

# **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**

# Wh-in-situ

艾米丽 发现了 外星人 三千年 前  
Emily faxian-le waixingren sanqiannian qian  
Emily discover-perf aliens three-thousand-year before

拜访过 哪座城市。  
baifangguo nazuochengshi  
visit-perf **which-CL-city**

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

# Syntactic/semantic assumptions: “covert” dependency

艾米丽	发现了	外星人	拜访过	哪座城市。
Emily	faxian-le	waixingren	baifangguo	nazuochengshi
Emily	discover-perf	aliens	visit-perf	which-CL-city

CP, +Q



the **scope** of the wh-phrase

(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<sub>1</sub>[CP<sub>1</sub>...V<sub>2</sub>[CP<sub>2</sub>...WH]



Does the parser access the local scope position faster?

✓ John **knew** which man the police protected.

↳ optionally +Q

✗ John **believed** which man the police protected.

↳ obligatorily -Q

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



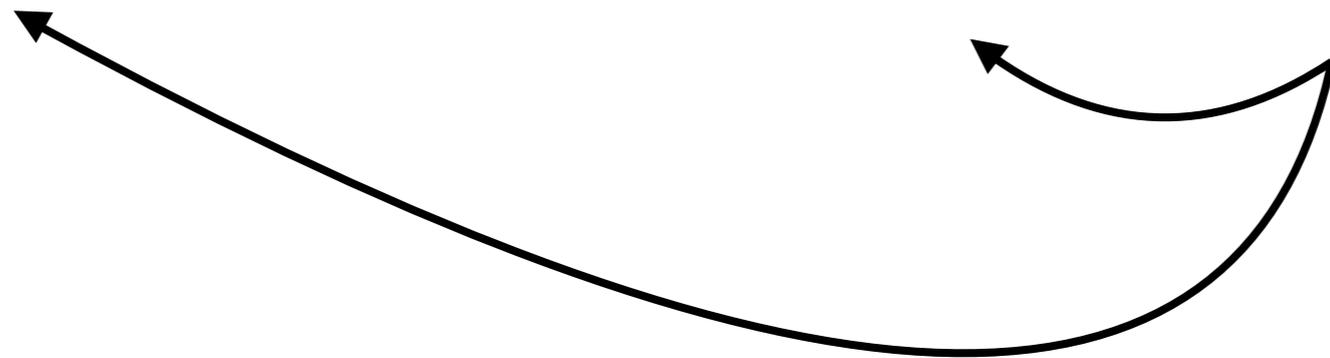
**a possible dependency**

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



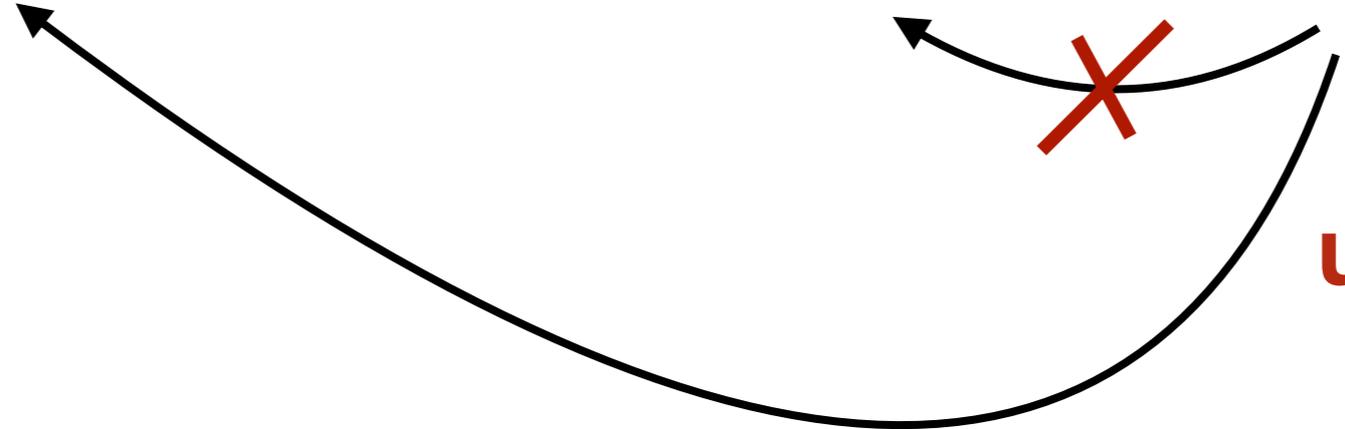
**an impossible dependency**

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



**ambiguous**

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



**unambiguous**

# Procedure

- Eyetracking reading
- acceptability judgment task after each trial
- Critical word (CW) is the sentence final wh-phrase
- 40 items

小王 打听到 工程队 知道 村民们 扩建了 哪座 水坝。  
W datingdao gongchendui zhidao cunminmen kuojianle nazuo shuiba  
Mr. W. **find out** construction-team **know** villagers rebuild **which-CL dam**

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

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

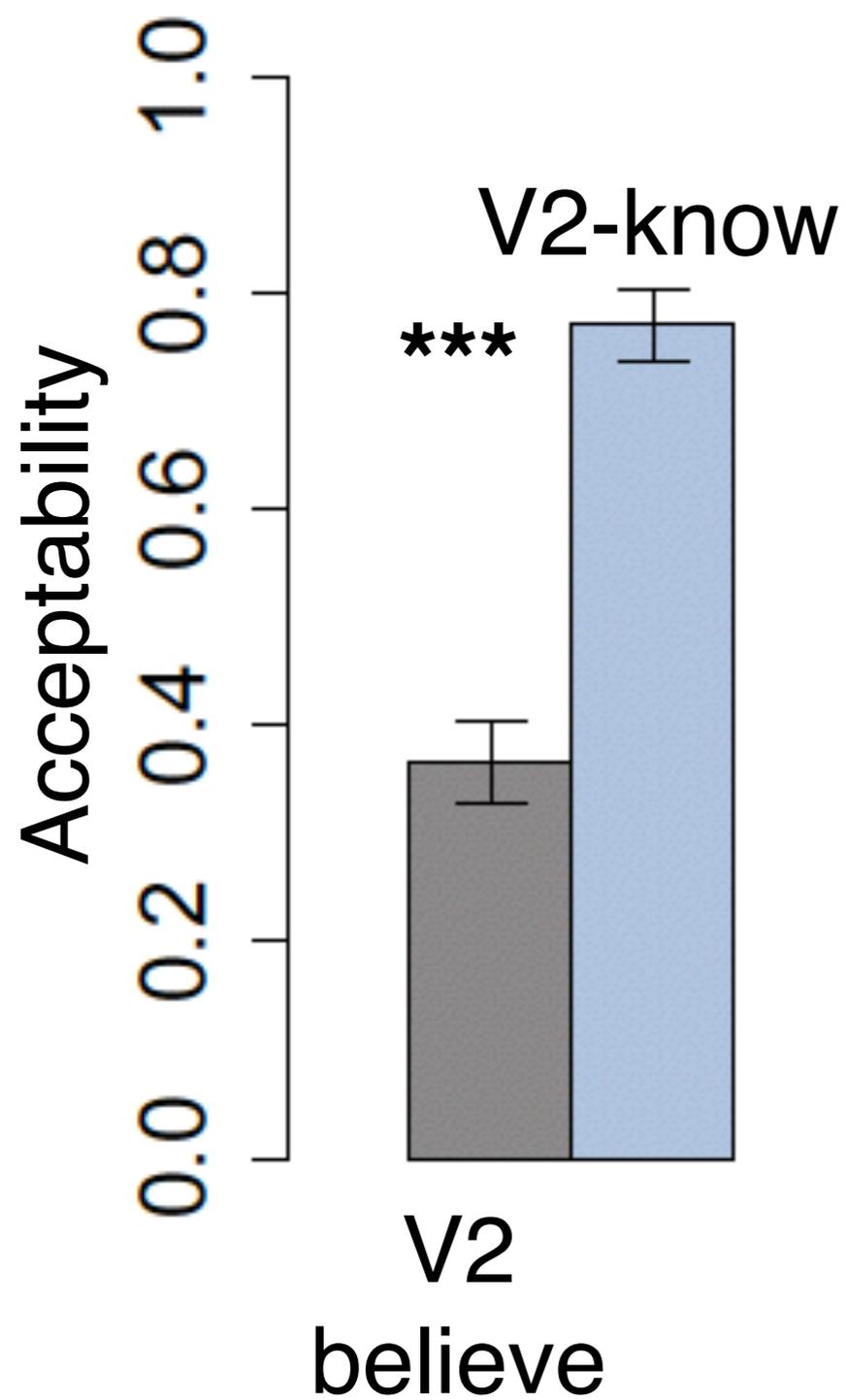
**V2 know, Low scope possible**

小王 打听到 工程队 相信 村民们 扩建了 哪座 水坝。  
W datingdao gongchendui zhidao cunminmen kuojianle nazuo shuiba  
Mr. W. **find out** construction-team **believe** villagers rebuild **which-CL dam**

