Journal of Linguistics (2025), **61**, 301–337
doi:10.1017/S002222672400001X

Journal of Linguistics

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Processing dissociations between raising and control in Brazilian Portuguese

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Received: 27 January 2023; **Revised:** 05 January 2024; **Accepted:** 27 November 2023

Keywords: cross-modal priming; empty categories; sentence processing; raising; repetition priming; syntactic control

Abstract

Generative approaches to syntactic control have traditionally viewed it as a distinct component of the grammar, one that governs the interpretation and distribution of the EMPTY CATEGORY (EC) PRO. However, the MOVEMENT THEORY OF CONTROL (MTC) proposes that control should instead be conceived of as a form of raising, with both sentence types involving the EC DP/NP TRACE. In addition to theoretical arguments, some behavioral research on antecedent reactivation has demonstrated that different ECs reactivate their antecedents to different degrees and at different points in the time course of comprehension. In this study, we used a cross-modal repetition priming paradigm to examine antecedent reactivation in Brazilian Portuguese. We found significantly greater activation at the gap position in raising sentences and in those with overt pronouns as compared to (exhaustive) control sentences, consistent with the standard account of raising and the traditional view of control as involving a distinct EC. Additionally, we found some evidence for a differentiation between exhaustive and partial control structures. Overall, our results suggest that 1) similar linguistic mechanisms are employed in the processing of sentences that involve overt pronouns and DP/NP traces, and 2) different mechanisms are employed in the processing of raising and control structures, a finding we view as inconsistent with the MTC.

1 Background

1.1 Empty categories

Among the most controversial claims of the models of the grammar that have contributed to the development of the Minimalist Program (e.g. Chomsky 1995) is the proposed existence of phonologically null (i.e. unpronounced) elements, often referred to as EMPTY CATEGORIES (ECs). Empty categories, which are similar to pronouns in that their referential properties are derived from another constituent, are predicted on the basis of theory-internal principles such as the Theta Criterion (Chomsky 1981). However, given that ECs have no phonological form, neither their distribution nor their very existence can be confirmed directly.

Empty categories come in several subtypes, including the WH Trace (Example 1), the NP/DP Trace (Example 2), 'big' PRO (Example 3), and, in null-subject languages, such as Spanish, 'little' *pro* (Example 4). All are coindexed with another phrase (or in the case of *pro*, potentially an entity in the discourse context), which indicates that both phrases refer to the same entity (i.e. they're coreferential):

Example 1

(1) $\textbf{What}_{\textbf{i}}$ do you want $\textbf{t}_{\textbf{i}}$ for breakfast?

Example 2

(2) $\textbf{Diogo}_{\textbf{i}}$ is likely $\textbf{t}_{\textbf{i}}$ to $\textbf{t}_{\textbf{i}}$ help.

Example 3

(3) $\textbf{Andy}_{\textbf{i}}$ wants $\textbf{PRO}_{\textbf{i}}$ to grill these sausages tonight.

Example 4

(4) *Spanish*

[$\textbf{\textit{pro}}_{\textbf{i}}$]	Llamaron	a la puerta.
	called.**pst**.3sg	to the door

'They/Somebody knocked on the door.'

The formal properties of the traces in Examples (1) and (2) differ from PRO and *pro* in Examples (3–4) in that traces are not independently assigned a thematic role, (i.e. the semantic role an argument plays with respect to a predicate), but rather bear the same thematic roles as their antecedents. Traces are linked to their antecedents in a movement chain and may be conceptualized either as the residue of syntactic displacement (i.e. what their antecedents leave behind in the position in which they are merged into a structure) or simply as unpronounced copies of their antecedents (Chomsky 1993; 1995; et seq.). For example, in Example (2), which is typically referred to as a Raising structure, *Diogo* originates in the embedded clause, where it receives a thematic role from *help*, before being displaced to the embedded subject position and then to the matrix subject position. Traces are thus intricately linked to their antecedents semantically, as they bear the same thematic role, as well as syntactically, as they are linked in a movement chain.

In contrast, the ECs PRO and *pro* are assigned thematic roles independently of the phrase with which they are coindexed. Indeed, the existence of PRO (and *pro*) is motivated in part by the Theta Criterion (Chomsky 1981:35), which holds that every predicate is lexically specified with a selection of Theta Roles (i.e. thematic roles) to assign, and that the mapping from thematic role to argument is one-to-one: Each theta role may be assigned only once, and a given argument can only be assigned a single thematic role. Thus, in Example (3), PRO is posited as the syntactic element which receives an external theta role from the embedded verb *grill*. Note that no movement is posited here; PRO and its antecedent (*Andy*) are not

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linked in a movement chain. Thus, although PRO is typically coindexed with an antecedent phrase, each bears a distinct theta role, so neither PRO nor *pro* is directly linked syntactically with any other phrase.

The question of the semantic relationship between null pronouns and their antecedents is a bit more complex. By hypothesis, neither PRO nor *pro* bears the same thematic role as its antecedent, so they are not semantically linked in this sense; each plays a distinct role with respect to a predicate (sometimes different predicates), However, where PRO is coindexed with an antecedent, both refer to the same discourse entity (as an anonymous reviewer correctly notes). Whether this constitutes a 'semantic relationship' is beyond the scope of this paper, but it is important to bear in mind that coindexation is simply a diacritic used for capturing possible and impossible referential properties of expressions and has no other interpretive value. In this sense, it may be more productive to view coindexation as determination of reference via discourse-information-structural properties.

Returning to the theoretical status of PRO, the component of the grammar which deals with its distribution is known as CONTROL; an EC that is coindexed with another phrase in the same sentence is said to be CONTROLLED by that phrase, which, in turn, is known as the CONTROLLER. Landau (2000; see also Landau 2013, 2015) distinguishes between two varieties of control relevant to our purposes: matrix predicates where the controller and PRO are coextensive in reference (EXHAUSTIVE CONTROL, ExC), as in Example (5) below, and predicates where the reference of a singular controller forms a proper subset of the reference of a plural PRO (PARTIAL CONTROL, PC), as in Example (6a). Matrix predicates which allow for PC include desiderative, factive, and propositional predicates; those which allow for ExC include implicative, aspectual, and modal predicates. Consider the following examples:

Example 5

(5) **Mary$_i$** remembered/forgot/planned/hated [**PRO**$_{i/*j}$/*Bill to lock the door].

Example 6

(6) (a) **The vice-president$_i$** preferred **PRO$_{*i/i+j}$** to meet in the morning.
(b) **The vice-president$_i$** tried **PRO$_{i/*i+j}$** to lock the door.
(c) ***The vice-president$_i$** tried **PRO$_{*i/*i+j}$** to meet in the morning.
(d) **Brazilian Portuguese (BP)**

O vice-presidente$_i$	preferiu	[**PRO$_{*i/i+j}$**	conhecer	pela	manhã]
the vice-president	prefer.PST.3SG		meet.INF	in-the	morning

'The vice-president preferred to meet in the morning.'

(e)

***O vice-presidente$_i$**	tentou	[**PRO$_{*i/*i+j}$**	conhecer	pela	manhã]
the vice-president	try.PST.3SG		meet.INF	in-the	morning

'The vice-president tried to meet in the morning.'

In Example (6a), we have a desiderative main-clause predicate, with *the vice-president* only one member of the set of individuals who comprise the grammatical subject of *meet*; this is an example of PC. In Example (6b), we see that the aspectual predicate *try* behaves differently, allowing only for an ExC reading and disallowing the PC reading in which more than one individual attempts to lock the door. In Example (6c), neither reading is available, with the result that the sentence as a whole is ungrammatical; the PC reading is

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unavailable due to *try* being aspectual, whereas the ExC reading is unavailable due to *meet* requiring a singular subject. A similar contrast exists between desiderative and aspectual predicates in Brazilian Portuguese (BP) (Example 6d, 6e).

Some readers might find Example (6c) and its BP equivalent in Example (6e) somewhat acceptable.[1] We suspect that this intuition comes from a different reading, one which allows for *meet* to take a singular subject (here, exhaustively controlled PRO) if it is understood to have a (null) object: 'The vice-president tried to meet [someone] in the morning'. This is consistent with BP's licensing of null objects, which may be possible in such contexts in English as well (see, e.g. Massam & Roberge 1989). Note that the acceptability of a null object crucially depends on a pre-existing context in which the vice-president regularly meets some individual in the morning.

1.2 Alternate accounts of control

The Movement Theory of Control (MTC; Hornstein 1999; Boeckx & Hornstein 2006; Boeckx, Hornstein & Nunes 2010; Hornstein & Nunes 2014) proposes that cases of apparent control, typically analyzed as involving the empty category PRO, can be more parsimoniously analyzed as resulting from movement analogous to raising. In this view, PRO is entirely eliminated as an EC, being reduced to a DP/NP trace in ExC contexts and to *pro* in PC contexts, with the result that control is eliminated as a distinct component of the grammar. Following Hornstein (1999: 69), the standard account proposes that control sentences (Example 7a) are analyzed as in Example (7b), while raising sentences (Example 8a) are analyzed as in Example (8b). Assuming the copy theory of movement (Chomsky 1993, et seq.), we can represent Example (8b) as Example (8c).

Example 7

(7) (a) John expects to win.
    (b) John_i expects [$\mathbf{PRO_i}$ to win]

Example 8

(8) (a) John seemed to win.
    (b) John_i seemed [$\mathbf{t_i}$ to win]
    (c) John seemed [**<John>** to win]

If, as Hornstein (1999: 72) argues, 'the general properties of OC [obligatory control] structures can be reduced to movement', Examples (7a–b) can be reanalyzed as Example (9), with PRO replaced with a copy of JOHN.

Example 9

(9) John expects [**<John>** to win]

[1] We thank an anonymous reviewer for pointing out this possibility.

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The analysis of OC as in Example (9) represents an important deviation from a standard assumption of theta theory: a constituent may be assigned one and only one theta role (Chomsky 1981). Furthermore, the assumption that movement to theta-related positions is restricted (Chomsky 1986, 1995) must be suspended as well.[2,3] Therefore, in Example (9), *John* receives two theta roles: one from *win* and another from *expect*. Clearly, then, the difference between the derivations for raising (Example 8c) and obligatory control (Example 9) is that *John* in the raising sentence (Example 8c) only receives one theta role, from the predicate *win*. What raising and control share, however, is that both structures feature two copies of the DP *John*. In the end, the MTC account has the desirable effect of simplifying the grammar by removing the control module entirely, thereby subsuming it under independently motivated analyses (i.e. the copy theory of movement), potentially bringing these phenomena in line with minimalist assumptions about how the grammar operates.

However, objections have been raised as to the empirical adequacy of this proposal, with Modesto (2010) arguing that certain agreement facts in PC contexts in Brazilian Portuguese make analyzing control as raising an untenable assumption. In Example (10), the embedded infinitive *reunirem* shows plural agreement, capturing the chair's meeting with additional individuals.

Example 10

(10) *Brazilian Portuguese (BP)*

O presidente$_i$	odiou	**PRO$_{i+}$**	se	**reun-ir-em**	às 6.
the chair	hated.3SG		self	meet-INF-3PL	at.the 6

'The chair hated to gather at six o'clock'.

