Production bias, but not parsing complexity, predicts wh-scope comprehension preferences

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Wh-dependencies

Dr. Emily discovered **which city** the aliens **visited __** three thousand years ago.

Wh-fronting
“Dr. Emily discovered which city the aliens visited three thousand years ago.”
Syntactic/semantic assumptions: “covert” dependency

Emily 发现了 外星人 拜访过 哪座城市。

(Huang, 1982; Li, 1992; Aoun & Li 1993; Tsai 1994; Cheng, 1991; 2003)
Processing a wh-in-situ construction involves memory retrieval of the correct scope position, which is located at the edge of a clause.

(Xiang et al. 2015)
Experiment 1&2: Structural parsing —establishing dependencies between the in-situ-wh and its scope position

Shorter dependencies are easier to process incrementally (the locality bias) even for covert dependencies.
Experiment 3&4: Interpreting the scope

But longer dependency is ultimately preferred for scope interpretation. This matches production preferences.
Experiment 1&2:

...$V_1[CP_1...V_2[CP_2...WH]$...

Does the parser access the local scope position faster?
John **knew** which man the police protected.

John **believed** which man the police protected.
...find out[CP1... know[CP2 ... WH]]

a possible dependency

...find out[CP1... believe[CP2, -Q ... WH]]

an impossible dependency
…find out[CP1… know[CP2 … WH]]

...find out[CP1… believe[CP2, -Q ... WH]]

ambiguous

unambiguous
Procedure

- Eyetracking reading
- acceptability judgment task after each trial
- Critical word (CW) is the sentence final wh-phrase
- 40 items
Mr. W. found out which dam the construction team knew the villagers rebuilt.

“Mr. W. found out which dam the construction team knew the villagers rebuilt.”
Acceptability Judgment

Regression Path Reading Time at the in-situ WH phrase

<table>
<thead>
<tr>
<th>Acceptability</th>
<th>V2-know</th>
<th>V2-belong</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Acceptability Judgment

V2-know

***

Reading Time (Log)

<table>
<thead>
<tr>
<th>Reading Time (Log)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
</tr>
<tr>
<td>6.5</td>
</tr>
<tr>
<td>7.0</td>
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<tr>
<td>7.5</td>
</tr>
<tr>
<td>8.0</td>
</tr>
<tr>
<td>8.5</td>
</tr>
</tbody>
</table>

Regression Path Reading Time at the in-situ WH phrase

V2-know

* (subj n=40)
Is the result due to dependency formation or ambiguity resolution? (e.g. Brian Dillon et al. 2017 CUNY talk on ambiguity advantage)
Experiment 2: Switching the position of V1 and V2

...know [CP1...find out[CP2 ... WH]]

a possible dependency

...believe [CP1, -Q...find out[CP2 ... WH]]

also a possible dependency
Acceptability Judgment

V2-know

V2-know

V1-know

Regression Path Reading Time
at the in-situ WH phrase

V2-know

V1-know

(analysis ongoing, subj n=19)
Evidence for locality bias

Ambiguous

…find out[CP1… know[CP2 ... WH]] easy

…know [CP1…find out[CP2 ... WH]] easy

unambiguous

…find out[CP1… believe[CP2, -Q ... WH]] hard

…believe [CP1, -Q…find out[CP2 ... WH]] easy
The locality bias in constructing covert dependencies

- The shorter covert dependency between the local scope position and the in-situ-wh is more easily accessed than the longer one. Greater processing difficulty arises if the local dependency is blocked.

- This effect can be modeled in terms of memory retrieval and memory decay under the assumption that encountering an in-situ-wh triggers memory retrieval of the relevant scope positions.
Interpreting scope

\[ \ldots V_1[CP_1 \ldots V_2[CP_2 \ldots WH] \ldots] \]

Does parsing difficulty predict the scope comprehension preference? That is, is the low scope interpretation preferred?
Experiment 3

Truth value judgment task (subj n=89)

Context:

At a recent archaeology conference, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. But she didn’t release the name of the city.
Target sentence (ambiguous)

(the example here is the English gloss in Chinese word order)

a. Emily *announced* her team *discovered* aliens built *which city*.

(艾米丽 公布了她的团队 发现了外星人建造了哪座城市。)

Question: Is this sentence true or false under the given context?
Target sentence (ambiguous)

a. Emily announced her team discovered aliens built which city.

