Online null subject licensing
in Brazilian Portuguese

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1 CONTEXT

What kind of algorithm is employed in the retrieval of linguistic representations from memory? The study proposed here will provide evidence that will be instrumental in answering this question. We exploit a grammatical constraint in Brazilian Portuguese that requires a specific structural relation between a null subject and its antecedent subject. Some retrieval algorithms rely heavily on such structural relations between constituents, while other do not. In the case of retrieving a null subject's antecedent, an algorithm's dependence on structure should determine whether it ever considers a structurally *ineligible* subject as a possible antecedent. Algorithms that are highly dependent on structure should not consider the structurally ineligible subject. On the other hand, algorithms less sensitive to structure should show signs of having considered the ineligible subject during the retrieval.

1.1 Retrieval algorithms

There are two dominant hypotheses for how retrievals into structured memory might proceed: retrieval through a structure-guided search and retrieval through content-addressable memory. The longstanding assumption in linguistics and psycholinguistics has been that retrieval is guided by linguistic structure. That is, the memory retrieval algorithm traverses the highly structured, hierarchical representation of a sentence in order to locate a queried node. In opposition to this hypothesis stand a recent spate of studies suggesting that the sentence processor builds, manipulates, and stores linguistic representations in a content-addressable workspace (McElree, 2000; McElree et al., 2003; Lewis and Vasishth, 2005; Lewis et al., 2006). The proponents of such as system do not make strong claims about whether or how

structural relationships are encoded under such a workspace, but they do claim that whatever structural information is encoded is not used during retrieval. Instead, the contents of memory can be addressed directly. To underscore the difference between these two algorithms, consider that with n encoded nodes, the average computational cost of searching a binary tree is $O(\log n)$, while for cost for searching content-addressable memory is $O(1)$ (Knuth, 1973).

2 DEPENDENCIES, CONSTRAINTS, AND RETRIEVAL

The grammar sets forth constraints on what elements can enter into dependency relations. In question is what role these constraints play in online processing. Experimental evidence indicates that there is a great deal of variability in how accurately grammatical constraints are implemented online. There is not a clear correlation between the theoretical complexity of a constraint and its apparent difficulty in processing. We owe an explanation for this variability. One dimension that seems to account for some of it is the *directionality* of dependencies

DEPENDENCIES   Grammatical dependencies have two elements, which I will call the *left-* and *right-hand* elements, based on their position in a sentence string. Further, I will call the element—left or right—that initiates a dependency[1] the *head* and the element that terminates it, or satisfies it, the *foot*. When the left-hand element is a head, as in (1), this is considered a *forwards* dependency because the parser must look *forwards* in time in order to locate the foot of the dependency. Oppositely, in a *backwards* dependency, like (2), the right-hand element is the head. The parser must look *backwards* in time (i.e., into memory) in order to locate the foot and satisfy the dependency.

(1)   While he   ate, John   watched TV.   FORWARDS DEPENDENCY
                L-HEAD   R-FOOT

(2)   John   watched TV while he   ate.   BACKWARDS DEPENDENCY
            L-FOOT   R-HEAD

As a consequence of the ordering of their elements, forwards dependencies have a predictive component while backwards dependencies do not. Typically, the identification of a head allows the parser to predict an upcoming foot. Feet, however, can only be identified in the context of a head. In (2), for instance, the parser cannot

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[1] As specified by the grammar.

predict at *John* that the head *he* is upcoming. It is only once the parser reaches *he* that a dependency is identified and a retrieval into memory necessitated. On the other other hand, in (1), the parser *can* predict that a foot may be upcoming upon reaching *he*, as pronouns typically have antecedents.

Possibly due to the prominent role of prediction in their satisfaction, forwards dependencies tend to be more "faithful" to the grammar and less vulnerable to interference. In contrast, backwards dependencies have not been so reliably faithful and have repeatedly been shown to be vulnerable. The need to retrieve elements from memory introduces an opportunity for fallibility not present in forwards dependencies.

2.1 Forwards dependencies

Forwards dependencies may be "easy" for the parser because it is cued to look for a foot to satisfy the dependency as soon as it detects a head. Two examples are *wh*-dependencies and backwards anaphora.

