

TÓPICO 1 – Cognição e computação

Resolving pronouns to antecedents in commanding and non commanding positions: first results from ERP research*

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ABSTRACT – We test the hypothesis that the implementation of dependencies at the level of discourse has a higher processing cost than the implementation of dependencies within syntax alone. To this end we use event-related potentials to examine the implementation of anaphoric links established between pronouns and non commanding antecedents (discourse-based dependency) and contrast that with the processing of anaphoric links to commanding antecedents (syntax-only dependency). The experimental results obtained show a N400-like effect associated with the formation of the pronoun-non-commanding antecedent dependency. This enhanced negativity for pronouns resolved to non-commanding antecedents supports our hypothesis that discourse-based processes place different computational demands on the comprehension system than syntax-only processes. This kind of evidence is thus consistent with models of pronominal representation whereby antecedents are established by both syntactic and non-syntactic means.

Keywords: cognitive processing; discourse; anaphora; pronoun resolution; event-related response potentials; N400; sentence comprehension.

RESUMO – Procedemos ao teste da hipótese de que a implementação de dependências ao nível do discurso tem custos de processamento mais elevados do que a implementação de dependências apenas em termos sintáticos. Para tanto, usamos potenciais evocados por forma a examinar a implementação de ligações anafóricas estabelecidas de pronomes para antecedentes não comandantes (dependência com base no discurso), a qual colocamos em contraste com o processamento de ligações anafóricas estabelecidas para antecedentes comandantes (dependência com base apenas na sintaxe). Os resultados experimentais obtidos mostram um efeito do tipo N400 associado à formação da dependência entre pronome e antecedente não comandante. Esta negatividade acrescida para pronomes que são resolvidos para antecedentes não comandantes apoia a nossa hipótese de que processos com base no discurso colocam exigências computacionais ao sistema de compreensão diferentes das exigências colocadas por processos baseados apenas na sintaxe. Este tipo de dados é assim consistente com modelos de representação pronominal através dos quais os antecedentes são estabelecidos através de meios sintáticos e não sintáticos.

Palavras-chave: processamento cognitivo; discurso; anáfora; resolução de pronomes; potenciais evocados; N400; compreensão de frases.

Introduction

According to the basic outline of anaphora resolution in terms of information processing, the anaphoric links between anaphors and their antecedents are established

according to a number of constraints and preferences: out of the antecedent candidates around, the constraints holding for a given anaphor circumscribe the set of its admissible antecedents, from which in turn the actual antecedent is selected by the preferences that may happen to apply (CARBONELL and BROWN, 1988; RICH and LUPERFOY, 1988; ASHER and WADA, 1988). The present work is an investigation of the processing

* This article reports on work in progress. As the underlying research proceeds and more results are gathered, it will be extended and further versions of it are planned to be presented elsewhere.

indicators of antecedent selection and how they serve to adjudicate among competing theoretical proposals on how this selection takes place.

Background: Grammatical studies

The subset of grammatical constraints impinging on intra-sentential anaphoric links i.e., binding principles, are defined in terms of two auxiliary relations: a) the command relation and b) the locality relation. We briefly describe each in turn.

An expression, which is an argument of a given predicator, is commanded by its less oblique co-arguments – i.e. by the other less oblique arguments of that predicator. This relation obtains recursively by the arguments of upwards predicators in the grammatical representation that command an argument containing commanders. A locality relation between two expressions obtains when they are co-arguments with respect to a given predicator.

For instance, for an expression to qualify as an admissible antecedent of the reflexive *himself*, it has to be one of its local commanders (principle A), as exemplified in (1a):

- (1) a. Peter_i said that [[[John's]_k brother]_j shaved himself_{*i/j/*k}].
 b. Peter_i said that [[[John's]_k brother]_j shaved him_{i/*j/k}].

As to the pronoun *he*, in turn, for an expression to qualify as one of its admissible intra-sentential antecedents, it cannot be one of its local commanders (principle B), as exemplified in (1b).

Background: Behavioral studies

While the grammatical notions of command and locality have empirically emerged chiefly to characterize grammatical competence concerning anaphors and their anaphoric capacity, there have been some proposals arguing that these notions make a psychological claim by capturing important aspects of the *real-time processing* of anaphora (GRODZINSKY and REINHART, 1993; REULAND, 2001).