The plural agreement here is problematic for the MTC, as it demonstrates that PC is not merely a semantic phenomenon but a morphosyntactic one as well, with plural agreement on the embedded verb despite the singular matrix subject *o presidente.*

On the face of it, then, no account positing a trace that forms a chain with the matrix subject seems likely to succeed. There have, however, been some proposals that attempt to account for this mismatch between the controller and the embedded predicate. Rodrigues (2007) proposes an account in which the singular controller is moved out of a complex plural DP in the embedded clause, one which also hosts a null associative *pro* that is subsequently stranded in the embedded subject position (see also Rodrigues & Hornstein 2013, and for a rebuttal, Modesto 2018). This account is still dependent on raising of the controller and movement into theta positions, however, so we do not find it to be meaningfully different from the MTC with respect to whether control and raising constitute separate phenomena, at least for our purposes here (i.e. with respect to how these sentences are processed).[4]

[2] See, however, Saito (2001) and Ito (2008) for arguments that movement into theta-positions is sometimes permitted.

[3] Hornstein (1999) further argues that given minimalist assumptions about the grammar (Chomsky 1993, et seq.), theta-marking is an unnecessary remnant of how D-structure was conceived in the Government and Binding era (e.g. Chomsky 1981), and so must be eliminated from the theory. We omit further discussion of the status of components of the grammar associated with D-structure for reasons of space.

[4] Other proposals for characterizing control without PRO have been advanced but generally suffer from the same inability to account for PC. For example, Janke (2008) proposes a 'theta-percolation' mechanism by which theta

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Furthermore, in a reply to Modesto (2010), Rodrigues & Hornstein (2013) argue that inflected infinitives are not truly part of the grammar of spoken dialects of BP but are rather an artificial feature learned at a late age and in school; Pires & Rothman (2009) make a similar argument based on the absence of inflected infinitives in the grammars of heritage speakers of BP living abroad who have not had formal education. If so, this would call into question the probative value of examples like Example (10).[5] As BP is unique among the major Romance languages in that it allows for inflected infinitives like *reunirem*,[6] we conducted an experimental study on the acceptability of PC structures in BP, finding that PC sentences were indeed judged acceptable by participants.[7] We report on this acceptability judgment task elsewhere (Gupton & Merchant 2024, ms.); in this paper, we report on the processing portion of our study.

To summarize, the MTC account suggests that OC and raising sentences can both be accounted for via movement. In such an account, the same number of copies of the matrix subject argument would be involved in control as in raising sentences. If these copies are not merely theoretical artifacts but are psychologically real in the sense that they reflect real linguistic processing mechanisms, then they should in principle be experimentally discoverable. In Sections 1.3 and 1.4, we review processing research on empty categories in general, including the processing of traces (which may be understood as the processing of copies) and the processing of sentences proposed to contain PRO specifically.

1.3 The psychological reality of empty categories

The experimental evidence for ECs is based on the hypothesis that ECs are covert elements analogous to overt pronouns (McElree & Bever 1989). Under this view, data suggesting a parallel between sentences with overt pronouns and sentences with theoretically predicted ECs are taken as evidence for the psychological reality of ECs, that is, as evidence that the parser makes active use of ECs in sentence comprehension (Featherston 2001).[8,9] Cross-modal

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roles are decomposed into multiple selectional restrictions. Space considerations preclude a more complete review of such proposals here.

5 Rodrigues & Hornstein (2013) also suggest that PC structures with inflected infinitives are not actually examples of partial control but rather should be construed as examples of non-obligatory control involving the EC *pro*.

6 Scida (2004) reports that inflected infinitives also exist in Galician, Sardinian, Old Neapolitan, Old Leonese, and Mirandese.

7 This was a typical grammaticality judgment task employing a four-point Likert scale ranging from -2 to 2 without a '0' midpoint in order to avoid the midpoint serving as a proxy for 'I don't know', following Ionin & Zyzik (2014). When converted to positive values (0 to 3), the mean acceptability for PC was 1.68/3.

8 An anonymous reviewer questions the assumption that syntactic representations are psychologically real, specifically whether the assumption that ECs are analogous to overt pronouns can provide evidence of 'their existence inside or outside of the psychological space', suggesting instead that the claim here should be limited to 'something is going on in these positions'. We will touch on this again in our discussion in Sections 5.2 and 6; however, we think an in-depth inquiry into the relationship between the grammar and effects found in behavioral research generally would take our discussion too far afield.

9 The processing literature on empty categories is vast, so the studies reviewed here are merely one thread in a complex tapestry. For another such thread, particularly pertaining to the processing of intermediate copies, see for example Gibson (1991, 1998), Gibson & Warren (2004), Grodner, Gibson & Turnall (2002), who have found that the processing of syntactic dependencies is reflected in faster reading times in long-distance extractions as compared to analogous sentences with comparatively simpler structures.

lexical priming (CMLP) studies, such as Nicol (1988, reported in Nicol & Swinney 1989),[10] in which sentence primes and probe targets are presented in different modalities (usually audio primes and visual probes), have demonstrated that overt pronouns access syntactically appropriate antecedents, such that *doctor* is primed at the position marked by '#' in Example (11a), but that both *boxer* and *skier* are primed in Example (11b):

Example 11

(11) The boxer told the skier that the doctor for the team…
 (a) would blame himself # for the injury.
 (b) would blame him # for the injury.

Swinney, Ford & Bresnan (1989), in another CMLP study, demonstrated that antecedents are also reactivated at the gap sites in relative clauses, where no overt element is available. In Example (12), *boy* was accessed faster than an unrelated word at both #2 and #3, but no effect was observed for *crowd* or *policeman* at these points, and no effect was observed at #1 for *boy*:

Example 12

(12) The policeman saw the $\mathbf{boy_i}$ that the crowd at the party **#1** accused $\mathbf{t_i}$ **#2** of the **#3** crime.

The conclusion from such studies has generally been that ECs are as psychologically real as overt pronouns and that the parser makes active use of them in processing. Featherston (2001) refers to this view as the TRACE REACTIVATION ACCOUNT (TRA) (Nicol 1993, Nicol & Swinney 1989). Under the TRA, when the parser encounters a filler (i.e. a displaced phrase), such as *the boy* in Example (12), it temporarily retains a copy. Upon encountering a gap (following *accused*), the parser reactivates the copy in the form of a trace, thus establishing a dependency between the filler and gap. This trace has the same formal syntactic features as its antecedent (e.g. gender) and the same semantic features as well.

It should be noted that an alternate view of reactivation effects has been proposed, one which Featherston (2001) refers to as the DIRECT ASSOCIATION HYPOTHESIS (DAH; Pickering & Barry 1991). The DAH maintains that a displaced argument is not in a dependency with an element in the gap position, but with the predicate that subcategorizes for that argument instead. If so, no EC is necessary, and reactivation effects that seem to point to traces can instead be attributed to the presence of the subcategorizer itself. To illustrate, compare Example (13a) and Example (13b), adapted from Pickering & Barry (1991, 1–2):

Example 13

(13) (a) [which woman]$_i$ do you think Mary loves $\mathbf{t}_i$
 (b) [which woman]$_i$ do you think Mary loves$_i$

Example (13a) makes use of a trace/copy, whereas Example (13b) does not. Note that in such contexts, the putative gap position and the subcategorizer (*love*) are adjacent. In order to

[10] For a critical review of CMLP in the context of bilingualism research, see Heredia & Cieślicka (2019); for an overview of the methodology, see Marinis (2018).

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distinguish these accounts on the basis of reactivation data, experimental materials would need to be devised in which the gap position and the subcategorizer are not adjacent; see, for example, Nicol (1993) and Featherston (2001: Experiments 1–3). Featherston concludes that TRA is 'the most empirically adequate' account of the reactivation effects, even if the DAH cannot be ruled out entirely (Featherston 2001: 138).

As our chief interest in this study is in addressing the empirical basis for distinguishing between different structures (viz., control and raising structures) from a behavioral perspective rather than arguing for or against a particular parsing implementation, we will not pursue the distinction between the TRA and DAH further here, but instead will tacitly assume that some version of the TRA is correct. However, we do touch on this issue again in Section 6.

1.4 The psychological reality of PRO

Given the theoretical differences between PRO and other empty categories discussed in Section 1.1, we expect corresponding differences in the processing of sentences argued to contain them. A lack of evidence for processing differences between raising and control structures might be taken as evidence for a view of syntactic control consistent with the Movement Theory of Control described in Section 1.2; if the parser does not appear to differentiate between these sentence types, it may be that control (and thus PRO) is an artifact of theoretical models of the grammar, one without any psychological reality. On the other hand, clear evidence of processing dissociations between raising and control would suggest that grammatical theory is on the right track in positing different empty categories in these sentence types.

Overall, the experimental evidence for PRO is somewhat thinner than for the ECs considered in the preceding section (see Featherston 2001: Section 5.1–3, for discussion), but it does suggest a dissociation with DP/NP traces in raising sentences. For example, Osterhout & Nicol (1988, reported in Nicol & Swinney 1989) found no significant activation at the gap position (#1) for PRO in sentences like Example (14), although some activation was found at probe point (#2):

Example 14

(14) The actress invited the dentist from the new medical center **PRO** to **#1** go to the party at the **#2** mayor's house.

This suggests that even if the parser is positing PRO in the gap position, it is only after a delay; this contrasts with DP/NP trace, where reactivation effects are more immediately apparent.

Similar results were reported in a series of cross-modal lexical priming experiments (conflated here) by Walenski (2002: Chapter 5), who tested visually presented probes that were semantically related to antecedent phrases in two positions in pre-recorded sentences: in the gap position and in a position 300 ms downstream.[11] Walenski (2002) found activation in raising sentences at the gap position but activation in control sentences only at the

[11] The task Walenski (2002) used here was not a typical lexical decision task; instead, participants were asked to name the target words out loud, with the response measure being the time elapsed before they began to speak.

https://doi.org/10.1017/S002222672400001X Published online by Cambridge University Press

downstream position, suggesting again the possibility that the processing of PRO is delayed compared to the processing of traces.

Larsen & Johansson (2020) have recently suggested a possible explanation for the delayed activation in control sentences: the relevant gap position in these sentences might actually be further downstream than the embedded subject position. Using a picture priming paradigm, they tested sentences like Example (15) at two positions with (e.g.) a cartoon drawing of an alligator as a probe; subjects were asked to decide whether the animal pictured had been mentioned earlier in the sentence.

Example 15

(15) *Norwegian*

Alligatoreni	lover	sjiraffen	**#1**	å	**[θ]**	**#2**	bade	i sjøen	snart
the.alligator	promises	the giraffe		to			bathe	in the.lake	soon

'The alligator promises the giraffe that he would bathe in the lake soon.'

