Evidence of accurate logical reasoning in online sentence comprehension

47th annual meeting of the Society for Philosophy and Psychology

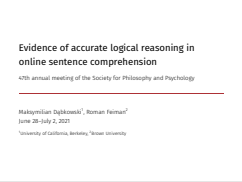
Maksymilian Dąbkowski[1], Roman Feiman[2]

June 28–July 2, 2021

[1]University of California, Berkeley, [2]Brown University

2021-05-29

Evidence of accurate logical reasoning in online sentence comprehension



Introduction

logic in thought

- what is the status of logic in thought?

What is the status of logic in thought?

logic in thought
- what is the status of logic in thought?

logic in thought

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

Logic, to characterize it broadly, is the formal study of relations which obtain among propositions.

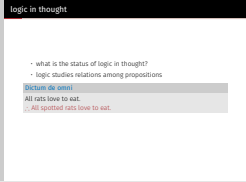
logic in thought

- 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.



Logical schemata capture rules which govern correct inference. The example here is the *dictum de omni*, which is the principle that whatever is affirmed of a kind can be affirmed of its subkind.

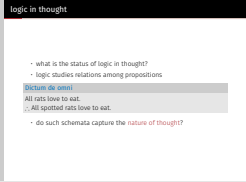
logic in thought

- 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?



While such schemata capture normatively accurate inferences, there has been a long standing debate over what their status is in human cognition. This is to say, are such logical schemata the rules of thought?

logic in psychology

logic in psychology

The status of logic in thought has been viewed very differently by the disciplines of psychology and linguistics.

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)

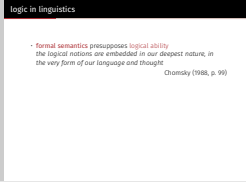
logic in psychology
- psychology has focused on difficulties in logical reasoning
  - Wason's (1968) selection tasks easier when ecologically valid (Cheng and Holyoak, 1985, 1989; Cheng, Holyoak, et al., 1986)
  - dual-process theories (Evans and Stanovich, 2013; Kahneman, 2011)

Research in psychology has tended to focus on documenting which logical tasks are more difficult than others and understanding why.

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)

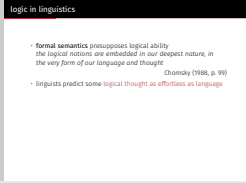


On on the hand, certain branches of linguistics posit that language has a kind of logical form. Thus, implicitly, linguists credit language-users with a rather high degree of logical sophistication.

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

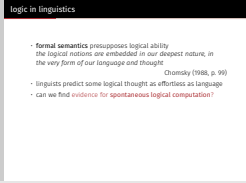
  Chomsky (1988, p. 99)
- linguists predict some logical thought as effortless as language



This view of language predicts that at least some inferencesshould be as intuitive, automatic, and effortless as thought and language themselves.

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**?



Thus, the following question arises: Can we find some evidence for fast and automatic reasoning?

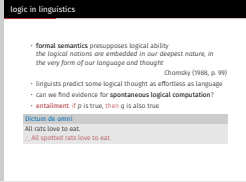
logic in linguistics

- **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.



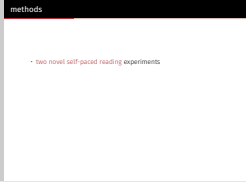
To answer this question, in our study, we focused on the notion of entailment. Entailment is a relation between propositions such that when one proposition is true, another proposition is always also true. Entailment has been argued to be based in the structure of language. Thus, it is a good candidate for a logical notion that is processed fast and automatically.

Methods

methods

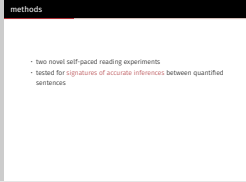
- two novel self-paced reading experiments

We designed two novel self-paced reading experiments.



methods

- two novel self-paced reading experiments
- tested for signatures of accurate inferences between quantified sentences



We tested for signatures of normatively accurate logical inferences between quantified sentences during sentence comprehension.

methods

- two novel self-paced reading experiments
- tested for signatures of accurate inferences between quantified sentences
- experiment 1 involved detecting logical contradictions

methods
- two novel self-paced reading experiments
- tested for signatures of accurate inferences between quantified sentences
- experiment 1 involved detecting logical contradictions

Experiment 1 tested whether speakers detect logical contradictions.

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

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

And Experiment 2 tested detecting something subtler... which is incorrect inferences in the absence of downright contradictions.