In this respect, a range of claims can be found that differ one from another mostly in terms of their theory-driven technical details. **One of the key hypotheses that emerges as common to all of them is that the processing of anaphoric links to recessors (i.e. non commanding antecedents) demands more cognitive resources than the processing of anaphoric links to commanders (i.e. commanding antecedents).** This tends to be interpreted as one of the possible pieces of evidence that discourse-based procedures require heavier cognitive processing than those that are based on grammar alone.

A couple of contributions have assessed this claim by resorting to behavioral experimentation. Piñango and Burkhardt (2002) studied possible differences in the processing of anaphoric links to commanders (2a) vs. links to recessors (2b) holding between reflexives and their antecedents. In one of the experiments, they used test materials like the following:

- (2) a. [The driver_i who caused a crash blamed himself_i].
 b. The therapist_i rolled a ball [around himself_i].

In (2b), the reflexive is in the (local) domain of the semantically-loaded preposition *around*, which domain is not a co-argument of the antecedent *the therapist*. Hence the reflexive is anaphorically resolved to this recessor.¹ In contrast, in (2a) the reflexive is anaphorically linked to a commander.

For their experiment, these authors resorted to the cross-modal lexical decision interference paradigm. They recorded reaction times to a visual probe (lexical decision task: pressing a button if the string displayed was a word) appearing immediately after the occurrence of the anaphor in the sentence being listened. The result was in line with the hypothesis as the reaction time for the condition concerning anaphors resolving to recessors was “statistically significantly higher” than the condition for anaphors resolving to commanders. This experiment was later replicated with materials involving the Dutch *zich*, leading to similar results (BURKHARDT et al., 2009).

Another experimental assessment of the hypothesis at stake was undertaken by Koornneef, Wijnen and Reuland (2006), but now resorting to eye-tracking experimental methodology. They studied possible differences in the processing of pronouns anaphorically resolved to commanders (3a) or to recessors (3b) by resorting to materials illustrated by the following excerpts:

- (3) a. [Every worker who just like Paul was running out of energy]_i thought it was very nice that he_i could go home early this afternoon.
 b. [Every worker who knew that Paul_i was running out of energy] thought it was very nice that he_i could go home early this afternoon.

The results were reported to be also in line with the above hypothesis in as much as “readers refixated the critical region (i.e. containing the pronoun) and the preceding region longer in the [recessor] condition than in the [commander] condition”.

¹ Note that this reflexive is behaving as a logophor (REULAND, 2001). In other theoretical settings, this behavior is explained on the basis that the reflexive is not locally commanded, hence it is in a so-called exempt position, i.e. in a position where it is exempt from the discipline of principle A (POLLARD and SAG, 1994).

Background: Brain studies

There are a number of previous ERP studies that focused on anaphora resolution. For instance, Streb, Rösler and Hennigshausen (1999) found a 270-400 ms frontal negativity and a 510-600 ms parietal negativity elicited by pronouns in contrast to nouns that are resolved to the same extra-sentential antecedent. Van Berkum et al. (2003, 2007) identified a sustained frontal negativity, emerging at about 300-400 ms, elicited by ambiguous pronouns in contrast to non ambiguous ones.

Some of other studies were concerned specifically with so-called preferences for anaphora resolution. Streb, Henningshausen and Rösler (2004) studied the recency preference and brought to light a N400 effect correlated with pronouns resolved to more distant inter-sentential antecedents than pronouns resolved to more recent ones. Streb, Rösler and Hennigshausen (1999), in turn, found a 510-630 ms parietal negativity elicited by pronouns that are resolved to inter-sentential antecedents in a non parallel grammatical function, in contrast to pronouns resolved to antecedents in parallel grammatical functions.

Harris, Wexler and Holcomb (2000), in turn, were concerned with a grammatical constraint on intra-sentential anaphora resolution. They identified a P600 effect in correlation with principle A violation by reflexives.

In this paper, we report on the results of an ERP study where we sought further empirical support to the hypothesis that intra-sentential anaphora resolution to recessors is more resource demanding than resolution to commanders.