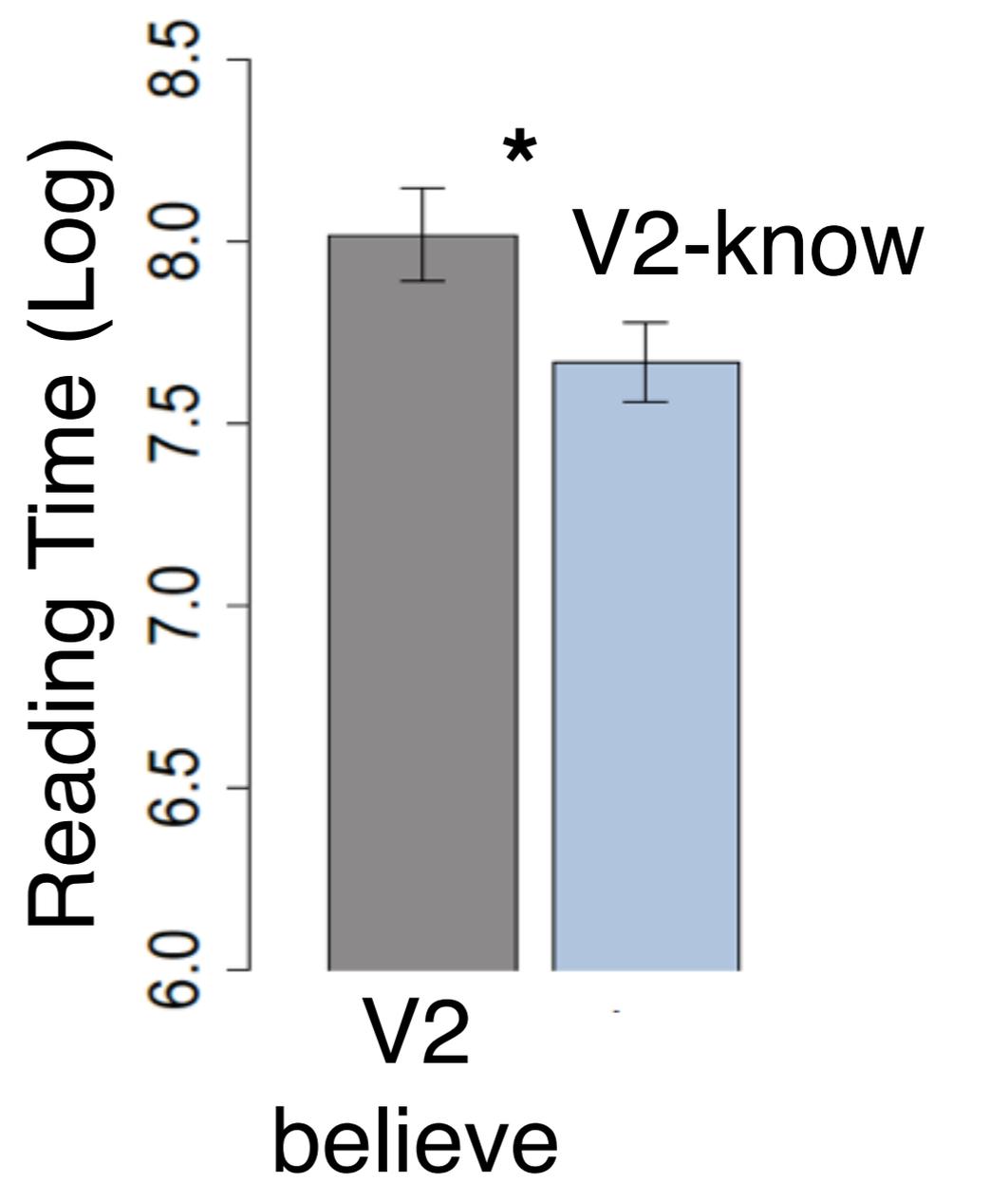
“Mr. W. **found out which dam** the team **believe** the villagers rebuilt.”

**V2 believe, Low scope impossible**

## Acceptability Judgment



## Regression Path Reading Time at the in-situ WH phrase

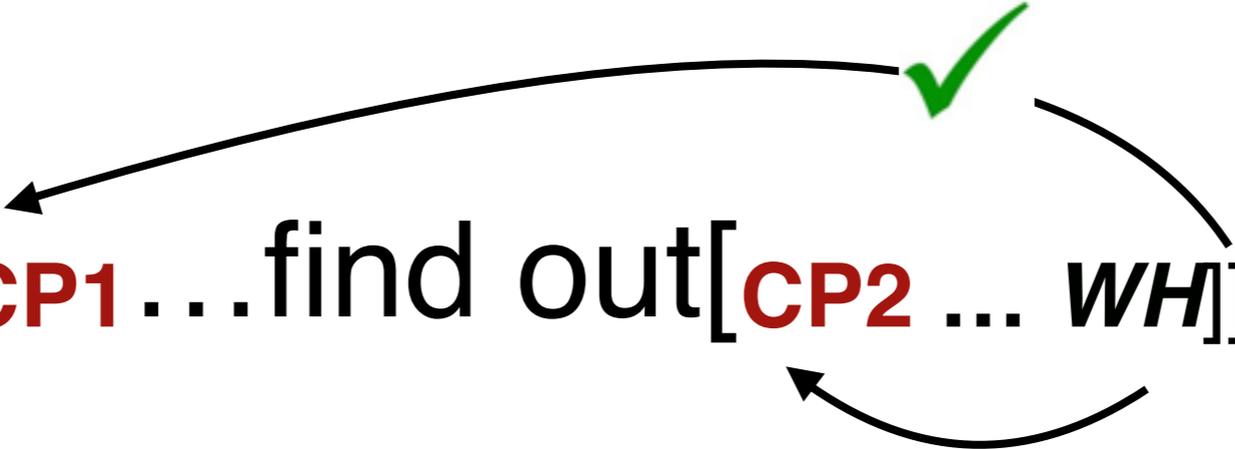


(subj n=40)

Is the result due to dependency formation or ambiguity resolution? (e.g. Brian Dillon et al. 2017 CUNY talk on ambiguity advantage)

