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Processing Hindi Doubly Center-embedded Structures

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Joint work with Sakshi Bhatia (UMass)

- Prediction is known to be pervasive in natural language comprehension (e.g., Marslen-Wilson (1973), Staub and Clifton (2006), Kamide, Scheepers, and Altmann (2003))

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- While working memory constraints have been implicated in comprehension extensively, previous work has found little or weak evidence for working memory constraints in such languages (e.g., Levy & Keller, 2013; Husain et al., 2014)

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- While working memory constraints have been implicated in comprehension extensively, previous work has found little or weak evidence for working memory constraints in such languages (e.g., Levy & Keller, 2013; Husain et al., 2014)

- In this talk I will question this assumption and I will present new evidence which makes this claim weak.

Introduction: Prediction in Hindi

- The reading times at **parhi thii** below (a < b) can be explained by the expectation-based account (Husain et al., 2014)

(1) a. vo larka, jisne <u>kitaab</u> bohot dilchaspii se **parhi thii**, meraa
     that boy who.ERG book lots interest INST read PAST my
     dost hai
     friend is

   'The boy who read the book with lots of interest is my friend.'

   b. vo larka, jisne bohot dilchaspii se **parhi thii** <u>kitaab</u>, meraa
     that boy who.ERG lots interest INST read PAST book my
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   'The boy who read the book with lots of interest is my friend.'

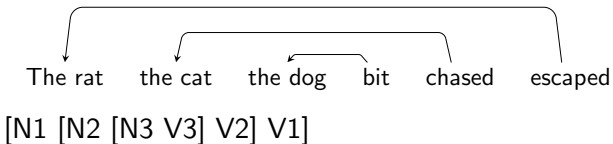## Introduction: Forgetting effects

- Center-embedding has been deemed syntactically complex (Chomsky & Miller, 1963)
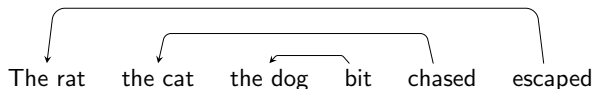

The rat   the cat   the dog   bit   chased   escaped

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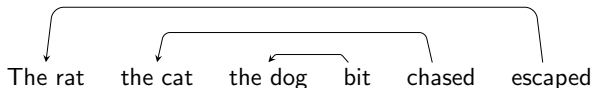The rat   the cat   the dog   bit   chased   escaped
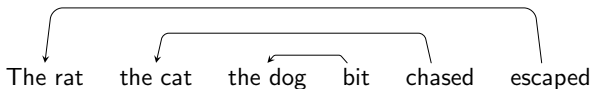
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- Such structures are known to induce forgetting effects in English (Gibson & Thomas, 1999)

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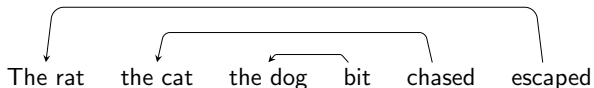

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- Such structures are known to induce forgetting effects in
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- However, such forgetting effects have not been attested in
  German and Dutch (Vasishth et al., 2010; Frank et al., 2016),
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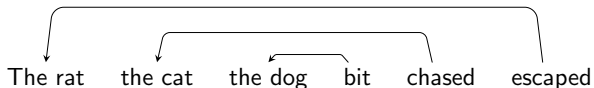The rat   the cat   the dog   bit   chased   escaped

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- However, such forgetting effects have not been attested in German and Dutch (Vasishth et al., 2010; Frank et al., 2016), but see Hussler and Bader (2015)

- This has been attributed to the parser's adaptability to handling head final structures

Introduction: Forgetting effects

- Again, this means that head-final languages are better at maintaining predictions of the the upcoming head (Konieczny, 2000), and that pre-verbal elements lead to processing facilitation at the predicted clause-final verb (Levy & Keller, 2013).

Introduction: Forgetting effects

- Again, this means that head-final languages are better at maintaining predictions of the the upcoming head (Konieczny, 2000), and that pre-verbal elements lead to processing facilitation at the predicted clause-final verb (Levy & Keller, 2013).

- This predicts that head final languages should not be susceptible to forgetting in a head final configuration

Can forgetting effects be induced in a head final language?