Experiment

Two conditions were tested in this study: pronouns resolved intra-sententially to commanding antecedents (ANTEC-COMM) and to non-commanding antecedents (ANTEC-RECESS). Gender agreement was used to disambiguate the intended resolution (test sentences are from Portuguese):

- (4) a. [O mordomo-MASC de [a condessa-FEM]]-MASC_i discutiu com [a criada]-FEM a quem ele-MASC_i tinha emprestado algum dinheiro. (ANTEC-COMM)
The butler of the countess quarreled with the servant to whom he had lent some money.
- b. [A empregada-FEM de [o talhante-MASC]_i]-FEM discutiu com [a cliente]-FEM a quem ele-MASC_i tinha vendido carne estragada. (ANTEC-RECESS)
The employee of the butcher quarreled with the client to whom he had sold spoiled meat.

Predictions: Given the established theoretical and processing distinction discussed, our hypothesis predicts a difference in processing whereby resolving a pronoun to a *recessor* will entail a higher computational cost

than resolving pronoun to a *commanding* antecedent: ANTEC-RECESS > ANTEC-COMM.

Analysis: ERP data from 61 electrodes were analyzed for the LAN (250-450 ms), N400 (400-600 ms) and P600 (550-800 ms) time windows, by means of repeated-measures ANOVAs. Separate ANOVAs were performed for lateral and central scalp regions. The electrodes were grouped into nine regions, on the basis of their topographical distribution. The lateral ANOVAs were conducted with the factors GRADIENT – anterior, medial and posterior – and HEMISPHERE – left and right –, corresponding to six regions: anterior left (AF7 AF3 F7 F5 F3), medial left (FT7 FC5 FC3 T7 C5 C3 TP7 CP5 CP3), posterior left (P7 P5 P3 PO7 PO3), anterior right (AF8 AF4 F8 F6 F4), medial right (FT8 FC6 FC4 T8 C6 C4 TP8 CP6 CP4) and posterior right (P8 P6 P4 PO8 PO4). The central ANOVAs were conducted with the factor GRADIENT, corresponding to three regions: anterior central (FP1 FPz FP2 AFz F1 Fz F2), medial central (FC1 FCz FC2 C1 Cz C2 CP1 CPz CP2), and posterior central (P1 Pz P2 POz O1 Oz O2).

Results: We report below the results for the two analyses that yielded significant effects or trends involving the ANTECEDENT COMMAND STATUS variable (ANTEC.STATUS).

The lateral ANOVA for the 250-450 ms window showed a significant main effect for the variable HEMISPHERE ($F(1, 11)=11.93, p<.05, MSE=0.62$), a significant interaction GRADIENT \times HEMISPHERE ($F(2, 22)=4.91, p<.05, MSE=.339$), and a marginally significant main effect for the variable ANTEC.STATUS ($F(1, 11)=3.89, p<.1., MSE=.09$). Inspection of estimated marginal means for HEMISPHERE reveals a more pronounced negativity over the left hemisphere. Follow-up pairwise comparisons for the GRADIENT \times HEMISPHERE interaction show that this **lateralized negativity only holds for the medial and posterior regions**; the anterior region bears a negativity that spreads to the right hemisphere. The marginally significant main effect for ANTEC.STATUS suggests that *pronoun resolution with a non-commanding antecedent elicits a more pronounced overall negativity*, which conforms to the previously described spatial distribution pattern.

The central ANOVA for the 400-600 ms window showed a significant main effect for the variable ANTEC.STATUS ($F(1, 11)=11.93, p<.01., MSE=.062$). Inspection of the estimated marginal means for this variable reveals a more pronounced negativity when the pronoun is bound to a non-commanding antecedent. A significant polynomial quadratic trend occurs for the GRADIENT \times ANTEC.STATUS interaction ($F(1, 11)=12.80, p<.01., MSE=.043$). Pairwise comparisons for the GRADIENT \times ANTEC.STATUS interaction show a significant effect