Larsen & Johansson (2020) found a significantly greater activation in the second position than the first. They, therefore, suggest that the parser may be positing PRO not in the embedded subject position (prior to the infinitive marker) but in its theta position (following the infinitive marker). (A follow-up study by the same authors is worth mentioning here as well: Larsen & Johansson (2022) looked at the processing of PRO using a grammar maze design, finding evidence to the effect that PRO is indeed processed differently from overt pronouns.[12])

In addition to these CMLP studies, other methods have been brought to bear on the question of the psychological reality of PRO and other ECs. In a series of self-paced reading studies, Bever & colleagues (Bever & McElree 1988; McElree & Bever 1989; Bever, Straub, Shenkman, Kim & Carrithers 1990; Bever & Sanz 1997) examined sentence-final reactivation of antecedents in a variety of sentence types. Unlike the CMLP studies, which test semantic associates of antecedents, these studies used the repetition of a word in the antecedent phrase as a probe; subjects were asked to decide whether the word had appeared earlier in the sentence. In these studies, a variety of sentence types were used as stimuli, including (*inter alia*) simple non-pronoun sentences (Example 16a), sentences with overt pronouns (Example 16b), control sentences with theoretically predicted PRO (Example 16c), and raising sentences with theoretically predicted DP/NP trace (Example 16d):

Example 16

(16) (a) The astute lawyer who faced the judge hated the long speech…[13]
(b) The astute lawyer who faced the judge hoped **he** would speak…
(c) The astute lawyer who faced the judge strongly hoped **PRO** to argue…
(d) The astute lawyer who faced the judge was certain **t** to argue…

[12] As this study sought evidence of interference rather than facilitatory effects and thus differed significantly from the methodology in the other studies described here, we will refrain from adding further details here and simply point the interested reader to the original.

[13] Examples abbreviated from the original for the purposes of presentation.

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Compared to non-pronoun sentences (Example 16a), McElree & Bever (1989) found significant facilitation for raising sentences (Example 16d) but no or little facilitation for control sentences (Example 16c), along with marginally significant response time differences between raising and control sentences. Differences in accuracy were apparent as well, with a significantly higher rate of incorrect responses in control than in raising sentences. McElree & Bever (1989) concluded that ECs in the gap positions in raising sentences access their antecedents to 'a greater degree'[14] than ECs in the gap positions in control sentences, perhaps due to a need to compute the theta role assigned to the antecedent in the former sentence type; they interpret this as providing converging evidence for the structural distinction between the two sentence types.

1.5 The present study

In this study, we use a partially novel paradigm we refer to as Antecedent Cross-Modal Repetition Priming (A-CMRP), similar to that used in the Bever & McElree (1989) studies but taking advantage of multiple modalities to investigate activation across the time course.[15] Cross-modal repetition priming combines the benefits of CMLP (e.g. Nicol 1988; Swinney et al. 1989), in which the online activation of an antecedent is measured indirectly by measuring response latencies to lexical decisions on semantic associates, and repetition priming, such as that in the studies by Bever & McElree (1988), McElree & Bever (1989), Bever et al. (1990), Bever & Sanz (1997). The difference between CMLP and repetition priming paradigms is that, in CMLP, the probe is a semantic associate of a word in the antecedent phrase, whereas in repetition priming, the probe is a word taken directly from the antecedent phrase.

Repetition priming has some key advantages over the semantic priming involved in the CMLP paradigm. Unlike lexical decisions on semantic associates, this task is relatively transparent and requires participants to pay closer attention to the words that appear in the sentences. A possible source of variance is removed, as well, as the relative strength of the semantic or associative relationships between primes and probes in different conditions need not be controlled for. Instead, the activation (or reactivation) of a lexical item can be measured directly. The advantage of cross-modal over unimodal end-of-sentence priming (the latter of which was used in the studies by Bever & McElree (1988), McElree & Bever (1989), Bever et al. (1990), Bever & Sanz (1997) cited in Section 1.4) is well-known (e.g. Marinis 2018); using a visual probe to interrupt the audio prime at a variety of target positions in the sentence makes it possible to measure incremental activation across the time course, rather than solely end-of-sentence activation.

Our intention here, then, was to compare activation of phonologically overt pronouns and theoretically predicted ECs at different points in the time course, with a particular interest in whether an EC or an overt pronoun reactivates its antecedent at the predicted gap positions and whether our target sentence types differ in the extent of reactivation. We expect that our

[14] An anonymous reviewer questioned what is meant here by 'a greater degree'. The phrase is taken from McElree & Bever (1989: 34), where it is not explicitly defined; we understand it to refer to their finding of significant facilitation in raising sentences and the lack of such facilitation in control sentences, as well as the lower accuracy rates in the latter.

[15] Cross-modal repetition priming has been used in other areas as well, for example, to investigate morphologically complex words (Marslen-Wilson, Tyler, Waksler & Older 1994).

results will inform two theoretical questions. Our primary interests are in establishing (1) whether the parser treats (subject-) raising sentences and sentences with overt pronouns in the embedded subject position similarly, and (2) whether the parser treats raising and control sentences differently. If we see a similar pattern of activation for raising sentences and sentences with overt pronouns, such that response time (RT) latencies are similar between the two sentence types in the embedded subject position (as well as in our other two probe positions; see below), this would be consistent with the standard account of raising as involving an EC analogous to a pronoun (viz., DP/NP trace). If we see a different pattern of activation with control sentences than with raising, specifically such that RTs in the gap position are greater for raising sentences than control sentences, this would be consistent with the traditional view of control as a distinct phenomenon from raising, lending credence to the notion that distinct ECs are involved. If, however, we see a similar pattern of activation in raising and control sentences, with similar RTs in the gap position and in our other probe positions, this would suggest that the MTC is on the right track in reducing the latter to a subtype of the former, potentially with the same EC involved.

As for the theoretical distinction between PC and ExC, we were uncertain as to whether to expect corresponding differences in processing. If both involve PRO, as in the standard model, then we might expect a similar pattern of activation in the gap position in both sentence types. If, as Rodrigues (2007) and Rodrigues & Hornstein (2013) propose in their MTC-based approach, PC involves not PRO but an associative *pro*, it is unclear whether this would be processed more similarly to sentence types that involve copies/traces (per the MTC, raising and ExC), or whether we would expect a wholly distinct pattern of activation. Complicating matters here, however, is a unique feature of PC sentences: Relative to the other sentence types under consideration, PC potentially involves additional possible referents in the discourse context beyond the matrix controller. The need to incorporate discourse context for reference in PC sentences may well pose an extra step for the parser; this may well lead to a greater response latency, particularly late in the time course. In ExC sentences, on the other hand, the referent is identical with the matrix subject, so this extra step/added complexity would not be present (this presumably would be true under either the MTC or the standard model, that is, whether the EC involved is a copy/trace, *pro*, or PRO).

It should be noted that these processing predictions are our own extrapolations from what we understand of this theoretical model (the MTC) and what we think is a reasonably transparent linking hypothesis (viz., that copies/traces associated with movement should be processed similarly in raising and control structures). To our knowledge, online processing studies have been neither carried out nor proposed by proponents of either theoretical account with an intention of comparing the different predictions involved.

In Table 1, we present a partial summary of our predictions for the reader's convenience.

2 Data availability

Data files with lists of stimuli, SPSS scripts and output, and associated materials are available at https://osf.io/a6y57/?view_only=fcad34408fb54f77a9c87e4f1497e12f.

3 Methods

Fifty-two native speakers of BP, all students at a large state university in the southeastern United States, were recruited for this study and were remunerated with gift cards for their

https://doi.org/10.1017/S002222672400001X Published online by Cambridge University Press

Table 1 Partial summary of processing predictions by theoretical account

	Raising	Exhaustive control (ExC)	Partial control (PC)
MTC	• Involves copy/trace • Activation in gap position presumably similar to ExC	• Involves copy/trace • Activation in gap position presumably similar to raising	• Involves either a copy/trace or (as in Rodrigues 2007), *pro* • Unclear
'standard' PRO	• Involves copy/trace • Activation in gap position (1) similar to sentences with overt pronouns, (2) dissimilar to ExC and PC	• Involves PRO • Activation in gap position dissimilar to raising/overt pronouns, possibly similar to PC • Fewer referential possibilities compared to PC might result in faster processing due to lower cognitive demand	• Involves PRO • Unclear; if PRO is involved, activation in gap position should be similar to ExC • However, more referential possibilities than ExC might be more cognitively demanding

participation. Participants all reported having acquired Brazilian Portuguese at birth (i.e. in early childhood). Mean self-reports of exposure to BP included 15.9 years of formal education in Brazil (standard deviation, SD = 4.9 years) and 25.2 years of residence in Brazil (SD = 7.9 years). Mean self-reported ratings of speaking (5.9/6), comprehension (5.98/6), reading (5.88/6), and writing abilities (5.67/6) were near ceiling (see Appendix 1 for a complete summary of the results of this questionnaire). Following subject elimination (see Section 3.3 below), we were left with 26 female and 22 male participants.[16] On the basis of the handedness questionnaires, one female subject was judged to be ambidextrous and four males and one female to be left-handed, for a total of six non-right-handers (nRh); this left 42 right-handers (24 female, 18 male).[17,18]

[16] This was not self-reported, but was rather inferred by the researchers on the basis of participants' visual gender presentation.

[17] In psycholinguistic studies generally and in EC processing studies specifically, few subject variables apart from language background are controlled for, with the result that potentially significant between-subject variance might not be accounted for. In particular, although some studies do control for individual handedness, very few consider the genetic background of participants' handedness. But evidence of both qualitative and quantitative differences on this count is accumulating, to the effect that righthanders who have left-handed family members, or Familial Sinistrals (RhFS+), seem to show a greater initial reliance on lexical and semantic processing; right-handers who have only right-handed family, or Familial Dextrals (RhFS-), in turn, show a greater initial reliance on grammatical processing and are more sensitive to syntactic manipulations (Bever et al. 1989, Lee 2018). We therefore hypothesized that some interaction with our stimulus variables might be seen here. As it turned out, the statistical power in our study was not sufficient for us to report significant interactions, so we have chosen not to report on these results here.

[18] Of the righthanders, 18 reported at least one first- or second-degree blood relative being non-right-handed (RhFS+); the other 24 reported no knowledge of familial RhFS-. There were 13 males in this latter group, with only 5 males reporting familial sinistrality (RhFS+); 11 females were RhFS- and 13 were RhFS+.

Data were collected in a quiet laboratory. Upon arrival, participants were presented with informed consent documentation and encouraged to ask any questions that they might have about the protocol or their participation in the study. Participants were then seated at a PC equipped with E-PRIME 3.0 (Psychology Software Tools, Pittsburgh, PA), at which they completed the online A-CMRP task. Next, they completed an offline grammaticality judgment task (these results will be reported in a separate paper; see Section 1.2 above and footnote 7). Finally, participants completed personal/familial handedness questionnaires (adapted from those used in the Bever Language & Cognition Lab at the University of Arizona), as well as a language history questionnaire (adapted from the Bilingual Language Profile; Birdsong, Gertken & Amengual 2012), in which they reported their age, personal history with English and Portuguese, and self-reported abilities in reading, writing, speaking, and comprehension.