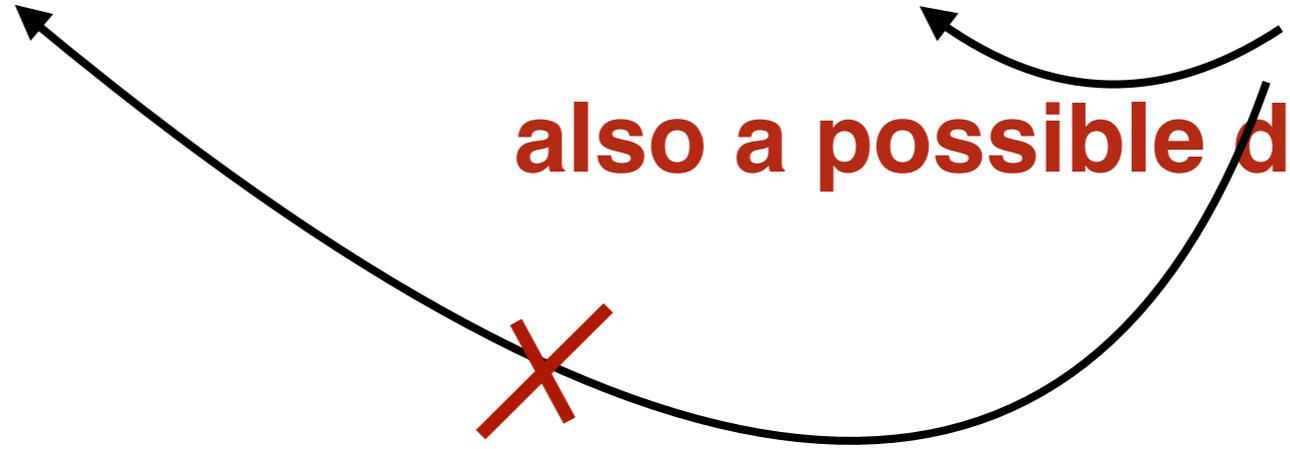
# Experiment 2: Switching the position of V1 and V2