Wh-dependencies have repeatedly been shown to be sensitive to island boundaries. In these cases, the sentence processor is not likely to posit a gap inside of an island. Using filled-gap effect evidence, Stowe (1986) showed that no gap is posited after the preposition inside a subject NP (3). Likewise, Traxler and Pickering (1996) showed that reading times were not affected by an implausible filler when the potential gap was within a relative clause, (4).

(3)   The teacher asked what the silly story about (__) Greg's older brother was supposed to mean.

(4)   We like the {book|?city} that the author who (__) wrote unceasingly and with great dedication saw while waiting for a contract.

Phillips et al. (2006), however, showed that only *some* island constraints are reflected online, reminding us that not all cases of fallibility can be attributed to the direction of the dependency. These authors find evidence for gaps being posited inside infinitival subject islands (5), but not finite subject islands (6). [2]

(5)   The school superintendent learned which {schools|?high school students} the proposal to expand drastically and innovatively upon the current cur-

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[2] Note to Colin: I know that this could be expanded upon to contain a lot more detail about the study, but I think it would only bog things down. The point I'm trying to make is that forwards dependencies aren't universally faithful and that direction can't explain all the variability in how grammatical constraints are applied online.

riculum would overburden during the following semester.

(6)   The school superintendent learned which {schools|?high school students} the proposal that expanded drastically and innovatively upon the current curriculum would overburden during the following semester.

Another forwards-looking phenomenon that seems to be fairly robust against interference and consistently respect grammatical constraints is backwards anaphora, or *cataphora*. In regular anaphora, antecedents precede pronouns (7). In cataphora, the situation is reversed. In contrast to anaphora, cataphoric dependencies are forward-looking because, in these cases, heads precede feet, so when a head is identified, a foot is sought out. (8). A cross-linguistically well-attested constraint on backwards anaphora is Binding Principle C (Chomsky, 1981), which prevents an R-expression and a c-commanding pronoun from coreferring (9). If the parser respects Principle C online, then it should not consider R-expressions that a cataphoric pronoun c-commands as possible antecedents.

(7)   While he ate, John watched TV.

(8)   John watched TV while he ate.

(9)   *He$_1$ said that John$_1$ saw the movie

Kazanina et al. (2007) find just this kind of evidence in a study that takes advantage of gender mismatch effects. In (10), there is a reading time slowdown when {boy|girl} mismatches with the preceding pronoun. This suggests that the parser considers this NP as a possible antecedent for the pronoun before deciding it is unsuitable. In (11), where the pronoun c-commands {Kathryn|Russel}, there is no such slowdown.

(10)   While he was at the party, the {boy|girl} cruelly teased the {girl|boy} during the party games.

(11)   Because last semester while she was taking classes full-time while {Kathryn|Russel} was working two jobs to pay the bills, Erika felt guilty.

BACKWARDS DEPENDENCIES   While forwards dependencies seem to be universally faithful to the grammar, results for backwards dependencies are mixed. One case of faithful backwards dependency completion is reported in Sturt (2003). Binding Principle A Chomsky (1981) requires that anaphors like *himself* have a c-commanding antecedent. In (12), upon reaching the anaphor, the parser must make a retrieval into memory to find antecedents. If Principle A is respected online, then the struc-

turally inaccessible NP *Jennifer/Jonathan* should not be considered in the search for an antecedent (there should be no reading time slowdowns). In (12), the subject *surgeon* is stereotypically biased towards masculine referents. There is evidence that readers are subject to this bias during online comprehension. This bias might lead readers to consider *Jennifer* as the antecedent to *herself* despite the fact that it is structurally inaccessible. However, Sturt's results show that readers did not consider the matching, but structurally inaccessible intervener, providing evidence that Principle A is respected online.

(12)   a.   The surgeon that treated Jonathan pricked himself with a needle
      b.   The surgeon that treated Jennifer pricked herself with a needle
      c.   The surgeon that treated Jonathan pricked herself with a needle
      d.   The surgeon that treated Jennifer pricked himself with a needle

Though there is some nuance to the findings, similar results have been replicated across experimental paradigms including self-paced reading (Kennison, 2003; Kush et al., 2009) and cross-modal lexical priming (Nicol and Swinney, 1989). Using ERP, Xiang et al. (2008) found that NPI licensing was not affected by the presence of an inaccessible intervener in reflexives.

