Acceptability, Decision-making, and Parsing

Seminar 3: Decision-making and agreement
The seminars

Seminar two (today):
- Reaction time methods. Focus on the drift diffusion model.
- Investigation of English S-V agreement.
- Investigation of Hindi subject and object agreement.
the nature of the inductive biases are of the utmost importance.
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**Agreement attraction**

Studied intensely in language production (Eberhard et al., 2005): one source of evidence for a level of linguistic encoding that is distinct from semantic (notional) meaning and phonological form (‘morphosyntax’). We know it is not simply proximity concord (Quirk, 1972): instead, abstract syntactic prominence plays a key role (Franck et al., 2002).
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- Sensitive to statistical learning (Haskell et al., 2010, Linzen et al., 2016): some, but not all, instances of agreement attraction arise naturally in RNN networks doing language modeling tasks; this can be primed

  (a lot of people are → the key to the cabinets are)
Agreement attraction

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- Short-term encoding of linguistic structure (Wagers et al., 2009): it also arises in comprehension, where it seems to reflect limitations in how we encode/access information in hierarchical syntactic structure.
Case Study 1: English agreement + Sequential Sampling Decision Models

Do agreement attraction errors arise because of errors during encoding, errors during retrieval, or both?

Adrian Staub, UMass
Chris Hammerly, UMass
ENCODING ERROR: Marking & Morphing model

Notional number has an influence at this stage.

Morphosyntactic number has further influence at this stage.

Eberhard et al., 2005
Spreading activation takes discrete, lexical morphosyntactic number and makes it continuous, ranging between -1 (SG), 0 (unmarked) and 1 (PL).

The morphosyntactic number is resolved at the phrasal level, and the all-in number value of a phrase is a function of notional number and morphosyntactic number of other phrases in parse: \( S(r) \).

**Encoding error:** Morphosyntactic features migrate (or percolate) to other nodes in a syntactic tree (c.f. feature migration, Tresiman & Gelade, 1980).

\[
S(r) = S(n) + \sum_j (w_j \times S(m)_j)
\]
ENCODING ERROR:
Marking & Morphing model

\[
[\text{The key to the cabinets}]_{S(r)} = 1.60
\]

\[
\frac{1}{1 + e^{-(S(r) + b)}} \sim
\]

The key to the cabinets are rusty (13%)

The key to the cabinets is rusty (77%)

Eberhard et al., 2005
ENCODING ERROR: 
Marking & Morphing model

- Provides a close quantitative fit to English data with very few free parameters, including effects of distributivity (single versus multiple tokens, as in *the label on the bottles*), and notional number.
- A prototypical case of a Control-based model of agreement. Multiple sources influence the morphosyntactic number marking on the subject phrase, which then transmits its number to the verb.

Eberhard et al., 2005
RETRIEVAL ERROR:
When comprehending or producing a verb, we must retrieve an agreement controller from (working) memory. That process is prone to error. When it fails, the wrong agreement controller is selected; when this occurs, agreement attraction results.

The **key** to the **cabinets**

**NP2**
- cat: **NP**
- num: **sing**
- case: **NOM**
- head: **key**

**NP4**
- cat: **NP**
- num: **plural**
- case: **OBL**
- head: **cabinets**

Badecker & Kuminiak (2007); Dillon et al., (2013); Wagers, 2008; Wagers, Lau & Phillips (2009)
The key to the cabinets are ...
The key to the cabinets are ...

NP2
- cat: NP
- num: sing
- case: NOM
- head: key

NP4
- cat: NP
- num: plural
- case: OBL
- head: cabinets

RETRIEVAL ERROR:

Badecker & Lewis (2007); Badecker & Kuminiak (2007)
RETRIEVAL ERROR: Formal similarity

- Provides a good explanation for the finding that nouns that look more like subjects tend to interfere more with agreement.
- In German and Dutch, unambiguous accusative case marking reduces attraction (but cf. Avetisyan et al. in Armenian).
- In Slovak and Russian, greater interference seen for attractors that are syncretic with nominative forms (Badecker & Kuminiak, 2007), even when those forms are not formally plural! (Slioussar, 2018)
- But: seems to predict difficulty / errors when the wrong item is retrieved.

