Local Anaphor Licensing in an SOV Language: Implications for Retrieval Strategies
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In order to establish grammatical dependencies between words across distance during routine sentence processing comprehenders rely heavily on their ability to encode and retrieve items from memory. For example, processing of a local anaphor such as the reflexive themselves or reciprocal each other in (1) requires recalling the previously seen noun phrase (NP) the people from memory so that it may be interpreted as the antecedent.

(1) The people talked to themselves/each other.

The mechanism by which previously encountered items are retrieved for subsequent processing has been the subject of recent research (e.g., Lewis, Vasishth & Van Dyke 2006). Recent studies have motivated a processing model that exploits a cue-based access mechanism to retrieve items from content-addressable memory (e.g. McElree 2000; McElree, Foraker & Dyer 2003; Lewis, Vasishth & Van Dyke 2006; Van Dyke 2007; Martin & McElree 2008, 2009; Van Dyke and McElree 2011).

A hallmark property of cue-based retrieval is that it is susceptible to interference. Untargeted items in memory (distractors) whose features overlap with a probe's retrieval cues can exert influence on the retrieval of a target item. In the context of sentence processing retrieval interference is said to occur when grammatically inappropriate distractors influence the processing of a phrase that must enter into a dependency with a previously encountered head. The influence of distractors can be inhibitory: a distractor may increase the difficulty of retrieving an appropriate item. Inhibitory interference has been observed in the retrieval of a subject for the purposes of thematic integration with a verb. Ineligible NPs that bear subject features increase the difficulty of retrieving the appropriate subject of a verb (see, e.g., Van Dyke 2007). A distractor’s influence may also be facilitatory if its presence decreases the difficulty of processing an otherwise ungrammatical or unlicensed element.

Facilitatory interference effects have been observed across a number of different dependencies: subject-verb agreement (e.g., Pearlmutter et al., 1999; Wagers, Lau & Phillips, 2009; Xiang et al., 2008), negative polarity item (NPI) licensing (e.g., Drenhaus, Frisch & Saddy, 2005; Vasishth et al. 2008), and the retrieval of antecedents for null pronominal subjects (PRO) in adjunct clauses (Parker, Lago & Phillips 2012). Researchers working within cue-based models of retrieval explain facilitatory interference as an effect of misretrieval of the distractor due to (partial) match with a set of retrieval cues.

For example, Wagers and colleagues found that reading times immediately following the plural verb were, which mismatched the features of the singular subject key, were decreased when an intervening distractor (cabinet(s)) was plural, compared to when the distractor was singular.

(2) The key to the cabinet(s) unsurprisingly were rusty from years of disuse.

The authors argued that facilitation arose because comprehenders erroneously retrieved the plural distractor on some portion of trials when attempting to find a licensor for the plural marking on the verb. Retrieving this distractor led to an ‘illusion of
grammaticality’, which reduced indices of processing difficulty.

Although facilitatory interference has been repeatedly observed in the processing of some dependencies, other dependencies that recruit retrieval have displayed virtual immunity to facilitation from distractors. Recent work has found that the processing of a local anaphor that lacks a grammatical antecedent is unaffected by the morphological feature-content of intervening distractors (e.g. Sturt 2003; Dillon 2013). For example, Dillon et al. (2013) demonstrated that the processing of the unlicensed plural reflexive *themselves* in (3) is not influenced by plural-marking on the distractor *manager(s)*.

(3) The new executive who oversaw the manager(s) apparently doubted *themselves*…

The lack of facilitatory interference effects is unexpected on the assumption that the same cues as those used to find licensors for agreement dependencies (e.g. morphological features such as number) are used to identify potential antecedents of reflexives. Reflexives must match their antecedents in number and gender, so the use of morphological features as cue for retrieval of appropriate antecedents would appear to be motivated a priori. On analogy to agreement licensing, the use of these morphological cues should in turn render antecedent retrieval subject to interference.

Dillon et al. (2013) proposed that antecedent retrieval for local anaphors avoids facilitatory interference because it forgoes the use of interference-prone morphological features, opting instead to exclusively use *positional* syntactic features that provide diagnostic access to the local subject. Selective use of features in this manner would go against the general assumption that retrieval identifies targets through the use of a maximal cue set that uniformly weights lexical, morphological, syntactic, and semantic features in dependency licensing (see Van Dyke & McElree 2011 for discussion).

It is also possible that the absence of facilitatory interference can be attributed to a confound that masks the contribution of morphological features. The anaphor's proximity to its verb in previous studies could potentially play in reducing the incidence of facilitatory interference. In all previous studies the critical anaphor immediately followed its verb.