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



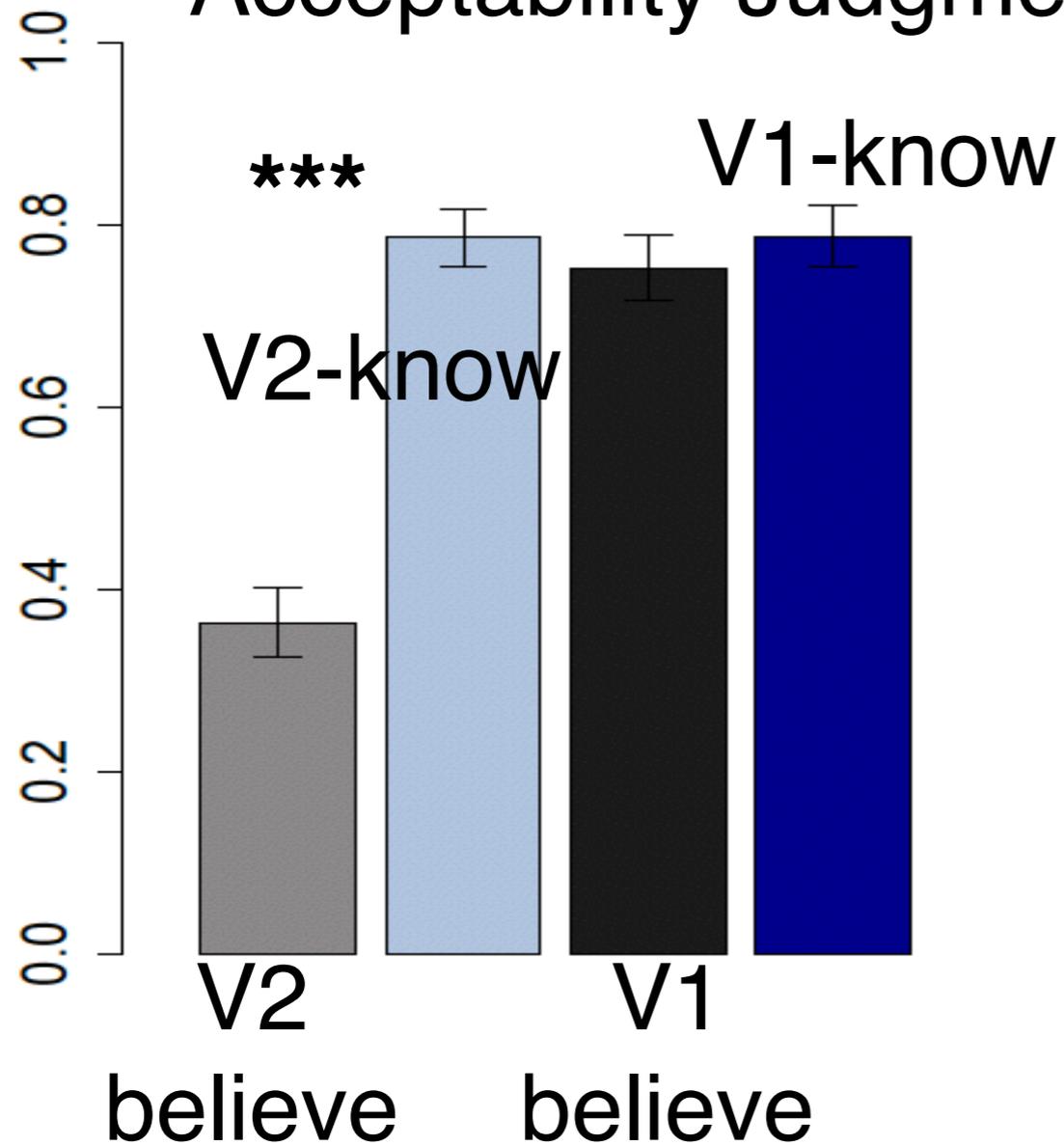
a possible dependency

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

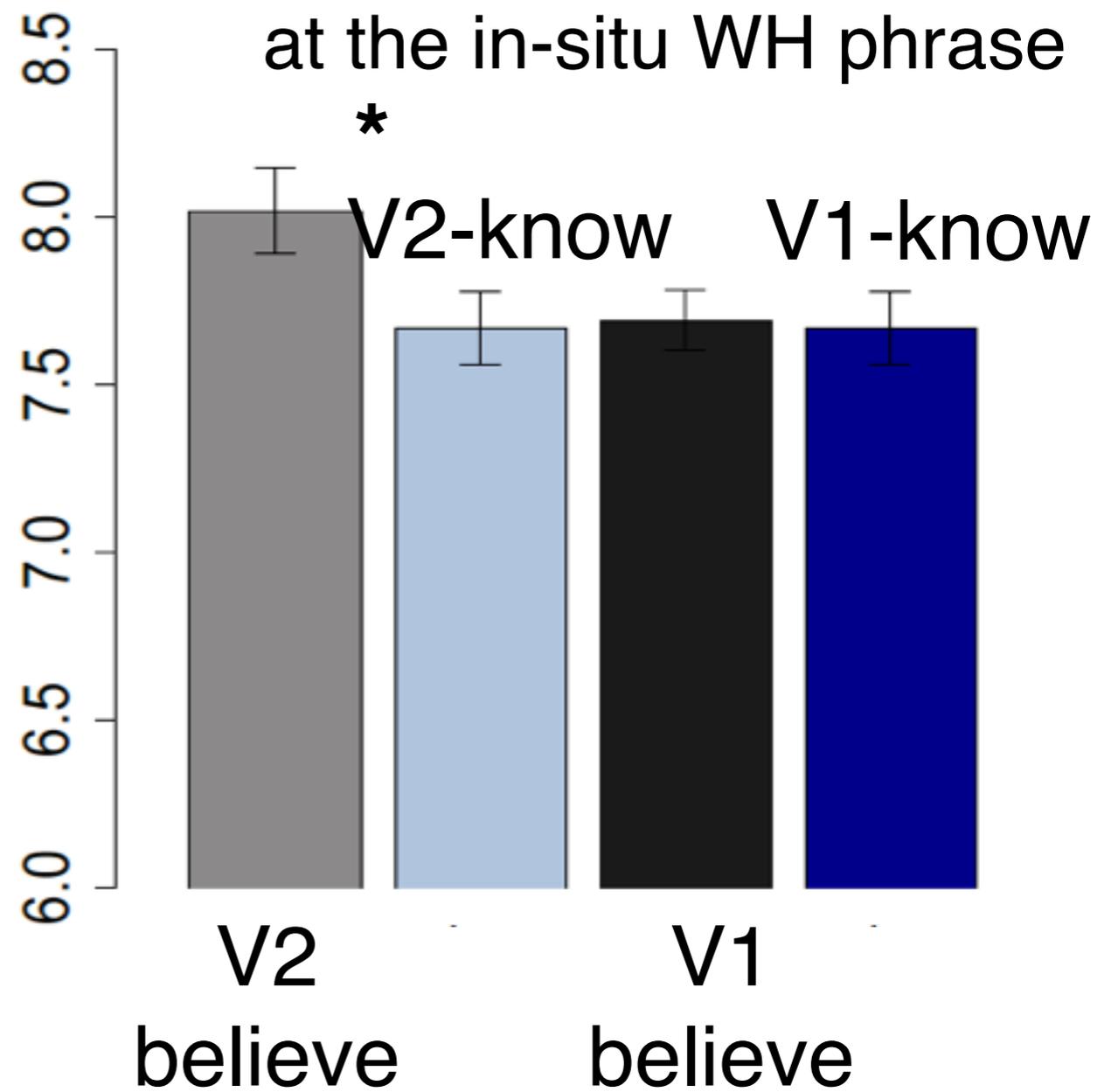


also a possible dependency

# Acceptability Judgment



# Regression Path Reading Time at the in-situ WH phrase



(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

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

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.**

在最近的一次考古界的学术会议上, 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。 **但目前她对这个名字保密。**

## 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**.

**low** scope reading

“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**.

**low** scope reading

- o **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?”.)

## Target sentence (ambiguous)

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

**high** scope reading

“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**.

**high** scope reading

o **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**.)

- o **False**

Indicate **low** scope reading

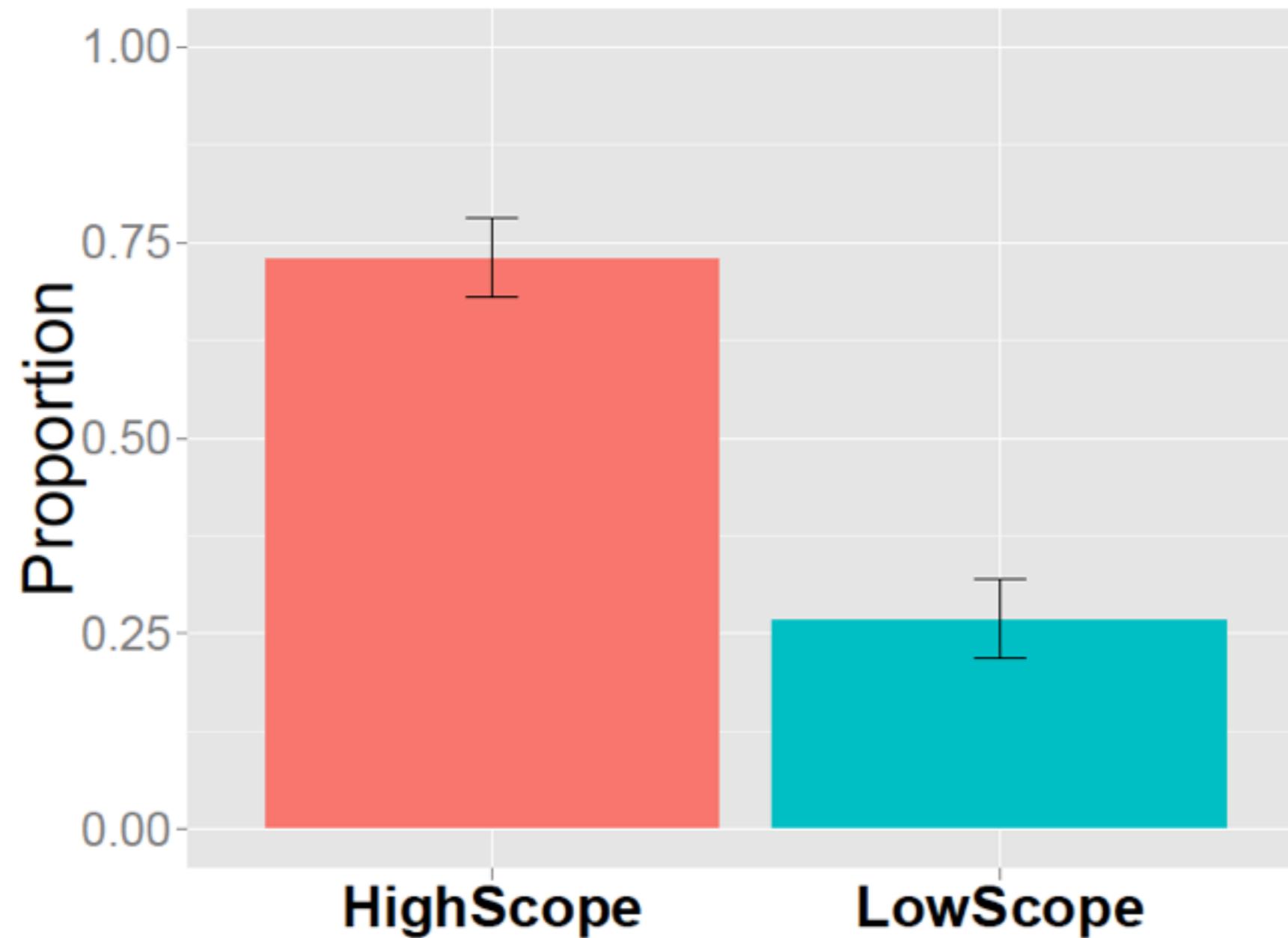
“Emily hid (the fact that) her team discovered **which city** was built by aliens.”