3.1 Stimuli

The materials consisted of 84 sentences of Brazilian Portuguese as auditory primes. Target sentence types were those that related to our chief hypotheses; these critical stimuli included 12 biclausal sentences with OVERT PRONOUNS (coreferential with the matrix subject) as subjects of the embedded clause,[19] 12 biclausal sentences with RAISING predicates in the matrix clause,[20] 6 biclausal sentences with ExC predicates in the matrix clause (including implicative, aspectual, and modal predicates), and 6 biclausal sentences with PC predicates in the matrix clause (including desiderative, factive, and propositional predicates). Non-target sentence types were included either as fillers or otherwise as non-critical stimuli; although we perform some analysis of these results below, they do not relate directly to our central hypotheses. Non-target stimuli included 12 monoclausal NON-PRONOUN sentences (i.e. without pronouns in the embedded subject position) with desiderative, factive/emotive, or propositional predicates, 12 biclausal sentences with TOUGH-CONSTRUCTION predicates in the matrix clause, and 24 filler sentences, which we refer to below as DISTRACTORS. The sentences for this latter category were selected from a novel written in Brazilian Portuguese (Carneiro da Cunha 1993) and thus varied significantly in their structure; however, we were careful to ensure that target and distractor sentences were all approximately the same length.[21] Example stimuli are as follows:

[19] In the studies by Bever & McElree (1988), McElree & Bever (1989), Bever et al. (1990), Bever & Sanz (1997), OVERT PRONOUNS are referred to as EXPLICIT ANAPHORS. We use the terms OVERT PRONOUN and NON-PRONOUN here in order to avoid confusion with the more restricted concept of anaphors in Government & Binding Theory (e.g. Chomsky 1981), in which only certain types of pronouns, in particular, reflexive pronouns like *myself*, *yourself*, *herself*, etc. are classified as anaphors.

[20] For those not familiar with tough-constructions, consider (i):

(i) The article was difficult to review <the article>.

Here, the DP *the article* is understood as moving from its base-generated thematic position as the object of *review* to the matrix subject position.

See Chomsky (1977) for further discussion; for a unified account of tough-constructions and passive constructions in English and German, see McGury (2018).

[21] Although the author of this novel is from the Rio Grande do Sul state in the south of Brazil, we were careful to choose sentences that lacked specific regional traits, consulting with speakers from different states to ensure that all sentences were broadly understandable and acceptable among BP speakers.

Example 17

(17) *Overt pronoun*[22]
Um eminente marinheiro dizia, cheio de convicção, que **ele**
the famous sailor say.IMPFV.3SG full of conviction that he
faria tudo para proteger a costa portuguesa.
do.COND.3SG all for protect.INF the coast Portuguese
'The famous sailor said, full of conviction, that he would do everything to protect the Portuguese coast.'

Example 18

(18) *Raising*[23]
Os dados recolhidos resultaram, surpreendentemente, ser muito
the data recent result. PST.3PL surprisingly be.INF very
problemáticos para as hipóteses existentes.
problematic for the hypotheses existing
'The recent data ended up, surprisingly, being very problematic for existing hypotheses.'

Example 19

(19) *Exhaustive control*
A dedicada recepcionista decidiu, após dez anos, avançar com seu
the dedicated receptionist decide.PST.3SG after ten years advance.INF with her
próprio projeto que há muito tempo sonhava.
own project that have.PRS much time dream.IMPFV
'The dedicated receptionist decided, after ten years, to go ahead with her own project that she had for a long time dreamt of.'

Example 20

(20) *Partial control*
O quieto estudante de medicina pediu, seguindo seu orientador, não
the quiet student of medicine ask.PST.3SG according to.his advisor not
falarmos do seu comportamento anti-social
talk.INF.1PL about his behavior antisocial
'The quiet medical student asked, according to his advisor, that we not talk about his antisocial behavior.'

[22] An anonymous reviewer objects to Example (17), claiming that *ele* is deictic and not obligatorily coindexed with the matrix subject *um eminente marinheiro*. While we acknowledge this referential possibility, in the absence of other context, it is the only reference discursively possible for *ele*, so we do not see any reason why a participant might interpret this differently.

[23] An anonymous reviewer claims that Example (18) is ungrammatical. We suspect that the postverbal adverb *surpreendentemente* is the source of this perceived ungrammaticality. When not read with a parenthetical intonation, it is indeed ungrammatical; however, this example was read with pauses preceding and following the adverb, and was deemed to be acceptable in the judgements of our Brazilian consultants.

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Example 21

(21) *Non-pronoun*:

O	professor	jovem	ressente,	apesar	do	discutido,	a	liberdade	do
the	professor	young	resent.PRS.3SG	despite	of.the	said	the	liberty	of.the

aluno	na	aula	contemporânea.
student	in.the	class	contemporary

'The young professor resents, despite what was said, the liberty of the contemporary classroom student.'

Example 22

(22) *Tough-construction*:

O	pequeno	pássaro	era	quase	impossível	para	o
the	small	bird	be.IMPFV.3SG	nearly	impossible	for	the

velho	perceber	na	árvore
old.man	see.INF	in.the	tree.

'The small bird was nearly impossible for the old man to see in the tree.'

Example 23

(23) *Distractor*:

Os	pedestres	se	protegiam	como	era	possível,
the	pedestrians	SE	protect.IMPFV.3PL	as	be.IMPFV.3SG	possible

na	tormenta,	guerreando	com	guarda-chuvas.
in.the	storm	struggling	with	umbrellas

'Pedestrians protected themselves as best as they could in the storm, struggling with umbrellas.'

For each sentence, a pair of corresponding probe words were chosen, an experimental target and a non-target (Table 2). For the first six sentence types, the target probe was an attributive adjective that appeared as part of that sentence's matrix subject; the non-target probe was a word that did not appear in the sentence. For both targets and non-targets in the distractor sentences and for non-targets in the other sentence types, words from a variety of categories (nouns, verbs, determiners) were used in addition to adjectives. We chose adjectives for our probes because they form part of the NP/DP to which an EC is anaphoric, so any facilitation would seem to guarantee that the antecedent has been accessed – and crucially that the antecedent as a WHOLE has been accessed, not just (e.g.) its head. We used some adjectives as non-target probes so that participants would not associate all adjectives with 'yes' responses; we used words of other syntactic categories as non-target probes as well so that participants would be less likely to conclude that only adjective probes were of interest.[24]

[24] An anonymous reviewer has questioned whether the fact that our target probes were adjectives while some of our non-target probes were not might have had an undesirable effect. We aren't aware of any evidence that it would, but regardless, we think our choice is justified by the literature (following the Bever & McElree (1988), McElree & Bever (1989), Bever et al. (1990), Bever & Sanz (1997) studies, which were based on recommendations in Cloitre 1985; see also Cloitre & Bever 1988).

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Table 2 Sentence prime examples with probe points for target and non-target probes

	Sentence prime **[Probe Points]**	Target probe	Non-target probe
Overt pronoun	*Um eminente marinheiro dizia,* **[#1]** *cheio de convicção, que ele* **[#2]** *faria tudo para proteger a costa portuguesa* **[#3]**	*eminente*	*pistola*
Raising	*Os dados recolhidos resultaram,* **[#1]** *surpreendentemente,* **[#2]** *ser muito problemáticos para as hipóteses existentes* **[#3]**	*recolhidos*	*falsos*
Exhaustive control	*A dedicada recepcionista decidiu,* **[#1]** *após dez anos,* **[#2]** *avançar com seu próprio projeto que há muito tempo sonhava* **[#3]**	*dedicada*	*canina*
Partial control	*O quieto estudante de medicina pediu,* **[#1]** *seguindo seu orientador,* **[#2]** *não falarmos do seu comportamento anti-social* **[#3]**	*quieto*	*bolsa*
Non-pronoun	*O professor jovem ressente,* **[#1]** *apesar do discutido,* **[#2]** *a liberdade do aluno na aula contemporânea* **[#3]**	*jovem*	*leões*
Tough-construction	*O pequeno pássaro era quase impossível* **[#1]** *para o velho* **[#2]** *perceber na árvore* **[#3]**	*pequeno*	*elaborado*
Distractor	*Os pedestres se protegiam* **[#1]** *como era possível* **[#2]** *na tormenta, guerreando com guarda-chuvas* **[#3]**	*pedestres*	*verdadeiramente*

As described below, probe position varied between groups, with the probe appearing at any of the points marked #1, #2, or #3.

3.2 Procedure

Participants were seated so that their eyes intersected a plane perpendicular to the edge of a desk, offset 18 inches from the display screen, and were instructed not to lean forwards or backwards during the experiment so as to maintain this distance. Following a practice session, all participants were observed to comply with these instructions. Participants were then asked to read on-screen instructions (in Portuguese) and proceed through two short,

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guided practice rounds. Three experimental blocks followed, each with 28 trials presented in a randomized order, with a self-paced break in between blocks during which participants could rest as long as they chose.

During each trial, participants listened through a headset to a recording of a sentence spoken by a (female) native speaker of Brazilian Portuguese, during which they were asked to focus their eyes on a fixation point (the '#' symbol) displayed in the center of the screen. At one of three points in the recorded sentence, the central fixation point was replaced by a probe word, which was displayed for 500 ms. Participants were asked to decide as quickly and accurately as possible whether the word they saw had appeared earlier in the same sentence. If it had, they were asked to press the spacebar on a keyboard; if it had not, they were to do nothing.[25] The computer recorded all response latencies, measured from the onset of the probe until the moment the spacebar was depressed in response. After a 2,000 ms delay, the next trial began.

The blocks were organized into three lists, corresponding to the three groups to which participants were randomly assigned upon arrival. The lists were identical except for two variables. First, the order of blocks was staggered across lists, so that (e.g.) Block A was presented first in List 1, second in List 2, and third in List 3. Second, the delay between the onset of the audio prime and the onset of the visual probe varied for a given prime/probe combination across lists, so that a given probe would appear (e.g.) at point #1 in List 1, at point #2 in List 2, and at point #3 in List 3.[26] This is illustrated in Table 3.

3.3 Subject elimination and data exclusion/Winsorization

Two subjects were eliminated due to either overall accuracy rates or accuracy rates to experimental targets exceeding three SDs below the mean for all subjects, one was eliminated for a mean RT in correct responses to experimental targets (CRETs) being more than three SDs above the mean for all subjects, and one was eliminated for not having spent significant time residing in Brazil and for self-reported low facility with reading and writing in Brazilian Portuguese. After subject elimination, 48 remained.

We chose a two-part strategy to address outliers in our data. In order to exclude data points that likely reflected errors on the part of the subject (e.g. lapses in attention), all CRETs greater than four SDs from a given subject's mean RT were discarded entirely; this affected 0.68% of the data. As for outliers which we believe may reflect real psychological processes but whose inclusion 'as is' would unduly impact the sample mean and SD, we decided to use WINSORIZATION[27] (see e.g. Tukey 1962; Baayen & Milin 2010; McDonough & Trofimovich

[25] This is the 'Go/No-go' response paradigm (see e.g. Gomez, Ratcliff & Perea (2007) and Verbruggen & Logan (2008) for discussion).

[26] An anonymous reviewer suggested using a measure of priming distance measured in milliseconds for each auditory stimulus. Our probe points are designed to measure activation at specific points in the structural representation of the sentences, thus allowing for direct comparisons between sentence types. If we understand the suggestion correctly, such a measure would use the beginning of the audio stimulus as a reference point. While we agree that this is a potentially interesting suggestion, we are concerned that what it might gain in terms of time sensitivity would sacrifice sensitivity to syntactic structure, our chief interest for the current study; we would also be concerned with overfitting the model. However, we will consider how to incorporate this suggestion in future studies and analyses.

[27] Named after Charles P. Winsor, although apparently coined by Tukey (1962), who uses WINSORIZATION and WINSORIZING interchangeably.

