Verbs may retrieve subjects and attachment sites

Netta Ben-Meir, Nick Van Handel, Matt Wagers

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Background

When subject verb dependencies are local, the parser does not usually experience difficulties:

The student…was studying.
Background

When subject verb dependencies are non-local, connecting the subject to the verb is sometimes easier:

The student [who was waiting for the exam] was studying.
Background

And sometimes harder:

The student [who knew the exam was important] was studying.
Background

Where does this difficulty come from?

**Cue-based retrieval** (Van Dyke & Lewis, 2003; Van Dyke, 2007; i.a.):

- The parser launches a search for the subject at the verb, specifying certain retrieval cues

The student [who knew the exam was important] was studying.
Interference occurs when multiple candidates in memory match the verb’s retrieval cues.

The student [who knew the exam was important] was studying.

Similarity-based: modulated by how distinctively potential targets match retrieval cues.
What cues matter?

An open question: what cues matter for retrieval?

Previous studies have examined different properties of subject DPs:

• Semantic overlap (Van Dyke, 2007)

• Structural Position (Van Dyke & McElree, 2011; Arnett & Wagers, 2017)

• Case (Fedorenko et al., 2004; Arnett & Wagers, 2017)
Is retrieval just about subjects?

Van Dyke & Lewis (2003) suggest that retrieval interference could also be due to multiple attachment sites for the verb

Upon encountering a subject DP, a left corner parser will invoke the rule $\text{TP} \rightarrow \text{DP T'}$, creating a potential attachment site for a later verb

```
      DP
     /\_____________________
    /                       /
   /                        /
  /                         /
 / The student…
```

8
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 /   |
/_____
  DP   T'

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```
TP
  / \   \
/   \  /   \
DP   T'  \\