Eberhard et al., 2005
**Haskell & MacDonald (2003)**

### Example Stimulus Items for Experiment 1

<table>
<thead>
<tr>
<th>Head type</th>
<th>Local noun type</th>
<th>Phrase</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-collective</td>
<td>Singular</td>
<td>The actor in the weekend performance</td>
<td>Famous</td>
</tr>
<tr>
<td>Collective</td>
<td>Singular</td>
<td>The cast in the weekend performance</td>
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<td>Famous</td>
</tr>
</tbody>
</table>
Staub (2009)

The key to the cabinets was were 250ms/word + 150ms ISI

judgment (1200ms deadline)
SS: The leader with the dangerous rival
SP: The leader with the dangerous rivals
SS: The gang with the dangerous rival
SP: The gang with the dangerous rivals
→ Correct responses in SP conditions are slowed relative to SS conditions, for both types of noun.
→ No significant difference in RTs to correct / incorrect responses for SP conditions.
**Staub (2009)**

**SS:** The door to the office  
**SP:** The door to the offices  
**PP:** The doors to the offices  
**PS:** The doors to the office
Staub (2009)

SS: The judge for the important criminal trial
SP: The judge for the important criminal trials
SS (relC): The judge who presided over the trial
SP (relC): The judge who presided over the trials
Across three experiments, Staub observed a regular relationship between response proportion and reaction time. As probability of selecting a plural verb approached 0.5, RTs increased. That was almost linear in $S(r)$, the logistic transformation of the response proportion. The 2AFC verb task replicates some of the major findings in agreement attraction: mismatch asymmetry, structural depth effect.
This mismatch penalty in verb choice selection occurs for the fastest and slowest responses alike in about a 4:1 ratio at the 1st and 9th quartiles.
Spreading activation takes discrete, lexical morphosyntactic number and makes it continuous, ranging between -1 (SG), 0 (unmarked) and 1 (PL).

The morphosyntactic number is resolved at the phrasal level, and the all-in number value of a phrase is a function of notional number and morphosyntactic number of other phrases in parse: $S(r)$.

**Encoding error:** Morphosyntactic features migrate (or percolate) to other nodes in a syntactic tree (c.f. feature migration, Tresiman & Gelade, 1980).

$S(r) = S(n) + \sum_{j} (w_j \times S(m)_j)$
Speeded decisions:

→ Show a right-skewed reaction time (RT) distribution. This is normal but not Normal.

→ Accuracy and RT are inversely correlated. As accuracy increases, RT decreases. As accuracy decreases, RT increases. Harder decision, longer RT.

→ Amount of RT variance depends on overall mean RT. Shorter RT distributions show less; longer RT distributions show more. But distributional shape changes little.

→ Error responses are typically slower than correct responses when accuracy is emphasized in instructions, and faster than correct responses when speed is emphasized.

Ratcliff & McKoon, 2008
Drift diffusion model:

Ratcliff & McKoon, 2008; Ratcliff et al., 2016
Drift diffusion model:
Bias in snap decisions:

Probability of One versus the Other Alternative (Case 1)

A decision boundary

z for P(A) > P(B)

z for P(A) = P(B)

z for P(A) < P(B)

B decision boundary

Start time

Q.1

Q.9

Low drift rate
20 random walks
a=20, z=5, p=0.55

Low drift rate
20 random walks
a=20, z=15, p=0.55

Ratcliff & McKoon, 2008
Sequential sampling models:

→ DDM is an example of a sequential sampling model, a close of models that holds decisions are made by accumulating noisy evidence until a response threshold is reached.

→ DDM assumes two response options; evidence for one alternative is implicitly evidence against the alternative. There are other sequential sampling models that do not make this assumption (but see Ratcliff et al., 2016)

→ Sequential sampling models have found surprisingly clear empirical support in cognitive neuroscience, including being linked to the P300 (Twomey et al., 2015)

→ For us: a formal linking hypothesis that lets us explore the cognitive mechanisms underlying agreement attraction.

Ratcliff & McKoon, 2008
The verb selection task:

→ Model verb selection judgments as an evidence accumulation process. Strength of evidence determines drift rate: how quickly you converge to a decision boundary.

Ratcliff, 1979; see also Chen & Husband, 2018
The verb selection task:

→ Idea: Strength of evidence is directly linked to $S(r)$ in a representational model (Staub, 2009). The more unambiguously ‘plural’ or ‘singular,’ $S(r)$ is, the stronger the evidence is in favor of one or another verb choice options.

