

# Evidence of accurate logical reasoning in online sentence comprehension

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Maksymilian Dąbkowski<sup>1</sup>, Roman Feiman<sup>2</sup>

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<sup>1</sup>University of California, Berkeley, <sup>2</sup>Brown University

slides available at <https://ling.auf.net/lingbuzz/005989>

# Introduction

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- what is the status of logic in thought?
- logic studies relations among propositions

## Dictum de omni

All rats love to eat.

∴ All spotted rats love to eat.

- do such schemata capture the nature of thought?

- **psychology** has focused on **difficulties in logical reasoning**
  - Wason's (1968) selection tasks easier when ecologically valid (Cheng and Holyoak, 1985, 1989; Cheng, Holyoak, et al., 1986)
  - dual-process theories (Evans and Stanovich, 2013; Kahneman, 2011)

- **formal semantics** presupposes **logical ability**  
*the logical notions are embedded in our deepest nature, in the very form of our language and thought*

Chomsky (1988, p. 99)

- linguists predict some **logical thought as effortless as language**
- can we find **evidence for spontaneous logical computation?**
- **entailment**: if  $p$  is true, **then**  $q$  is also true

## Dictum de omni

All rats love to eat.

∴ All spotted rats love to eat.

## Methods

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- two novel self-paced reading experiments
- tested for signatures of accurate inferences between quantified sentences
- experiment 1 involved detecting logical contradictions
- experiment 2 leveraged variable entailments of the first and second arguments of quantifiers to detect incorrect inferences
- preregistered design and analyses on OSF

## Experiment 1

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# experiment 1

- tested whether speakers detect logical contradictions
- 400 participants on Amazon Mechanical Turk
- 12 target items displayed line by line
- 6 conditions differing in quantifiers

## Test item

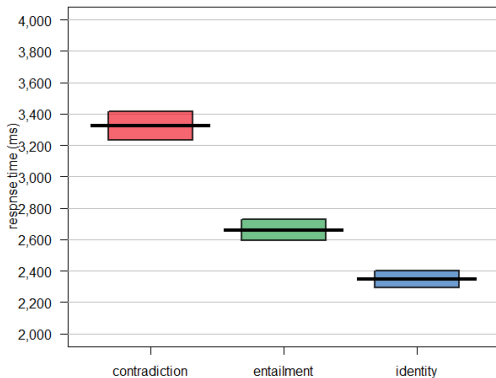
- (1) *A group of scientists wanted to know whether spotted rats,*
- (2) *who are pickier eaters than other rats, liked a new kind of food.*
- (3) *They tested white, black, and spotted rats of both sexes.*
- (4) *The scientists discovered that QUANT1 of the rats loved the food.*
- (5) *Now that they knew that QUANT2 of the rats loved the food,*
- (6) *they decided to issue a recommendation based on their findings.*

- measured variable: RT of the conclusion line (5)
- participants were asked unrelated comprehension questions
  - *The researchers studied rodents.*

# experiment 1 conditions

	QUANT1	QUANT2
IDENTITY	<i>some</i> of the rats loved . . . . they knew that	<i>some</i> of the rats . . .
IDENTITY	<i>not all</i> of the rats loved . . . they knew that	<i>not all</i> of the rats . . .
ENTAILMENT	<i>all</i> of the rats loved . . . . . they knew that	<i>some</i> of the rats . . .
ENTAILMENT	<i>none</i> of the rats loved . . . . they knew that	<i>not all</i> of the rats . . .
CONTRADICTION	<i>none</i> of the rats loved . . . . they knew that	<i>some</i> of the rats . . .
CONTRADICTION	<i>all</i> of the rats loved . . . . . they knew that	<i>not all</i> of the rats . . .

# experiment 1 results



- identity
- entailment
- contradiction

LMER effect between  
contradiction and  
entailment:  $\chi^2 = 161.31$   
 $p < 0.001$

## Experiment 2

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## experiment 2

- same paradigm to detect subtler unlicensed inferences (n = 400)
- manipulated quantifiers and premise quantifier's 1<sup>st</sup> arg

### Test item

- (1) *A group of scientists wanted to know whether spotted rats,*
- (2) *who are pickier eaters than other rats, liked a new kind of food.*
- (3) *They tested white, black, and spotted rats of both sexes.*
- (4) *The scientists discovered that QUANT of the ((male) spotted) rats loved the food.*
- (5) *Now that they knew that QUANT of the spotted rats loved the food,*
- (6) *they decided to issue a recommendation based on their findings.*