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

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

But first, experiment 1.

experiment 1
- tested whether speakers detect logical contradictions

experiment 1

- tested whether speakers detect logical contradictions
- 400 participants on Amazon Mechanical Turk

We ran 400 participants on Amazon Mechanical Turk.

experiment 1
- tested whether speakers detect logical contradictions
- 400 participants on Amazon Mechanical Turk

experiment 1

- tested whether speakers detect logical contradictions
- 400 participants on Amazon Mechanical Turk
- 12 target items displayed line by line

experiment 1
- tested whether speakers detect logical contradictions
- 400 participants on Amazon Mechanical Turk
- 12 target items displayed line by line

Participants read 12 target items displayed line-by-line, with line breaks at clausal boundaries.

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

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

Across participants, each item appeared in six conditions which differed in what quantifiers were used.

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,*

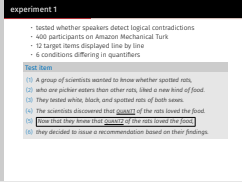
(2) *who are pickier eaters than other rats, liked a new kind of food.*

(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.*



Each item contained a “premise” in line 4 and a “conclusion” in line 5, which began with *now that they knew that …*, presupposing that what comes next appeared earlier in the discourse. Otherwise, the two lines differed only in the quantifiers they used.

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.*

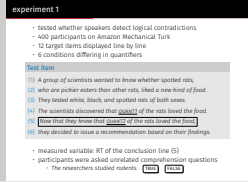
(3) *They tested white, black, and spotted rats of both sexes.*

(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.*

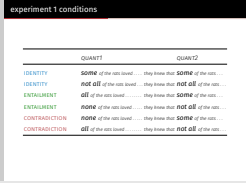
- measured variable: RT of the conclusion line (5)
- participants were asked unrelated comprehension questions
  - *The researchers studied rodents.* TRUE FALSE



We measured the reading times of the boxed conclusion line as a proxy for processing costs.

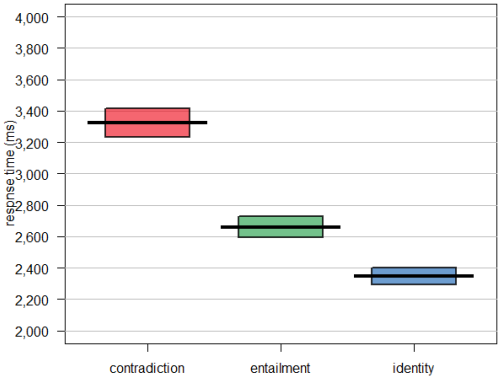
experiment 1 conditions

	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 . . .*



There were two conditions where the premise was identical to the conclusion, two conditions where it differed from but entailed the conclusion, and two conditions where it contradicted it.

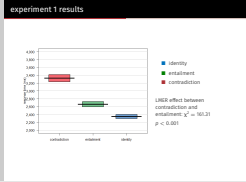
experiment 1 results



identity
entailment
contradiction

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

$p < 0.001$



All of the conditions were significantly different from each other. Participants took significantly longer to advance to the conclusion line when it contradicted the premise than when it was entailed by the premise. This is consistent with rapid, normatively accurate sensitivity to the logical relations between these clauses.

Experiment 2

experiment 2

- same paradigm to detect subtler unlicensed inferences (n = 400)

experiment 2
- same paradigm to detect subtler unlicensed inferences (n = 400)

Experiment 2 used the same paradigm to test for the capacity to detect subtler unlicensed inferences, even in the absence of strict contradictions.

experiment 2

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

experiment 2
- same paradigm to detect subtler unlicensed inferences (n = 400)
- manipulated quantifiers and premise quantifier's 1st arg

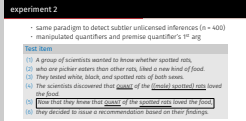
We manipulated the quantifiers in both the premise and the conclusion … … as well as the noun phrase in first argument of the quantifier in the premise.

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.*



In the test items, we changed lines four and five to manipulate whether the conclusion was entailed by the premise.

Unlike experiment 1, here, the quantifier was kept constant between the premise and the conclusion. The premise noun phrase appeared with two, one, or zero modifiers. The conclusion noun phrase always appeared with one modifier.

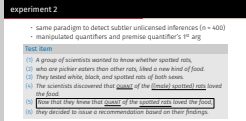
experiment 2

- 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



Thus, the premise noun phrase was a subset of, identical to, or a superset of the conclusion noun phrase. **Four** quantifiers and **three** containment relations yielded twelve experimental conditions in total, which will ultimately reduce to a two-by-two.