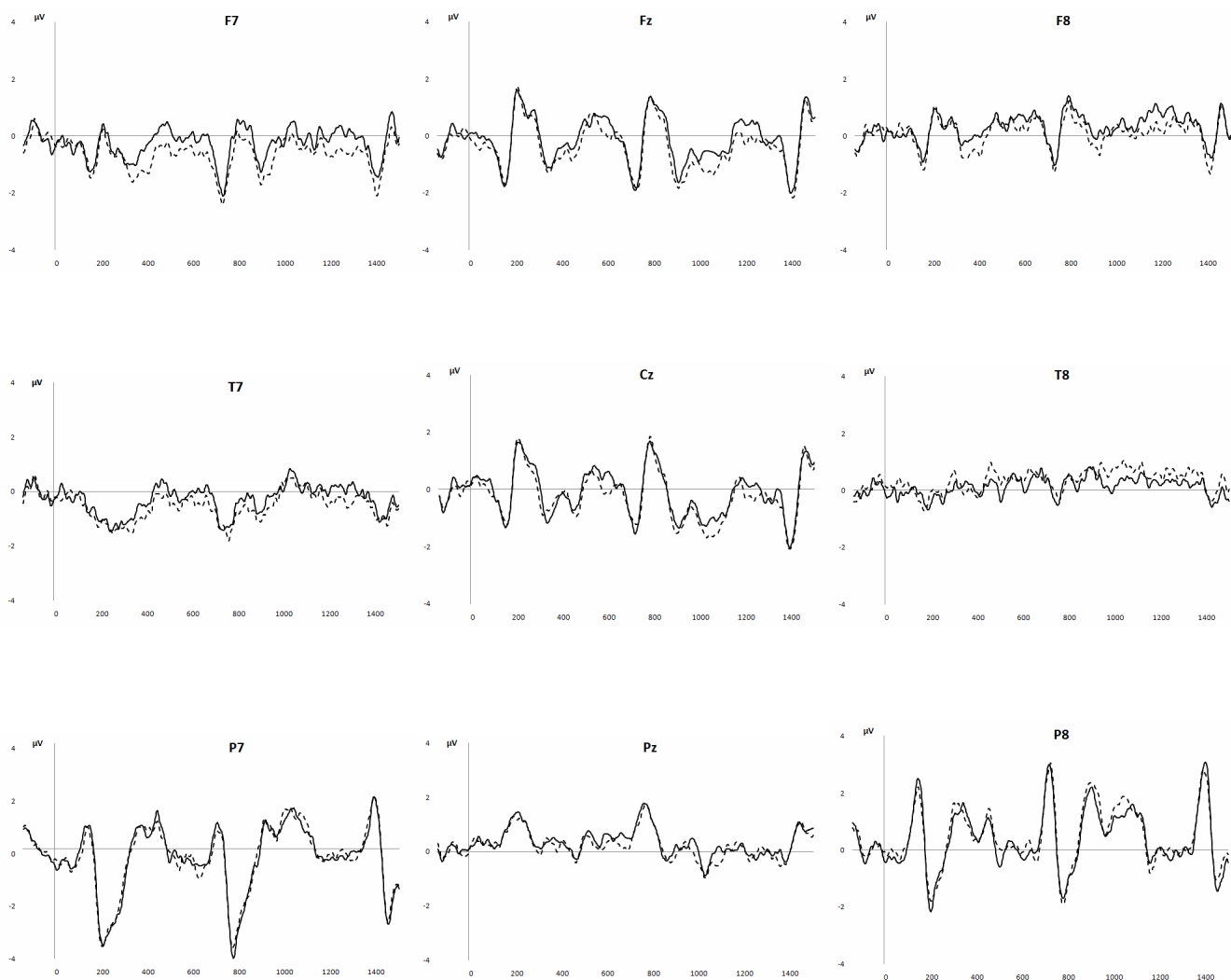


Figure 1 – Grand average ERPs (n=12) measured to the onset of the critical pronoun resolved with a commanding antecedent (dark line) and pronoun resolved with a non-commanding antecedent (light line). Waveforms are plotted from a 150 msec pre stimulus baseline to 1500 msec post stimulus. Pronouns resolved with a non-commanding antecedent elicit a fronto-lateral dominant negativity in the 250ms-450 window, as illustrated at F7 and F8, and a central negativity in the 400ms-600 window, as illustrated at Cz. Negative is plotted down.

for the ANTEC.STATUS variable only for the medial central region.

Concluding remarks

In line with Streb, Rösler and Hennighausen (1999), we interpret the medial relative negativity found in the 400-600 ms window as an N400-like effect, signaling the effects of the experimental manipulation upon the formation of the pronoun-antecedent dependency. This enhanced negativity for pronouns resolved to non-commanding antecedents suggests that, as hypothesized, resolving a pronoun to a repressor is a more resource demanding process than resolving it to a commander.

