see Table 1).

Sixteen conditions divided into 4 quadruplets per item have been created. Items were divided into 4 lists. In total, 128 target quadruplets and 42 filler items were used, so each participant saw 170 items. The filler items were completely

Table 1
Example of sentence preambles and adjectives.

Condition	*Adjective*	*Preamble*
Control-N1Masc-N2MascSing	*peinad_* groomed	*Sorprendentemente eligió el cuñado del verdulero anoche estar* (Surprisingly chose the brother in law (N1Masc) of greengrocer (N2MascSing) last night be)
Control-N1Masc-N2MascPl		*Sorprendentemente eligió el cuñado de los verduleros anoche estar* (Surprisingly chose the brother in law (N1Masc) of greengrocers (N2MascPl) last night be)
Control-N1Masc-N2FemSing		*Sorprendentemente eligió el cuñado de la verdulera anoche estar* (Surprisingly chose the brother in law (N1Masc) of greengrocer (N2FemSing) last night be)
Control-N1Masc-N2FemPl		*Sorprendentemente eligió el cuñado de las verduleras anoche estar* (Surprisingly chose the brother in law (N1Masc) of greengrocers (N2FemPl) last night be)
Control-N1Fem-N2MascSing	*preocupad_* worried	*Indiscutiblemente eligió la tía del panadero anoche estar* (Undoubtedly chose the aunt (N1Fem) of baker (N2 MascSing) las night be)
Control-N1Fem-N2MascPl		*Indiscutiblemente eligió la tía de los panaderos anoche estar* (Undoubtedly chose the aunt (N1Fem) of bakers (N2 MascPl) las night be)
Control-N1Fem-N2FemSing		*Indiscutiblemente eligió la tía de la panadera anoche estar* (Undoubtedly chose the aunt (N1Fem) of baker (N2 FemSing) las night be)
Control-N1Fem-N2FemPl		*Indiscutiblemente eligió la tía de las panaderas anoche estar* (Undoubtedly chose the aunt (N1Fem) of bakers (N2 FemPl) las night be)
Raising-N1Masc-N2MascSing	*peinad_* groomed	*Sorprendentemente parecía el cuñado del verdulero anoche estar* (Surprisingly seemed the brother in law (N1Masc) of greengrocer (N2MascSing) last night be)
Raising-N1Masc-N2MascPl		*Sorprendentemente parecía el cuñado de los verduleros anoche estar* (Surprisingly seemed the brother in law (N1Masc) of greengrocers (N2MascPl) last night be)
Raising-N1Masc-N2FemSing		*Sorprendentemente parecía el cuñado de la verdulera anoche estar* (Surprisingly seemed the brother in law (N1Masc) of greengrocer (N2FemSing) last night be)
Raising-N1Masc-N2FemPl		*Sorprendentemente parecía el cuñado de las verduleras anoche estar* (Surprisingly seemed the brother in law (N1Masc) of greengrocers (N2FemPl) last night be)
Raising-N1Fem-N2MascSing	*preocupad_* worried	*Indiscutiblemente parecía la tía del panadero anoche estar* (Undoubtedly seemed the aunt (N1Fem) of baker (N2MascSing) las night be)
Raising-N1Fem-N2MascPl		*Indiscutiblemente parecía la tía de los panaderos anoche estar* (Undoubtedly seemed the aunt (N1Fem) of bakers (N2MascPl) las night be)
Raising-N1Fem-N2FemSing		*Indiscutiblemente parecía la tía de la panadera anoche estar* (Undoubtedly seemed the aunt (N1Fem) of baker (N2FemSing) las night be)
Raising-N1Fem-N2FemPl		*Indiscutiblemente parecía la tía de las panaderas anoche estar* (Undoubtedly seemed the aunt (N1Fem) of bakers (N2FemPl) las night be)

different from the experimental items. The fillers were designed so that the adjective should not agree with the subject of the sentence, but the agreement is established with another noun (e.g. La tía dice que el patio de atrás es LINDO ''*The aunt says that the backyard is NICE*'').

2.1.3. Procedure

Participants were tested individually while seated in front of a computer screen. Prior to the experimental items, they went through four practice items with the experimenter still in the room and received feedback regarding the task. Each participant was tested in a single session of approximately 25 min.

The presentation of the items was carried out on a computer-controlled video display using DmDX (Forster and Forster, 2003). Trials consisted of the visual presentation of the adjective's stems for 500 ms. The adjective stem then disappeared and was followed by a blank screen for 300 ms. Participants had been instructed not to read the adjectives aloud, but to hold them in memory for the completion of the subsequent sentence. Then, a sentence preamble appeared in the center of the screen (e.g. *Felizmente prometió el abuelo del chico siempre estar* (''Happily, the kid's grandfather promised to always be''). Participants had to read the preamble aloud and complete the sentence by using the adjective stem they had previously seen, properly inflected. The sentence preamble remained on the screen for 6000 ms and participants needed to press the spacebar for a new item. All responses were recorded.