Ratcliff, 1979; see also Chen & Husband, 2018
The judgment task:

- Number mismatch creates ambiguous number marking in encoding of subject DP; this should decrease drift rate; this should:
  - Increase probability of error.
  - Increase reaction times.
Simulating Staub (2009)

Simulated relationship between RT and correct choices

Simulated relationship between RT and correct choices
Overall:

→ Mismatching number slows production latencies even when correct singular form is chosen.

→ RT evidence in snap verb-choice decisions supports encoding errors as in a Marking-and-Morphing style model of agreement attraction. There is genuine uncertainty in the number marking on the subject; this translates to variable response rates and slowed decision making. Critically, this occurs even when the right choice is made.

→ The quantitative form relating response proportion to response RT matches expectations from a sequential sampling model.

→ What about comprehension?
The Grammaticality Asymmetry:
attractor number clearly ameliorates acceptability/facilitates processing of ungrammatical sentences; it does not clearly degrade acceptability of grammatical sentences.

**Grammatical (+/- mismatch)**

The *key* to the *cabinet* definitely *was* getting rusty from years of disuse.

The *key* to the *cabinets* definitely *was* getting rusty from years of disuse.

**Ungrammatical (+/- mismatch)**

The *key* to the *cabinet* definitely *were* getting rusty from years of disuse.

The *key* to the *cabinets* definitely *were* getting rusty from years of disuse.
The key to the cabinets definitely were getting rusty from years of disuse.
The Grammaticality Asymmetry:

→ Not (obviously) compatible with encoding error; if morphosyntactic number is misencoded, this error should exert its effect no matter the verb number.

→ Predicted on retrieval accounts that rely on feature-matching processes to search memory (Wagers et al., 2009; Lago et al., 2015).

Wagers et al., 2009; Lago et al. (2015)
The Grammaticality Asymmetry:

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→ Predicted on retrieval accounts that rely on feature-matching processes to search memory (Wagers et al., 2009; Lago et al., 2015).
The judgment task:

determine if the key to the cabinets rust is present.

judgment (3ms deadline) YES NO
The judgment task:

Model binary judgments as an evidence accumulation process. Strength of evidence determines **drift rate**: how quickly you converge to a decision boundary.

Ratcliff, 1979; see also Chen & Husband, 2018
The judgment task:

→ Idea: Strength of evidence is directly linked to \( S(r) \) in a model like Marking & Morphing (Staub, 2009). The more unambiguously ‘plural,’ or ‘singular,’ the morphosyntactictic encoding, the stronger the evidence to support an acceptability judgment (one way or another).

Ratcliff, 1979
The judgment task:

→ Number mismatch creates ambiguous number marking; this should decrease drift rate; this should:
  - Increase probability of error.
  - Increase reaction times.

High drift rate (*The key to the cabinet is...*)

- Grammatical response
- Ungrammatical response

Low drift rate (*The key to the cabinets is...*)

- Grammatical response
- Ungrammatical response
The judgment task:

→ However: this is no longer true when response bias is introduced.
The judgment task: Simulation

![Graph showing accuracy against grammaticality with two conditions: Grammatical Bias and No Bias. The graph compares accuracy between grammatical and ungrammatical stimuli, with dashed lines indicating mismatch and solid lines indicating match.]
The judgment task: Interim summary

→ **Diffusion modeling shows** that the grammaticality asymmetry is *possible* even if the impact of attraction is identical for grammatical/ungrammatical sentences.

→ **The grammaticality asymmetry** can no longer be taken as an unqualified argument for retrieval-only models.

**Prediction:** If encoding errors + response bias hypothesis is correct, then the grammaticality asymmetry should disappear if we can eliminate the ‘grammatical’ bias.
The experiments

In three SVP, speeded 2AFC judgment experiments we tested:

1. The key to the cabinet always *rusts* grammatical, match
2. The key to the cabinets always *rusts* grammatical, mismatch
3. The key to the cabinet always *rust* ungrammatical, match
4. The key to the cabinets aways *rust* ungrammatical, mismatch

\[N_{item} = 60;\] 2x2 design crossing grammaticality and number match in subject phrase; RT and response measured from verb onset; word-by-word presentation (200ms on/125ms off).
The experiments

Experiment 1 (neutral bias, $N_{subj} = 40$): 50% grammatical fillers, 50% ungrammatical. No special instructions.

