Evidence of accurate logical reasoning in online sentence comprehension

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

Introduction

logic in thought

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

Dictum de omni

All rats love to eat.
$\therefore$ All spotted rats love to eat.

- do such schemata capture the nature of thought?

logic in psychology

- 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)

logic in linguistics

- **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

methods

- 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

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,*

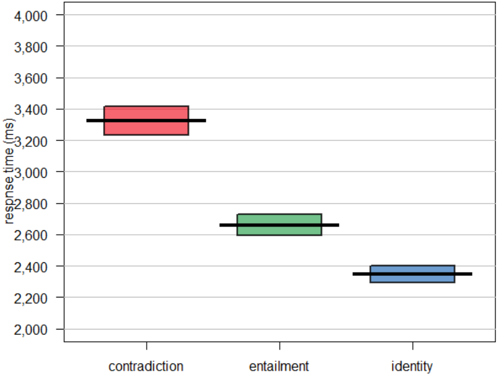
(6) *they decided to issue a recommendation based on their findings.*

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

experiment 1 conditions

	QUANT1	QUANT2
IDENTITY	***some*** *of the rats loved . . . .*	*they knew that* ***some*** *of the rats . . .*
IDENTITY	***not all*** *of the rats loved . . .*	*they knew that* ***not all*** *of the rats . . .*
ENTAILMENT	***all*** *of the rats loved . . . .*	*they knew that* ***some*** *of the rats . . .*
ENTAILMENT	***none*** *of the rats loved . . . . .*	*they knew that* ***not all*** *of the rats . . .*
CONTRADICTION	***none*** *of the rats loved . . . . .*	*they knew that* ***some*** *of the rats . . .*
CONTRADICTION	***all*** *of the rats loved . . . .*	*they knew that* ***not all*** *of the rats . . .*

experiment 1 results



- identity
- entailment
- contradiction

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

$p < 0.001$

Experiment 2

experiment 2

- same paradigm to detect subtler unlicensed inferences (n = 400)
- manipulated quantifiers and premise quantifier's 1st 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.*

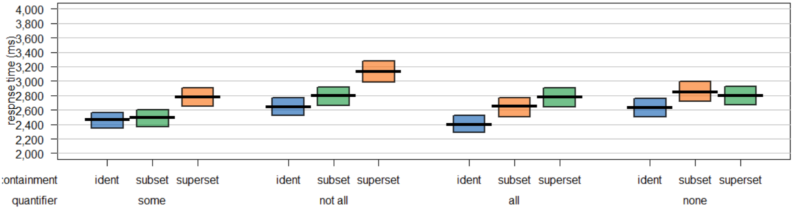
- 4 quantifiers × 3 containment relations = 12 conditions
  - 4 conditions: premise identical to (trivally entails) conclusion
  - 4 conditions: premise entails conclusion
  - 4 conditions: premise does not entail conclusion
- within quantifier, critical lines have identical lexical content

experiment 2 conditions, full

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

- trivially entailed
- entailed
- not entailed

experiment 2 results



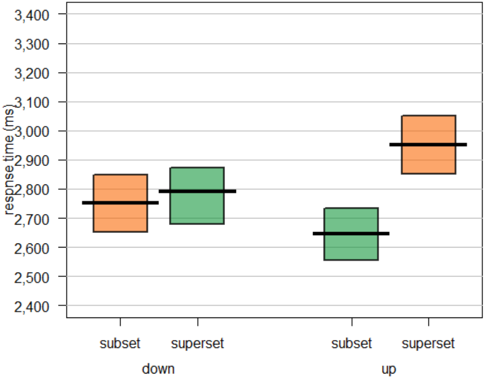
- trivial
- entailed
- not entailed

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) × entailment (up vs. down): $\chi^2 = 10.9$, $p < 0.001$

Discussion

discussion

- 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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