As Dillon et al. (2013) note, the post-verbal position can provide an anaphor privileged access to the local subject by means of recent activation alone. If subjects are retrieved by their verbs for thematic integration, the local subject *the executive* should be recalled by the verb *doubted*. Retrieval of the local subject entails that it should have the highest baseline activation out of all other items in memory immediately following the verb. At the time that a verb-adjacent reflexive is encountered, this high degree of activation may be strong enough to guarantee retrieval of the local subject instead of the feature-matching distractor even if morphological cues were used.

It may be that previous studies do not provide a measure of antecedent retrieval’s susceptibility to facilitatory interference because establishing a dependency between the local subject and an immediately post-verbal anaphor might not require retrieval at all. Many theories assume that the most recently retrieved item is maintained in a state that
the parser can access without retrieval. In some theories this state is referred to as the *focus of attention* (e.g. McElree 2000), in others such as Lewis and Vasishth’s (2005) parsing model it is the *problem buffer*. When an anaphor is encountered immediately following the verb, it is possible that it consults the contents of this buffer to find its antecedent rather than initiating a retrieval from memory.

In this study we address the extent to which the lack of facilitatory interference in anaphoric licensing is predicated on an anaphor’s post-verbal position. If the absence of interference is predicated on the target anaphor occupying an immediately post-verbal position, we would predict that local anaphoric licensing in languages where anaphors uniformly precede their verbs should display facilitatory effects absent in English. We tested prediction by investigating the processing of Hindi reciprocals. Hindi is a language in which all arguments and adjuncts precede the verb in unmarked word order. In (3), for example, the subject *LaRkoN* (‘boys’), reciprocal object *ek-dusre* (‘each other’), and the adjunct *kal* (‘tomorrow’) precede the verb *dekhaa* (‘saw’).

(3)  *LaRkoN-ne ek-dusre-ko kal dekhaa.*
    Boys-Erg each.other-Acc yesterday saw.
    ‘(The) boys saw each other yesterday.’

Hindi reciprocals provide a minimal contrast to English reflexives because they are subject to nearly identical licensing conditions as English local anaphors. Their antecedent must have matching morphological features as seen in (4). In order to license the reciprocal in (4), the local subject must bear plural features. The reciprocal’s antecedent must be contained in the same local clause as the reciprocal (5). The main subject in (5) cannot anteced the reciprocal in the embedded clause, despite bearing the correct number marking, because it is not local to that reciprocal. Finally, the reciprocal’s antecedent must also c-command the reciprocal (cf. Dayal 1994). In (6), the plural NP *boys* does not c-command the reciprocal because it is embedded inside the adjunct phrase *at the boys’ party*. It is therefore ineligible to license the anaphor.

(4)  *LaRk-{*-e/oN}-ne ek-dusre-ko kal dekhaa.*
    Boy-{Sing./Pl.}-Erg each.other-Acc yesterday saw.
    ‘(The) boy*(s) saw each other yesterday.’

(5)  *LaRkoN-ne kahaa ki Mary-ne ek-dusre-ko dekhaa.*
    Boys-Erg said that Mary-Erg each.other-Acc saw.
    *(The) boys said that Mary saw each other.*

(6)  *Mary-ne [larkoN-ki parTi me] ek-dusre-ko dekhaa.*
    Mary-Erg boys’ party in one.another-Acc saw
    *Mary saw each other at the boys’ party.*

In Experiments 1 and 2 we test whether morphological number features engender facilitatory interference effects during the processing of Hindi reciprocals.
Experiment 1

In order to obtain an estimate of the amount of facilitation predicted to occur if retrieval used morphological features to identify antecedents of a pre-verbal reciprocal in Hindi, we ran a series of computational simulations that local anaphor antecedent retrieval in Hindi. Modeling interference effects provided qualitative predictions about the character and direction of interference from the distractor’s morphological features that could then be compared with empirical reading times in Experiment 2.

Procedure

Experiment 1 implemented a modified version of Lewis & Vasishth’s (2005) ACT-R model of sentence processing. ACT-R is a general cognitive architecture that has been used to model a wide range of phenomena and behavior in cognitive psychology (Anderson 1990). In the model, items are stored as ‘chunks’ in a content-addressable memory and are retrieved with a success proportional to their overall activation at the time of retrieval, which is in turn determined by the overlap of their features with those of a retrieval probe. Memory access is modeled as a rational procedure that employs a general retrieval strategy that minimizes retrieval error in the limit (Anderson 1989; Anderson & Milson 1989; Anderson & Schooler 1991). Although fully implemented ACT-R parsing models exist (e.g. Lewis & Vasishth’s 2005 ACT-R parser), the simulations here focus solely on modeling retrieval latencies, abstracting away from the contributions of other modules. Because the model assumes a proportional, monotonic relation between retrieval latencies and behavioral measures of processing time (Anderson & Milson 1989), the qualitative profile of retrieval latencies predicted by the model is expected to be carried forward to reaction time measures.