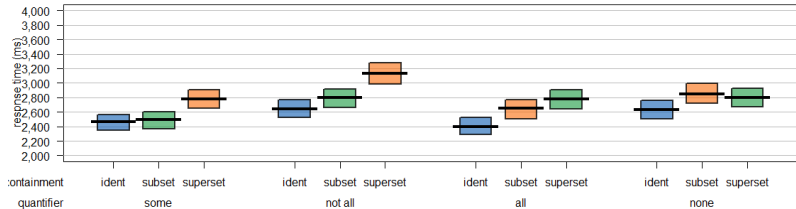
- 4 quantifiers × 3 containment relations = 12 conditions
  - 4 conditions: **premise identical to (trivially entails) conclusion**
  - 4 conditions: **premise entails conclusion**
  - 4 conditions: **premise does not entail conclusion**
- within quantifier, critical lines have identical lexical content

# experiment 2 conditions, full

	SOME	NOT ALL	ALL	NONE
SUBSET →	... <b>some</b> of the <b>male spotted rats</b> loved the food. Now that they knew that <b>some</b> of the <b>spotted rats</b> ...	... <b>not all</b> of the <b>male spotted rats</b> loved the food. Now that they knew that <b>not all</b> of the <b>spotted rats</b> ...	... <b>all</b> of the <b>male spotted rats</b> loved the food. Now that they knew that <b>all</b> of the <b>spotted rats</b> ...	... <b>none</b> of the <b>male spotted rats</b> loved the food. Now that they knew that <b>none</b> of the <b>spotted rats</b> ...
of spotted rats →				
IDENTICAL →	... <b>some</b> of the <b>spotted rats</b> loved the food. Now that they knew that <b>some</b> of the <b>spotted rats</b> ...	... <b>not all</b> of the <b>spotted rats</b> loved the food. Now that they knew that <b>not all</b> of the <b>spotted rats</b> ...	... <b>all</b> of the <b>spotted rats</b> loved the food. Now that they knew that <b>all</b> of the <b>spotted rats</b> ...	... <b>none</b> of the <b>spotted rats</b> loved the food. Now that they knew that <b>none</b> of the <b>spotted rats</b> ...
to spotted rats →				
SUPERSET →	... <b>some</b> of the <b>rats</b> loved the food. Now that they knew that <b>some</b> of the <b>spotted rats</b> ...	... <b>not all</b> of the <b>rats</b> loved the food. Now that they knew that <b>not all</b> of the <b>spotted rats</b> ...	... <b>all</b> of the <b>rats</b> loved the food. Now that they knew that <b>all</b> of the <b>spotted rats</b> ...	... <b>none</b> of the <b>rats</b> loved the food. Now that they knew that <b>none</b> of the <b>spotted rats</b> ...
of spotted rats →				

- trivially entailed
- entailed
- not entailed

# experiment 2 results



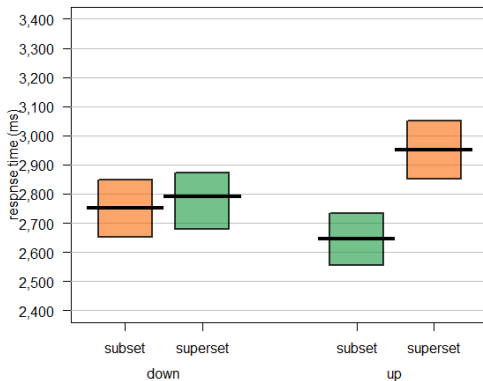
- trivial
- entailed
- not entailed

subset: *male spotted rats*  $\prec$  *spotted rats*

ident: *spotted rats*  $\prec$  *spotted rats*

superset: *rats*  $\prec$  *spotted rats*

## experiment 2 results, quantifiers grouped by entailment



■ entailed

subset: *male spotted rats*  $\prec$  *spotted rats*

■ not entailed

superset: *rats*  $\prec$  *spotted rats*

containment (subset vs. superset)  $\times$  entailment (up vs. down):  $\chi^2 = 10.9$ ,  $p < 0.001$



## Discussion

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- language involves accurate and spontaneous logical computations
- differs from dual-process theories of cognition
  - it is assumed that people's intuitive logical knowledge emerges from a learning process in which key principles have been practiced to automaticity*

De Neys and Pennycook (2019)

- consistent with some logic being naturally intuitive
  - natural logic in reasoning (e.g. Braine and O'Brien, 1998)
  - logic (L-analyticity) in grammar (e.g. Gajewski, 2002)
- inference derives from compositionality?

thank you!

slides available at

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