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Similarity-based interference in sentence comprehension: Literature review and Bayesian meta-analysis

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ABSTRACT

We report a comprehensive review of the published reading studies on retrieval interference in reflexive-/reciprocal-antecedent and subject-verb dependencies. We also provide a quantitative random-effects meta-analysis of eyetracking and self-paced reading studies.

We show that the empirical evidence is only partly consistent with cue-based retrieval as implemented in the ACT-R-based model of sentence processing by Lewis and Vasishth (2005) (LV05) and that there are important differences between the reviewed dependency types. In non-agreement subject-verb dependencies, there is evidence for inhibitory interference in configurations where the correct dependent fully matches the retrieval cues. This is consistent with the LV05 cue-based retrieval account. By contrast, in subject-verb agreement as well as in reflexive-/reciprocal-antecedent dependencies, no evidence for inhibitory interference is found in configurations with a fully cue-matching subject/antecedent. In configurations with only a partially cue-matching subject or antecedent, the meta-analysis reveals facilitatory interference in subject-verb agreement and inhibitory interference in reflexives/reciprocals. The former is consistent with the LV05 account, but the latter is not. Moreover, the meta-analysis reveals that (i) interference type (proactive versus retroactive) leads to different effects in the reviewed dependency types and (ii) the prominence of the distractor strongly influences the interference effect.

In sum, the meta-analysis suggests that the LV05 needs important modifications to account for the unexplained interference patterns and the differences between the dependency types. More generally, the meta-analysis provides a quantitative empirical basis for comparing the predictions of competing accounts of retrieval processes in sentence comprehension.

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Introduction

Several researchers in sentence comprehension have argued that the formation of dependencies between non-adjacent words relies on a cue-based retrieval mechanism that leads to interference effects (McElree, 2000; Van Dyke & Lewis, 2003; Lewis, Vasishth, & Van Dyke, 2006; Van Dyke & McElree, 2011). For example, in a sentence like *The girl who the man saw laughed*, the dependency between the main clause subject (*girl*) and the main-clause verb (*laughed*) needs to be completed. In order to complete this dependency when reaching the verb, a memory retrieval is initiated for a noun that is the grammatical subject and has an animate referent. The assumption is that so-called retrieval cues, here *subject* and *animate*, allow the cognitive system to seek out the relevant item in memory by direct access. One appeal of this account is that it assumes the same memory access mechanism for language processing that governs recall in general information processing (Watkins & Watkins, 1975; Anderson & Lebiere, 1998; Anderson et al., 2004; McElree, 2006; Ratcliff, 1978; Van Dyke, 2002).

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In this paper, we review the empirical evidence presented in the sentence processing literature and synthesize the evidence quantitatively by means of a Bayesian meta-analysis. We then compare the evidence with the predictions of the computationally implemented cue-based retrieval model of Lewis and Vasishth (2005), henceforth LV05.

The LV05 model is based on the general cognitive architecture *Adaptive Control of Thought-Rational* (ACT-R, Anderson & Lebiere, 1998; Anderson et al., 2004).[1] The LV05 model provides quantitative predictions of retrieval speed and accuracy by using an incremental parser that relies on associative retrievals which are subject to activation decay and similarity-based interference. The model's quantitative predictions, derived using simulations, have been investigated by carrying out experiments covering a range of syntactic dependency types:

(i) Subject-verb dependencies
  (a) Subject-verb dependencies (other than agreement) in unimpaired populations (Lewis & Vasishth, 2005; Vasishth & Lewis, 2006; Nicenboim, Logačev, Gattei, & Vasishth, 2016) and in aphasic populations (Patil, Hanne, Burchert, Bleser, & Vasishth, 2016).
  (b) Subject-verb agreement dependencies (Dillon, Mishler, Sloggett, & Phillips, 2013; Wagers, Lau, & Phillips, 2009).
(ii) Antecedent-reflexive dependencies (Dillon et al., 2013; Jäger, Engelmann, & Vasishth, 2015; Parker & Phillips, 2014; Patil, Vasishth, & Lewis, 2016) and antecedent-reciprocal dependencies (Kush & Phillips, 2014; Kush, 2013);
(iii) Negative polarity items (Parker & Phillips, 2016; Vasishth, Bruessow, Lewis, & Drenhaus, 2008);
(iv) General dependency resolution difficulty in a large-scale model of parsing (Boston, Hale, Vasishth, & Kliegl, 2011)