2.1.4. Scoring criteria

Sentences were scored according to the following criteria: (1) Correct responses: when the participant read correctly the preamble and completed it using the correct form of the adjective. (2) Agreement errors: adjective produced with incorrect gender or number marking. (3) Omission responses: adjective not produced.

We have studied the error pattern for agreement, the omission pattern and the response time (RT) for the adjective production, measured as the subtraction between the onset of the infinitive verb and the onset of the adjective. Thus, RT corresponds to the time elapsed between the preamble reading and the onset of the agreeing adjective.

Table 2
Total and type of agreement errors. Parenthesis indicates whether the error is a gender (G), number (N), or gender and number (G&N) error.

	Agreement errors	
Control-N1Masc-N2MascSing	0	
Control-N1Masc-N2MascPl	3	(N)
Control-N1Masc-N2FemSing	9	(G)
Control-N1Masc-N2FemPl	1	(G&N)
Control-N1Fem-N2MascSing	6	(G)
Control-N1Fem-N2MascPl	3	(G&N)
Control-N1Fem-N2FemSing	0	
Control-N1Fem-N2FemPl	0	
Raising-N1Masc-N2MascSing	0	
Raising-N1Masc-N2MascPl	1	(N)
Raising-N1Masc-N2FemSing	10	(G)
Raising-N1Masc-N2FemPl	0	
Raising-N1Fem-N2MascSing	5	(G)
Raising-N1Fem-N2MascPl	1	(G&N)
Raising-N1Fem-N2FemSing	1	(G)
Raising-N1Fem-N2FemPl	0	

2.1.5. Data analysis

2.1.5.1. Errors and omissions. Two analyses of variance were performed (by item (F1) and by participant (F2)) using as dependent measure the transformation of the proportion of agreement errors and omission responses (Jaeger, 2008). The variables manipulated (type of verb, gender of N1, gender and number of N2) were part of a within-participant, within-item design.

2.1.5.2. Response times. A linear mixed model was used (Baayen et al., 2008), with participants and items as crossed random factors, and the experimental manipulations (type of verb, gender of N1, gender and number of N2) as well as all their interactions as fixed effects. Analyses were carried out using R (lm4 and lmer Test packages. Bates et al., 2009).

3. Results

For all lists, one item was eliminated because of a problem in programming, leaving 127 experimental items per list. Thus, analyses were performed over a total of 3048 data points. There were 2869 correct responses (94.13%), 40 agreement errors (1.33%), and 138 omissions (4.54%).

3.1. Agreement errors

Participants produced 40 agreement errors, out of which 31 were gender errors (77.5%), 4 were errors of number (10%), and 5 errors of both gender and number (12.5%) (see Table 2). Table 2 also shows that the 5 agreement errors of number occurred only when N1 and N2 had a number mismatch (N1 singular and N2 plural) and gender match (both masculine nouns).

Table 3 displays mean transformed (M) and standard deviation of transformation (SD). The ANOVAs showed a main effect of the Number of N2 ($F_1(1, 23) = 11.63$, $p = .001$; $F_2(1, 23) = 14.34$, $p = .001$) with more errors (only gender errors) produced by the participants in the match condition (both N1 and N2 singular). The following interactions were found: gender of N1 and gender of N2 ($F_1(1, 23) = 21.85$, $p = .000$; $F_2(1, 23) = 16.44$, $p = .001$); gender of N2 and number of N2 ($F_1(1, 23) = 6.30$, $p = .018$; $F_2(1, 23) = 5.63$, $p = .026$); and finally, gender of N1, gender of N2, and number of N2 ($F_1(1, 23) = 18.80$, $p = .000$; $F_2(1, 23) = 17.27$, $p = .000$).

In order to investigate the interaction between the gender attraction errors (the gender N1-gender N2 interaction) and the number of N2, two ANOVAs by item were carried out. In the first, only items where N2 was singular were used, and we found a significant interaction between the gender of N1 and the gender of N2 ($F(1, 23) = 26.32$, $p = .000$). In the second analysis we kept only items with N2 plural, and no gender interaction was found, but a main effect of the Gender of N2 was found ($F(1, 23) = 5.63$, $p = .018$) (see Fig. 1). It is important to note that in conditions with N2 plural, the number of errors was very low: only 8 errors occurred when N2 was masculine and 1 when N2 was feminine (compared to 20 in the case of a singular N2).