Experiment 2 (no bias version #1, $N_{subj} = 20$): 25% grammatical fillers, 75% ungrammatical. Participants were told “2 out of 3 sentences will be ungrammatical.”

Experiment 3 (no bias version #2, $N_{subj} = 40$): 25% grammatical fillers, 75% ungrammatical. Participants were told “the majority of sentences will be ungrammatical.”
Origin represents an unbiased responder; predicted grammaticality asymmetry in absence of bias.
our studies
previous lit
The experiments: Reaction time data

![Graphs showing mean reaction time (ms) for grammatical and ungrammatical sentences in Experiment 1, Experiment 2, and Experiment 3. The graphs display different patterns of reaction time across conditions.]
Interim summary

→ **Grammaticality asymmetry** in judgments is partially due to response bias. When response bias is neutralized, (more) symmetrical attraction effects arise in judgments.

→ **Reaction time** in judgments is always slower in mismatch cases, even when the 'correct' judgment is made (Avetisyan et al., 2019). Model fits do not suggest this is due to slowed processing time, but rather, decreased drift rate (Parker, 2019).

→ **Supports** encoding error as one source of agreement attraction: ambiguous number encoding leads to slower rate of evidence accumulation, which means i) more errors, ii) asymmetrical attraction in absence of response bias and iii) longer decision RTs.
Open questions

→ What about self-paced reading, eye-tracking-while-reading, or ERP measures? Unclear yet if explanation extends to these measures; ET study in progress.

→ There does remain some residual grammaticality asymmetry: model estimates are around 5% more errors in ungrammatical conditions than grammatical conditions. Suggests that retrieval errors do still play a role, insofar as the number marking on the verb does matter.
Case study: Hindi agreement attraction

Are Hindi speakers susceptible to agreement attraction effects in a way similar to English/Spanish/Russian/… speakers?

Sakshi Bhatia, UMass
Raam[+SG,+M] bhaag gayaa[+SG,+M]*gayii[+SG,+F]*gae[+PL,+M]
Raam run go.PERF.M.SG
“Raam ran away.”
Hindi agreement


Raam run go.PERF.M.SG

“Raam ran away.”


Raam many mice catch PROG.M.SG WAS.M.SG

“Raam was catching many mice.”
Raam [+SG,+M] bhaag gayaa [+SG,+M]/*gayii [+SG,+F]/*gae [+PL,+M]
Raam run go.PERF.M.SG
“Raam ran away.”

*rahe [+PL,+M] the [+PL,+M]
Raam many mice catch PROG.M.SG WAS.M.SG
“Raam was catching many mice.”

Raam-ne [+SG,+M] kai chuuhe [+PL,+M] pakaRe [+PL,+M] the [+PL,+M]/
*pakaRaa thaa [+SG,+M]
Raam-ERG many mice catch WAS.M.PL
“Raam had caught many mice.”
“Mixed Agreement”

“Raam was catching many mice.”

“Raam had caught many mice.”

**HINDI AGREEMENT GENERALIZATION**: Agree with the most syntactically prominent, non-case marked DP (but cf. Bhatia, 2019).

→ In non-perfect clauses, subject is unmarked, and thus controls agreement.
→ In perfect clauses, subject takes ergative case; if object is unmarked, then the object controls agreement. If the object is marked, then ‘default agreement’ occurs (=3SG.MASC).
“Mixed Agreement”

Raam many mice catch PROG.M.SG WAS.M.SG
“Raam was catching many mice.”

Raam-ne[+SG,+M] kai chuuhe[+PL,+M] pakaRe[+PL,+M] the[+SG,+M]
Raam-ERG many mice catch WAS.M.PL
“Raam had caught many mice.”

→ Attraction occurs in languages with both subject and object agreement (e.g. Basque; Santesteban et al., 2013).
→ Hindi is importantly different from these languages: there is no ‘fixed object/subject’ agreement slot on the verb. Instead, the argument that controls the sole agreement slot on the verb varies by context / case-marking.

Does agreement attraction occur even in this highly configurational, mixed agreement system?
What is the role of cue-based retrieval in Hindi agreement processing?