In this paper, we will focus on the empirical evidence from the first three types of dependencies (ia, ib and ii) in unimpaired adult native speakers, because evidence from mainly these dependency types has been invoked to argue in favor of or against cue-based memory retrieval subserving sentence processing. The comparison between experiments on interference effects in reflexives and subject-verb agreement has even led researchers to argue that subject-verb number agreement and reflexive-antecedent dependency processing rely on qualitatively different memory access mechanisms (Dillon et al., 2013; Phillips, Wagers, & Lau, 2011). Moreover, the experimental designs used in experiments examining these three types of dependencies are very similar across studies. This makes it possible to quantitatively summarize this literature in a Bayesian meta-analysis.

Target-match and target-mismatch configurations

In this review, we focus on four key syntactic configurations that are often used to investigate effects of retrieval interference in sentence processing. These are shown in Example 1, and are taken from Sturt (2003). We will use this example to introduce key terminology that is used in the present paper; a summary of the terms appears in Table 1. In Example 1, the reflexive *himself* or *herself* must be connected with its antecedent, *surgeon*. Hence, when reading or hearing the reflexive, a retrieval process must be triggered to access the antecedent. We will refer to the noun that is the syntactically correct antecedent (*surgeon*) as the **target** of the retrieval process. The target must be a noun phrase inside the reflexive's binding domain that c-commands the reflexive (Chomsky, 1981). We will say that in this case a **retrieval cue**, *c-command*, is set by the reflexive *himself/herself* to seek out a noun that has the *+c-command* **feature** (here, *surgeon*).[2] In the examples below, the retrieval specification is shown as a set of cues in curly brackets behind the critical word (the reflexive) that triggers retrieval. The feature value associated with a word is represented by the name of the feature prefixed with either a − (absent) or a + (present). Note that only those features that are subject to the experimental manipulation are considered here. For the sake of simplicity, other cues such as *noun phrase* are not considered.

Table 1
Definitions of key terms used in the present paper in connection with cue-based retrieval as implemented in the ACT-R framework and adopted in the Lewis and Vasishth (2005) model.

Term	Definition
Feature	A property of an item in memory Example: The feature *+animate* in the noun *girl*
Retrieval cue	A property used to seek out an item in memory Example: the retrieval cue *animate* is used to seek out the subject of *laughed*
Target	The item that is the syntactically correct target for retrieval
Distractor	An item that is not the syntactically correct target for retrieval
Misretrieval	The retrieval of a distractor rather than the target
Match	A match occurs when a retrieval cue and a feature on an item have the same value
Mismatch	A mismatch occurs when a retrieval cue and a feature on an item do not have the same value
Cue overload	This occurs when a retrieval cue matches the features of two or more items
Fan	The number of items whose features match a retrieval cue
Fan effect	Reduction in activation of items in memory as a result of a fan $\geqslant 2$
Feature overlap	If any two items have an identical feature value, then we have a feature overlap between the two items
Interference	The consequence of a (partial) match of the distractor with the retrieval cues
Inhibitory effect	A slowdown in processing during retrieval
Facilitatory effect	A speedup in processing during retrieval

[1] The source code of the LV05 model is available from http://www.ling.uni-potsdam.de/~vasishth/code/LewisVasishthModel05.tar.gz.

[2] Note that in contrast to other syntactic (e.g., *case*) or semantic (e.g., *animacy*) features, *c-command* is a relational feature that one item can only have with respect to another item (i.e., no item can be a c-commander per se, but can only be in a c-commanding relation with another syntactic constituent). Thus, keeping track of the *c-command* features of the items in memory is computationally more complex than keeping track of static, i.e., non-relational, features (Kush, 2013). Although in this paper, we will not pursue the distinction between relational and static cues any further, we want to point out that this distinction is an important issue that should be addressed in future research.

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