Table 3
Mean rating (M) and standard deviation (SD) of agreement errors, omissions, and response times (RT) in the different experimental conditions. The transformation of the accuracy mean in the errors and omissions is presented.

	Agr. error		Omissions		RT	
	M	SD	M	SD	M	SD
Control-N1Masc-N2MascSing	7.6	.128	7.28	.229	334.23	161.05
Control-N1Masc-N2MascPl	7.34	.130	6.71	.231	347.23	165.31
Control-N1Masc-N2FemSing	6.86	.128	7.18	.234	352.88	190.79
Control-N1Masc-N2FemPl	7.51	.130	6.88	.229	369.58	228.47
Control-N1Fem-N2MascSing	7.09	.131	6.62	.232	353.31	194.12
Control-N1Fem-N2MascPl	7.34	.132	6.31	.231	354.37	189.13
Control-N1Fem-N2FemSing	7.6	.132	6.17	.229	362.86	221.85
Control-N1Fem-N2FemPl	7.6	.133	6.48	.229	347.58	211.73
Raising-N1Masc-N2MascSing	7.6	.129	7.12	.229	301.58	114.87
Raising-N1Masc-N2MascPl	7.51	.130	6.8	.229	327.77	178.68
Raising-N1Masc-N2FemSing	6.8	.127	7.43	.235	341.23	201.78
Raising-N1Masc-N2FemPl	7.6	.129	7.04	.229	367.38	216.88
Raising-N1Fem-N2MascSing	7.19	.128	7.27	.232	318.36	139.78
Raising-N1Fem-N2MascPl	7.51	.129	7.12	.229	331.18	154.88
Raising-N1Fem-N2FemSing	7.5	.138	6.96	.245	345.14	237.11
Raising-N1Fem-N2FemPl	7.6	.129	7.04	.229	298.5	104.78

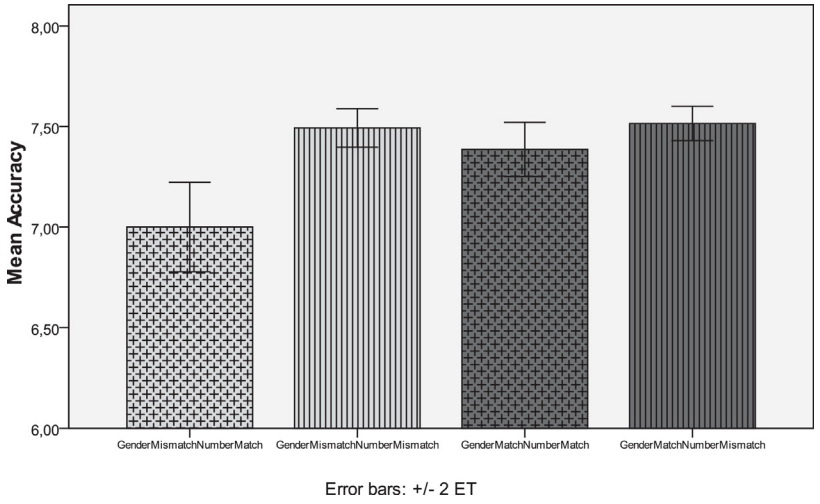

Fig. 1. Mean accuracy (accuracy-agreement errors analysis) in gender match and mismatch conditions and number match and mismatch conditions in all combinations. Gender mismatch appears in light gray, and gender match in dark gray. Number match is represented by crosses, and number mismatch by lines.

The difference between Control and Raising structures was not significant ($F_1(1, 23) = .500$, $p = .480$; $F_2(1, 23) = .871$, $p = .360$).

3.2. Omissions

Table 3 displays mean transformed (M) and standard deviation of transformation (SD).

A main effect of the Type of verb was found ($F_1(1, 23) = 11.61$, $p = .001$; $F_2(1, 23) = 11.02$, $p = .003$). Participants omitted more target adjectives when the preambles contained a Control verb. A main effect of the Gender of N1 was also found in $F_1(1, 23) = 7.15$, $p = .008$ (but not in $F_2(1, 23) = 16.44$, $p = .127$). More responses were omitted when the head noun was Feminine than when the head noun was Masculine. The interaction between these two factors (type of verb and gender of N1) was significant too ($F_1(1, 23) = 7.13$, $p = .008$; $F_2(1, 23) = 6.75$, $p = .016$).