On the other hand, there are several studies that show that backwards search is fallible. Badecker and Straub (2002) found that readers were slower to read items with two matching antecedents, like (13-a), than items with only matching antecedent (13-b). This is interesting because though (13-a) has two matching antecedents, one of them is grammatically illicit and should not be considered in the search. Both of these were read faster than (13-c) and (13-d), where the structurally accessible antecedent is semantically incompatible with the pronoun. This pattern of results suggests that the parser was temporarily considering the illicit antecedent *Bill* in (13-a), and importantly, that it was ignoring useful structural cues to do so.

(13)   a.   John thought that Bill owed him another chance
      b.   John thought that Beth owed him another chance
      c.   Jane thought that Bill owed him another chance
      d.   Jane thought that Beth owed him another chance

Finally, another group of results looking at subject-verb agreement over a distance also suggest that the parser does not always take advantage of structural cues (Pearlmutter et al., 1999; Wagers et al., 2009; Alcocer and Phillips, 2009). Though both are ungrammatical due to subject-verb agreement mismatch, readers are faster to read (14-b) than (14-a). Accounts of the exact mechanism differ, but the consen-

sus seems to be that in (14-b), when performing a backwards search to find the verb's subject, the parser incorrectly retrieves the plural feature on *cabinets* and illegitimately satisfies the dependency. It clear, however, that simple linear adjacency is not enough to explain the errors, as an arbitrary amount of material can be place between agreeing elements with no change in acceptability patterns.

(14)   a.   The key to the cabinet are on the table.
        b.   The key to the cabinets are on the table.

3   THE PRESENT STUDY

3.1   *Background*

As discussed in section 2, in the case of reflexives, the retrieval of an antecedent is generally faithful to the grammar. This can be taken as evidence for structure-guided search. It is possible, however, that the antecedents in these cases are positionally unique, and can be specially encoded in a content-addressable system. BP gives us a case where the position of the antecedent subject is not unique and therefore evades special encoding in the memory representation. This study, therefore, would be strong evidence for the structure-guided search hypothesis if the results showed that the parser ignored illicit antecedents.

In partial null subject (NS) languages, null subjects are licensed under more restricted conditions than full NS languages. Holmberg et al. (2009), examining several partial NS languages, reduce the conditions under which null subjects are licensed in these languages to two: (i) when the subject is a generic pronoun corresponding to English "one" and (ii) when the subject is controlled by an argument in an immediately higher clause.

In (15) we see what condition (ii) looks like. In (15-a), the pronoun *he* corefers with the subject *John*. In a non-null subject language, like English, the pronoun is obligatorily overt. In full and partial NS languages, the pronoun is obligatorily null. In (15-b), however, full and partial NS languages differ. The pronoun in this example would again be null in full NS languages, but crucially, would be obligatorily overt in partial NS languages. To restate condition (ii): the NS must be c-commanded by immediately higher overt subject for the NS to be bound to that subject; an unbound NS is illicit.

(15)   a.   John$_1$ said that he$_1$ bought the house
        b.   John$_1$ said that he$_2$ bought the house

THE IMMEDIATELY HIGHER OVERT SUBJECT C-command is necessary but not sufficient to license NS coreference. It really must be the immediately higher overt c-commanding subject. In **??**, we know that the NS is intended to corefer with the non-immediate c-commanding subject *João* because the NP *doutor* has masculine gender marking. This is ungrammatical. On the other hand, in **??**, we know that the NS is intended to corefer with the immediately higher overt subject *Maria*. This is grammatical.

(16)   a.   *João acha   que Maria pensa que é obvio   que é doutor
              J.   thinks that M.   thinks that is obvious that is doctor-MASC
         b.   João acha   que Maria pensa que é obvio   que é doutora
              J.   thinks that M.   thinks that is obvious that is doctor-FEM
              "J thinks that M. thinks that it is obvious that she is a doctor"

In the present study, we exploit this second condition in order to test whether backwards search is sensitive to syntactic structure. It has traditionally been tacitly assumed that a backward-looking dependency search uses syntactic structure as a guide to locate the dependency in memory. Under this system, locating the appropriate c-commander is straightforward. Importantly, however, cue-based retrieval in content-addressable memory makes no reference to structural relations like c-command, making it impossible to selectively retrieve a c-commanding subject.