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Table 3 Ordering of experimental blocks, illustrating how the probe point for a given prime/probe combination varied across lists

	First Block	Second Block	Final Block	Probe point for *quieto / bolsa*	Probe point for *jovem / leões*	Probe point for *dedicada / canina*
List 1	Block A	Block C	Block B	#1	#2	#3
List 2	Block B	Block A	Block C	#2	#3	#1
List 3	Block C	Block B	Block A	#3	#1	#2

2011). Winsorization involves replacing outlier data points with either (1) the most extreme observation at some chosen point in the distribution or (2) a data point equivalent to the value at a chosen standard deviation. This procedure preserves (some of) the original information present in extreme outliers without allowing measures such as the sample mean and standard deviations to be unduly influenced; these measures are consequently much more robust estimates of the true population mean, and, as Tukey (1962: 18) notes, means produced by Winsorization are more stable than means produced by data trimming.[28] Consequently, we decided to replace all RTs between three and four SDs greater than a subject's mean with the three SD value; this affected 1.47% of the data.

Finally, a handful of responses that may have been affected by a programming error were removed, as were the responses on trials immediately following; this affected 1.42% of correct responses to experimental targets.

3.4 Data analysis

Following subject elimination and data exclusion, RTs for correct responses were run through a generalized linear mixed model (GLMM) in SPSS (Baayen & Milin 2010; Lo & Andrews 2015). The best-fitting model which included the variables of interest, was one assuming a gamma distribution with a logarithmic link function.[29,30] SubjectID and Probe were included as random factors (along with an intercept for subjects), so as to accommodate

[28] Tukey (1962) cites Dixon (1957, 1960) to this effect.

[29] Also attempted were Gaussian (normal) and inverse Gaussian distributions, with both identity and log links, as well as the gamma distribution with the identity link, all as suggested by Lo & Andrews (2015). Observations of the normal plots showed the least deviation from homoscedasticity when using the gamma distribution and log link, as compared to those mentioned above. Model selection was accomplished in part via comparing the Akaike information criterion (AIC; Akaike 1974) produced by candidate models; models with lower values for the AIC are estimated to involve less information loss and more parsimoniously account for the data (Burnham & Anderson 2002; Müller, Scealy & Welsh 2013; Stoica & Selen 2004; Ding, Tarokh & Yang 2018).

[30] An anonymous reviewer suggested including more detailed information about residuals and the variance explained by our model here. There are a number of conceptual and technical difficulties with using traditional measures of variance in GLMMs; Nakagawa & Schielzeth (2013: 136) note that 'residual variance… cannot be easily defined for non-Gaussian responses'. Instead, they suggest reporting the marginal and conditional R^2, with the former describing the variance explained by fixed factors alone and the latter the variance when random factors are taken into account. In our model, the marginal pseudo R^2 was .107, and the conditional was .481. Another measure of variance we can report for those interested is the intra-class correlation coefficients (ICCs; Nakagawa, Johnson & Schielzeth 2017), which quantify the proportion of variance explained by the clustering of data; these came out to. 418 (adjusted) and. 374 (conditional).

correlations between an individual subject's responses and correlations between responses to a given probe. Fixed factors included SEX, FAMILIAL SINISTRALITY/[PERSONAL] HANDEDNESS (FSH), PROBEPOINT, and SENTENCETYPE. The following interactions were included in the model as well: PROBEPOINT * SENTENCETYPE and FSH * PROBEPOINT * SENTENCETYPE. Finally, PROBEFREQUENCY,[31] PROBESIZE (# of characters), PREVIOUSRESPONSE (with five levels: CORRECT YES, CORRECT NO, INCORRECT YES, INCORRECT NO, and INITIAL RESPONSE IN BLOCK),[32] BLOCK (whether the response occurred in the first, second, or third block of trials, which had been pseudorandomized by list), and TRIAL (order of presentation within a block, which had been randomized) were included as potential covariates. PROBESIZE, BLOCK, and TRIAL[33] were nonsignificant and decreased model fit, so they were removed from the final model. PROBEFREQUENCY was indeed significant in the model ($p = .033$). However, models that included interactions between frequency and the stimulus variables found no significant interactions, so we refrained from analyzing this variable further.

Accuracy was analyzed in two separate GLMMs: one including all responses and one including only responses to experimental targets. In both cases, we used a binomial distribution with a logit link function (Jaeger 2008), with PROBEPOINT, SENTENCETYPE, and the interaction between the latter as fixed effects; random effects were the same as in the RT model.

4 Results

In the following, we report on the main effects and interactions between our stimulus variables in the RT model, as well as some descriptive statistics from the two accuracy models.[34]

4.1 Main effects

No main effect was apparent for PROBEPOINT ($p = .175$), but the pairwise contrast[35] between the third probe point (i.e. end-of-sentence) and the second (i.e. the gap or equivalent position)

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[31] Probe frequency was determined by consulting the *Web/Dialects Corpus of O Corpus do Português* (Davies 2016), using results tagged as originating in Brazil. Frequency values in this calculation are per million.

[32] Also coded for were a handful of cases where a programming error on the previous response may have affected the response (see end of Section 3.3). We thank an anonymous reviewer for suggesting that we control for PREVIOUS RESPONSE and BLOCK.

[33] An anonymous reviewer questioned why we might not have found any 'learning effect', that is, any effect whereby RTs decreased for later trials. We can only speculate as to why no such effect was found; although it is possible simply that the practice round was sufficient, it may be more likely because the task was at a level of difficulty which did not lend itself to any such effect (i.e. it did not become significantly easier as the experiment progressed).

[34] Results associated with subject variables (sex and familial/individual handedness) will be reported separately and/or inform future studies; although interesting in their own right, few significant interactions with our variables of interest were found (see Section 3 and 16 above).

[35] Planned comparisons were conducted using Fisher's Least Significant Difference (LSD) test (Fisher 1935); *post hoc* comparisons involving interactions were conducted using the Šidák correction (Šidák 1967). An anonymous reviewer questioned the legitimacy of examining pairwise contrasts for PROBEPOINT when no main effect was found. We feel that in this case, more information is better than less, and it helps to paint the overall picture to know that subjects trended towards responding faster at point #3 than they did at point #2, even though the contrast was not significant.

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showed a trend towards subjects being faster at probe point #3 than at point #2 (27 ms; p = .066; 95% confidence interval (CI): -54.2, 1.69).

Overall accuracy was similar at probe points #1 and #2 (94.65%; 94.06%) but decreased at point #3 to 89.56%. In the experimental-targets-only model, we found a similar pattern, from 91.23% at probe point #1 and 90.40% at probe point #2 to 81.22% at probe point #3. The difference between points #2 and #3 was significant in both models (p <. 001 in the all-responses model, p = .002 in the experimental targets model).[36]

There was no significant main effect of SentenceType (p = .851), but nonsignificant (n.s.) variation in accuracy was apparent in both models. Accuracy in the all-responses model ranged from 86.7% for exhaustive control and 86.9% for partial control to 93.4% for overt pronoun sentences and 98.3% for raising. In the experimental-targets-only model, accuracy for exhaustive control was at a mere 74.0%, with partial control at 72.6%; accuracy for overt pronouns was 90.8%, and raising sentences at 97.6%.

Finally, PreviousResponse was significant in the overall model. Pairwise comparisons indicated further that RTs following a correct yes response on the previous trial (in which the subject correctly identified that a probe had indeed appeared in the sentence) were significantly faster than RTs following correct no responses (in which a subject correctly identified that the probe had not appeared), by 39 ms (p <. 001; CI: -56.09, -22.37). Additionally, RTs following correct no responses were significantly faster than RTs following both incorrect yes (in which the subject incorrectly responded that a word had appeared when it had not) and incorrect no (in which the subject failed to respond that a word had appeared when it in fact had). The difference between RTs following correct yes and incorrect yes was 71 ms (p <. 001; CI: -108.9, -33.7); the difference between RTs following correct yes and incorrect yes was 129 ms (p = .016; CI: -233.4, -24.1).

4.2 Interactions

The interaction between SentenceType and ProbePoint was highly significant in the RT model (p = .015). In what follows, we summarize findings first by time course (comparing RTs at different probe points for each sentence type) and then by contrasts between sentence types; we will mention just one omnibus finding first, which is that we found no significant difference between any of the sentence types at probe point #1. RTs are illustrated visually in Figure 1.

4.2.1 Time course

In ExC sentences, RTs were significantly faster at the third probe point than at the second (164 ms; p = .002; CI: 58.13, 269.35), with a trend towards being faster at the first than the second as well (107 ms; p = .078; CI: -11.81, 225.94). In tough-construction sentences, RTs were significantly faster at the third probe point than at the second (88 ms; p = .003; CI: 29.25, 146.38) and were significantly faster at the third than at the first as well (59 ms; p = .044; CI: 1.71, 115.81). In partial control sentences, there were trends towards subjects being faster at the first probe point compared to the third (96 ms; p = .084; CI: -12.95, 204.55) and at the second point compared to the third as well (93 ms; p = .077; CI: -10.08, 196.64). Finally, no

[36] See Section 4.2.3 below for accuracy data for the interaction between ProbePoint and SentenceType.

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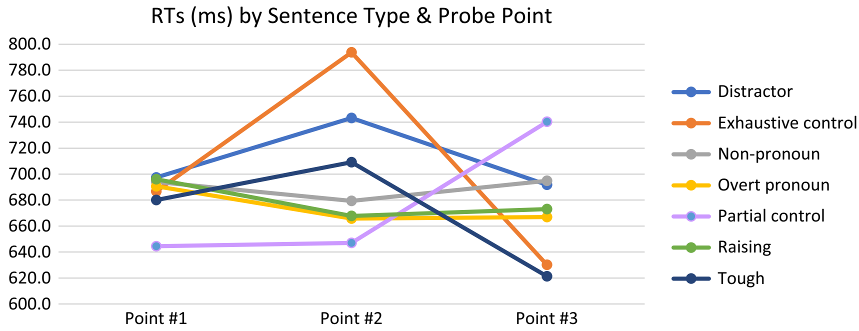

Figure 1 Reaction times (RTs) in milliseconds (ms) by SENTENCETYPE and PROBEPOINT.

Table 4 Reaction time (RT) differences across the time course by SENTENCETYPE; effects in **bold** significant at α = 0.05

	Reaction time (RT) differences	Effect size/p value	95% Confidence interval (CI)
Exhaustive control	Probe point #1 faster than #2	107 ms; p =. 078	–11.81, 225.94
	Probe point #3 < #2	**164 ms; p =. 002**	58.13, 269.35
Tough-construction	**Probe point #3 < #2**	**88 ms; p = 0.003**	29.25, 146.38
	Probe point #3 < #1	**59 ms; p =. 044**	**1.71, 115.81**

significant differences between probe points were apparent in raising, non-pronoun, or overt pronoun sentences.[37] These results are summarized in Table 4.

4.2.2 Contrasts between sentence types

At probe point #2 (the gap position), RTs were significantly slower in ExC sentences than in both raising (147 ms; p = .042; CI: 4.67, 247.43) and overt pronoun sentences (128 ms; p = .043; CI: 4.11, 251.85); these results are illustrated in Figure 2. Responses in ExC sentences were significantly slower than in PC sentences in this position as well (147 ms; p = .034; CI: 11.30, 282.31),[38] and a trend was apparent whereby ExC RTs were slower than no pronoun RTs in this position (114 ms; p = .065; CI: -7.35, 236.09). These results are summarized in Table 5, and the key results of interest are illustrated in Figures 2 and 3.