In the model the probability of retrieving an item $i$ is governed by its activation $A_i$, computed as in (7). $B_i$ is chunk $i$’s baseline activation. $S_{ji}$ is the strength of association between cue $j$ and chunk $i$. PM in the equation below is a term that penalizes partial matches. The term $\varepsilon$ introduces stochastic noise.

\[
A_i = B_i \Sigma w_j S_{ji} + \text{PM} + \varepsilon
\]

(7) $S_{ji}$ is calculated according to the equation in (8), where $S$ is a parameter that specifies the maximum strength of association allowed. The $\text{fan}_j$ term reflects the number of items that bear cue $j$. The term provides a way of quantifying the distinctiveness of a particular cue. The fan serves to decrease the associative strength between item $i$ and cue $j$ as a function of the number of total cues in memory that bear $j$.

\[
S_{ji} = S - \ln(\text{fan}_j)
\]

(8) Baseline activation is calculated according to (9), where $d$ is the decay rate of a chunk’s activation in memory at a given point since retrieval time $t_m$.

\[
B_i = \ln[\Sigma_m t_m^{-d}]
\]

(9) The chunk with the highest activation will have the shortest retrieval latency ($T_i$), or time
to retrieve, as calculated according to the equation below, where $F$ is a scaling parameter. The chunk with the shortest retrieval latency is the chunk that is retrieved in simulations.

$$T_i = F e^{-AI}$$

The model equations above contain a number of free parameters whose settings could impact the results of the simulation. We ran a series of simulations that systematically combined parameter values from across the range of those reported in previous work. This resulted in the construction of 324 different models with unique parameter value combinations. As noted by Dillon et al. (2013), conducting such a sweep through the space of possible parameter values and combinations enables the identification of model predictions that are independent of idiosyncratic parameter combinations. 1000 Monte Carlo simulations were run for each model, which provided a prediction of the most probable retrieval target per simulation and its retrieval latency.

**Materials**

Experiment 1 simulated antecedent retrieval time-locked to a position corresponding to the critical reciprocal in a sentence that contained three preceding NPs. The first NP, the subject, corresponded to a structurally appropriate antecedent for the reciprocal. The second NP, introduced at a lag after the subject NP, corresponded to a structurally inappropriate distractor. A third NP (NP3) was also introduced to more directly model Experiment 2's materials, the design of which are discussed at length later.

Each NP in the simulation was marked with three features relevant for retrieval: its category, number, and clause index. All NPs bore the NP category feature. Number features could be either singular or plural. The clause index feature was used as a proxy feature for encoding an NP's structural appropriateness for the purposes of binding the reciprocal.

Models were run to simulate four distinct conditions that corresponded to different feature combinations on the subject and distractor. The number features on the subject and the distractor were manipulated, resulting in a $2 \times 2$ factorial design schematized in (11). In **Grammatical** conditions the subject was plural-marked, in **Ungrammatical** conditions the subject was singular. In **NoInterference** conditions the distractor was singular, while in **Interference** conditions it was plural-marked. The structurally appropriate subject NP was marked with the main clause feature, while both the distractor and NP3 were marked as embedded and were therefore ineligible to antecede the reciprocal.

$$\begin{align*}
   \text{a. Grammatical-NoInterference} & \quad [\text{Subject}]^{+PL} \ldots [\text{Distractor}]^{+SG} \ldots [\text{NP3}]^{+SG} \ldots \\
   \text{b. Grammatical-Interference} & \quad [\text{Subject}]^{+PL} \ldots [\text{Distractor}]^{+PL} \ldots [\text{NP3}]^{+SG} \ldots \\
   \text{c. Ungrammatical-NoInterference} & \quad [\text{Subject}]^{+SG} \ldots [\text{Distractor}]^{+SG} \ldots [\text{NP3}]^{+SG} \ldots \\
   \text{d. Ungrammatical-Interference} & \quad [\text{Subject}]^{+SG} \ldots [\text{Distractor}]^{+PL} \ldots [\text{NP3}]^{+SG} \ldots 
\end{align*}$$
Antecedent retrieval at the reciprocal was modeled as specifying NP as a category cue and main clause as the clause cue. The number feature plural was also used in the retrieval cue set, to measure the interference effect associated with morphological features.

Results

We report three measures of interest from the simulations run for each condition: (i) predicted error rate, (ii) average predicted latency by condition, and (iii) predicted interference effect.

Predicted error rate reports the percentage of the model runs when the distractor, rather than the appropriate subject, was retrieved as an antecedent for the reciprocal. This measure is a relevant index of facilitatory interference if facilitation stems from erroneous retrieval of the distractor instead of an appropriate target NP.