“Emily announced her team discovered which city was built by aliens.”

(Emily announced her team discovered the answer to this question “which city was built by aliens?”.)
Target sentence (ambiguous)

a. Emily **announced** her team **discovered** aliens built **which city**.

- **True**
  
  "Emily announced her team **discovered which city** was built by aliens."

  (Emily announced her team discovered the answer to this question “which city was built by aliens?”.)
a. Emily announced her team discovered aliens built which city.

“Emily announced which city her team discovered was built by aliens.”

(Emily announced the answer to this question “which city did her team discover was built by aliens?”.)
Target sentence (ambiguous)

a. Emily **announced** her team **discovered** aliens built **which city**.

- **False**

  “Emily **announced** **which city** her team discovered was built by aliens.”

  (Emily announced the answer to this question “which city did her team discover was built by aliens?”.)
Target sentence (ambiguous)

a. Emily announced her team discovered aliens built which city.

○ True  Indicate low scope reading

  “Emily announced her team discovered which city was built by aliens.”

○ False  Indicate high scope reading

  “Emily announced which city her team discovered was built by aliens.”
Target sentence (ambiguous)

b. Emily hid her team discovered aliens built which city. (艾米丽 隐瞒了她的团队发现了外星人建造了哪座城市.)

- False  
  Indicate low scope reading  
  “Emily hid (the fact that) her team discovered which city was built by aliens.”

- True  
  Indicate high scope reading  
  “Emily hid which city her team discovered was built by aliens.”
Proportion of High vs. Low Scope Readings
Proportion of High vs. Low Scope Readings

![Bar chart showing the proportion of high vs. low scope readings for 'Announce' and 'Hide'. The chart indicates a higher proportion for high scope readings in both categories.](Image)
The puzzle

- Ambiguity is resolved towards a more complex parse
- High scope readings are preferred for ambiguous sentences, despite their enhanced parsing complexity
Bayes rule predicts the following

$$P \left( \text{High scope reading} \mid \text{ambiguous sentence form} \right)$$

$$= \frac{P \left( \text{ambiguous form} \mid \text{High reading} \right) \times P \left( \text{High reading} \right)}{P \left( \text{ambiguous form} \mid \text{High reading} \right) \times P \left( \text{High reading} \right) + P \left( \text{ambiguous form} \mid \text{Low reading} \right) \times P \left( \text{Low reading} \right)}$$
Linking comprehension and production

\[ P \text{(High scope reading I ambiguous sentence form)} \]

\[ \propto \]

\[ P \text{(ambiguous form I High reading)} \]

\[ P \text{(ambiguous form I High reading)} \]

\[ + \]

\[ P \text{(ambiguous form I Low reading)} \]
Linking comprehension and production

\[ P (\text{High scope reading} \mid \text{ambiguous sentence form}) \]

\[ \propto P (\text{ambiguous form} \mid \text{High reading}) \]

\[ \& \]

\[ P (\text{ambiguous form} \mid \text{High reading}) + P (\text{ambiguous form} \mid \text{Low reading}) \]

estimated by the truth value judgment task

estimated by a production task
Experiment 4: estimating the production bias (subject n=100)

Basic procedure:

Using the given fragments, participants produced sentences that are compatible with the biased context.

Context that biases towards a particular scope interpretation

Dependent variable:

We calculated the proportion of the ambiguous wh-in-situ sentence form, as the ones used in the truth value judgment task.
Example trial: High scope compatible context (for the announce type of matrix verbs)

Context
At a recent archaeology conference, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. She also released the name of the city.

Fragments for production
Emily announced which city built her team discovered
Example trial: **Low scope compatible context** (for the **announce** type of matrix verbs)

**Context**
At a recent archaeology conference, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. But she didn’t release the name of the city.

**Fragments for production**
Emily **announced** which city **built** her team discovered
Example trial: **High scope compatible context** (for the *hide* type of matrix verbs)

**Context**

At a recent archaeology conference, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. **But she didn’t release the name of the city.**

**Fragments for production**

Emily *hid* which city *built* her team discovered
Emily’s research team found evidence to prove that a famous ancient city was actually built by aliens. But at a recent archaeology conference, she didn’t mention this finding at all.