[37] We did also find significant effects across the timecourse for our distractors: RTs were faster at probe point #1 than at #2 (by 46 ms; p = .048; CI: 0.37, 91.36) and faster at #3 than at #2 as well (51 ms; p = .039; CI: 2.64, 100.28).

[38] At probe point #3, we found a sizable (n.s.) effect, whereby PC RTs were slower than ExC (110 ms; p = .107; CI: -244.297, 23.868).

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Table 5 Reaction time (RT) differences between target sentence types; effects in **bold** significant at α = 0.05

	Reaction Time (RT) differences	Effect size	95% Confidence interval (CI)
Probe point #2	**Raising faster than ExC**	**147 ms; p =. 042**	4.67, 247.43
	Overt pronoun < ExC	**128 ms; p =. 043**	4.11, 251.85
	PC < ExC	**147 ms; p =. 034**	**11.30, 282.31**
	Non-pronoun < ExC	114 ms; p =. 065	-7.35, 236.09

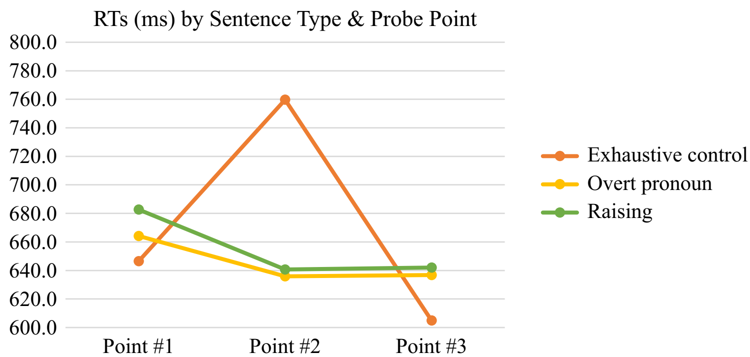

Figure 2 Reaction times (RTs) by SENTENCETYPE and PROBEPOINT: Exhaustive control, overt pronoun, and raising sentences.

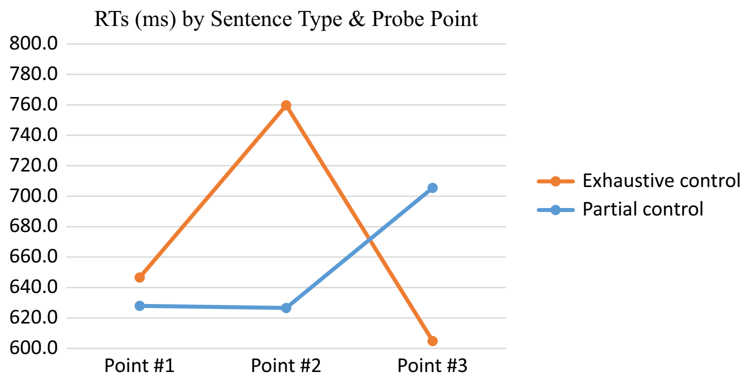

Figure 3 Reaction times (RTs) by SENTENCETYPE and PROBEPOINT: Exhaustive and partial control sentences.

4.2.3 Accuracy (interactions)

Accuracy rates are summarized in Table 6. The only statistically significant contrast of note was in the all-responses model, where accuracy was significantly higher for raising

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Table 6 Accuracy rates by SENTENCETYPE and PROBEPOINT (% correct)

	Accuracy, all responses			Accuracy with experimental targets only		
	Point #1	Point #2	Point #3	Point #1	Point #2	Point #3
Overt pronoun	93.6	95.2	91.6	92.0	94.1	86.7
Raising	100	99	95.8	100	99.0	93.3
Exhaustive control (ExC)	90.0	92.3	78.4	80	83.7	61.4
Partial control (PC)	89.5	88.8	82.4	75.0	78.6	65.2
Tough-construction	96.2	95.3	94.1	97.9	95.1	91.9
Non-pronoun	98.2	96.5	90.2	98.89	95.8	82.3
Distractor	92.8	90.9	87.9	85.3	82.9	77.5

sentences than for distractors at the first probe point ($p = .047$). However, a pattern of relatively high accuracy for raising, non-pronoun, overt pronoun, and tough-construction sentences and relatively low accuracy for both control types (exhaustive and partial) is apparent, especially in the experimental-targets-only model and especially at probe point #3.

5 Discussion

In the following, we discuss the results pertaining to our two stimulus variables and their interaction.

5.1 Discussion of main effects

Although there was no significant main effect of SENTENCETYPE, we did see a trend towards a significant effect of PROBEPOINT, with faster RTs at probe point #3 (end of sentence) than at point #2 (mid-sentence). This may be attributable to a wrap-up stage of comprehension (Just & Carpenter 1980; see also Stowe, Kaan, Sabourin & Taylor 2018), with some reactivation across the board regardless of sentence type; it may also be due to a sentence-final drop-off in processing complexity. We also see significantly lower accuracy with experimental targets at point #3 compared to point #2, suggesting that a speed–accuracy trade-off may take hold at this stage. However, these do not appear to be true omnibus effects but are dependent on sentence type, as we will see in the next section.

5.2 Discussion of interactions between stimulus variables

Tough-construction sentences. We begin with this sentence type because of a small but perhaps fortuitous error in experimental design, which may shed light on the results for the other sentence types. For our target sentence types, probe point #2 was designed to PRECEDE the embedded predicate, as the argument that surfaces in the matrix subject position is predicted to be coindexed with an EC or pronoun in the embedded subject position (whether an overt pronoun, a DP/NP trace, or PRO). However, for the tough-constructions here, the

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matrix subject is instead coindexed with an EC in the embedded OBJECT position, yet we still placed probe point #2 at the embedded SUBJECT position. To illustrate:

Example 24

(24)	[O	pequeno	pássaro]$_i$	era	quase	impossível	**#1**	para	o
	the	small	bird	was	nearly	impossible		for	the
	velho	**#2**	perceber	$\mathbf{t_i}$	na	árvore	**#3**		
	old.man		see.INF	$\mathbf{t_i}$	in.the	tree.			

‘The small bird was nearly impossible for the old man to see in the tree.’

Here, the second probe point (**#2**) is immediately preceding the embedded predicate, as would be correct for other sentence types. However, the target phrase here is instead coindexed with an EC in the object gap, following *perceber.*

As a result of this error, any reactivation at the object gap position would not yet be reflected at probe point #2, as the parser would not yet have encountered it. Presumably, then, we would not see any reactivation effect at this point, but only a slowly deteriorated initial activation. In fact, this is precisely what our results suggest; tough-construction RTs were indeed slower (by 29 ms) at probe point #2 than at point #1, although this effect failed to reach significance. Extending this interpretation of the data to other sentence types, any lack of a deteriorated activation at point #2 relative to #1 may indeed be evidence of a reactivation at the (subject) gap position since, absent this, we would expect the result seen here with tough-constructions.

As for the tough-construction sentence type itself, we see significantly faster responses at probe point #3 than at point #1, and faster responses at point #3 than at point #2 as well. Although this sentence-final increase in activation could be interpreted as a wrap-up effect, we see only a small decrease in accuracy in this position, suggesting another possibility: the relatively fast RTs and high accuracy may be due to lingering activation from the gap position, which (as noted above) occurs later in tough-construction sentences than in other sentence types.[39] The finding that RTs are faster in this position than in our distractor sentences, which have no EC or pronoun available to reactivate the target phrase, seems to point to lingering activation; this certainly looks like evidence of facilitation.

Distractor sentences. Given that the distractor sentences we used here do not have any predicted null or overt element coindexed with the target phrase which might serve to reactivate it, one would not expect anything here other than a unidirectional deterioration of activation over the timecourse. We do indeed see a significantly decreased activation at probe point #2 relative to #1, suggesting that this explanation may be correct.

Non-pronoun sentences. As with distractors, no EC or pronoun is available to reactivate the target phrase in non-pronoun sentences. All else being equal, we would therefore expect nothing more than a continuing deterioration of activation as the sentence progresses, as no source of reactivation is available. Although not statistically significant, this deterioration is apparent in the accuracy rate, and the absence of any decrease in RTs at probe points #2 and

[39] In fact, we saw relatively high accuracy at probe position #3 for raising and, to a certain extent, overt pronoun sentences as well, despite significantly reduced accuracy in ExC, PC, distractor, and non-pronoun sentences. An anonymous reviewer asked why this may have been the case. If these effects are indeed real, we would interpret this as the result of a lingering reactivation in the gap position in raising and *tough*-construction sentences, a reactivation that is not present or not as significant in the other sentence types.

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#3 (which might otherwise be suggestive of reactivation) is partially consistent with this as well. However, we see no significant difference between points #1 and #2, which might suggest an initial activation fading over time, and although responses were indeed slower at point #3 than at point #2, this was again not statistically significant.

Instead, we think that the pattern of results here suggests that participants had an easier time retaining the target phrase in short-term memory in these (monoclausal) non-pronoun sentences than in other sentence types simply due to the relative lack of complexity involved; this may have aided retention and averted a measurable deterioration of activation. If (unlike distractors) these sentences lack a significant sentence-final drop in complexity, we would not expect to see increased RTs at probe point #3; indeed, this is precisely what we found.

In Bever & colleagues' self-paced reading studies (Bever & McElree 1989; McElree & Bever 1989; Bever et al. 1990), similarly structured non-pronoun sentences were used as the experimental controls, with any evidence of greater activation in target than in non-pronoun sentences interpreted as reactivation by an EC/anaphor. This was considered here as well, but in this case, we see no evidence of differences between non-pronoun sentences and our target sentence types, with two exceptions: (1) RTs at probe point #2 showed a trend towards being faster than in ExC sentences, which we interpret as a greater lingering activation in non-pronoun sentences and an absence of reactivation in ExC sentences; and (2) RTs at probe point #3 were significantly slower in non-pronoun sentences than in tough-construction sentences, which we interpret as facilitation in the latter sentence type late in the timecourse.

Overt pronoun and raising sentences. The expectation here was that if the embedded subject indeed reactivates its antecedent, we would see a significant contrast between RTs at points #1 and #2 for both sentence types. Instead, we found no effect approaching significance for either sentence type. Notably, the data at least point in the right direction: responses were indeed faster at points #2 and #3 than at point #1 in both sentence types. Indeed, we see a similar overall pattern in overt pronoun and raising sentences, consistent with the results of, for example, Bever & McElree (1988), and with the view that raising sentences involve an empty category analogous to an overt pronoun.

As to why we found no significant contrasts between probe points #1 and #2, one interpretation would be that multiple sources of activation are involved: an initial activation that has not completely faded by point #1, a reactivation by the EC (pronoun or trace) at point #2, and a wrap-up activation at the end of the sentence (with perhaps a speed–accuracy trade-off, at least for overt pronoun sentences). If these disparate sources of activation are roughly similar in size, we would see no measurable differences between them, as observed here.