In order to investigate the interaction between verb type and gender of N1, two new ANOVAs of repeated measures of the verb type effect were performed. In one, we took all the trials in which N1 was feminine and the differences between control and raising were significant ($p = .000$). In the second, we took only trials in which N1 was masculine and the

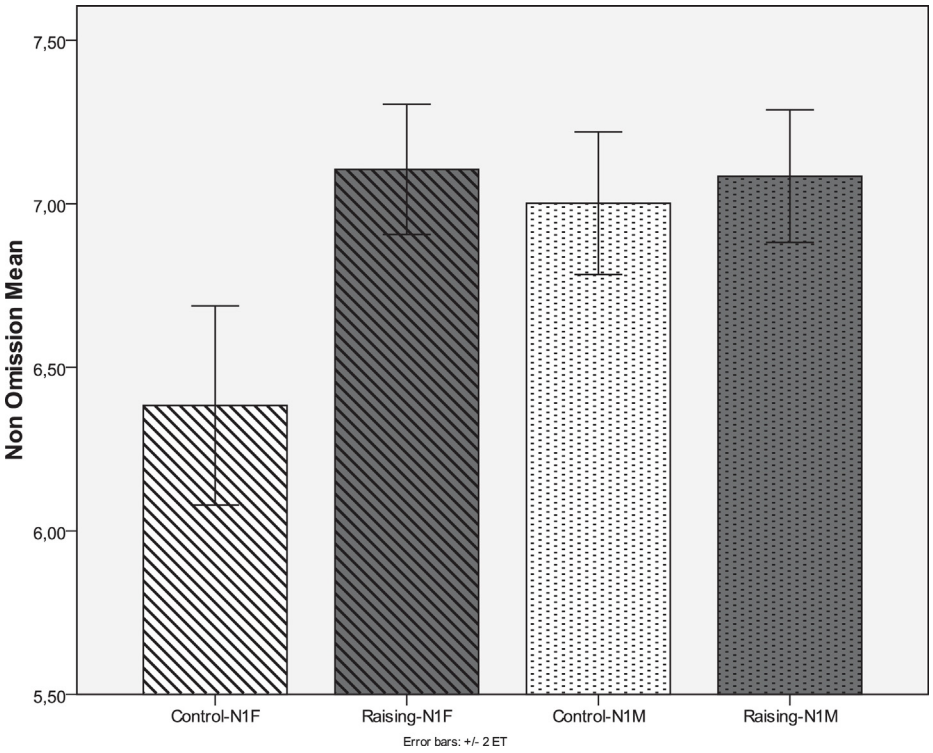

Fig. 2. Non-omission Mean (non omission–omission analysis) for Feminine and Masculine head noun in the Raising and Control conditions. Control condition appears in white and Raising condition in dark gray. N1 Feminine is represented by diagonal lines and N1 Masculine with points.

difference between the two types of verbs was not significant (p = .572). The t-test indicated that between the pair Control N1 Masculine and ControlN1 Feminine the differences were significant (t(753) = 3.38; p = .001), and between the pair Raising N1 Masculine and Raising N1 Feminine the differences were not significant (t(736) = 3.38; p = .882) (see Fig. 2).

3.3. Response time

For the mean (M) and standard deviation (SD) of the RT in the different experimental conditions see Table 3. Table 4 shows parameter estimates, errors, and t values for the fixed effects and their interactions in the linear mixed model.

Table 4
Estimates, standard errors (SE), and t values of RT with type of verb, gender of N1 and gender and number of N2 as fixed effects. In bold, the main effect and significant interaction is shown.

	Estimate	SE	df	t	Pr(>|t|)
(Intercept)	5.74	0.04	83	133.58	0.000
verb type (Control)	−0.09	0.03	2767.9	−2.68	**0.007**
genN1masc	0.06	0.04	290	1.51	0.131
genN2masc	0.02	0.03	2768.7	0.74	0.454
numN2sing	0.03	0.03	2768.6	1.12	0.261
verb type:genN1masc	0.10	0.04	2767.9	2.07	**0.038**
verb type:genN2masc	0.04	0.04	2767.9	0.99	0.318
genN1masc:genN2masc	−0.05	0.04	2768.7	−1.05	0.290
verb type:numN2sing	0.02	0.04	2772.3	0.59	0.551
genN1masc:numN2sing	−0.07	0.04	2768.8	−1.42	0.153
genN2masc:numN2sing	−0.03	0.04	2768.8	−0.79	0.428
verb type:genN1masc:genN2masc	−0.11	0.06	2767.9	−1.67	0.094
verb type:genN1masc:numN2sing	−0.07	0.06	2770.3	−1.04	0.297
verb type:genN2masc:numN2sing	−0.10	0.06	2770.2	−1.49	0.134
genN1masc:genN2masc:numN2sing	0.02	0.06	2768.9	0.39	0.694
verb type:genN1masc:genN2masc:numN2sing	0.16	0.09	2769.1	1.72	0.085