The marginally significant effect found in the 250-450 ms window indicates a wide-spread relative negativity elicited by pronouns resolved to recessors. This negativity occurs within an overall pattern of HEMISPHERE and GRADIENT effects, characterized by (i) irrespectively from lateralization effects, a similar gradient pattern over each hemisphere with anterior and medial regions more negative than the posterior region (ii) a left-lateralized negativity for the medial and posterior regions, (iii) a bi-hemispheric negativity for the anterior region. The spreading of the anterior negativity to the right hemisphere is mainly due to the contribution of the ANTEC.-RECESS condition. The relative negativity elicited by pronouns resolved to recessors is therefore indicative of a (short-

lived) Nref-like effect. Van Berkum et al. (2003, 2007) describe the Nref as a bilaterally and globally distributed negativity, frontally dominant, elicited by pronouns with two admissible antecedent candidates in contrast to pronouns with a single admissible antecedent candidate. They interpret this pattern as evidence of increased working memory load.

Along similar lines, we tentatively interpret this Nref-like effect found here as indicative of an increased memory load associated to blocked resolution to commanders (viz. by gender mismatch), in contrast to the case when it is the resolution to the repressor that is hampered. This may indicate that, in the first case, but not in the second, items of both types, that is, commanders and repressors, are held in working memory as antecedent candidates. A plausible explanation for this contrast in terms of processing activity may be put forward along the following lines: *Since the resolution to a repressor is more resource demanding (cf. the concomitant N400-like effect), the resolution system by default will not engage in the expensive processing of the repressor as an antecedent candidate if a commander is available as an admissible candidate.*

References

- ASHER; WADA. A computational account of syntactic, semantic and discourse principles for anaphora resolution. *Journal of Semantics*, v. 15, p. 83-113, 1988.
- BURKHARDT; PIÑANGO; RUIJGENDIJK; AVRUTIN. Reference assignments in dutch: Evidence for the syntax-discourse divide, (under review). 2009.
- CARBONELL; BROWN. Anaphora resolution: A multi-strategy approach. *Proceedings of COLING88*. p.96-101. 1988.
- GRODZINSKY; REINHART. The Innateness of Binding and Coreference. *Linguistic Inquiry*, v. 24, p. 60-101, 1993.
- HARRIS; WEXLER; HOLCOMB. An ERP Investigation of Binding and Coreference. *Brain and Language*, v. 75, p. 313-346, 2000.
- KOORNNEEF; WIJNEN; REULAND. Towards a modular approach to anaphor resolution. *Ambiguity in Anaphora Workshop Proceedings – ESSLLI2006*. 2006. p. 65-72.
- PIÑANGO; BURKHARDT. Pronominal interpretation and the syntax-discourse interface: Real-time comprehension and neurological properties. In: BRANCO; MCENERY; MITKOV. *Anaphora processing: Linguistic, cognitive and computational modelling*. 2002. p. 221-237.
- POLLARD; SAG. *Head-driven phrase structure grammar*. CSLI. 1994.
- REULAND. Primitives of binding. *Linguistic Inquiry*, v. 32, p. 439-492, 2001.
- RICH; LUPERFOY. An architecture for anaphora resolution. *Proceedings of ANLP88*. 1988. p. 18-24.
- STREB; HENNINGHAUSEN; RÖSLER. Different anaphoric expressions are investigated by event-related brain potentials. *Journal of Psycholinguistic Research*, v. 33, p. 175-201, 2004.
- STREB; RÖSLER; HENNIGHAUSEN. Event-related Responses to Pronoun and Proper Name Anaphors in Parallel and Nonparallel Discourse Structures. *Brain and Language*, v. 70, p. 273-286, 1999,
- VAN BERKUM; BROWN; HAGOORT; ZWITSERLOOD. 2003. Event-related brain potentials reflect discourse-referential ambiguity in spoken-language comprehension. *Psychophysiology*, v. 40, p. 235-248.
- VAN BERKUM; KOORNNEEF; OTTEN; NIEUWLAND. Establishing reference in language comprehension: An electrophysiological perspective. *Brain Research*, n. 1146, p. 158-171, 2007.

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