In BP, therefore, the optional pronouns in (17) can only be made null if they are meant to corefer with the matrix subject.

(17)   a.   O João$_1$ disse que (ele$_1$) tinha comprado   uma   casa
              DET João said that he   have-PST.3SG bought a   house
              "João said he bought a house"
         b.   Os meninos$_1$ ficavam contentes quando (eles$_1$) tinham um
              DET   children were   happy   when   they   have-PST.3PL
              dia de   folga
              a   day of   holiday
              "The children were happy when they had the day off"
         c.   A Maria$_1$ admite que   (ela$_1$) não fala muito   bem inglês
              DET   Maria admits that   she NEG speak-PRS.3SG very well

              English
              "Maria admits that she doesn't speak English very well"

We can exploit this fact experimentally in order to establish the role of c-command in online dependency processing. There is an ongoing debate as the role of linguistic structure in memory search during online sentence processing. In the present case, in order to establish a c-command relation between a null subject and an overt c-commanding NP, there must be some dependence on structure in memory search. Whether the retrieval mechanism relies on structure for retrieval is up for debate.

4 PRE-EXPERIMENTS: VERIFYING ASSUMPTIONS

4.1 Assumption: Holmberg et al. (2009)'s generalizations hold

A major assumption of this study is that the generalizations about the constraints on BP null subjects made explicit by Holmberg et al. hold true for the population we will be testing in Rio de Janeiro. This assumption needs to be validated. The claim that null subjects in BP are as restricted as they are is not widely known. What's more, European Portuguese (EP), a close relative of BP, is a full NS language which does not have the same NS restrictions as BP. Reviewers or readers with intuitions about EP, who may mistakenly assume that they also apply to BP, may disagree with the generalization and cast doubt upon our results. In order to get this study accepted for publication, it will be necessary to demonstrate that the effect exists in the first place.

Here we propose two ways to probe this. In (18), the null subject has two c-commanding subjects, but only the one in the clause immediately higher to it (*Maria*) should be a legal antecedent to the NS. Therefore, an adjective agreeing with the NS should agree with the immediately-higher c-commanding subject, and not any others. If participants are as sensitive to the NS constraint as Holmberg et al. would have us believe, then we should see much higher acceptance rates for (18-b) than (18-a).

(18)   a. *João acha   que Maria pensa que é obvio   que é doutor
              J.   thinks that M.   thinks that is obvious that is doctor-MASC
    b. João acha   que Maria pensa que é obvio   que é doutora
              J.   thinks that M.   thinks that is obvious that is doctor-FEM
             "J thinks that M. thinks that it is obvious that she is a doctor"

A second way to test for sensitivity would be to ask a comprehension question that probes for the identity of the antecedent of the NS. In (19), I present a sentence that under a full NS language would be ambiguous. However, under a partial NS

language, like BP, there should be no ambiguity: the correct answer should be *Maria* because this is the subject that immediately c-commands the NS.

(19)   João acha   que Maria pensa que vai chegar tarde. Q: Quem vai chegar
        J.   thinks that M.   thinks that will arrive late.   Q: Who   will arrive
        tarde?
        late?
        a.   *João
        b.   Maria

4.2 Assumption: BP speakers are sensitive to number morphology

França, Maia, and other informants (p.c.) have noted that there is some variability in the sensitivity of BP speakers to number morphology. If we intend to manipulate number as part of our experimental design, we should make certain that participants are sensitive to it.

In particular, some dialect of BP mark number agreement only on the determiner and not on the noun, as in (20).

(20)   As   casa   do   barrio   são brancas
        DET-PL house-SG of-the neighborhood are white
        "The houses in the neighborhood are white"

A possible noteworthy innovation in BP over EP is the grammaticalization of the pronoun *a gente* (lit.: the people). *A gente* is used in a way analogous to *nós*, the first-person plural pronoun, but takes third-person singular agreement.