Introduction: Forgetting in Hindi I

(2) a. vo   larka [jisne   kitaab bohot dilchaspii se   parhi thii] mujhe
         that boy who.ERG book lots   interest   INST read PAST I.DAT
         khariidni padii
         bought had

     b. vo   larka [jisne   bohot dilchaspii se   parhi thii
         that boy who.ERG lots   interest   INST read PAST
         kitaab] mujhe **khariidni padii**
         book I.DAT bought had

Bhatia and Husain (2018)

- **We show that the prediction of the main clause verb is forgotten**

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- i.e, RT at *khariidni padii* 'bought had' was less in (b) vs (a)
- This is the first demonstration of a forgetting effect in Hindi
- The failure of prediction is due to a local coherence effect

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- This is the first demonstration of a forgetting effect in Hindi
- The failure of prediction is due to a local coherence effect
- The results demonstrate fallibility in prediction processes in a head-final language using a relatively simple structure
- Therefore, it is important to further investigate broad claims about the absence of forgetting effects caused by memory constraints in head-final languages (cf. Vasishth et al., 2010)

Introduction: Forgetting in Hindi II

- Sentences with self center-embedded relative clauses (RC)
- The baseline condition was of the form:
    - [N1 [N2 [N3 V3] V2] V1] . . .
- The other condition was ungrammatical:
    - [N1 [N2 [N3 V3] $\emptyset$] V1] . . .

Introduction: Forgetting in Hindi II

(3)   a. Grammatical

vo larka jo   usa doctor ko   jo   mareez se   paise   le raha tha
The boy who the doctor ACC who patient ABL money taking PAST
dekh raha thaa gussa kar raha thaa, magar baad me uskaa gussa
looking PAST   angry do PAST,   but   later   his anger
kam ho gaya
subsided.

The boy who was was looking at the doctor who was taking money from
the patient was getting angry, but later his anger subsided.

b. Ungrammatical

vo larka jo   usa doctor ko   jo   mareez se   paise   le raha tha
The boy who the doctor ACC who patient ABL money taking PAST
∅ gussa kar raha thaa, magar baad me uskaa gussa kam ho gaya
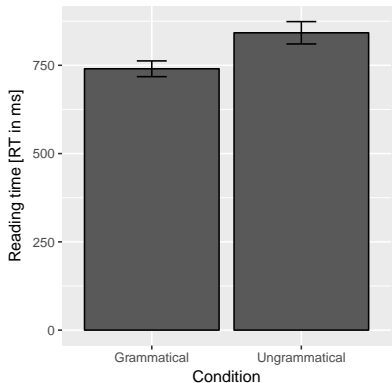∅ angry do PAST,   but   later   his anger   subsided.

. . .

Introduction: Forgetting in Hindi II
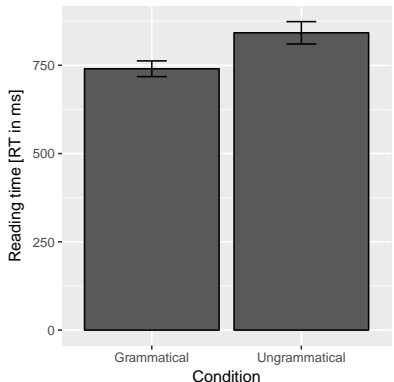
Husain and Bhatia (2018)

- Significant effect at the postcritical region (t=2.21)
- Hindi speakers are able to correctly identify the ungrammatical sentence as illustrated by elevated RTs in such sentence

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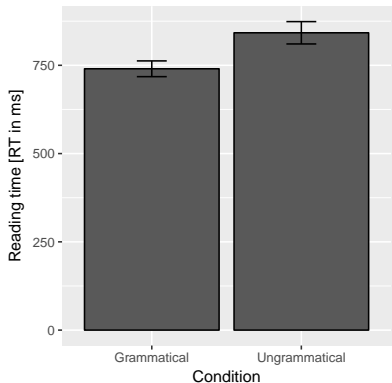- What can explain this?

Introduction: Forgetting in Hindi II

Husain and Bhatia (2018)

- Significant effect at the postcritical region (t=2.21)
- Hindi speakers are able to correctly identify the ungrammatical sentence as illustrated by elevated RTs in such sentence
- What can explain this?
  - Participants doing structural integration correctly
  - Participants tracking clause boundaries

Introduction: Forgetting in Hindi II

- By subject accuracies. Participants struggling with comprehension question.
- Given the low comprehension accuracies it seems that clause boundary tracking might be a better explanation
- The relative pronoun provides an unambiguous cue for the start of a clause

Introduction: Forgetting in Hindi

- So, we find 'prediction failure' and yet there is an 'ability to detect ungrammaticality'
- Is this due to shallow parsing?

Current experiment

- 2×2 design
- Embedded non-finite clauses, **no clause boundary cues**

(4) a. Grammatical, ko

sita ne   hari ko   [ravi se   [kitaab **dhundne-ne ke liye**] bol-neko] kahaa . . .
Sita ERG Hari DAT [Ravi ACC [book   for search-inf]   tell-inf] told   . . .

'Sita told Hari to inform Ravi to search a book'

b. Ungrammatical, ko

sita ne   hari ko   [ravi se   [kitaab **dhundne-ne ke liye**] ∅] kahaa . . .
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. . .