→ Overall, we expect to see agreement attraction in Hindi: possibly reflecting retrieval errors or encoding errors.
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→ For **SUBJECT AGREEMENT**, we should see more agreement attraction from distractor **subjects** than **objects**, because subjects are more similar to target of retrieval than objects. (E1)
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→ For **OBJECT AGREEMENT**, we should see more attraction from *objects* than *subjects*, because subjects are more similar to target of retrieval than objects. (E2)
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→ For **SUBJECT AGREEMENT**, we should see more agreement attraction from distractor **subjects** than **objects**, because subjects are more similar to target of retrieval than objects. (E1)

→ For **OBJECT AGREEMENT**, we should see more attraction from **objects** than **subjects**, because subjects are more similar to target of retrieval than objects. (E2)

→ For both, we expect more attraction from non-case marked NPs than case-marked NPs, because case-marked NPs can never control agreement. (E3)
SUBJECT AGREEMENT (E1)

→ OBJECT DISTRACTOR CONDITIONS
Vo billi[+SG,+F] jisne ek chuuhiya[+F,+SG] DhuunDh nikaalii thii bhaag gayii that cat that-ERG many mice find remove.F.SG WAS.F.SG run go.F.SG “The cat that had found a mouse ran away.”
Vo billi[+SG,+F] jisne kai chuuhe[+PL,+M] DhuunDh nikaale the bhaag gayii that cat that-ERG many mice find remove.M.PL WAS.M.PL run go.F.SG “The cat that had found many mice ran away.”

→ SUBJECT DISTRACTOR CONDITIONS
Vo billi[+SG,+F] jise ek chuuhiya[+F,+SG] dekh rahii thii bhaag gayii that cat that-ACC many mice saw PROG.F.SG WAS.F.SG run go.F.SG “The cat that a mouse had been staring at ran away.”
Vo billi[+SG,+F] jise kai chuuhe[+PL,+M] dekh rahe the bhaag gayii that cat that-ACC many mice saw PROG.M.PL WAS.M.PL run go.F.SG “The cat that many mice had been staring at ran away.”
OBJECT AGREEMENT (E2)

→ OBJECT DISTRACTOR CONDITIONS
Mira-ne ...
... vo billi[+SG,+F] jisne ek chuuhiya[+F,+SG] DhuunDh nikaalii thii pakaR lii that cat that-ERG many mice find remove.F.SG WAS.F.SG catch took.F.SG “Mira caught the cat that had found a mouse.”
... vo billi[+SG,+F] jisne kai chuuhhe[+PL,+M] DhuunDh nikaale the pakaR lii that cat that-ERG many mice find remove.M.PL WAS.M.PL catch took.F.SG “Mira caught the cat that had found many mice.”

→ SUBJECT DISTRACTOR CONDITIONS
... vo billi[+SG,+F] jise ek chuuhiya[+F,+SG] dekh rahii thii bhaag pakaR lii that cat that-ACC many mice saw PROG.F.SG WAS.F.SG catch took.F.SG “Mira caught the cat that a mouse had been staring at.”
... vo billi[+SG,+F] jise kai chuuhhe[+PL,+M] dekh rahe the bhaag pakaR lii that cat that-ACCmany mice saw PROG.M.PL WAS.M.PL catch took.F.SG “Mira caught the cat that many mice had been staring at.”
SUBJECT AGREEMENT+CASE (E3)

→ NO CASE MARKING (-ko)
Vo billi[+SG,+F] jo ek chuuhiya[+F,+SG] dekh rahii thii bhaag gayii
that cat that many mice saw PROG.F.SG WAS.F.SG run go.F.SG
“The cat that had been staring at a mouse ran away.”
Vo billi[+SG,+F] jo kai chuuhe[+PL,+M] dekh rahii thii bhaag gayii
that cat that many mice saw PROG.F.SG WAS.F.SG run go.F.SG
“The cat that had been staring at many mice ran away.”