We do see, however, significant contrasts at the gap position (probe point #2) between raising and ExC sentences and between overt pronoun and ExC sentences as well. If there is indeed reactivation by the pronoun/EC in these sentence types, it is quite evidently absent in ExC sentences. This is consistent with the hypothesis that sentences with theoretically predicted PRO differ from sentences with pronouns (overt or theoretically predicted null pronouns) with respect to the extent of reactivation in the embedded gap position.

ExC sentences. The significantly increased RTs at probe point #2 in ExC sentences as compared to the same position in raising and overt pronoun sentences clearly indicate an absence of reactivation of the target phrase at the predicted gap position; the trend towards a significant difference between probe points #1 and #2 for ExC supports this as well. This would seem to speak directly to our initial hypothesis. Indeed, we believe our findings provide real experimental evidence that the linguistic mechanisms employed by comprehenders when processing exhaustive control sentences differ substantively from the mechanisms employed when processing sentences with raising structures and with overt pronouns.

We did, however, also find evidence of increased activation with ExC sentences sentence-finally, with RTs significantly faster at probe point #3 than in the gap position (#2). As with other sentence types, this could be attributed to a sentence-final drop-off in processing complexity or to some sort of wrap-up effect. As we noted in Section 1.2, however, Larsen & Johansson (2020) raise the possibility that delayed activation in control sentences might be due to the parser positing PRO not in the subject gap position but rather in its theta position, where it is originally merged into the structure (i.e. not in the specifier of TP, the typical subject position for BP, but rather in the specifier of vP).[40] This would be consistent with results by Walenski (2002) and Osterhout & Nicol (1988, reported in Nicol & Swinney 1989) showing only downstream activation in these contexts.

Although this is certainly plausible on the basis of the RT data, we also observed a large drop-off in accuracy in sentence-final position (i.e. at point #3); with experimental targets, accuracy drops from 83.7% at probe point #2 to just 61.4% at probe point #3. Due to the relatively small number of responses, this contrast was not significant, but it is highly suggestive that even if there is some reactivation by PRO in its theta position, this reactivation is either not total or its totality is fleeting. It is possible, for example, that only a conceptual representation of the controller phrase is reactivated, without the kind of direct lexical reactivation that would be expected under a copy theory of movement (Chomsky 1993, et seq.),[41] or that only the head of the phrase is fully reactivated, with the attributive adjective not reactivated at all. To illustrate what we mean by this, consider again Example (19), repeated here.

Example 19

(19) **A** **dedicada** **recepcionista** decidiu **#1** após dez anos **#2**
the dedicated receptionist decided after ten years
avançar **[θ-position]** com seu próprio projeto que há
advance.INF with her own project that have.PRS
muito tempo sonhava **#3**
much time dream.IPFV
'The dedicated receptionist decided after ten years to go ahead with her own project that she had for a long time dreamt of.'

If only an abstract, conceptual representation of *a dedicada recepcionista* is accessed in its theta position, then any number of near-synonyms of *dedicada* (e.g. *devotada*, 'devoted') might also be accessed as well.[42] This more diffuse activation could well result in a lower

[40] As in the Norwegian sentences tested by Larsen & Johansson (2020), the infinitive marker is clearly in T in English (however, Larsen & Johansson (2022) consider the possibility that the infinitive marker *å* is instead interpreted as a complementizer). In verb-raising languages such as Brazilian Portuguese, finite verbs are generally assumed to raise to T, and Galves (1994) suggests that infinitives raise to T in BP as well. As our second probe point occurred prior to the embedded infinitive, this means that the parser will not have encountered the theta position (to the right of the infinitive in T) until after this point.

[41] If, indeed, a copy/trace is involved here, as the MTC would have it. However, if the activation is due to PRO (as we believe), then we are dealing with a different flavor of EC, one which might well have different properties; see below.

[42] This scenario would be most compatible with models that assume a separation between the phonological and semantic components of lexical items, that is, 'late insertion' models, such as some versions of Distributed

accuracy rate, even if RTs were faster due to the conceptual representation being accessed. Alternatively, if only the head of the phrase (*recepcionista*) is reactivated, RTs might similarly be speeded, but with accuracy lower due to the adjective itself not being accessed. In either scenario, a subject's confidence in their response might outstrip their ability to respond accurately.

These are speculations, of course, and we have no way of distinguishing them with the current experimental design. But both would be consistent with the theoretically predicted differences between the pronouns/ECs involved in, on the one hand, sentences with overt pronouns and raising traces, and, on the other hand, sentences with PRO. In theories that admit them, traces are argued to be full syntactic and semantic copies of their antecedents. PRO, however, is merely coindexed with its antecedent; they bear separate theta roles and are not linked in a movement chain. It seems quite plausible, therefore, that reactivation in control sentences might differ from reactivation in raising sentences qualitatively as well as quantitatively; indeed, we believe our results lend support to this view.

PC sentences. The pattern of results here is quite different from what we see for ExC sentences. At probe point #2, we found significantly slower RTs for ExC than for PC, with RTs for PC responses instead equivalent to those obtained at probe point #1. At probe point #3, we have the opposite situation: a sizable (though n.s.) effect whereby RTs are slower for PC than for ExC.

Not only is the pattern of results obtained for PC sentences dissimilar to that for ExC, it is perhaps somewhat similar to the results for raising and overt pronoun sentences, at least at the first two probe points.[43] Specifically, the gap position in PC sentences is at least superficially similar in the extent of activation to the gap position in overt pronoun and raising sentences. On this basis, one might even speculate that, as with raising sentences, a DP/NP trace is involved in PC sentences as well. However, as we noted in Section 1.2, Modesto's (2010) objection regarding PC sentences and the nature of syntactic copies as we currently understand them poses a formidable empirical challenge for this notion. What is more, recent versions of the MTC argue that more than one EC is involved in PC sentences, favoring an account that combines movement out of a complex DP in which *pro* is therefore stranded (Rodrigues 2007; Rodrigues & Hornstein 2013; Hornstein & Nunes 2014). The processing predictions that would be associated with Rodrigues's proposal are not entirely clear, so we leave this possibility aside at present.

One plausible explanation for the slower sentence-final RTs in PC than in ExC sentences might appeal to the referential differences between these sentence types: in an ExC sentence, the controller and PRO are coextensive in reference, whereas in PC sentences, the reference of a singular controller forms a proper subset of the reference of a plural PRO. The need to incorporate discourse context for reference in PC sentences may well pose an extra step for the parser, the incorporation of a singular controller with a plural PRO thus adding a layer of complexity that slows processing sentence-finally.[44] At the moment, however, we have no explanation for the greater activation in the gap position in PC sentences. Given that ours is (to our knowledge) the first study of its kind to examine the differences in online processing between PC and ExC, we hesitate to speculate further on this point; clearly, much more research needs to be done in this area.

Morphology (Halle & Marantz 1993, et seq.); see also Merchant (2019: Chapter 4), as well as Pfau (2009) and Siddiqi (2009).

[43] Unlike the latter two sentence types, we found much slower RTs for PC responses sentence-finally (point #3) than at the first two points, although both effects showed only a trend towards significance.

[44] Idan Landau (p.c.) has also suggested this to us as a possibility.

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6 General discussion; conclusions

In this study, we examined the online processing of a variety of complex sentence types in Brazilian Portuguese in an effort to shed some light on the ongoing debate over the status of control as a module of the grammar, specifically on whether it can plausibly be reduced to a subtype of raising with the associated empty category DP/NP trace, as argued by proponents of the MTC, or whether the traditional view of control as a separate phenomenon from raising, with the associated empty category PRO, must somehow be maintained – even though for some, it appears to counter Minimalist efforts toward theoretical economy.

Our main conclusions are as follows. First, although it is not the main focus of this study, we believe our results add to the body of evidence that the parser makes active use of DP/NP traces in comprehension, in favor of what Featherston (2001) refers to as the TRA, and contra traceless accounts such as Pickering & Barry (1991), in which reactivation of a displaced element is attributed not to the parser positing an EC in a gap position but rather to the parser encountering the element that subcategorizes for the displaced element. Reactivation of antecedents in raising sentences in the gap position in our study occurs prior to the parser encountering the (embedded) predicate that subcategorizes for it, so these effects likely cannot be attributed to the subcategorizer. However, any end-of-sentence activation – in particular, the apparent facilitation we found for tough-construction sentences at this probe point – could indeed be attributed to the subcategorizer, although for this sentence type, we think that it is more likely the result of recent reactivation by an EC in the object gap position. This would be consistent with the results from raising sentences, in which we attribute the reactivation we found in the subject gap position to DP/NP trace.

Second, we found evidence that the parser treats DP/NP traces in raising sentences similarly to overt pronouns, with an almost identical pattern of activation across the time course of processing, including crucially at the gap position. This result is consistent with the notion that traces are unpronounced copies analogous to overt pronouns and that, in both cases, the parser reactivates their antecedents upon encountering the gap. This would seem to lend support to models of the grammar which explicitly treat traces as unpronounced copies of overt pronouns (Chomsky 1993, et seq.).

Third, our results suggest that different linguistic mechanisms are involved in the processing of raising and (exhaustive) control structures, a finding that we view as inconsistent with the MTC, at least under a reasonably transparent linking hypothesis between the properties of formal models of the grammar and how the parser makes use of these properties. Although it is important to note that the MTC does not (to our knowledge) make any specific predictions about how these structures are processed, we believe it is a rather straightforward extrapolation from the theoretical claim that control is a subtype of raising and that both involve a DP/NP trace to the prediction of a similar pattern of antecedent reactivation in the position in which this trace is posited (i.e. the gap position). As we found the opposite result here, we believe we have added to the empirical evidence that control differs from raising in crucial ways that have direct implications for the parser and that the MTC, therefore, lacks theory-external support in this regard.

It may be worth underlining here, however, that we do not consider our findings to provide direct evidence for the existence of PRO as an empty category per se. Rather, we would argue merely that if exhaustive control sentences do indeed involve an EC in the embedded subject position, it is not identical to the EC involved in raising sentences in that same position; it is not a DP/NP trace. Our findings are certainly consistent with the existence of PRO as traditionally conceptualized, but they may also be consistent with other representational distinctions between raising and control; however, they are not consistent with representational distinctions which posit an identical EC in the raising and control sentences.

We will, however, note that although we believe that the dissociations in processing between raising and control are due to different ECs in the gap positions in these sentences, one might still argue that the same EC is involved but that the observed effects are due to other differences between these sentence types. For example, the MTC proposes that although raising and control both involve a DP/NP trace, the antecedent in control sentences is assigned a different number of theta roles than the antecedent in raising sentences, due to movement into multiple theta positions. Assuming that the latter is possible, it is conceivable that the MTC is correct but that our result was due to this thematic difference rather than a difference in the syntactic entities involved. However, we are not aware of any behavioral studies on the comparative processing of phrases with different numbers of theta roles or arguments that this would produce different patterns of activation, so we will not entertain this possibility any further here.