Predictions for RTs at Critical region

- Main effect of GRAMMATICALITY
    - RTs at V1 in the grammatical condition should be less than that of ungrammatical condition
- Interaction of GRAMMATICALITY × CASE
    - However, if there is forgetting then a reverse pattern should be seen
    - In particular, the 'Ungrammatical.ko' condition might show forgetting due to lack of robust prediction (Apurva & Husain, 2016), while in 'Ungrammatical.se' no such forgetting because of good prediction
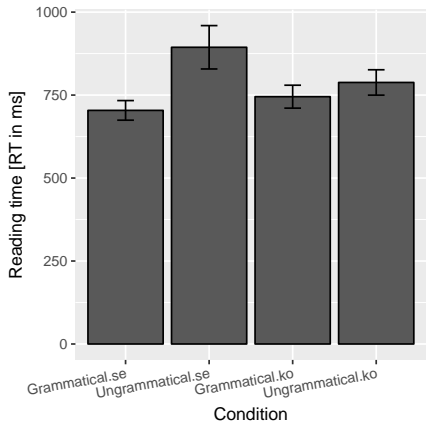
Method

- Centered self-paced reading
- 24 latin-squared items
- N=63 native speakers of Hindi at the Indian Institute of Technology, Delhi

Results: RT
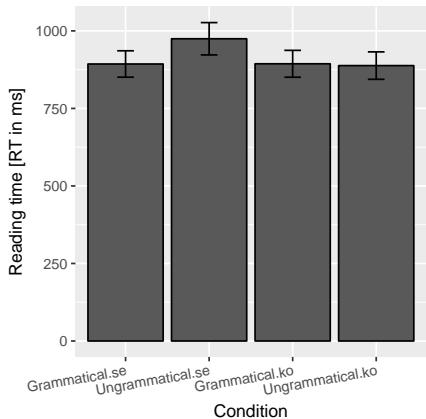
- No significant effect at the critical region (t=0.26)

Results: RT

- Marginal effect of grammaticality (t=-1.8)
- Marginal interaction (t=-1.9)

Discussion

- Hindi speakers are able to correctly identify the ungrammatical sentence as illustrated by elevated RTs in 'Ungrammatical.se' vs 'Grammatical.se'

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- Hindi speakers are able to correctly identify the ungrammatical sentence as illustrated by elevated RTs in 'Ungrammatical.se' vs 'Grammatical.se'
- At the same time, no difference between 'Ungrammatical.ko' vs 'Grammatical.ko'

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Discussion

- Hindi speakers are able to correctly identify the ungrammatical sentence as illustrated by elevated RTs in 'Ungrammatical.se' vs 'Grammatical.se'
- At the same time, no difference between 'Ungrammatical.ko' vs 'Grammatical.ko'
  - Offline results show not much prediction happening in 'Grammatical.ko' and 'Ungrammatical.ko' (Apurva & Husain, 2016)
  - This implies that forgetting will be contingent on the strength of the prediction based on case-markers

Discussion
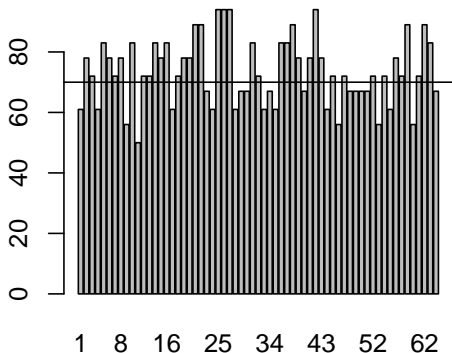
- By subject accuracies.
  Participants struggling with
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Wrapping Up!

Research Question

Can forgetting effect be induced in a head final language? ✓

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Can forgetting effect be induced in a head final language? ✓ ✗

Wrapping Up!

Can forgetting effect be induced in a head final language? ✓

Due to local coherence

Wrapping Up!

> **Can forgetting effect be induced in a head final language? ✓**
>
> Due to local coherence

> **Can forgetting effect be induced in a head final language? ✗ ✓**
>
> Depends on case marker combination
> If prediction happens: no forgetting
> If prediction doesn't happen: forgetting

Wrapping Up!

- Together these results show that prediction in a language like Hindi can be constrained/overridden (cf. Apurva & Husain, 2016, 2018b, 2018a)

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- The claim is not that there is no (robust) prediction in head-final languages, rather,
- rather, prediction processes are constrained (for e.g. by working memory limitations)

Wrapping Up!

- Together these results show that prediction in a language like Hindi can be constrained/overridden (cf. Apurva & Husain, 2016, 2018b, 2018a)
- The claim is not that there is no (robust) prediction in head-final languages, rather,
- rather, prediction processes are constrained (for e.g. by working memory limitations)
- Forgetting effects can be observed even in head-final languages
- This will happen due to less strength of prediction or due to local coherence

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