→ YES CASE MARKING (+ko)
that cat that many mice-ACC saw PROG.F.SG WAS.F.SG run go.F.SG
“The cat that had been staring at the/a certain mouse ran away.”
Vo billi[+SG,+F] jo kai chuuhoN-ko[+PL,+M] dekh rahii thii bhaag gayii
that cat that many mice-ACC saw PROG.F.SG WAS.F.SG run go.F.SG
“The cat that had been staring at many mice ran away.”
The task: 2AFC continuation

Choose appropriate continuation
(for option on left, press F; for option on right, press J)
Timeout=3 s

Inter stimulus interval (Blank): 50 ms
Word display time: 375 ms
Fixation Cross (Press any key to start)

The task: 2AFC continuation

Mira-ne vo billi[+SG,+F] jisne kai chuuhe[+PL,+M] DhuunDh nikaale the pakaR...

correct → lii

incorrect → liye

N_{subj} = \{59,60,58\} per experiment (exclusions from post-experiment questionnaire to test Hindi fluency/dialect)
N_{item} = 36 per experiment
RT and response measured at critical choice point
Half items had [+F,+SG] target, other half had [+M,+SG] target.
Distractor always mismatched in two features: [+M,+PL] or [+F,+PL]**
Animacy of target/distractor counterbalanced across items
All items normed for plausibility
Verb choices by condition in Experiment 1
Verb choices by condition in Experiment 2
Verb choices by condition in Experiment 3

Subject Agreement
Object Agreement
Non-Perfect SRCs

RT (correct answers only) in Experiment 1
RT (correct answers only) in Experiment 2
RT (correct answers only) in Experiment 3
As in Staub (2009), increase error rates generally saw an increase in RTs.

Object agreement (red) was overall slower than subject agreement.

Quantile-quantile plots of match versus mismatch suggest linear relationship: shape of the RT distribution is largely the same across match and mismatch conditions.
more agreement errors with number mismatched distractor
longer RTs to correct responses
Number-mismatched distractors interfered with verb choice selection in both E1 (subject agreement) and E2 (object agreement):

- LONGER RTS
- INCREASED P(ERROR)
- ANECDOTAL EVIDENCE FOR MORE INTERFERENCE IN OBJECT AGREEMENT

No evidence that grammatical role modulates this effect.

- NO EVIDENCE FOR CUE-BASED RETRIEVAL OF AGREEMENT CONTROLLER
No evidence for interference in either measure in non-perfect (NPF) relative clause constructions.

→ NO EVIDENCE THAT OVERT CASE PER SE INFLUENCES THE ATTRACTION EFFECT.
Provisional generalization:

less interference

that cat that was seeing many mice ran ... 

more interference

Mira caught that cat that many mice were seeing ...
Provisional generalization:

vo billi jo kai chuhee dekh rahii thii bhaag ...
that cat that was seeing many mice ran ...

vo billi jisne kai chuhee dekh rahe the bhaag ...
that cat that had seen many mice ran ...

Mira-ne vo billi jise kai chuhee dekh rahe the pakaR ...
Mira caught that cat that many mice were seeing ...

→ Retrieval interference? But: no effect of grammatical role or case marking.
→ Agreement type? But: subject and object agreement both susceptible to attraction.
→ RC type? But: distractors in ORCs and SRCs alike caused interference to similar degree.
Provisional generalization:

→ Interference seems to occur when the distractor noun independently controls agreement elsewhere. *Merely having a recent plural noun did not clearly trigger attraction in Hindi.*

→ It is the features of the most recent *verb* that interfered in our Hindi experiments, not recent unmarked or subject-like nouns.

→ Could reflect form-to-form priming of morphological forms (Haskell et al., 2010; Lorimor et al., 2018). But this seems perhaps implausible with the size of an effect, and has only been observed (to date) in cases where speakers show variable agreement patterns.

A proposal:

1) Hindi structural generation proceeds predictively left to right (*left corner parsing*), and involves actively elaborating VP phrase (Vasishth & Lewis, 2006)

2) When agreement controllers are identified in left to right processing, they pass their features to a predicted VP (TP).

3) When there are multiple active VP (TP) encodings with conflicting features, encoding interference arises.
vo billi ... 
वो बिल्ली ... 
that cat ... 

\[
S \\
\text{NP}_{[+SG,+F]} \quad \text{VP}_{[+SG,+F]} \\
\text{vo billi} \\
\text{...}
\]
vo billi jise kai chuhe ...
voice cat whom many mice ...

that cat whom many mice ...