Predicted latency provides a measure of how long on average the winning retrieval would take in each condition. In simulations, the chunk with the shortest retrieval latency is the chunk that is retrieved from memory. According to the fully implemented ACT-R model, reading times on a particular word or phrase are the sum of the latency of retrieval triggered at that phrase and the amount of time associated with subsequent processing required by that word or phrase. Retrieval latencies should therefore map monotonically to reading times, with longer retrieval latencies corresponding to longer overall reading times, although the mental processes that intervene between retrieval and button-press may interact or contribute additional difficulty in such a way as to distort the underlying pattern of retrieval. Despite the possibility of later processing concealing underlying retrieval patterns, previous work has found a degree of relative transparency between the qualitative pattern of retrieval latencies furnished by the model and observed effects of facilitatory interference in self-paced reading or eye-tracking measures (see, e.g., Wagers, 2009; Dillon et al., 2013). It is important to note that these values are not intended to reflect direct numerical predictions of reading times, but instead they serve as a qualitative guide to a pattern of difficulty that should manifest in overall reading times.

The interference effect is a difference measure that compares average retrieval latencies between two conditions that differ on a single feature as a way of estimating the magnitude and direction of interference contributed by the retrieval probe matching that one feature. We report two interference effects: the difference between Grammatical conditions, as well as the difference between Ungrammatical conditions. These comparisons provide a quantitative prediction of the effect of plural marking on the distractor when the features of the appropriate subject are held constant.

Predicted Error Rates

Model error rates are reported in Table 1. The error rates are consistent with the profile of
facilitatory interference. Between the *Ungrammatical* conditions, plural marking on the distractor is predicted to increase rates of erroneous retrieval compared to when there is no NP in the sentence that matches the reciprocal in features (29.6% v. 15.3%). On some proportion of trials, the recency of the distractor is predicted to increase the NP’s baseline level of activation enough to result in its being the most highly-activated NP at retrieval. In the *Ungrammatical-NoInterference* condition, the distractor does not share any features with the reciprocal’s cue set, so the main subject is still more likely to be retrieved, as it matches the retrieval probe’s clause index cue. The model predicts a negligible difference in error rate between the *Grammatical* conditions, where the main subject matches the retrieval cues completely.

<table>
<thead>
<tr>
<th>Model</th>
<th>Ungrammatical-NoAttraction</th>
<th>Ungrammatical-Attraction</th>
<th>Grammatical-NoAttraction</th>
<th>Grammatical-Attraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological Model</td>
<td>15.3%</td>
<td>29.6%</td>
<td>10.5%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

Table 1. Retrieval error rates for retrieval using morphological and syntactic cues by condition calculated as the percentage of trials on which the distractor was retrieved.

*Average Predicted Retrieval Latencies*

![Predicted Retrieval Latencies](image)

Figure 1. Retrieval latencies by condition as predicted by the model in Experiment 1.

The model predicts an overall effect of the presence of a feature-matching subject.
Overall, retrieval times should be faster in the *Grammatical* conditions because the grammatical subject, which matches the reciprocal's morphological and syntactic retrieval cues completely, is predicted to be retrieved. Increased activation due to greater feature-match with the probe results in faster retrieval latencies in accordance with Equation (10). In the *Ungrammatical* conditions, where the main subject matches only on syntactic cues, retrieval latencies should be longer because the retrieved chunk should never match the probe completely. The appropriate subject only matches the probe’s category and positional cues, whereas the distractor only matches the category and number features. The model further predicts a pairwise effect between the average latency of *Ungrammatical-NoInterference* and *Ungrammatical-Interference* conditions, which can be linked to the presence of morphological plural marking on the distractor. On the proportion of trials where the distractor is retrieved in the *Ungrammatical-Interference* condition, latencies are reduced relative to when the matrix subject is retrieved. This results in a reduction of average latency across retrievals.

### Interference Effects

<table>
<thead>
<tr>
<th>Condition</th>
<th>Interference Effect</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grammatical</td>
<td>+35ms</td>
<td>+8, +84ms</td>
</tr>
<tr>
<td>Ungrammatical</td>
<td>-63ms</td>
<td>-15, -148ms</td>
</tr>
</tbody>
</table>

Table 2. Interference effects predicted by the model in Experiment 1. 95% confidence intervals correspond to the range of average interference effects observed across 1000 runs each of 324 different models with unique parameter combinations.

Predicted interference effects are shown in Table 2. The *Grammatical* interference effect was calculated by subtracting the average predicted latency in the *Grammatical-Interference* condition from the *Grammatical-NoInterference* condition. The same difference was calculated between *Ungrammatical* conditions. 95% confidence intervals represent the range of predicted interference effects across simulations.

The model predicts that a plural-marked distractor should cause facilitatory interference in *Ungrammatical* conditions. The *Ungrammatical-Interference* condition exhibits faster average retrieval latencies than the *Ungrammatical-NoInterference* condition. Though the size of the effect varies across parameter combinations, all models consistently predict a facilitatory effect.

The model also predicts a small effect of inhibitory interference in *Grammatical* conditions. This inhibition can be attributed to the fan effect (see equation 8). In the *Grammatical-Interference* condition, the strength of association between the appropriate subject and the plural retrieval cue is decreased relative to the *Grammatical-
**NoInterference** condition due to the presence of another plural-marked NP (the distractor).