(21)   a.   A   gente é estudante
             The people is student
             "We are students"
        b.   Nós somos estudantes
             We are   students
             "We are students"

4.3 Administering the pre-experiments

There are at least two ways to validate the effect: (i) with a between subjects pre-experiment or (ii) with a within subjects pre-experiment.

BETWEEN-SUBJECTS   By "between subjects" I mean that the subjects who would participate in this pre-experiment would not participate in the main experiment.

Any conclusions drawn about the participants in this pre-experiment would be extended to the participants of the main experiment under the assumption that they were being drawn from the same population. The main benefit of doing it this way is that the pre-experiment could be conducted remotely, over the Internet, before leaving for Brazil.

WITHIN-SUBJECTS   A within-subjects pre-experiment would be administered to the participants of the main experiment before the main experiment began (or perhaps as fillers to the main experiment). The benefit of this method is that it allows us to quantify how sensitive each participant is to the effects we are interested in. This would give us a principled way to exclude participants who were not sensitive to the effects. Additionally, a participant's "sensitivity score" could later be entered as a covariate in a linear mixed-effects model.

5   EXPERIMENT 1: NUMBER

Three conditions: ACCESSIBLE MATCH, NO MATCH, and INACCESSIBLE MATCH. The ACCESSIBLE MATCH condition should always be grammatical and the NO MATCH condition should always be ungrammatical. The INACCESSIBLE MATCH condition, however, should be ungrammatical, but is liable to intrusion by the subject embedded in the relative clause in the matrix subject NP.

   The INACCESSIBLE MATCH case: Upon encountering the null subject, the parser must look for a licensor. If the parser follows structure in its search, then it should not consider the structurally inaccessible intervener NP and the sentence should be judged as ungrammatical. However, if some other search mechanism is employed—one that ignores structure to some degree—then the structurally inaccessible NP may be considered as the null subject licensor and the sentence may pass as grammatical.

(22)   a.   ACCESSIBLE MATCH
             Os meninos que **o professor** viu no boteco de esquina disseram que era provável que *pro* **fossem** chegar atrasados na sala de aula.
       b.   NO MATCH
             O menino que **o professor** viu no boteco de esquina disse que era provável que *pro* **fossem** chegar atrasados na sala de aula.
       c.   INACCESSIBLE MATCH
             O menino que **os professores** viram no boteco de esquina disse que era provável que *pro* **fossem** chegar atrasados na sala de aula.

An additional factor that may be worth manipulating is the number of the critical verb. As agreement attraction experiments have shown, it

(23) a. ACCESSIBLE MATCH
        O menino que **os professores** viram no boteco de esquina disse que era provável que *pro* **fosse** chegar atrasado na sala de aula.
     b. NO MATCH
        Os meninos que **os professores** viram no boteco de esquina disseram que era provável que *pro* **fosse** chegar atrasado na sala de aula.
     c. INACCESSIBLE MATCH
        Os meninos que **o professor** viu no boteco de esquina disseram que era provável que *pro* **fosse** chegar atrasado na sala de aula.

5.1 Predictions

If search is entirely guided by structure, then the condition in which a number-agreeing, but structurally inaccessible NP intervenes between the verb and the subject head NP (INACCESSIBLE MATCH) should be just as slow as a condition where neither of the subject NPs before the verb agrees with it. This should return a pattern of reading times like those in (24).

(24) ACCESSIBLE MATCH < INACCESSIBLE MATCH = NO MATCH

If cues other than structure are used in search, then a structurally inaccessible, but number agreeing subject NP might be temporarily considered as the antecedent of the null subject. In this case, we would expect that, on average, reading times at the critical word in the INACCESSIBLE MATCH would be somewhere between the average reading times at the same word in the ACCESSIBLE MATCH condition (fastest) and the NO MATCH condition (slowest).

(25) ACCESSIBLE MATCH < INACCESSIBLE MATCH < NO MATCH

5.2 Materials requirements

Experimental stimuli will be presented to participants pseudo-randomly in a Latin square design. This entails that every participant will be presented with exactly one condition from each item set and equal amounts of each condition across the whole experimental session. As a result, in order to get an equal number of observations for each experimental item, the total number of participants should be a multiple of the number of conditions. For instance, with 3 conditions, 3 participants would be require in order for each experimental item to have been seen once. In order to get

enough statistical power to bring effects of the size typically seen in psycholinguistic experiments like this one into significance, at least 6 observations per experimental item would be necessary.