S
  └── VP[+SG,+F]
      ├── NP[+SG,+F]
      │   └── NP[+SG,+F]
      │       └── vo billi
      │           └── RelPro[+ACC]
      │               └── jise
      │                   └── S
      │                       └── NP[+PL,+M]
      │                                       └── kai chuhe
      │                                           └── VP[+PL,+M]
      │                                               └── ...
vo billi jise kai chuhe  …
वो बिल्ली जिसे कई चूहे  …
that cat whom many mice  …

similarity-based interference → feature overwriting/migration
vo billi jise kai chuhe dekh rahe the bhaag ...
that cat whom many mice saw ran ...

See also Smith et al. (2018), Avetisyan et al. (2019)
vo billi ...  
वो बिल्ली ...  
that cat ...
vo billi jo kai chuhe   ...

ved billi jo kair chouhe   ...

that cat who many mice   ...

\[
\text{S} \\
\text{NP}_{[+SG,+F]} \rightarrow \text{NP} \rightarrow \text{vo billi} \rightarrow \text{RelPro}_{[+NOM]} \rightarrow \text{RC} \rightarrow \text{S} \rightarrow \text{VP}_{[+SG,+F]} \rightarrow \text{V} \rightarrow \text{dekh rahii thii} \rightarrow \text{NP}_{[+SG,+F]} \rightarrow \text{NP} \rightarrow \text{t} \rightarrow \text{kai chuhe} \rightarrow \text{RelPro}_{[+NOM]} \rightarrow \text{jo} \rightarrow \text{vo billi} \rightarrow 1
\]
vo billi jo kai chuhe  ...  
वो बिल्ली जो कई चूहे  ...  
that cat who many mice  ...

VPs share features →  
no (detectable) feature migration
vo billi jo kai chuhe dekh rahii thii bhaag ...
that cat who saw many mice ran ...

See also Smith et al. (2018), Avetisyan et al. (2019)
more interference

less interference

→ Broadly consistent with *control-based* approaches to agreement production, which involve structural copying of features from agreement controller onto agreement target (Bock & Middleton, 2011)

→ The timing of this copying process in Hindi, along with head-final structure, could be the source of the different attraction profile.
Interim summary

→ **Hindi shows agreement attraction** in 2AFC task, but in (apparently) more limited contexts than other languages studied. Provisional generalization: intervening agreement dependencies cause agreement errors, not intervening nouns.

→ **Reaction time** is again slower when correct choice is made, reflecting uncertainty about true agreement value.
The experiments: Open questions

→ What makes Hindi more resistant to attraction?
  - Mixed agreement system
  - SOV word order (Mertzen et al., 2016; but c.f. Lago et al., 2018)
  - Main effect of construction (Linzen & Leonard, 2018)

→ How to distinguish ‘predictive VP computation’ from other hypotheses?
  - Look for effect in other tasks without RSVP
  - Look for interference effects at embedded verb
  - Test non-agreeing verb in embedded clause
Stepping back

→ In the studies we saw, there seem to be clear cross-linguistic differences in where and when see attraction; these need to be further explored.

→ What is consistent is that RTs and errors travel together in experimental manipulations of agreement production. Broadly speaking, these models suggest that it is critical to modeling the uncertainty / competition behind agreement production.

→ Sequential sampling models may be one fruitful formal tool to do so: they provide a well-worked out linking hypothesis between encoding and decision processes.
THANK YOU FOR LISTENING!

Done with the support of:
NSF DDRI 1749290 to BD & SB
NSF GRFP (DGE-1451512) to CH

WITH SPECIAL GRATITUDE TO:
Ria Geguera
Niralee Gupta
Samar Husain
Bhavya Pant
Jacob Prescott
Shravan Vasishth
Mira …

… vo billi[+SG,+F] jise va raani[+F,+SG] DhuunDh rahii thii pakaR [rahi hai/rahe haiN]
… vo billi[+SG,+F] jise kuchh raajaa[+M,+PL] DhuunDh rahe the pakaR [rahi hai/rahe haiN]
DDM fits

Mean Accuracy

Grammatical  Ungrammatical

Experiment 1

Experiment 2

Experiment 3

Match Mismatch  Match Mismatch

Attractor

Source  ○ Experimental  × Model
DDM Parameter recovery

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
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<tbody>
<tr>
<td>$z_r$ (BIAS)</td>
<td>0.57</td>
<td>0.493</td>
<td>0.447</td>
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<tr>
<td>$a$</td>
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<td>1.571</td>
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<table>
<thead>
<tr>
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<td>Mismatch</td>
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<tr>
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