**Experiment 2**

The modeling results from Experiment 1 predict that retrieval of a pre-verbal reciprocal's antecedent should display facilitatory interference effects from structurally inappropriate distractors if morphological features such as number are used as retrieval cues. Experiment 2 investigated whether evidence of the predicted facilitatory interference would be found using the self-paced reading method.

**Materials**

The experiment had a 2×2 factorial design that corresponded to the abstract template for conditions in Experiment 1. The design manipulated the factors **GRAMMATICALITY** and **INTERFERENCE**. The structure of test items is schematized in (12) and an example item is given in (13). All conditions contained a critical reciprocal (*ek-dusre*) that required a plural-marked antecedent in the main clause. The reciprocal was contained in a post-positional phrase that preceded a manner adverbial (*gupt-rup-se, 'secretly'*) and the main clause verb (*baat kii, 'chatted' lit. ‘chat did’*).

**GRAMMATICALITY** controlled whether the main clause subject (*Doctor(-oN), ‘doctor(s)’*) matched the critical reciprocal in number features. Plural marking was unambiguously marked by the inflectional suffix –*oN*. In **Grammatical** conditions, the local subject was plural and could therefore act as a grammatical antecedent for the reciprocal. In **Ungrammatical** conditions, the local subject was singular and the reciprocal therefore lacked a clause-mate antecedent. **INTERFERENCE** controlled whether the distractor (*mariiz(-oN), ‘patient(s)’*) was plural-marked.

In previous studies on local anaphor licensing (e.g. Sturt 2003, Dillon et al. 2013) distractors have been positioned within RCs attached to the main clause subject. The present study embedded the distractor inside a locative phrase that preceded a manner adverbial because RC-modification of subjects is a marked construction in Hindi.

The locative phrase contained an NP denoting a location modified by an animate possessor (*nurse-ke steSan, ‘the nurse's station’*). The distractor was embedded as the object of a verb within a prenominal RC that was attached to this possessor. In this position the distractor was not a clause-mate of the reciprocal and was therefore ineligible to act as a potential antecedent.

(12) Subject- {sg/pl} [PP[RC Distractor- {sg/pl} V ] NP's Location] Reciprocal P Adv V

(13) a. **Grammatical-NoInterference**

DoctoroN-ne mariiz-ki dekhbaal karne-wali nars-ke sTeSan-me ek-dusre ke-bare-me gupt-rup-se baat kii.

Doctors-Erg patient-Gen care doing-RP nurse’s station-in each-other about secretly chat did.

‘The doctors secretly spoke about each other in the station of the nurse taking care of (a/the) patient.’
b. Grammatical-Interference

Doctors-Erg patients-Gen care doing-RP nurse’s station-in each-other about secretly chat did.

‘The doctors secretly spoke about each other in the station of the nurse taking care of (the) patients.’

c. Ungrammatical-NoInterference

Doctors-Erg patient-ki care doing-RP nurse’s station-in each-other about secretly chat did.

‘The doctor secretly spoke about each other in the station of the nurse taking care of (a/the) patient.’

d. Ungrammatical-Interference

Doctors-Erg patients-Gen care doing-RP nurse’s station-in each-other about secretly chat did.

‘The doctor secretly spoke about each other in the station of the nurse taking care of (the) patients.’

Inside the pre-nominal RC the distractor bore either accusative or genitive case (dependent on the verb's requirements). Although this increases the distinctiveness between the nominative grammatical subject and the distractor, it is unlikely that the Case difference could play a role in distinguishing appropriate from inappropriate NPs. Accusative and genitive-marked NPs can serve as antecedents for local anaphors under the right structural conditions (see, e.g., Dayal 1994, Bhatt and Dayal 2007).

A second concern with the experimental materials is that there exists a potential for temporary misanalysis of the structural position of the distractor during incremental parsing. Upon initially encountering the distractor, the parser has not encountered any information to indicate that the distractor is contained within an embedded clause. In the absence of this information an incremental parser is likely to analyze the distractor as the a constituent of the main clause. This type of temporary misparse is common in head-final languages where embedded arguments can be encountered prior to the verb that licenses them (e.g. Masuka & Itoh, 1995; Miyamoto, 2003). The misanalysis would be disconfirmed at the relative pronoun wali, at which point the object would be correctly reanalyzed as a constituent of the relative clause. This misparse should occur across all conditions, but it may have a greater impact on processing in the Ungrammatical-Interference condition. Under this misanalysis the RC-internal object would initially be analyzed as a suitable antecedent for an upcoming. We return to the misparse’s ability to affect later parsing decisions in the Ungrammatical-Interference condition in the discussion.