- o **True**

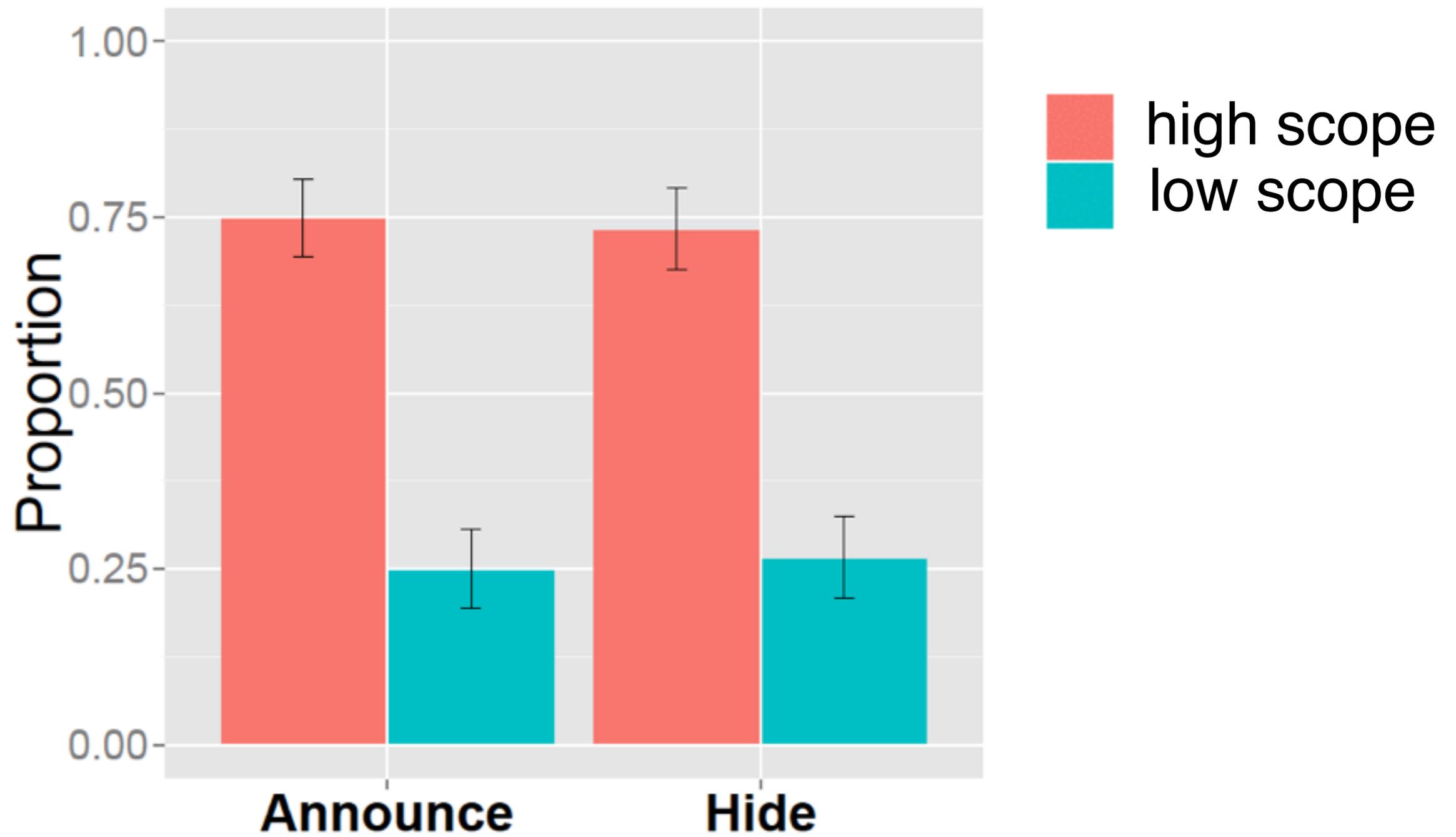
Indicate **high** scope reading

“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



# 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

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

$$= \frac{P(\text{ambiguous form} \mid \text{High reading}) \times P(\text{High reading})}{P(\text{ambiguous form} \mid \text{High reading}) \times P(\text{High reading}) + P(\text{ambiguous form} \mid \text{Low reading}) \times P(\text{Low reading})}$$

# Linking comprehension and production

P (High scope reading | ambiguous sentence form)

$$\propto \frac{P(\text{ambiguous form} \mid \text{High reading})}{P(\text{ambiguous form} \mid \text{High reading}) + P(\text{ambiguous form} \mid \text{Low reading})}$$

# Linking comprehension and production

estimated by the truth value judgment task

P (High scope reading | ambiguous sentence form)

$\propto$   $\frac{P(\text{ambiguous form} | \text{High reading})}{P(\text{ambiguous form} | \text{High reading}) + P(\text{ambiguous form} | \text{Low reading})}$

estimated by a production task

# Experiment 4: estimating the production bias (subject n=100)

## Dependent variable:

Context that biases towards a particular scope interpretation

We calculated the proportion of the ambiguous wh-in-situ sentence form, as the ones used in the truth value judgment task

Basic procedure

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

# 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

# Example trial: **Low scope compatible** context (for the **hide** type of matrix verbs)

## Context

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.**

## Fragments for production

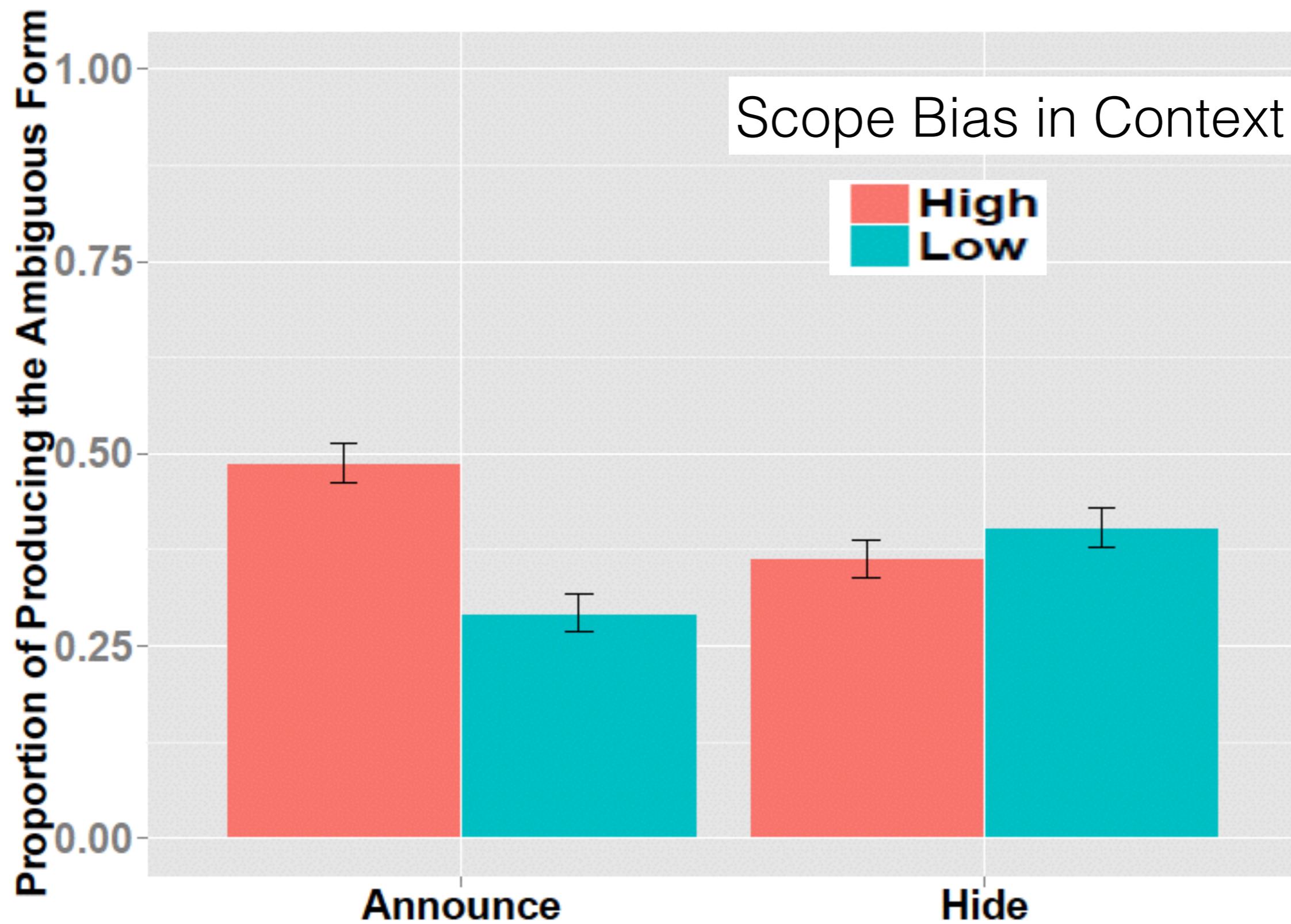
Emily **hid**

which city

built

her team discovered

# Averaged Production Bias



# Linking comprehension and production



estimated by the truth value judgment task

P (High scope reading | ambiguous sentence form)