Depending on the combination of the quantifier and containment,

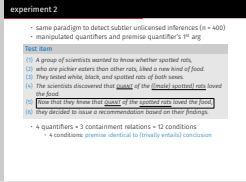
experiment 2

- 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



there were four conditions where the premise was identical to the conclusion, and so it trivially entailed it,

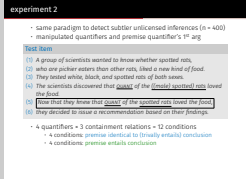
experiment 2

- 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



four conditions where the premise differed from but entailed the conclusion,

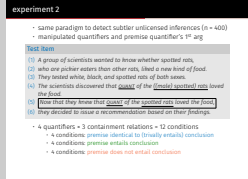
experiment 2

- 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



and four conditions where the premise did not entail the conclusion.

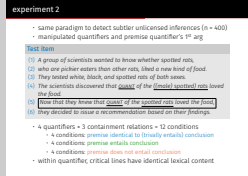
experiment 2

- 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

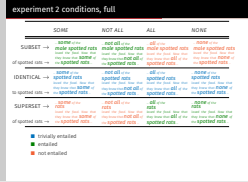


An elegant feature of our design is that within quantifier, we're looking at differences in reading times among lines that have identical lexical content, so whatever the difference is on the critical line, that difference *must be* due to preceding context.

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

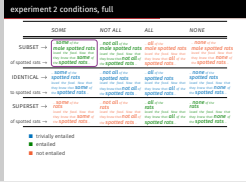


Here, you can see the twelve conditions schematized.

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

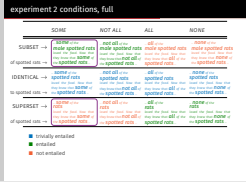


For example, if we look at a quantifier which is upward entailing, such as "some," when the premise noun phrase is a subset of the conclusion noun phrase, the conclusion follows.

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

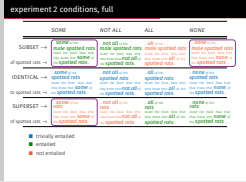


When the premise noun phrase is a superset of the conclusion noun phrase we get an unlicensed inference.

experiment 2 conditions, full

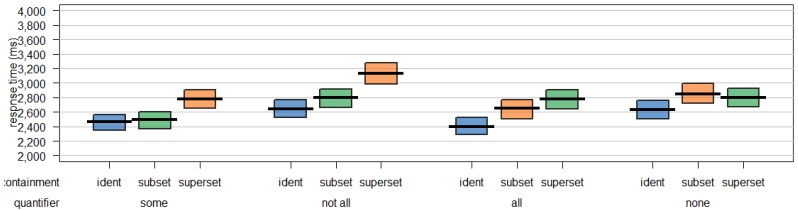
	SOME	*NOT ALL*	*ALL*	*NONE*
SUBSET → of spotted rats →	… **some** of the **male spotted rats** loved the food. Now that they knew that **some** of the **spotted rats** …	… **not all** of the **male spotted rats** loved the food. Now that they knew that **not all** of the **spotted rats** …	… **all**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



When we look at a quantifier that is downward-entailing, such as “none,” the pattern reverses.

experiment 2 results

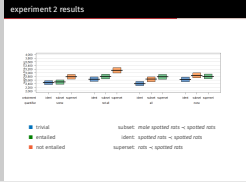


- trivial
- entailed
- not entailed

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

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

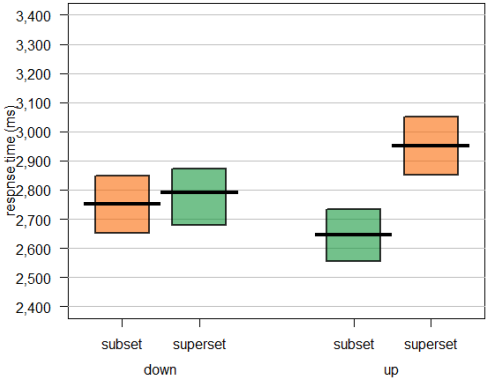
superset: *rats* $\prec$ *spotted rats*



In the results of Experiment 2, the twelve conditions are grouped by quantifiers.

We find a main effect of containment, with superset conditions generally slower than subset. What matters, however, is the interaction of entailment and containment, which you can see as the difference between the green bars and the orange bars within each quantifier.