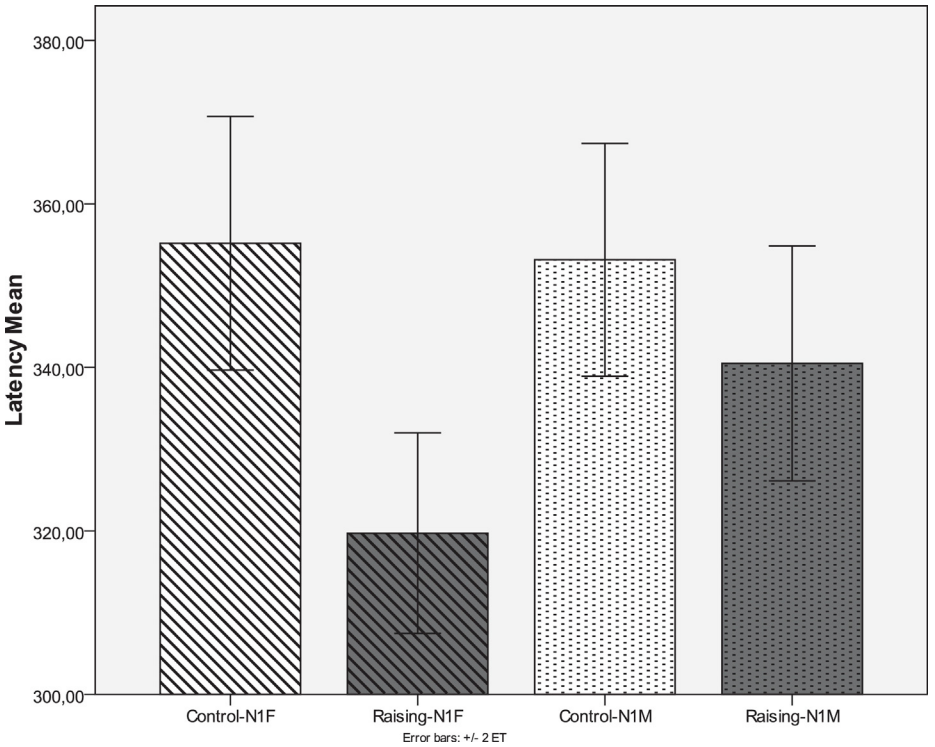

Fig. 3. Latency mean for Feminine and Masculine head noun (N1) in the Raising and Control conditions. Control condition appears in white and Raising condition in dark gray. N1 Feminine is represented by diagonal lines and N1 Masculine with points.

Verb type had a significant effect on time to onset of the adjective production. Specifically, Control verbs were associated with a longer latency compared to Raising (p = .007). In addition, the interaction between the verb type and the gender of N1 was significant (p = .038). No other main effects or interactions were significant. Fig. 3 presents the mean latency for Raising and Control conditions in the feminine and masculine head noun.

To summarize, the experimental data showed the following: (1) for errors, we did not find number attraction, but we found gender attraction with feminine local nouns, specifically when both the head noun and the local noun are singular, for both Control and Raising structures. (2) For omissions, we found that participants omitted the adjective more often in the Control verb condition, particularly when the head noun was feminine. (3) The RT analysis showed a main effect of verb type (the adjective was produced faster in the Raising condition) and an interaction between gender and syntactic condition. The adjective was produced slower in the Control condition compared to the Raising condition specifically when the head noun was feminine.

4. Discussion

In the present study we investigated the processing of gender and number agreement between head nouns of the matrix subject and predicative adjectives in an embedded infinitival complement in Spanish sentences that involved two types of matrix verbs: Control verbs and Raising verbs. Aiming to see if these structures showed differences in processing, we designed an oral completion task in which gender of N1, gender and number of N2, and type of verb were manipulated. We analyzed attraction error and omission patterns, as well as response times, measured as the time elapsed between the preamble reading and the onset of the agreeing adjective. For both Control and Raising verbs we found a small but significant number of gender attraction errors. The rate of errors was not different across the two syntactic conditions. We did not observe the well established number attraction errors. In addition, gender errors appeared more often when both N1 and N2 had a matching number agreement (singular). We will address these two issues below.

While Control and Raising verbs were not associated with differences in the produced errors, the two verb classes were associated with significantly different number of target omissions. Furthermore, omissions in the Control condition were specifically associated with (expected) feminine agreeing adjectives. Adjective production latency reflected a similar pattern. The production onset time for feminine adjectives was shorter in the Raising verb condition compared to the Control verb condition (see Fig. 1).