Participants

32 self-reported native speakers of Hindi were recruited from the student bodies of IIT, Delhi and Jawaharlal Nehru University in New Delhi (18 male, mean age = 20.1). Participants were compensated Rs. 300 for their participation.

Procedure

Participants were run on one of two laptop PCs using the Linger software package (Doug Rohde, MIT) in a self-paced word-by-word moving window paradigm (Just, Carpenter, & Woolley, 1982). Each trial began with a sentence masked by dashes appearing on the screen. Letters and punctuation marks were masked, but spaces were left unmasked so that word-boundaries were visible. As the participant pressed the spacebar, a new word appeared and the previous word was re-masked. All text appeared in Devanagari font.

A comprehension question followed each sentence. Participants were instructed to read
sentences at a natural pace and to respond to the comprehension questions as accurately as possible. Participants responded to questions using the f-key for ‘yes’ and the j-key for ‘no’. If the question was answered incorrectly the word galat (‘incorrect/wrong’) appeared briefly in the center of the screen. Each participant was randomly assigned to one of the lists and the order of the stimuli within the presentation list was randomized for each participant.

Analysis
Data from 5 participants whose mean comprehension question accuracy fell below 60% were excluded from further analysis and data from one participant were excluded due to failure to comply with experimental guidelines. This resulted in the data of 26 subjects being used for later analysis. In the remaining data, RTs that fell outside a 100ms – 3000ms range were excluded, resulting in an average of 1.8% data loss across conditions.

Statistical analyses were carried out using linear mixed effects regression (Baayen, Davidson & Bates 2008). Experimental fixed effects were the simple difference sum-coded factors GRAMMATICALITY and INTERFERENCE and their interaction. The model included random intercepts for both Subject and Item. Reported coefficients reflect the magnitude of the difference between levels of a given factor in milliseconds. P-values were estimated by MCMC sampling using the LanguageR() package (Baayen 2008).

Analysis of effects in the immediate post-reciprocal critical region was performed in two ways. First, the complex post-position that followed the reciprocal (e.g. ke bare me in 8) was decomposed into 2 distinct regions: the genitive morpheme ke, found in all complex post-positions, and the content word(s) associated with the post-position. This division reflects the order of presentation in the experiment - the words were presented as distinct units. Analysis was also performed pooling the two words as a single region to reflect the intuition that these words are often thought of as a single unit (a complex post-position). These results are reported as the ‘pooled post-reciprocal region’.

Results

Comprehension Question Accuracy
Comprehension question accuracy averaged 71.4%. No significant differences were found in average accuracy across conditions (logistic mixed effects model, all zs < 1).

Reading Time Results
Figure 2. Full sentence self-paced reading times for Experiment 2.
Post-reciprocal reading times under two different regioning schema. (a) Reading times on the post-reciprocal particle. (b) Average by-word reading time pooling all regions associated with the post-position. Error bars indicate standard error.

Reading times from the post-reciprocal region under un-pooled and pooled analysis procedures are given in Figure 2.

**Pre-reciprocal region.** No significant effects were found in the pre-reciprocal region (all ts < 1).

**Reciprocal region.** No significant effects were found immediately in the reciprocal region.

**Post-reciprocal genitive region.** A reliable main effect of GRAMMATICALITY was observed in the region immediately following the critical reciprocal (b = -46.01, s.e. = 20.79, t = 2.2, p < .05). This effect reflected faster RTs on average in the Grammatical conditions, relative to the Ungrammatical conditions. Despite the fact that there was a numerical difference between the two Grammatical conditions, with the faster RTs being observed in the Grammatical-Interference condition, the pairwise difference between the two conditions did not achieve significance (t < 1). No significant pairwise differences were observed between Ungrammatical conditions (t < 1).

**Reciprocal+2 region.** There were no significant main effects two regions after the critical reciprocal, but a the model revealed a marginally significant GRAMMATICALITY $\times$ INTERFERENCE interaction (b = 52.55, s.e. = 31.29, t = 1.68, p < .10). This interaction was due to the fact that the Ungrammatical-Interference was read more slowly than any other condition, including the Ungrammatical-NoInterference condition. The pairwise comparison between the two Ungrammatical conditions revealed the numerical difference between the two conditions to be marginally significant (t = 1.86, p < .10). These effects may reflect increased difficulty in the Ungrammatical-Interference condition, a numerical effect towards which there was a trend in the previous region.

**Reciprocal+3-5 region.** No significant effects were observed (all ts < 1).

**Final verb region.** A main effect of GRAMMATICALITY was observed in the sentence-final verb region (b = -77.51, s.e. = 43.48, t = -1.78, p < .10), with Grammatical sentences being read more quickly than Ungrammatical sentences. No other effects achieved significance.