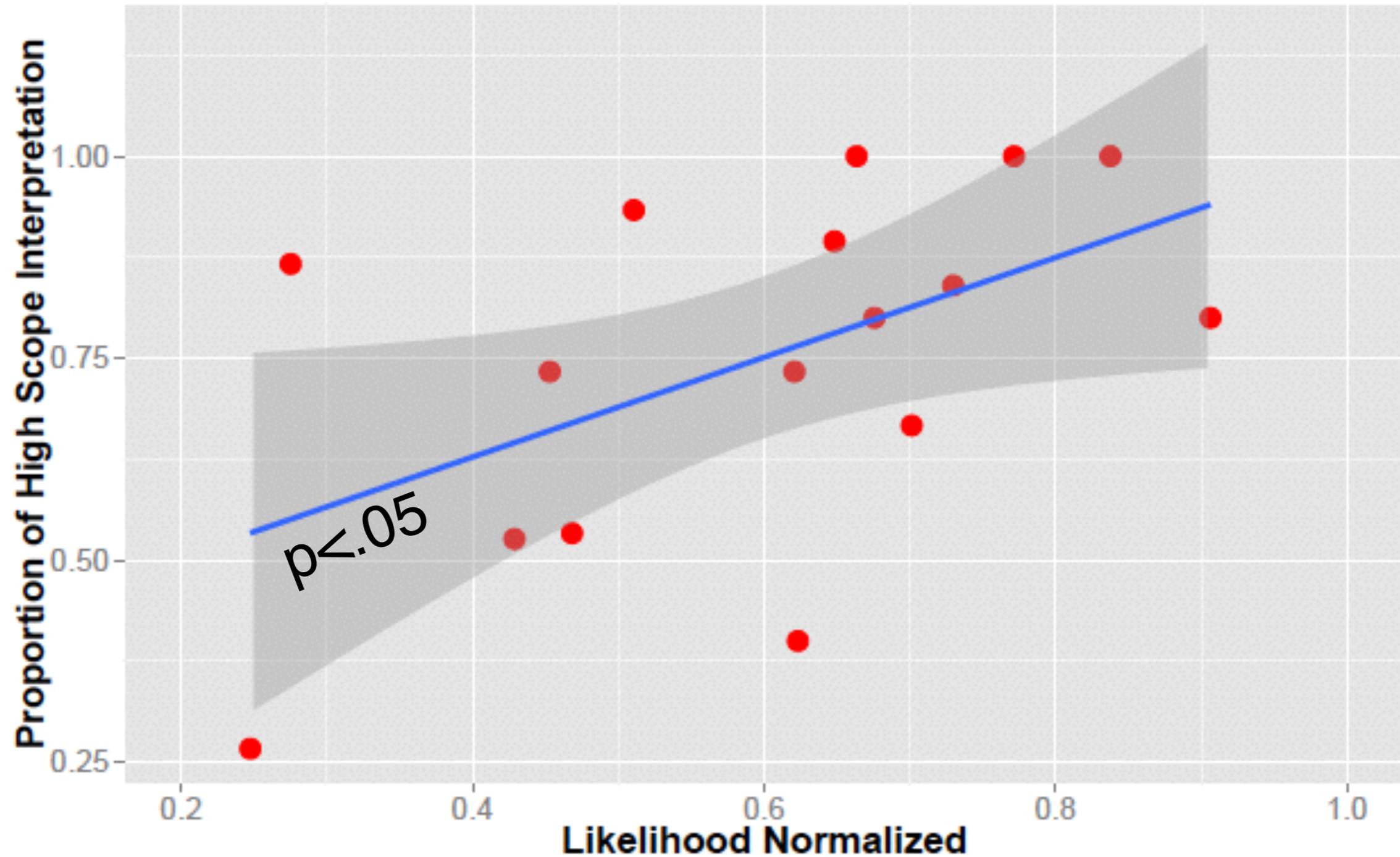
$\propto$   $\frac{P(\text{ambiguous form} \mid \text{High reading})}{$