There are two degrees of freedom we can manipulate when deciding on the number of experimental stimuli required for this experiment. The first is an experimental consideration: the number of factors (2 or 3). This affects the number of conditions (3 or 6). The second is a statistical consideration: the number of observations per condition per subject (6 or 8). Table 1 summarizes how different choices impact the total experiment time.

Conditions	Experimental items	Filler items	Total items	Observations per condition	Est. completion time (minutes)
3	18	36	54	6	9
3	24	48	72	8	12
6	36	72	108	6	18
6	48	96	144	8	24

Table 1: Estimated completion time calculations. Assumes that each trial takes 10 s to complete and that a filler-to-item ratio of 2:1 is appropriate.

The major limiting factor to take into consideration is time. No session should go over one hour. Given this constraint, Table 1 shows that including the number factor (for a total of 6 conditions) and 48 item sets is feasible. Even if the timing and filler-to-item ratio parameters were made more conservative (15 s per trial; 3:1 ratio), the session would still last well under an hour (48 minutes). If we wish to combine Experiments 1 and 2 into a single session, however, we may need to cut back the number of experimental items for Experiment 1 to 36. More on this in section 6.1.

Finally, in order to get a reasonable number of observations per item, we will need at least 18 subjects. With this number of subjects, each item will have been observed 6 times.

5.3 Things to consider

Sensitivity to number marking is variable in BP. We need a measure to assess how sensitive subjects are to number marking.

6 EXPERIMENT 2: GENDER

There seems to be wide variation in Brazilian Portuguese speakers' sensitivity to number. For this reason, we require a second experiment that manipulates NS-adjective gender agreement rather than subject-verb number agreement.

(26)   a.   ACCESSIBLE MATCH
               O menino que **o professor** viu no boteco de esquina disse que era lógico que *pro* estava **cansado** por que não tinha dormido muito
        b.   NO MATCH
               A menina que **a professora** viu no boteco de esquina disse que era lógico que *pro* estava **cansado** por que não tinha dormido muito
        c.   INACCESSIBLE MATCH
               A menina que **o professor** viu no boteco de esquina disse que era lógico que *pro* estava **cansado** por que não tinha dormido muito.

6.1 Materials requirements

The materials requirements for Experiment 2 are the same as Experiment 1, except that no third factor is being considered for inclusion.

Conditions	Experimental items	Filler items	Total items	Observations per condition	Est. completion time (minutes)
3	18	36	54	6	9
3	24	48	72	8	12

Table 2: Estimated completion time calculations for Experiment 2. Assumes that each trial takes 10 s to complete and that a filler-to-item ratio of 2:1 is appropriate.

Given how short this experiment is, we may want to combine it with Experiment 1.

7 DETAILS

Here I mention some of the details of testing that should be addressed. In particular, I am interested in hearing feedback about the feasibility of maintaining the pace of testing established below.

PACE OF TESTING   We will have 20 weekdays in Brazil. If we test 3 participants

every day, we should be able to run 60 participants during our stay. Depending on the size of the subject pool and students' willingness to participate, more participant per day should be feasible, but 3 seems like an accomplishable goal.

PARTICIPANT ELIGIBILITY   Our participants should be native speakers of Brazilian Portuguese between the ages of 18 and 35. Participants may be speak languages other than Brazilian Portuguese, but not natively or at a fluent level. Participants should also have never suffered from a linguistic or neurological impairment or disability.

If students are participating for credit, they will still be granted credit if they do not meet any of the above criteria.

PRE-EXPERIMENT QUESTIONNAIRE   In order to make sure that participants can be included in the study, each participant will be presented with a short questionnaire before every experimental session. The questionnaire will include questions about age, sex, language-impairment history, educational history, and about what languages the participant speaks and how well. Additionally, in order to account for possible dialectical differences between participants, they will be asked questions about where in Brazil they grew up and where they have lived.

IRB   We intend to translate the Institutional Review Board (IRB) consent form that we use at the University of Maryland into Portuguese. All participants must read and sign this form at the very beginning of each experimental session. Does the Universidade Federal do Rio de Janeiro have any consent forms that they require?

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