**Pooled Post-Reciprocal Region.** When the two regions immediately following the critical reciprocal were pooled, the effect of GRAMMATICALITY remained reliable (b = -33.35, s.e. = 12.72, t = -2.62, p < .05). Grammatical conditions were read significantly more quickly
than *Ungrammatical* conditions on average. The statistically reliable `GRAMMATICALITY × INTERFERENCE` interaction observed in the reciprocal+2 region achieves marginal significant in the pooled analysis (b = 46.37, s.e. = 25.45, t =1.82, p < .10). RTs in the *Ungrammatical-Interference* condition are marginally slower than in the *Ungrammatical-NoInterference* condition (b = -30.16, s.e. = 18.29, t = -1.65).

**Discussion**

Experiment 2 sought to determine whether the processing of a pre-verbal reciprocal in Hindi was subject to facilitatory interference. The study manipulated the number features on a structurally appropriate antecedent for the reciprocal, as well as the features of the structurally inappropriate distractor, as a means of testing whether morphological cues are used to access a local anaphor's antecedent.

When a structurally appropriate feature-matching antecedent was present to license the pre-verbal reciprocal regions following the critical reciprocal were read more rapidly than when there was no feature-matching appropriate antecedent. The presence of a feature-matching distractor did not impact processing in the region immediately following the reciprocal, regardless of whether the structurally appropriate subject could license the reciprocal. Two words downstream from the reciprocal, reading times were longest when the local subject did not match the features of the reciprocal but the features of the distractor did match the reciprocal's number features. This effect was marginally significant when the region was analyzed alone as well as when it was pooled with the preceding region.

To first address the primary aim of the study, the profile of reading times immediately following the reciprocal suggests an absence of facilitatory interference. The presence of a feature-matching distractor did not ease processing of an unlicensed reciprocal. The post-reciprocal region in the *Ungrammatical-Interference* condition was read at a comparable or slightly slower rate than the processing of the reciprocal in the *Ungrammatical-NoInterference* condition. These findings stand in stark contrast to the predictions of the model simulations in Experiment 1. As seen in Figure 4, the model predicted that the presence of a feature-matching distractor would result in facilitated processing in *Ungrammatical* conditions, as well as a slight increase in processing difficulty in *Grammatical* conditions. The empirical effects trend in the opposite direction from the model's predictions. The presence of a distractor resulted in a slight facilitation within the *Grammatical* comparison, while there was a marginally significant effect of inhibition between the *Ungrammatical* conditions. Although there does appear to be an effect of the distractor's number features in the *Ungrammatical* comparison, it is crucially not an effect of facilitatory interference.
The increase in post-reciprocal reading times in the Ungrammatical-Interference condition was not predicted by the model. Although they were not predicted, these effects do potentially indicate that the distractor’s morphological features may effect overall processing of the reciprocal. We consider two possible explanations of this inhibitory effect and the role that number features play in guiding initial retrieval under each scenario.

The first possible interpretation of the inhibitory effect links the slightly delayed slowdown to erroneous retrieval of the distractor during initial memory access. Previous work on online anaphor licensing has found slowdowns that have been argued to relate to the presence of a structurally illicit distractor on otherwise unlicensed pronouns (Kazanina & Phillips 2010). The authors took a post-anaphoric slowdown to indicate temporary consideration and subsequent inhibition of an unlicensed distractor. Under this interpretation the increased reading times in Experiment 2 would reflect initial misretrieval of the distractor based on its morphological overlap with the probe, followed by the increased processing cost of inhibiting that distractor. We consider this interpretation unlikely for the present data because we see no evidence of the erroneous retrieval on which the explanation is predicated. On analogy to subject-verb agreement and NPI licensing effects, we would expect initial misretrieval to result in some degree of facilitation, however fleeting, that would be observable in the self-paced reading times. No such facilitation is observed prior to the inhibitory interference is observed.
An alternative interpretation of the effect connects the slowdown to repair strategies that are triggered by failure of initial antecedent retrieval (as proposed for similar effects by, e.g., Sturt 2003; Chow, Lewis & Phillips 2012). On this interpretation failure to retrieve an appropriate antecedent for the reciprocal would initiate a more liberal search for a feature-matching phrase, or would attempt to find an alternative parse for the sentence under which the reciprocal could be grammatically bound. These repair procedures are argued to be less constrained by the structure of the previous parse (and therefore structural constraints), perhaps reflecting uncertainty in the structural analysis in light of the error signal.

A repair strategy that sought an alternative parse that permitted the reciprocal to be licensed might be susceptible to interference from the abandoned early garden-path parse that analyzed the distractor as a constituent of the main clause. The previous partial parse would provide an appropriately marked antecedent for the reciprocal, but would fail to provide a coherent global parse. There are no grammatical re-parse of the sentence that would allow the distractor to be reanalyzed as an appropriate antecedent for the reciprocal. We hypothesize that resolving the tension between attempting to license the reciprocal and building a globally grammatical parse of the sentence is the source of the observed interaction. The misparse is expected to intrude on the processing of the reciprocal in the 

In sum, Experiment 2 failed to find the characteristic profile of facilitatory interference that has been found in other studies on the construction of subject-verb agreement and NPI-licensing dependencies and is predicted under a cue-based retrieval model that uses morphological cues to access potential antecedents for a local anaphor. Instead, a slightly delayed inhibitory effect accompanied a feature-matching distractor when the local subject could not antecede the reciprocal in Hindi. We argued that this process was not an indication of interference during antecedent retrieval, but rather interference during a repair process subsequent to antecedent retrieval.