The student...TP
  /   \
/     \\
DP  T'
   / \
the exam
```
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Upon encountering a subject DP, a left corner parser will invoke the rule $\text{TP} \rightarrow \text{DP } T'$, creating a potential attachment site for a later verb

The student…$\text{TP}$

$\text{TP}$

$\text{DP}$ $\text{TP}$

$\text{DP}$ $\text{T'}$

$\text{DP}$ $\text{T'}$

The exam $\ldots$ $\text{T}$

was
Is retrieval just about subjects?

Clausal attachment sites could also bear features targeted by the verb
Is retrieval just about subjects?

Subject properties are correlated with clausal properties

- Arnett and Wagers (2017): greater interference when embedded subject has nominative case

- Abstract case is used as a retrieval cue

<table>
<thead>
<tr>
<th></th>
<th>The explorer [who believed … ] was insane.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominative</td>
<td>… that the monster <em>was prowling</em> the ruins for the expedition …</td>
</tr>
<tr>
<td>Accusative</td>
<td>… the monster <em>to be prowling</em> the ruins for the expedition …</td>
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Is retrieval just about subjects?

Subject properties are correlated with clausal properties

- Abstract case, or clausal finiteness?

- Nominative Case ~ Finite; Accusative Case ~ Non-finite

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Unclear whether interference is due to cues targeting the subject or the attachment site
Current Study

- 2 self-paced reading experiments

- Disentangle the contribution of subjects and clauses to determine what retrieval cues are used to integrate verbs

- Vary properties of both the intervening attachment site (aspect) and subject (animacy)
  
  - Animacy (“semantic match”) previously shown to be relevant (Van Dyke 2007)
Experiment 1: Design

- SPR (n = 54, recruited via Prolific)
- 32 items, 72 fillers
- Manipulate ANIMACY (MISMATCH, MATCH) and Aspect (MISMATCH, MATCH) of interveners

<table>
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<tr>
<th>ANIMACY</th>
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<th>Before the election, the politician [who believed … ] was campaigning for the environment at the conference.</th>
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</tr>
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Question: Was the politician campaigning for the environment?
Experiment 1: Design

• Matrix verb was campaigning should target animates

• Animacy-Mismatch: the construction not targeted by [+ANIM] cue

• Animacy-Match: the businessman is targeted by [+ANIM] cue

• Therefore, more interference in Animacy-Match

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<td>Match</td>
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<td></td>
</tr>
</tbody>
</table>

| Mismatch | the businessman had violated the regulations very often |
| Match   | the businessman was violating the regulations very often |
**Experiment 1: Design**

- Matrix verb **was campaigning** should target clauses compatible with progressive aspect

- **ASPECT-MISMATCH:** \textit{had violated} → embedded clause is perfective; incompatible

- **ASPECT-MATCH:** \textit{was violating} → embedded clause is compatible with [+PROG]

- Therefore, more interference in **ASPECT-MATCH**

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Experiment 1: Predictions

Following Van Dyke & Lewis, 2003, et seq., interference will lead to delayed or incorrect retrieval, resulting in:

- Worse performance on comprehension questions for MATCH

- Slower reading times at the matrix verb (the retrieval site) and spillover region for MATCH

If both attachment site and subject are targeted:

- MATCH penalty for both ASPECT and ANIMACY

- Multiple sources of interference may be additive (e.g. slowest in ANIMACY-MATCH, ASPECT-MATCH)
Experiment 1: Results

Overall comprehension accuracy: no differences between conditions, although ANIMACY-MATCH, ASPECT-MATCH is worst

<table>
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<tr>
<th>ANIMACY</th>
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<th>% Correct</th>
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<tr>
<td>MISMATCH</td>
<td>MISMATCH</td>
<td>76 (2)</td>
</tr>
<tr>
<td></td>
<td>MATCH</td>
<td>76 (2)</td>
</tr>
<tr>
<td>MATCH</td>
<td>MISMATCH</td>
<td>75 (2)</td>
</tr>
<tr>
<td></td>
<td>MATCH</td>
<td>72 (2)</td>
</tr>
</tbody>
</table>

But, some questions targeted information unrelated to the subject-verb dependency: object DP, PP
Experiment 1: Results

Questions probing subject-verb dependency provide insight into outcome of retrieval

Comprehension accuracy on (17 of 32) questions about subject-verb dependency: main effect of ANIMACY ($p < .05$)

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</tr>
<tr>
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</tr>
<tr>
<td>MATCH</td>
<td>MISMATCH</td>
<td>79 (2)</td>
</tr>
<tr>
<td>MATCH</td>
<td>MATCH</td>
<td>74 (2)</td>
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E.g. Was the politician campaigning for the environment?
Experiment 1: Results

Reading: interaction of ANIMACY and ASPECT, such that reading times are faster when both interveners (embedded subject and clause) MATCH

- At matrix auxiliary was (-21 ms ± 11 ms; p = .061)
- At main verb campaigning (-35 ms ± 15 ms; p < .05)
Experiment 1: Discussion

Both subjects and attachment sites are relevant for retrieval

- An intervening animate hurts comprehension performance
  - Inhibitory interference
  - Replicates semantic match effect of Van Dyke (2007)

- Having two competitive interveners facilitates reading
  - Speed-up in ANIMACY-MATCH, ASPECT-MATCH
Experiment 1: Discussion

Why do we find facilitatory interference when both interveners match (ANIMACY-MATCH, ASPECT-MATCH) but inhibitory interference when only one intervener does?
Experiment 1: Discussion

When only the subject interferes (ANIMACY-MATCH, ASPECT-MISMATCH), the parser is likely to:

i) correctly retrieve the matrix TP
ii) misretrieve the embedded subject DP

- Encodings may contain information indicating they are incompatible, e.g. pointers to separate items

- This produces an error signal: inhibitory interference
Experiment 1: Discussion

When both subject and clause interfere (ANIMACY-MATCH, ASPECT-MATCH), the parser is likely to:

i) misretrieve the embedded TP
ii) misretrieve the embedded subject DP

- The misretrieved encodings point to one another

- More difficult to detect error: facilitatory interference
Experiment 1: Discussion

Facilitatory interference leads to reading speed-up, but failure to detect retrieval error still leads to poor comprehension accuracy

- Recall: worst performance in Animacy-Match, Aspect-Match condition

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Interim Conclusions

Experiment 1 suggests that both subjects and clauses are targets of retrieval.

Facilitatory interference in ANIMACY-MATCH, ASPECT-MATCH was unexpected.

Explanation of the findings relies on a particular theory of retrieval with multiple highly competitive interveners.

Do the results replicate?
Experiment 2: Design

- Attempt to replicate Experiment 1
- All questions for experimental items target one of the subject-verb dependencies
- SPR (n = 53; recruited via Prolific)
- 32 items, 72 fillers

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Experiment 2: Results

Comprehension accuracy: no differences between conditions

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<td>MATCH</td>
<td>81 (2)</td>
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Experiment 2: Results

Reading:

• No differences at retrieval site (*was campaigning*)

• Marginal effect of ANIMACY: speed-up at spillover preposition (-11 ms ± 6 ms; p < .087)
Experiment 2: Discussion

We do not replicate results of Experiment 1

No evidence of interference in comprehension or reading

Why?
Experiment 2: Discussion

Small effect size, not enough power?

Type I error in Exp 1?

Issues with running SPR online?
Conclusions

Too early to draw strong conclusions about the role of clausal attachment sites during retrieval

But, some ideas for how to proceed
Future Directions

• In-lab replication (in progress)
  - Eye-tracking?
  - Maze?

• RSVP

• Experiments in other languages
RSVP Experiment: Design

• Test our account of Experiment 1 results

• RSVP, Speeded binary acceptability judgment + 3-point confidence rating

• Items from Experiment 1, without the final PP
  - Judgment made immediately after retrieval site
  - Increase likelihood that judgment reflects interference

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RSVP Experiment: Predictions

If both clauses and subjects interfere

- **Higher** proportion of “unacceptable” responses in ANIMACY-MATCH, ASPECT-MISMATCH and ANIMACY-MISMATCH, ASPECT-MATCH, because the retrieved encodings (one correct, one incorrect) are incompatible.

If interference from two sources is facilitatory, due to difficulty detecting error:

- **Lower** proportion of “unacceptable” responses in ANIMACY-MATCH, ASPECT-MATCH, because the two misretrieved encodings are compatible, and detecting error is more difficult.
Thank you!

Amanda Rysling

Jed Pizarro-Guevara

Kelsey Sasaki

s/lab @ UCSC
Spanish

• Other languages might rely more on clausal cues, leading to greater interference from attachment sites

• E.g. Spanish: pro-drop; richer TAM morphology

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<td>Mismatch</td>
<td>espera que el proyecto obedezca la ley federal</td>
<td>hopes that the project obeys federal law</td>
</tr>
<tr>
<td>Match</td>
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<td>believes that the project obeys federal law</td>
</tr>
<tr>
<td>Mismatch</td>
<td>espera que el empresario obedezca la ley federal</td>
<td>hopes that the businessman obeys federal law</td>
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