Our partially novel methodology, which we have A-CMRP, builds on previous methodologies and incorporates multiple modalities, thus contributing to a growing bibliography suggesting that substantive structural differences in the syntax are reflected in processing. However, we are aware of a number of potential methodological shortcomings that we would like to briefly discuss. First, a reviewer noted that we did not have an equal number of target items and fillers. Of the 48 non-target items included, 24 were true fillers, bearing no particular similarity to other stimuli apart from basic length, and 24 were other non-critical stimuli: TOUGH-CONSTRUCTION and NON-PRONOUN sentences (see Keating & Jegerski 2015 for further discussion on the filler-distractor distinction). The number of fillers was viewed as sufficient due in part to our inclusion of these two non-critical conditions. This numerical decision was partly informed by market research (e.g. la Bruna & Rathod 2005), which suggests that the ideal questionnaire length for avoiding participant fatigue is 17–20 min. Given that our methodology involved two linguistic tasks (each of which took 20–25 min), as well as a handedness and linguistic history questionnaire (around 10 min), we chose to include a relatively low number of fillers; this allowed sufficient time for participants to rest between blocks and between tasks if they chose. The total participation time for most participants was approximately 60 min. In the end, given the unexpected processing asymmetry between PC and ExC sentences, future replications should strive to include greater numbers of each, perhaps at the expense of some of the other sentence types we used (e.g. TOUGH-CONSTRUCTIONS).

Additionally, there were some linguistic variables which we did not control for. For example, the target antecedents in our study were not uniform in number (singular vs. plural) or definiteness. Although we do not suspect that either of these factors had an impact on the results reported on here, we recognize that this is perhaps not ideal. However, as always in experimental studies, there is a trade-off between (1) precisely manufacturing stimuli so that they are minimally distinct from one another and (2) ecological validity, that is, the extent to which we can generalize our findings to naturally occurring instances of language processing. Given that we chose to use a relatively low number of fillers as compared to critical stimuli, we wanted a certain degree of variety in our critical stimuli to help combat the artificial nature of the task and so, hopefully, more closely approximate naturalistic processing. Similarly, where adjectives were involved in the antecedent, these were not uniform with respect to position (pre-nominal vs. post-nominal). Although there may be a potential

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for effects related to linear distance, the structural distance is nonetheless identical for post-nominal and pre-nominal adjectives, and since our hypotheses concerned structural distance only, we have no reason to suspect that this variable resulted in substantive differences in processing of these antecedents. Finally, with respect to the adverbial adjuncts used to create syntactic distance from the antecedent, these served varying functions (time-adverbial, speaker-oriented, adversative, etc.). We are unaware of any research suggesting that adjunct function type might impact EC processing, but future research should certainly strive to control for these and the other linguistic variables mentioned above to the extent possible, while still varying examples sufficiently to avoid monotony and potential anticipatory effects on the part of the participant and to maintain ecological validity.

Finally, we would like to add some further comments about our finding that ExC sentences are processed differently from PC sentences. This was not predicted, and as our study is the first to our knowledge to separate out these two types of control and to examine whether they are processed differently,[45] we have relatively little to go on in attempting to construct an explanatory account for this finding. Even from a formal perspective, it is unclear whether ExC and PC differ structurally with respect to the identity and distribution of the empty categories involved; although languages with inflected infinitives (such as BP) show that PC has a morphosyntactic reflex, the most salient difference between these types of control may well be semantic. Furthermore, this distinction itself is relatively new in the literature, so our understanding of the formal properties of PC is likely incomplete.[46] It may be that the difference we are seeing here is merely an increase in processing complexity, perhaps occasioned by the need for the processor to consider additional referential possibilities for the antecedent in PC sentences, given that the embedded infinitive has plural features and the antecedent has singular features. The presence of additional entities within the discourse context may well take additional time to identify and reconcile. However, this is merely an initial hypothesis; a great deal more research more carefully constructed to contrast the processing of ExC and PC sentences must be done before we would be comfortable making stronger claims on the basis of these results.

Acknowledgements. We would like to thank our Brazilian consultants, Camila Livio Emidio and Diogo Cosme, who were instrumental in designing and validating our stimuli (Camila especially for lending her voice), along with Rachel Olsen for her tireless work on our sound files and on the recording process, and Kit Callaway for her assistance with participants. We would also like to thank several anonymous reviewers whose suggestions greatly improved the present work. Finally, we also benefited greatly from discussions with Marcello Modesto, Idan Landau, and the audiences at Going Romance XXXV, the UGA Linguistics Colloquium, and Penn State's Morphology and Syntax Syndicate (now the Morphology Circle), as well as Tom Bever, Acrisio Pires, Vera Lee-Schoenfeld, Paula Schwanenflugel, Luke Smith, Sara Carter, Sandra McGury, Jonathan Crum, the Department of Linguistics, Department of Romance Languages, and The Graduate School at UGA, the Department of Linguistics and Asian/Middle Eastern Languages at San Diego State University, and the Department of Linguistics at the University of Michigan.

Ethics. This study was approved by the Institutional Review Board of the University of Georgia (Athens, GA, USA) as STUDY #00002939 and was performed in accordance with the terms of this approval and with the standards of the 1964 Declaration of Helsinki.

[45] See White & Grano (2014) for an experimental study of acceptability of PC in English; this was not, however, an online processing study.

[46] PC was to our knowledge first identified by Lawler (1972; cited in Landau 2000), but the first detailed account was not until Martin (1996), and it is still a relatively understudied phenomenon, often not mentioned at all in studies of control.

https://doi.org/10.1017/S002222672400001X Published online by Cambridge University Press

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Appendix 1

Table A1 Participant demographics and self-reported abilities in Brazilian Portuguese (BP).

Subject ID	Gender	Years of formal education in BP	Years lived in Brazil	Speaking BP	Understand BP	Reading BP	Writing BP
316	F	20	29	6	6	6	6
216	F	19	16	6	6	6	6
116	F	20	29	6	6	6	4
101	M	20	28	6	6	6	6
201	M	20	28	6	6	6	6
103	F	8	8	6	6	5	4
202	M	20	24	6	6	6	5
102	F	0	0	4	6	**3**	**2**
203	M	3	6	4	5	4	4
104	F	3	4	5	6	6	5
204	F	7	11	6	6	5	4
303	M	11	24	6	6	6	6
304	F	11	25	6	6	6	6
105	F	10	26	6	6	6	6
205	M	15.5	26	6	6	6	5.5
305	M	17	28	6	6	6	6
106	M	12	29	6	6	6	6
206	F	20	24	6	6	6	6
306	F	20	25	6	6	6	6
107	M	18	23	6	6	6	5
207	M	20	25	6	6	6	6
307	F	20	28	6	6	6	6
108	F	20	32	6	6	6	6
208	M	12	17	6	6	6	6
308	F	15	18	6	6	6	5
109	F	16	26	6	6	6	6
309	M	17	23	6	6	6	5
110	F	15	33	6	6	6	6
210	M	17	27	6	6	6	6
111	M	14	26	6	6	6	6
211	M	17	28	6	6	6	6
311	M	13	35	6	6	6	6
112	F	17	27	6	6	6	6
212	F	14	37	6	6	6	6
113	M	18	19	6	6	5	5
213	M	20	50	6	6	6	6
313	F	20	25	6	6	6	6
114	M	3	27	6	6	6	6
214	M	12	26	NR	NR	NR	NR

Table A1 *Continued*

Subject ID	Gender	Years of formal education in BP	Years lived in Brazil	Speaking BP	Understand BP	Reading BP	Writing BP
314	M	10	13	6	6	6	6
115	F	20	23	6	6	6	6
215	F	20	25	6	6	6	6
315	M	16	29	6	6	6	6
321	F	20	24	6	6	6	6
220	M	20	30	6	6	6	6
319	F	13	32	5	6	6	6
318	F	20	24	6	6	6	6
118	F	20	26	6	6	6	6
117	M	17	24	6	6	6	6
219	F	20	30	6	6	6	6
317	F	20	41	6	6	6	6
218	M	18	24	5	6	5	4

NR, no rating.

Appendix 2

Accuracy and mean response times by subject

N.B.: Subject #102 was eliminated from the analysis for not having spent significant time residing in Brazil, as well as for self-reported low facility with reading and writing in Brazilian Portuguese. Subject #106 was eliminated for a mean RT in CRETs being more than three SDs above the mean for all subjects. Subject #314 was eliminated due to an accuracy rate to experimental targets exceeding three SDs below the mean for all subjects. Finally, subject #114 was eliminated for multiple reasons: (1) a mean RT in CRETs being more than three SDs above the mean for all subjects; (2) an accuracy rate to experimental targets exceeding three SDs below the mean for all subjects; and (3) an overall accuracy rate exceeding three SDs below the mean for all subjects.

Table A2 Accuracy and mean response times (RTs) and standard deviations (StDevs) by subject; eliminated subjects highlighted, along with the descriptive statistics which correspond to the reason(s) for their elimination.

SubjID	Overall accuracy	Accuracy w/ experimental targets	Mean RT	StDev RT
101	94.0%	89.3%	849	245
102	85.4%	75.0%	751	241
103	92.7%	90.7%	627	181
104	90.4%	81.4%	990	456
105	85.5%	68.4%	589	106
106	86.8%	75.6%	1,672	776
107	90.2%	85.4%	733	218
108	92.7%	86.1%	621	162
109	86.8%	79.6%	722	184

https://doi.org/10.1017/S002222672400001X Published online by Cambridge University Press

Table A2 *Continued*

SubjID	Overall accuracy	Accuracy w/ experimental targets	Mean RT	StDev RT
110	94.0%	86.5%	900	232
111	90.4%	84.0%	695	280
112	93.9%	88.6%	634	133
113	89.0%	81.0%	538	127
114	43.9%	42.9%	1,637	1,224
115	91.5%	82.9%	657	192
116	94.0%	86.1%	578	97
117	91.6%	82.9%	869	278
118	87.8%	80.8%	745	136
201	91.5%	80.0%	660	146
202	94.0%	86.5%	642	187
203	82.9%	70.0%	628	162
204	92.8%	87.2%	691	218
205	84.3%	79.1%	591	143
206	88.0%	84.1%	591	158
207	96.4%	93.2%	610	179
208	86.8%	82.9%	568	203
210	92.7%	87.5%	486	102
211	91.6%	84.2%	625	205
212	96.3%	92.3%	680	189
213	90.2%	82.9%	721	430
214	90.4%	84.3%	787	238
215	95.2%	89.5%	589	93
216	90.4%	79.4%	582	137
218	88.0%	85.4%	486	93
219	92.7%	83.3%	717	126
220	92.8%	89.4%	494	149
303	91.5%	87.5%	497	96
304	92.7%	86.1%	520	120
305	89.2%	80.4%	630	202
306	89.0%	81.8%	1,031	604
307	91.6%	82.1%	925	463
308	90.4%	86.4%	513	160
309	91.5%	86.7%	648	147
311	89.2%	82.1%	571	98
313	81.9%	61.1%	903	397
314	73.2%	51.1%	954	195
315	87.8%	77.5%	814	436
316	91.5%	85.7%	657	120
317	90.2%	84.4%	739	444

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Table A2 *Continued*

SubjID	Overall accuracy	Accuracy w/ experimental targets	Mean RT	StDev RT
318	86.8%	75.6%	857	439
319	91.6%	84.1%	807	213
321	91.6%	83.7%	841	361
mean	**89.2%**	**81.6%**	**728**	**197**
stdev	**7.4%**	**9.0%**	**230**	

Cite this article: Merchant, Doug and Gupton, Timothy. 2025. "Processing dissociations between raising and control in Brazilian Portuguese." *Journal of Linguistics*. 61, 301–337. doi:10.1017/S002222672400001X