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



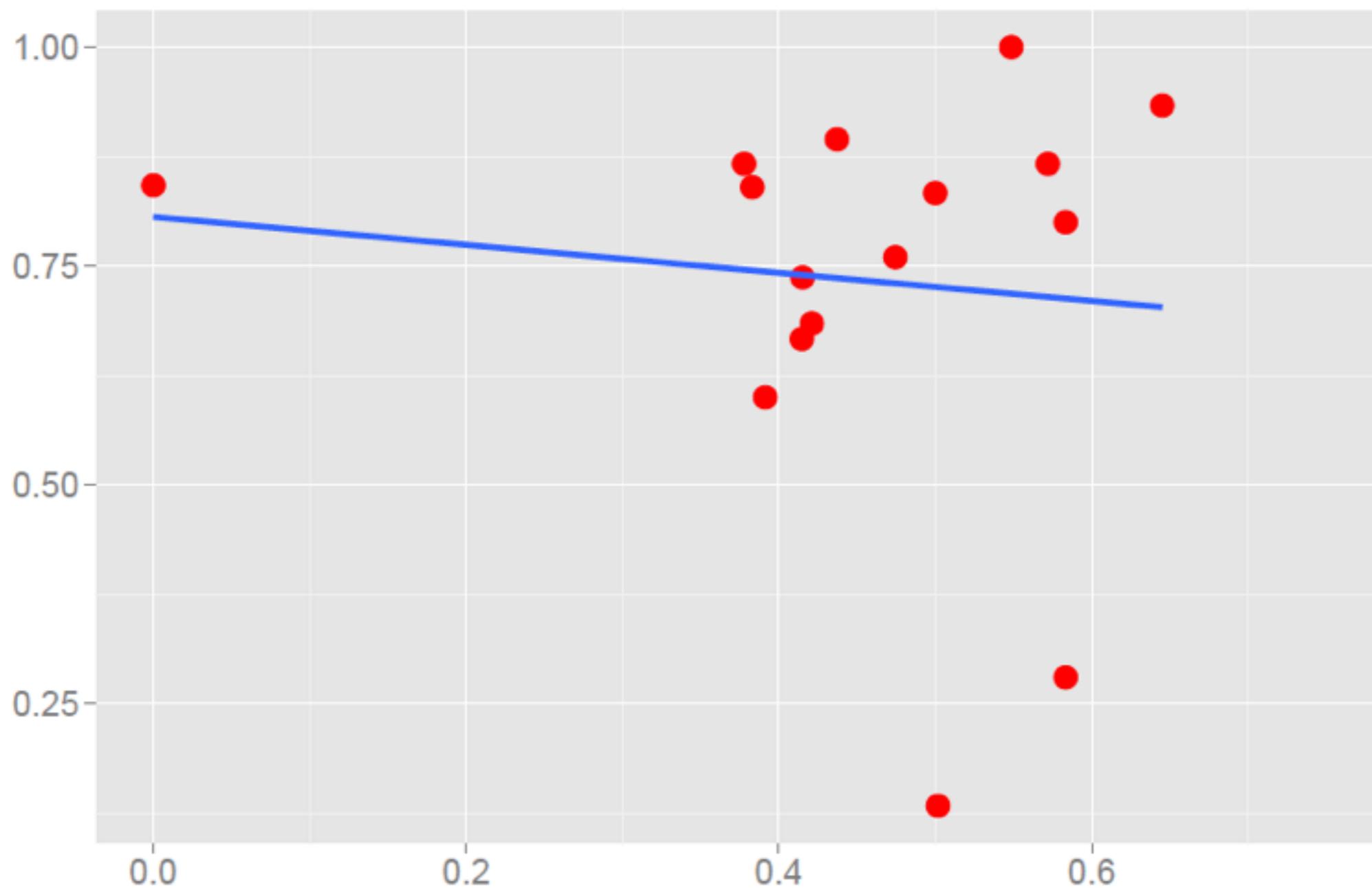
estimated by a production task

# When the matrix verb is the “announce” type



# When the matrix verb is the “hide” type

**Proportion of High Scope Interpretation**



**Normalized Likelihood**

**hide + proposition = didn't announce + proposition**

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

∝

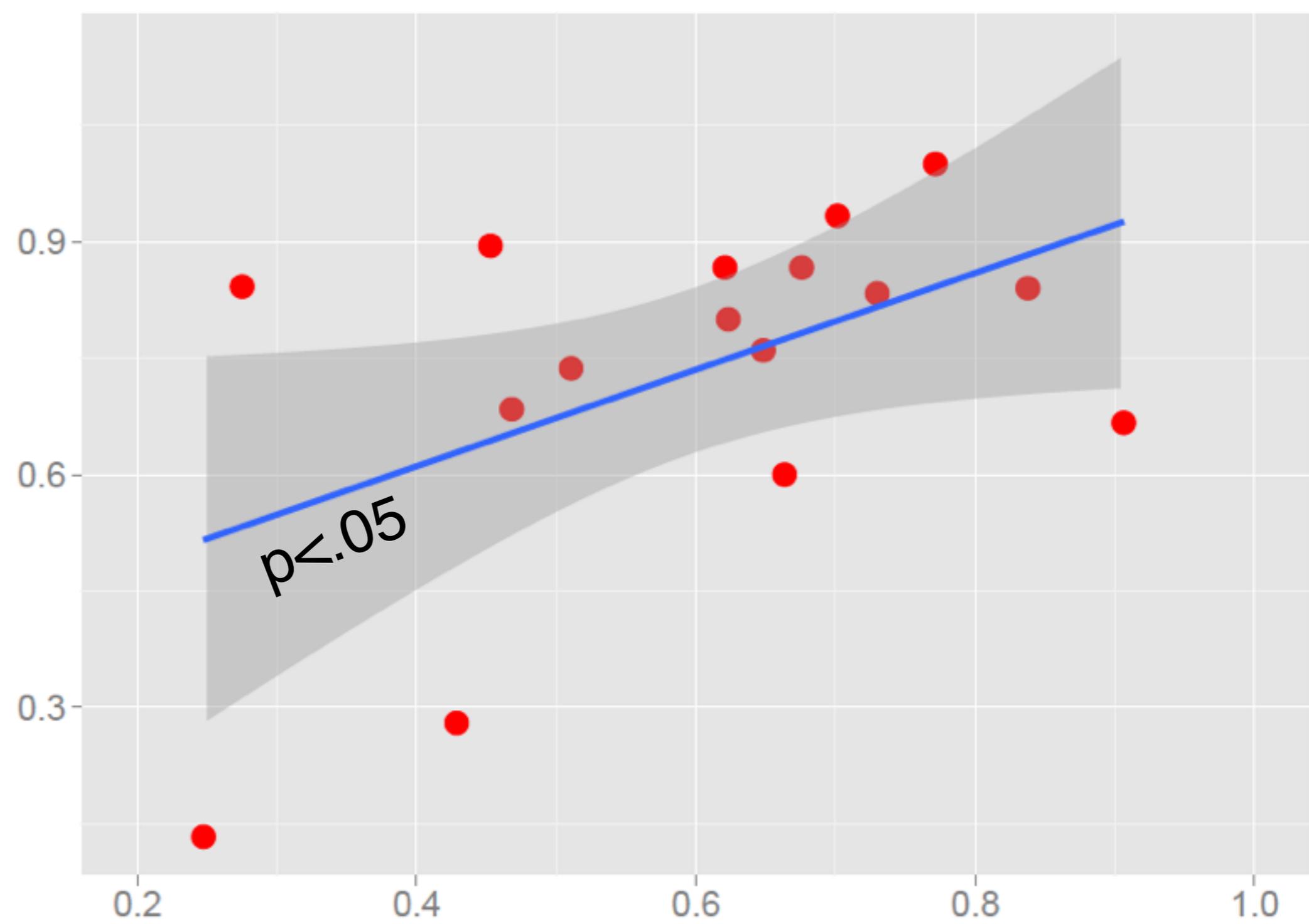
P (ambiguous form with “**announce**” | **High** reading)

---

P (ambiguous form with “**announce**” | **High** reading)

+ P (ambiguous form with “**announce**” | **Low** reading)

**Proportion of High Scope Interpretation  
estimated for “hide”**



**Normalized Likelihood estimated for “announce”**

# 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)

$$\propto \frac{P(\text{ambiguous form} \mid \text{High reading}) \times P(\text{High reading})}{P(\text{ambiguous form} \mid \text{High reading}) \times P(\text{High reading}) + P(\text{ambiguous form} \mid \text{Low reading}) \times P(\text{Low reading})}$$

## Target sentence (unambiguous)

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

o **True**

parsing failure

o **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**.

- o **True**

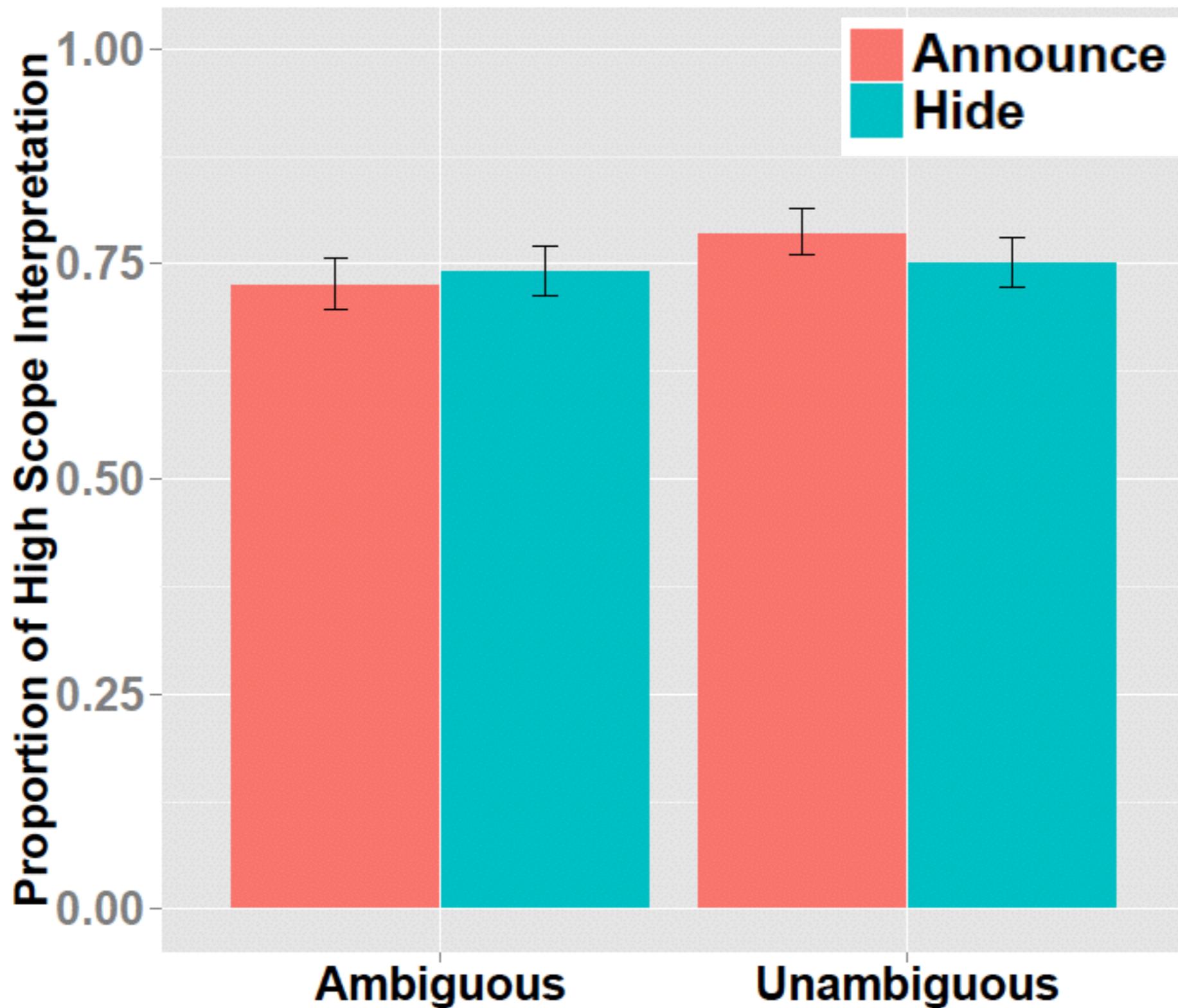
Indicate **high** scope reading

“Emily hid (the fact that) **which city** her team believed was built by aliens.”