We turn now to a discussion of the agreement error pattern and then the omission and production time results in view of the production model described in the Introduction. Finally, we discuss the consequences of these results to the theoretical debate regarding the analysis of Control verb infinitival constructions.

4.1. Agreement errors

Our results regarding errors showed a subset of the usual pattern of attraction errors, where feminine agreement replaces the expected masculine. For both Control and Raising sentences, N2 interfered with the agreement with N1 to a similar extent. The fact that the error pattern generalized across syntactic classes (Control vs. Raising) suggests that in both cases the adjective gender agreement is evaluated in a similar manner (via search for the appropriate NP antecedent). In terms of syntactic theory, even if Control and Raising were to be instances of different syntactic derivations (as stated by the PRO hypothesis), agreement in both cases is still sensitive to the internal structure of the antecedent NP or, in processing terms, to the presence of competing antecedents in working memory.

As expected in the WM retrieval model adopted here (Badecker and Kuminiak, 2007; Lewis and Vasishth, 2005), the gender attraction effect was significantly stronger when both N1 and N2 were singular. As it has been established for filler-gap dependencies and for speech errors, attraction of a distractor during retrieval is a function of its similarity to the target (Badecker and Kuminiak, 2007; Gordon, 2002). In our case, similarity in the number feature (or, given under-specification, a lack of feature clash), makes N1 and N2 more similar and enhances attraction.

The dependency of gender errors on number match bears potentially also on the question of the structural (syntactic or morphological) organization of inflectional features in the DP. It suggests that these features are bundled together rather than distributed between different functional projections within the DP. Given that the experiment here was not designed to investigate this question, it is not possible to draw any firm conclusions regarding this issue.

It is worthwhile to note that we observed only very few cases of the well documented number agreement error where a plural N2 triggers (erroneous) plural agreement on the adjective (when N1 is singular). There are at least two different explanations for the near absence of this type of errors. One option is that the low number of number errors is due to the presence, in our preamble, of a (number only) inflected verb. Previous studies of agreement production errors in Romance did not use an inflected verb as part of their preamble (Antón-Méndez et al., 2002; Franck et al., 2002; Rodrigues, 2006; Vigliocco et al., 1995, 1996). However, our interest in studying complex infinitival constructions required the use of inflected verbs. A second explanation could be more specifically the fact that we used subject–verb inversion in our materials (and not simply the presence of an inflected verb). Franck et al. (2006) did not find attraction errors on the verb in V-S word order in Italian.

It is not possible to chose, given our design, between these two explanations, but both share a critical feature. The absence of agreement errors on the adjective depends (in one way or another) on the matrix verb. Why should the presence of a (sentence initial) inflected verb reduce number agreement errors in a model were agreement is modeled as re-activation of nominal features?

One possible explanation could be that number adjective agreement in Spanish or Romance is formally dependent not only on the antecedent noun but also on the verb. This could be implemented as a requirement to not only search for an active nominal number feature in WM but also to check for agreement correspondence with the inflected verb (similar in spirit to the notion of index sharing in HPSG, Polard and Sag, 1994). This hypothesis is supported by data from intuitive acceptability judgment experiments in Spanish with group denoting subject nouns (Mare, 2012). Verb agreement for group denoting nouns such as *grupo de estudiantes* (“a group of students”) can be either plural or singular (van Koppen, 2005):

(6)	*El*	*grupo*	*de*	*estudiantes*	*esta*	*acá*
	The	group-$_{\textbf{sing.}}$	of	student-$_{pl.}$	BE-$_{\textbf{sing.}}$	here
(7)	*El*	*grupo*	*de*	*estudiante**s***	*está**n***	*acá*
	The	group-$_{\textbf{sing.}}$	of	student-$_{\textbf{pl.}}$	BE-$_{\textbf{pl.}}$	here
	“The group of students is here”					

However, once a plural agreeing adjective is added, the verb must also be plural

(8)	*El	grupo	de	estudiantes	está	listo**s***
	The	group-$_{\textbf{sing.}}$	of	student-$_{pl.}$	BE-$_{\textbf{sing.}}$	ready-$_{pl.}$
(9)	*El*	*grupo*	*de*	*estudiante**s***	*está**n***	*listo**s***
	The	group-$_{sing.}$	of	student-$_{\textbf{plu.}}$	BE-$_{\textbf{pl.}}$	ready
	“The group of students is ready”					

These data argue for interdependence between noun-adjective and noun-verb agreement (at least in Spanish), where the number value on the verb and on the adjective must agree. Independently of how this requirement should be encoded in the agreement production, it would strongly reduce any number agreement errors in the presence of a (correctly) produced agreement on the (sentence initial) verb. Once no inflected verb is present, or in the case of gender agreement (which is not encoded in the verb), attraction errors would surface.[3]

4.2. Omissions and RT

While the total number of errors in our experiment was rather small (1.33%), presumably due to the presence of an inflected verb (thus strongly reducing number attraction errors), we observed a surprisingly large number of omissions (4.54%). To our knowledge omissions have not been discussed or highlighted in the elicited error paradigm literature. Unlike for the error pattern, the observed omission rate was not sensitive to attraction. That is, it was not the case that more omissions were produced when N2 was Feminine and N1 Masculine (or plural and singular respectively). Instead, omissions were particularly prevalent in Control structures when N1 was Feminine (see Fig. 2).