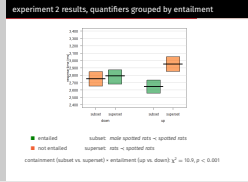
experiment 2 results, quantifiers grouped by entailment



■ entailed — subset: *male spotted rats* ≺ *spotted rats*

■ not entailed — superset: *rats* ≺ *spotted rats*

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

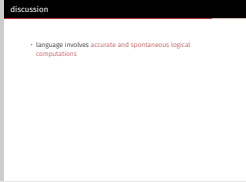


Here, we group the upward- and downward-entailing quantifiers together and drop the "ident" conditions to show the relevant interaction of containment and entailment more clearly. This interaction is significant, showing rapid sensitivity to logical relations between clauses.

Discussion

discussion

- language involves accurate and spontaneous logical computations

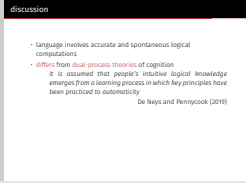


In summary, our findings suggest that language processing involves automatic, accurate, and spontaneous logical computations, even in the absence of a task that requires making these inferences to verify text comprehension.

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)



This view differs from what is assumed by dual-process theories of cognition.

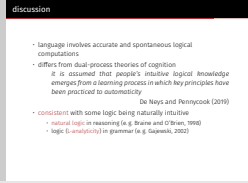
discussion

- 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)

On the other hand, our findings are anticipated by frameworks which take some logical inferences as naturally intuitive.

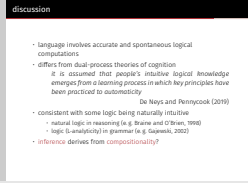


discussion

- 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?



Thus, we conclude the compositionality of language and at least *some* inferential thought may both derive from the same cognitive mechanisms.

thank you!

thank you!

Thank you very much!

references i

- Braine, Martin D. S. and David P. O'Brien (1998). *Mental logic*. Psychology Press.
- Cheng, Patricia W. and Keith J. Holyoak (1985). "Pragmatic Reasoning Schemas". In: *Cognitive Psychology* 17.4, pp. 391–416.
- Cheng, Patricia W. and Keith J. Holyoak (1989). "On the natural selection of reasoning theories". In: *Cognition*.
- Cheng, Patricia W., Keith J. Holyoak, Richard E. Nisbett, and Lindsay M. Oliver (1986). "Pragmatic versus syntactic approaches to training deductive reasoning". In: *Cognitive Psychology* 18.3, pp. 293–328.
- De Neys, Wim and Gordon Pennycook (2019). "Logic, fast and slow: Advances in dual-process theorizing". In: *Current Directions in Psychological Science* 28.5, pp. 503–509.

references i

Braine, Martin D. S. and David P. O'Brien (1998). *Mental logic*. Psychology Press.
Cheng, Patricia W. and Keith J. Holyoak (1985). "Pragmatic Reasoning Schemas". In: *Cognitive Psychology* 17.4, pp. 391–416.
Cheng, Patricia W. and Keith J. Holyoak (1989). "On the natural selection of reasoning theories". In: *Cognition*.
Cheng, Patricia W., Keith J. Holyoak, Richard E. Nisbett, and Lindsay M. Oliver (1986). "Pragmatic versus syntactic approaches to training deductive reasoning". In: *Cognitive Psychology* 18.3, pp. 293–328.
De Neys, Wim and Gordon Pennycook (2019). "Logic, fast and slow: Advances in dual-process theorizing". In: *Current Directions in Psychological Science* 28.5, pp. 503–509.

references ii

- Evans, Jonathan St. B. T. and Keith E. Stanovich (2013). “Dual-process theories of higher cognition: Advancing the debate”. In: *Perspectives on Psychological Science* 8.3, pp. 223–241.
- Gajewski, Jon (2002). “L-analyticity and natural language”. Manuscript. Cambridge, MA: MIT.
- Kahneman, Daniel (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.
- Wason, Peter C. (1968). “Reasoning about a rule”. In: *Quarterly Journal of Experimental Psychology* 20.3, pp. 273–281.

references ii

Evans, Jonathan St. B. T. and Keith E. Stanovich (2013). “Dual-process theories of higher cognition: Advancing the debate”. In: *Perspectives on Psychological Science* 8.3, pp. 223–241.
Gajewski, Jon (2002). “L-analyticity and natural language”. Manuscript. Cambridge, MA: MIT.
Kahneman, Daniel (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.
Wason, Peter C. (1968). “Reasoning about a rule”. In: *Quarterly Journal of Experimental Psychology* 20.3, pp. 273–281.