- o **False**

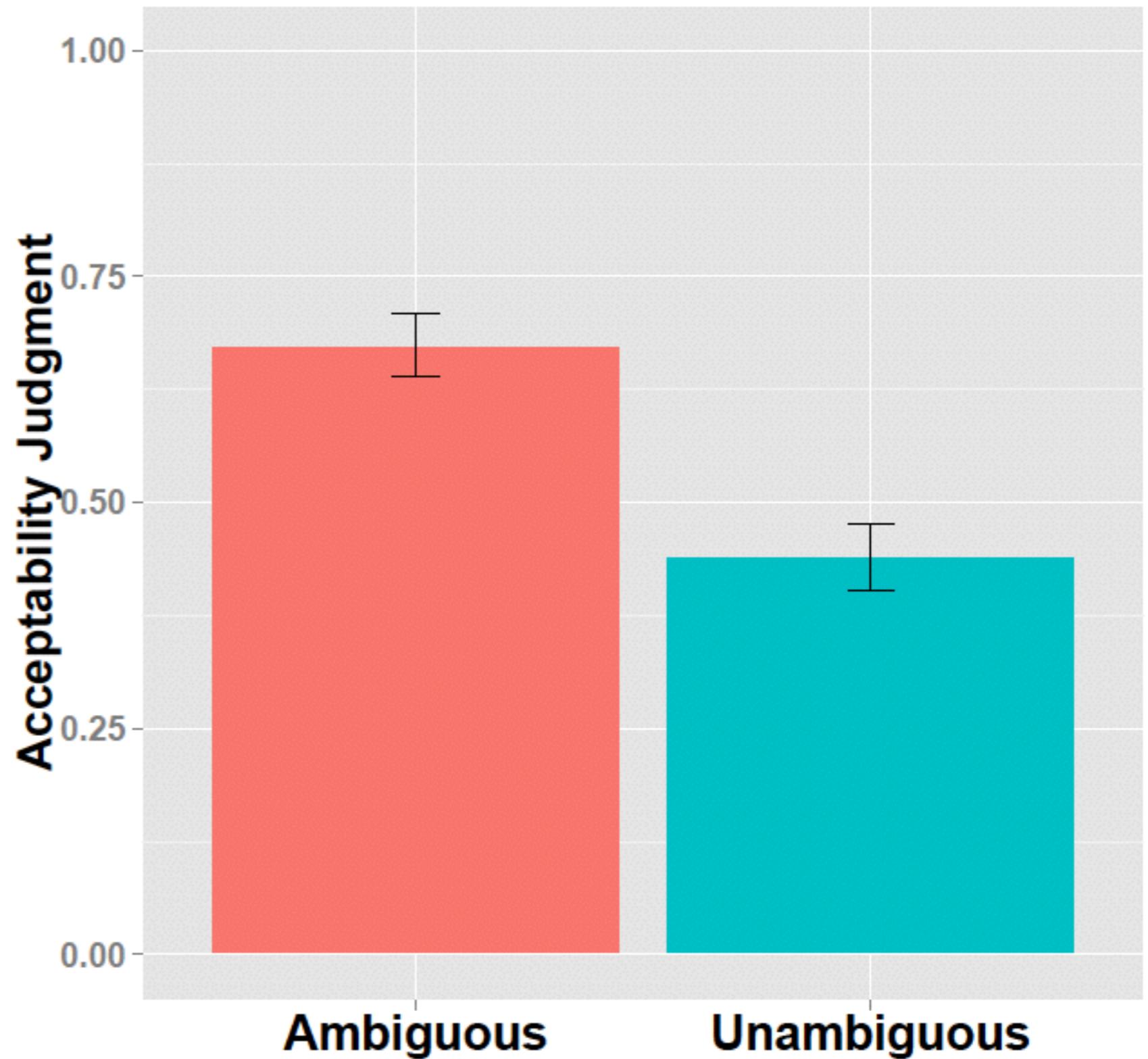
parsing failure

# Proportion of High Scope Readings



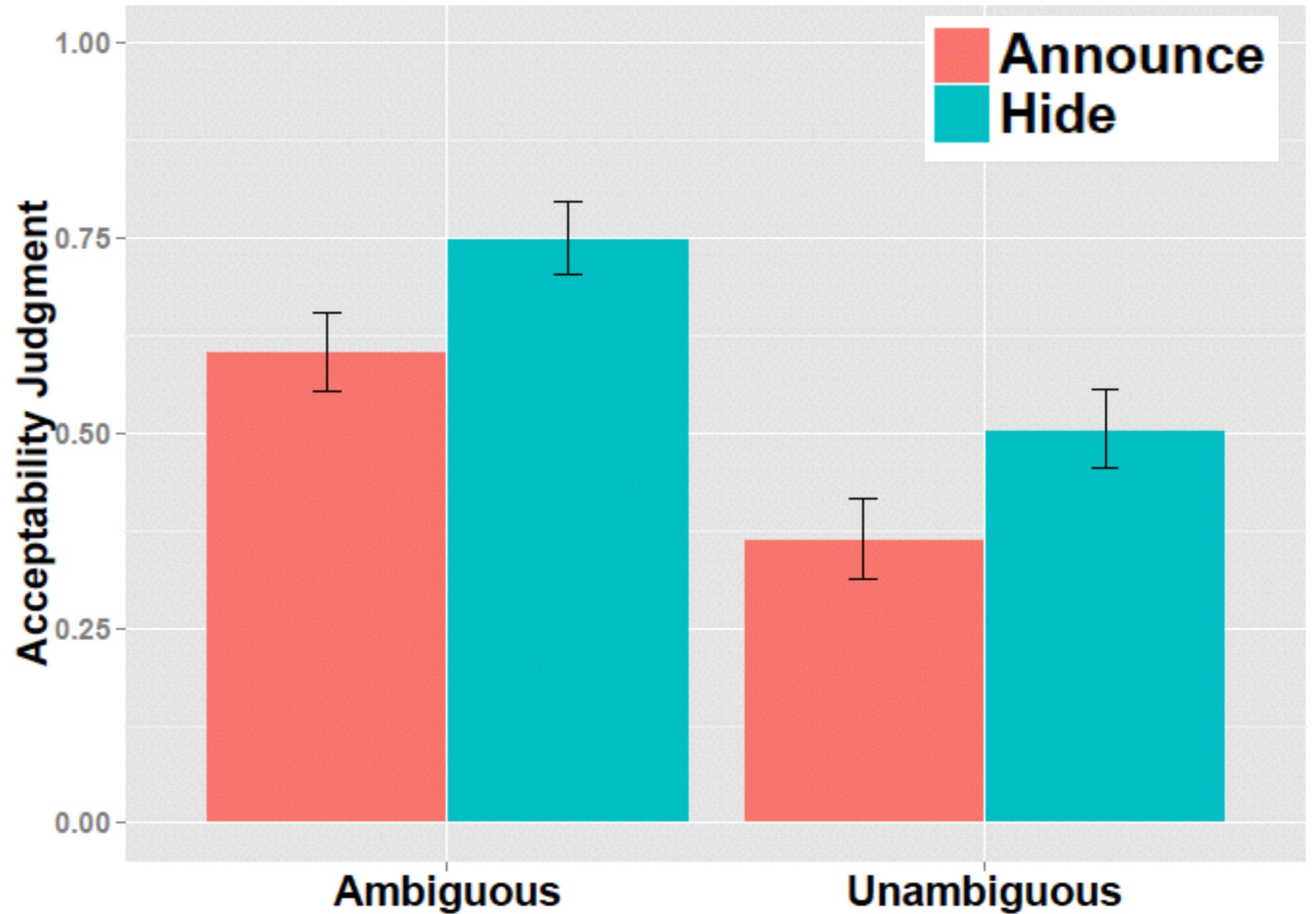
# Experiment 6

## Acceptability in context



# Experiment 6

## Acceptability in context



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*]

V2 know

...wonder[CP1, +Q... believe[CP2, -Q ... *WH*]

V2 believe

# Experiment 5: estimating the prior (subject n=30)

## Dependent variable:

We calculated the preference proportion for each of the scope interpretations

A neutral context



A force choice task between two situations that represent the two scope interpretations

Basic procedure

# 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名字保密。”

**What we get:**



The prior probability of  
each scope interpretation

P (Low scope situation)

P (High scope situation)

# The average prior probability of the two interpretations