Interestingly we find a very similar picture once we look at the time course of production. Initiation of the adjective took overall longer in Control compared to Raising sentences. However, as is clearly visible in Fig. 3, there was an interaction between the syntactic condition and gender. The difference between Control and Raising was particularly large when N1 (or the produced adjective) was feminine. The apparent shorter RT for Raising verbs was largely driven by the feminine agreement.

What could explain this pattern?

Lower RT for feminine adjectives is indeed expected given our assumptions regarding under-specification and the search based WM model. If only feminine value is activated in WM, feminine value of agreement can be determined as soon as the feature was detected with confidence during search. However, masculine agreement would only be applied in the *absence* of feminine features (or a failed search). As a consequence, we would expect longer RT for masculine compared to feminine agreement (in analogy to longer RT for non-words in lexical decision, Forster and Chambers, 1973; Meyer and Schvaneveldt, 1971). However, we find this expected RT advantage for feminine agreeing adjectives only in the Raising condition. In light of our assumptions, our results strongly suggest that the difference observed between Raising and Control (in RT) is the consequence of the absence of this feminine advantage in the Control condition. The pattern here is different from the one observed for example by Walenski (2002), since he found a main temporal delay effect of Control compared to Raising (while here the effect is tied to the feminine agreement). Walenski studies English where there is no grammatical gender, so it is hard to interpret the differences between the two studies. Featherston et al. (2000) found the processing of the empty category in Raising to be more 'costly' than Control (using ERP). Our results do not suggest such an asymmetry (or even suggest an opposite asymmetry). The differences in language, modality and method make the interpretation of these differences, once again, difficult.[4]

So why do we find this specific pattern of interaction between gender agreement and syntactic structure? We propose that this pattern should be interpreted as piece of evidence for a syntactic difference between Control and Raising. More specifically, we suggest that it argues for some version of the PRO theory.

[3] Another possible explanation for the infrequency of number agreement errors could be that the level of activation of the N1 number feature is simply boosted by the verbal agreement process and so is more robust to interferences once the adjectival agreement is computed. While this explanation does not require changing our formal assumptions regarding noun-adjective agreement, it is not compatible with our account of the error asymmetry in terms of under-specification (singular number is simply the absence of plural agreement). Under this view, there are no features to be boosted in the case of singular N1. A different line of explanation of the difference between gender and number was suggested to us by 2 reviewers. Number is semantically interpretable while gender is (often) a purely morphological feature with no semantic basis. It might be the case that for some reason 'semantic' agreement is either more robust in inter-clausal contexts compared to morphological agreement or that the presence of an inflected verb differently affects semantic and morphological agreement. This line of investigation would require further experimentation.

[4] Featherstone and colleagues found a more positive P600 component in the ERP signal at the empty subject position in raising constructions compared to control constructions. They interpreted this result as indicating an increase in processing cost due to the movement chain (absent in control). This result could seem somewhat at odds with our result here since it is the control condition that appears to be more costly. As pointed out by Polinsky and Potsdam (2002), the EEG result reported by Featherstone et al. could also be due to differences in predictions between the two conditions. The German raising verb used by the authors of the EEG study has multiple frame options and so the increased P600 component could indicate re-analysis cost. Putting aside this alternative interpretation, our experiment was not designed to evaluate the cost of the empty category processing but of the agreement production. It is possible (and indeed compatible with the interpretation of our results) that at the empty subject position of a raising verb there is indeed an extra step (re-activation of the antecedent in a gap position) compared to control, and it is exactly this re-activation that then makes agreement at the adjective more robust or easy (since the memory trace is stronger), as we observe here.

Put in the most theory neutral way, according to the MTC the subject position of the infinitive contains a copy of the matrix subject in both Control and Raising. Under this scenario, the difference in omissions related to the expected feminine gender or the increase in RT are wholly unexpected. Furthermore, it is not clear what can be added to the theory to derive this particular pattern, apart from an ad-hoc stipulation. On the other hand, the PRO account clearly distinguishes between the content of the embedded subject position in Raising (a copy of the matrix subject) and Control (a null pronoun).