Emily hid which city her team discovered built.
Averaged Production Bias

Scope Bias in Context

Proportion of Producing the Ambiguous Form

- Announce
- Hide

High
Low
Linking comprehension and production

P (High scope reading | ambiguous sentence form)

P (ambiguous form | High reading)

\&

P (ambiguous form | High reading) + P (ambiguous form | Low reading)

estimated by the truth value judgment task

estimated by a production task
When the matrix verb is the “announce” type

\[ p < 0.05 \]
When the matrix verb is the “hide” type
hide + proposition = didn’t announce + proposition

P (High scope reading | ambiguous items with “hide” as matrix verb)

P (ambiguous form with “announce” | High reading) ∝ P (ambiguous form with “announce” | High reading) + P (ambiguous form with “announce” | Low reading)
Proportion of High Scope Interpretation estimated for "hide" vs. Normalized Likelihood estimated for "announce". The trend line indicates a significant positive correlation, p < .05.
Interpreting scope

- The scope interpretation bias is better explained by the production bias, instead of parsing difficulty.

- More work is needed to understand how negative predicates or predicates with negative implications are interpreted.
Conclusions and future work

To parse and comprehend a wh-in-situ construction in Chinese:

- A covert dependency is established between the in-situ-wh and its scope position. Longer covert dependencies evoke more parsing difficulties than shorter ones.

- But the ultimate scope interpretation preference is not entirely determined by parsing difficulty.
Conclusions and future work

- The current findings call for a processing model that can accommodate certain degree of dissociation between incremental structure parsing and global interpretation.

- More work is needed to understand the interaction between production and comprehension.
Thank you!
Linking comprehension and production

P (High scope reading | ambiguous sentence form)

\[ \propto \]

\[ P \text{ (ambiguous form | High reading)} \times P \text{ (High reading)} \]

\[ + \]

\[ P \text{ (ambiguous form | Low reading)} \times P \text{ (Low reading)} \]
Target sentence (unambiguous)

c. Emily **announced** her team **believed** aliens built **which city**.

- True  
  parsing failure

- False  
  Indicate **high** scope reading

“Emily announced **which city** her team believed was built by aliens.”
Target sentence (unambiguous)

d. Emily hid her team believed aliens built which city.

- True
  Indicate high scope reading
  “Emily hid (the fact that) which city her team believed was built by aliens.”

- False
  parsing failure
Proportion of High Scope Readings

- Announce
- Hide

Proportion of High Scope Interpretation

Ambiguous vs. Unambiguous
Experiment 6

Acceptability in context

![Bar graph showing acceptability judgments for ambiguous and unambiguous contexts.]
Experiment 6  Acceptability in context

![Bar chart showing acceptability judgments for Announce and Hide in ambiguous and unambiguous contexts.](chart.png)
Locality effect can be overridden with top-down prediction

...wonder[CP, +Q .......]

A strongly predictive +Q feature is incrementally encoded
...wonder[CP1, +Q... know[CP2 ... WH]]

...wonder[CP1, +Q... believe[CP2, -Q ... WH]]
Experiment 5: estimating the prior (subject n=30)

Dependent variable:
We calculated the preference proportion for each of the scope interpretations

A neutral context

Basic procedure

A force choice task between two situations that represent the two scope interpretations
Example trial (in English)

Context
At a recent archaeology conference, Emily reported on work from her research team.

Question
“Which of the following situation is more likely to happen?”

“In her report, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. She also released the name of the city.”

“In her report, Emily said that her research team found evidence to prove that a famous ancient city was actually built by aliens. But she didn’t release the name of the city.”
Example trial (in Chinese)

**Context**
在最近的一次考古界的学术会议上，艾米丽代表她的研究团队作了一个报告。

**Question**
以下的哪种情况更有可能发生？

“在她的报告里，艾米丽说她的团队找到了证据证实某一个有名的古城市其实是外星人建造的，她也同时宣布了这个城市的名字。”

“在她的报告里，艾米丽说她的团队找到了证据证实某一个有名的古城市其实是外星人建造的，但目前她需要对这个城市的名字保密。”
What we get:

The prior probability of each scope interpretation

\[ P(\text{Low scope situation}) \]

\[ P(\text{High scope situation}) \]
The average prior probability of the two interpretations