



Relation-sensitive retrieval: Evidence from bound variable pronouns



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ABSTRACT

Formal grammatical theories make extensive use of syntactic relations (e.g. c-command, Reinhart, 1983) in the description of constraints on antecedent-anaphor dependencies. Recent research has motivated a model of processing that exploits a cue-based retrieval mechanism in content-addressable memory (e.g. Lewis, Vasishth, & Van Dyke, 2006) in which item-to-item syntactic relations such as c-command are difficult to use as retrieval cues. As such, the c-command constraints of formal grammars are predicted to be poorly implemented by the retrieval mechanism. We tested whether memory access mechanisms are able to exploit relational information by investigating the processing of *bound variable pronouns*, a form of anaphoric dependency that imposes a c-command restriction on antecedent-pronoun relations. A quantificational NP (QP, e.g., *no janitor*) must c-command a pronoun in order to bind it. We contrasted the retrieval of QPs with the retrieval of referential NPs (e.g. *the janitor*), which can co-refer with a pronoun in the absence of c-command. In three off-line judgment studies and two eye-tracking studies, we show that referential NPs are easily accessed as antecedents, irrespective of whether they c-command the pronoun, but that quantificational NPs are accessed as antecedents only when they c-command the pronoun. These results are unexpected under theories that hold that retrieval exclusively uses a limited set of content features as retrieval cues. Our results suggest either that memory access mechanisms can make use of relational information as a guide for retrieval, or that the set of features that is used to encode syntactic relations in memory must be enriched.

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Introduction

Pronouns typically depend for their interpretation on antecedents in the previous linguistic and non-linguistic context. Accessing these antecedents in memory requires retrieval processes (Foraker & McElree, 2007; Gordon & Hendrick, 1998b; Sanford & Garrod, 2005). The relations

between pronouns and their antecedents are also subject to numerous constraints, which have been extensively studied in linguistics and psycholinguistics. Pronoun resolution, therefore, provides a valuable test case for investigating the interplay of linguistic constraints and memory access mechanisms in language: by examining how constraints on pronoun antecedents guide antecedent retrieval processes, we can gain insight into how linguistic memory is encoded and navigated. In this study we focus on the resolution of so-called *bound variable pronouns*, because their standard linguistic analysis involves a

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configurational constraint on antecedents that is not easily captured in otherwise well-motivated cue-based models of memory access.

Pronouns can have referential antecedents (1) or quantificational antecedents (2a,b).

(1) *The cyclist* was convinced that the spectators adored *him*.

(2a) *Every cyclist* thought that the spectators adored *him*.

(2b) *No cyclist* suspected that the spectators loathed *him*.

The choice of antecedent determines how the pronoun is interpreted. In (1) the pronoun *him* enters into a *co-reference* relation with its antecedent *the cyclist*; both expressions point to the same single individual in a discourse model (e.g., Büring, 2005). In (2a,b) the pronouns are said to be 'bound' by their respective antecedents *every cyclist* and *no cyclist*. These bound-variable pronouns do not refer to a single individual in the discourse model, but rather *co-vary in interpretation* with the quantified phrase (QP), which provides instructions on how to iterate through individuals in the discourse model.

Antecedent-pronoun relations are governed by two kinds of constraints: (i) morphological constraints, which enforce *feature-match* relations between the antecedent and the pronoun, and (ii) syntactic constraints, which determine an antecedent's eligibility based on its *relative structural position* to a pronoun. Morphological constraints apply to co-reference and binding relations alike; all pronouns must agree with their antecedents.

(3) {*The/No*} {*boy/*girl*} thought that the spectators adored *him*.

Certain syntactic constraints also apply uniformly to antecedent-pronoun relations, such as Principle B (Chomsky, 1981), which prohibits a pronoun from taking a prominent clause-mate antecedent.

(4) *{*The/No*} *boy* adored *him*.

Other syntactic constraints appear to target binding dependencies specifically. For example, the QP *no cyclist* cannot bind the pronoun *him* because it is embedded within a relative clause that does not contain the pronoun.

(5) The photographers [that **no cyclist* posed for] still had pictures of *him*.

Co-reference is not subject to the same restriction. A referential NP in the same position as the QP in (5) can readily serve as an antecedent for the pronoun.

(6) The photographers [that *the cyclist* posed for] still had pictures of *him*.

Thus, QP-pronoun binding relations are subject to a stringent positional constraint that does not influence NP-pronoun co-reference relations.

Many theorists have formalized this positional constraint in terms of c-command (Büring, 2005;

Reinhart, 1983; among many others).¹ An item *X* c-commands another item, *Y*, if *Y* is contained within *X*'s sister in the syntactic tree (or is *X*'s sister itself). For example, the quantificational phrases (QPs) in (2a,b) c-command the pronouns because they are contained within the verb phrase (VP) that is the QP's sister.

Relational constraints such as the c-command constraint on bound variable pronouns are particularly interesting for models of memory access in sentence processing because they pose a potential challenge for otherwise well-motivated models of retrieval. Popular cue-based models assume that retrieval makes use of intrinsic, item-specific features that are encoded during initial processing (e.g., Anderson, 1990; Gillund & Shiffrin, 1984; Lewis, Vasishth, & Van Dyke, 2006). These features can be drawn from an item's lexical entry (e.g., phrasal category, number, gender, and lexical semantics) or from its local syntactic context (e.g., grammatical role). It is straightforward to implement morphological feature-match constraints because a candidate antecedent's morphological features are item information (drawn directly from a noun's lexical entry). Accordingly, many studies report that a gender and/or number mismatch between an anaphor and a potential antecedent has immediate effects on early pronoun processing, consistent with the hypothesis that this information is used as a cue to guide retrieval (e.g., Badecker & Straub, 2002; Chow, Lewis, & Phillips, 2014; Ehrlich & Rayner, 1983; Garnham, Oakhill, Ehrlich, & Carreiras, 1995; Garrod & Terras, 2000; Gerrig, 1986; Nieuwland, 2014; Osterhout & Mobley, 1995).

C-command relations that encode the relative position of two distant items in a representation are difficult to encode as inherent features of individual items. First, a relation like *X* c-commands *Y* cannot be encoded through the use of a generalized \pm c-command feature that marks the c-commander *X* as structurally prominent. Such an encoding scheme would fail to represent the crucial item-to-item configuration between *X* and *Y*. Encoding the relation on item *X* would therefore require a feature that made direct reference to *Y* (perhaps through use of a pointer as in [c-commands: *Y*]). Although features of this kind would be relatively easy to encode if *X* and *Y* were adjacent to one another, they present an encoding challenge as the distance between *X* and *Y* grows. When an incremental parser first encodes an item *X*, any subsequent item *Y* does not exist in the local syntactic context because *Y* has not yet been encountered. Encoding that *X* c-commands *Y* would require look-ahead, or prediction of *Y*. This might be possible in a narrow range of linguistic dependencies that are highly predictable, but that is less feasible in the case of pronouns, which are not, in general, predictable. Alternatively, encoding c-command relations would require that as each new item is introduced into the structure, all prior items that c-command that item are retroactively updated, which would impose a

¹ For purposes of the current article we adopt the standard view that the relational constraint on bound variable pronouns involves c-command. Some work has questioned whether c-command is the appropriate relational constraint (e.g., Barker, 2012), but there is little dispute over the notion that some kind of relational constraint is needed.

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