Though more needs to be said, the fact that in Raising the embedded subject is local to the domain of agreement of the adjective within the infinitival while in Control it is not provides a basis for a principled explanation for the processing differences we observed. Given the architecture we assumed for this paper, the observed pattern can be explained in the following way: the agreement operation between PRO and the antecedent subject is theoretically different from reactivation of a filler in a gap (there is no re-Merge of a constituent, only valuation of features on PRO) and is also different from clause internal agreement (being a long distance search triggered by a pronoun rather than a head specifier Agree operation). It is this added step in the agreement calculus, we propose, that results in a weaker memory trace of the feminine feature compared to raising (or intra-clausa agreement). The weaker memory trace slows down the search for the (feminine) gender feature (as can be seen by the increase in production latency for the feminine agreeing adjectives in the Control sentences). In addition, this weaker memory trace increases the rate of non-converging searches (the algorithm cannot determine whether the agreement should be feminine or the default masculine), which are (we suggest) the source of the omissions found overwhelmingly in the case of feminine matrix subjects in Control sentences.

We must remain agnostic concerning the exact nature of this weaker memory trace since this would depend on the assumptions made regarding the processing model as well as the nature of PRO and that would require further testing. For example, it could be that in general the calculation of pronominal agreement is ''noisier'' than intra-clausal agreement. This would predict overall slowing down for feminine agreement in pronominal contexts beyond that of PRO (Betancort et al., 2006; Cowart and Cairns, 1987; Fodor, 1989; McElree and Bever, 1989; Nicol, 1988; Sag and Fodor, 1995). An alternative explanation could be the specific nature of agreement on PRO. While overt pronominal elements (pronouns, reflexives) often agree in either gender or number or both with their antecedent, PRO is a null anaphoric element and so it is not clear to what extent it agrees morphologically (or at least in gender) with its antecedent (Bosque and Gutiérrez-Rexach, 2009; Dalmi, 2005; Das, 2014; Ritter, 1993). If PRO, lacking any phonologically overt morphology, does not agree with its antecedent, we would expect no reactivation of any morphological features of the matrix subject DP inside the infinitival. In that case, agreement on the adjective will be computed in relation to the features activated in WM by the original realization of the matrix subject. Since no reactivation has taken place, the retrieval operation would require more effort and time given a lower signal to weaker memory trace due to decay (increase in search time). In other words, the weaker memory trace is the result of the absence of agreement on PRO.

An alternative hypothesis regarding the source of this weaker memory trace could be that, while PRO actually agrees in gender with its antecedent, once the adjective agreement is computed, the lack of overt phonological expression of this agreement slows down the search for a feminine feature. One possible avenue for future research would be to compare PRO and pro (the null pronoun that can be freely placed in matrix subject position in languages such as Spanish).

Our experiment was not constructed to distinguish between theories of processing more generally or agreement production more specifically. The assumptions made in the Introduction and here regarding the processing model were necessary in order to be able to spell out concrete predictions and interpret the results. At the same time the specific assumptions made here are backed by various psycholinguistic studies cited in the Introduction. It is always possible that different assumptions regarding the processing model could in principle alter the interpretation of our results in terms of structural differences between OC and Raising.[5] An in depth comparison of different processing models or architectures is beyond the scope of this paper (cf. Acuña-Fariña, 2012 for a review of existing models). We do believe that any processing architecture that will be able to handle the various findings here, such as the gender intervention errors in both OC and Raising, the lack of number intervention in either, the dependency of gender intervention on number matching and the relative speed of feminine agreement production in Raising (as well as known facts from the literature) will be required, ultimately, to assume structural differences between OC and Raising in order to explain the differences observed in our experiment.

In sum, the data of this experiment show that the rate of error was not different across the two syntactic conditions (Control vs. Raising), but the two verb classes were associated with significantly different number of target omissions. Omissions in the Control condition were specifically associated with feminine agreeing adjectives. This pattern was also reflected in the adjective production latency and is taken as an evidence for a Control by PRO analysis of Control

[5] As pointed out by an anonymous reviewer, the agreement model assumed here makes use primarily of 'look back' mechanisms (convincingly argued for by Lewis and Vasishth, 2005 and others). To what extent a model incorporating look ahead mechanisms would shed different light on our results is an interesting question that should be addressed by future research specifically assessing the role of these complementary mechanisms in agreement production.

constructions. Our findings provide data to both theoretical and experimental discussions about the difference between Control and Raising structures and is, as far as we know, the first study that has compared Raising and Control in Spanish sentence production and that has investigated the interaction of these structures with online agreement mechanisms.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.lingua.2015.12.014.

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