General Discussion

The purpose of the foregoing experiments was to assess whether morphological cues are used in the retrieval of antecedents of pre-verbal reciprocals in Hindi. Investigating the processing of Hindi reciprocals helps to establish whether antecedent retrieval for local anaphors avoids using morphological cues as a general rule, or whether the absence of facilitatory interference effects from morphologically-matched distractors in previous
experiments was due to a confound of anaphor position. We hypothesized that if the absence of interference were solely due to the post-verbal position of the anaphor, interference would be observable in local anaphor antecedent retrieval in an SOV language such as Hindi, in which anaphors typically precede their verb.

In Experiment 2, a self-paced reading study, native Hindi speaking participants exhibited faster reading times when resolving a local reciprocal dependency when a plural-marked NP occupied a structurally appropriate position than when no grammatical antecedent was present. The presence of a feature-matching distractor did not induce reliable effects of facilitatory interference when the local subject did not match the reciprocal in features. These findings are consistent with a general lack of facilitation in the licensing of local anaphors found in previous work (e.g. Sturt 2003; Xiang et al. 2009; Dillon et al. 2013), and with lack of interference during local anaphor licensing more generally (e.g. Nicol & Swinney 1989; Clackson 2011). The presence of a feature-matching distractor produced a delayed inhibitory effect when an appropriate antecedent for the reciprocal could not be found. We reasoned that this effect arose as a result of post-hoc error-driven repair strategies, and not from participants' initially accessing the distractor during initial antecedent retrieval.

The empirical results of Experiment 2 were compared against the model predictions from Experiment 1. Both the model’s predictions of facilitatory interference between Ungrammatical conditions and the prediction of a slight inhibitory effect in Grammatical conditions were not borne out.

Overall, the results lend support to the hypothesis that the lack of facilitatory interference in local anaphor antecedent retrieval is not primarily determined by an anaphor's post-verbal position. In particular, the Hindi results seem incompatible with a number of the possible ways in which verbal adjacency could influence retrieval of antecedents for local anaphors discussed at the outset. The results cast doubt on explanations that rely on the grammatical antecedent to have been recently reactivated immediately preceding the reciprocal. In the Hindi materials there is no point at which retrieval of the subject is required between the distractor and when the reciprocal is encountered.

The results comport with a variety of retrieval strategies couched within a cue-based model of memory access. First, the present results are consistent with a retrieval strategy that invariantly uses structural information to the exclusion of interference-prone morphological cues (as argued by Dillon et al. 2013). The results are also consistent with conditional use of morphological cues, as suggested by Kush (2013), so long as linear order is not the sole conditioner. Kush proposed that retrieval relies exclusively on structural cues only when such cues would provide diagnostic access to the appropriate antecedent. In both previous work and the above study, the structural context uniquely identifies the local subject as the anaphor's only grammatical antecedent. In such instances, retrieval should use only those cues that identify the subject and none that might overlap with other NPs. If, however, the anaphor were encountered in a position in which the local subject was no longer the only possible antecedent (e.g. if another clause-mate preceded the anaphor as in 14), retrieval would resort to a richer cue set that might
include morphological cues.

(14) Mary introduced the boys at the party to each other.

This proposal is consistent with recent findings from Wagers and colleagues, which suggest that that resistance to interference is, in fact, selectively conditioned on whether the anaphor is encountered after another co-argument (King et al. 2012). Conditional accounts would predict that interference would emerge if a co-argument preceded the reciprocal in Hindi, as in (15).

(15) *Larke-ne Mary-ko baccoN-ki party me ek-dusre ke-bare-me bataayaa.
    Boy-Erg Mary-Acc kids' party in one-another about told.
    *The boy told Mary during the kids' party about each other.'

We leave testing this prediction to future work.

**Conclusion**

In this paper we asked whether the absence of intrusive licensing during local anaphor antecedent retrieval is restricted to post-verbal anaphors, or whether the lack of interference indicates more general cross-linguistic trend. We investigated the effect of a feature-matching distractor on the processing of unlicensed pre-verbal reciprocals in Hindi and found no indication of facilitative interference. The results suggest that immunity to interference does not arise as a result of a retrieval strategy that is predicated on an anaphor directly following its verb. Rather, the results appear to be better explained by a cue-based retrieval process that prioritizes, or exclusively uses, structural cues over morphological features.
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