Evidence of accurate logical reasoning in online sentence comprehension

47th annual meeting of the Society for Philosophy and Psychology

Maksymilian Dąbkowski¹, Roman Feiman² June 28–July 2, 2021

Evidence of accurate logical reasoning in online sentence comprehension

online sentence comprehension

Maksymilian Dąbkowski¹, Roman Feima June 28-July 2, 2021 ¹universty of California, Beckelay, ²krown Universi

¹University of California, Berkeley, ²Brown University

Introduction

Evidence of accurate logical reasoning in online sentence comprehension

Introduction

Introduction

• what is the status of logic in thought?

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Introduction

logic in thought

· what is the status of logic in thought?

What is the status of logic in thought?

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

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Introduction
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.

- 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.

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Introduction

└ logic in thought

a kind can be affirmed of its subkind.

	· what is the status of logic in thought?
	 logic studies relations among propositions
D	ictum de omni
	II 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

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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?

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Introduction

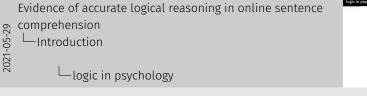


—logic in thought

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?

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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)

Evidence of accurate logical reasoning in online sentence comprehension Introduction -logic in psychology

(Cheng and Holyoak, 1985, 1989; Cheng, Holyoak, et al., 1986)

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

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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)

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- 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)

—logic in linguistics

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.

- 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

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Introduction

-logic in linguistics

- formal semantics prosupposes logical ability:
the logical nations are embedded in our despets nature, in
the very form of our longuage and thought
Chamsky (1988, p. 9)
- linguists predict some logical thought as effortiers as language.

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

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 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?

Evidence of accurate logical reasoning in online sentence comprehension

Introduction

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	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?	

—logic in linguistics

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

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 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.

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Ingo in timpostos

* Termal seasatos, privapipora higinal ability
ste la logical nitribine are embedded in our despect nitribine, in
the very from it can be impose and thought the consequence of the distribution as logical temporal very can use find evidence for segmentation?

- can take the distribution of the consequence of the cons

—logic in linguistics

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.

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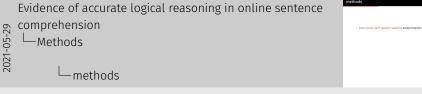
Methods

Evidence of accurate logical reasoning in online sentence comprehension

Methods

Methods

two novel self-paced reading experiments



We designed two novel self-paced reading experiments.

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

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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.

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∟methods

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

Evidence of accurate logical reasoning in online sentence comprehension

Methods

methods

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

Experiment 1 tested whether speakers detect logical contradictions.

- 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

Evidence of accurate logical reasoning in online sentence comprehension

Methods

 two novel self-paced reading experiments.
 tested for signatures of accurate inferences between quantified sentences.
 experiment limeland detecting logical contradictions.
 experiment 2 leveraged variable restallments of the first and second arguments of quantifiers to detect incorrect inferences.

—methods

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2021

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

- 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

Evidence of accurate logical reasoning in online sentence comprehension

Methods

two novel salf-paced reading experiments
 tested for signatures of accurate inferences between quantified
 experiment 1 involved detecting logical contradictions
 experiment 2 low-paced variable entailments of the first and
 second arguments of countries to detect incorrect inferences
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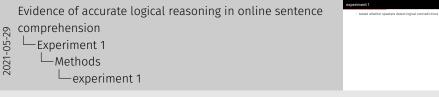
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-methods

Experiment 1

Experiment 1

 \cdot tested whether speakers detect logical contradictions



But first, experiment 1.

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

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Experiment 1

Methods

experiment 1

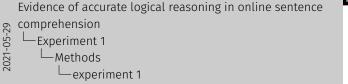
experiment 1

- teach shadher pepalven deact legod controlictors

- 400 participants on Amazon Mechanical Turk

We ran 400 participants on Amazon Mechanical Turk.

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



experiment 4

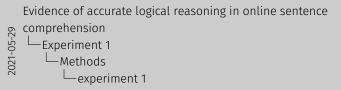
- seade whether opeales deset legical contradictions

- 4-do percipant or Annual Machines fluid

- 10 larger dates displayed the ky large

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

- 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 speaker, detect tagged contradictions
- 400 participants on Associate the second from
- 400 participants on Associate the second from
- 10 tagged time slighbyful libe by live
- 6 sandstons differing in quantifiers

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

- 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.

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 1

Methods

experiment 1



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.

- 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.

FALSE

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Experiment 1

Methods

Lexperiment 1



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 th	at SOME of the rats
IDENTITY	not all of the rats loved they knew th	at not all of the rats
ENTAILMENT	all of the rats loved they knew th	at SOMe of the rats
ENTAILMENT	none of the rats loved they knew th	at not all of the rats
CONTRADICTION	none of the rats loved they knew th	at SOMe of the rats
CONTRADICTION	all of the rats loved they knew th	at not all of the rats

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 1

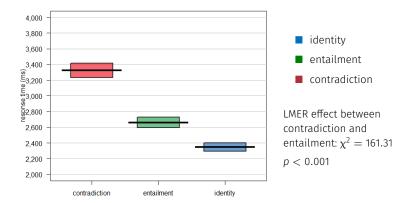
Methods

experiment 1 conditions



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

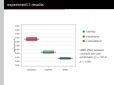


Evidence of accurate logical reasoning in online sentence comprehension

Experiment 1

Results

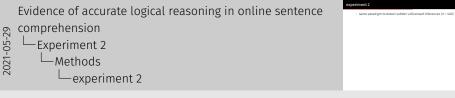
experiment 1 results



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.

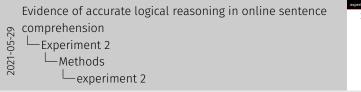
Experiment 2

• 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.

- same paradigm to detect subtler unlicensed inferences (n = 400)
- $\boldsymbol{\cdot}$ manipulated quantifiers and premise quantifier's 1^{st} arg



metal * 2

same pusadigm to detect subtler unificancial informace (n + 440)
manaputation quantiflers and premise quantiflers * 1º 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.

- 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.

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2



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.

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-Methods

-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

Evidence of accurate logical reasoning in online sentence comprehension

LExperiment 2



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,

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-Methods

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,
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- (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

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Methods

experiment 2



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

- 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 identical to (trivally entails) conclusion
 - · 4 conditions: premise entails conclusion

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Methods

experiment 2



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

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- 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

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Methods

experiment 2



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

- 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

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Methods

experiment 2



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.

	SOME	NOT ALL	ALL	NONE
$\overline{\text{SUBSET}} \rightarrow$	SOMe of the male spotted rats loved the food. Now that	male spotted rats	all of the male spotted rats loved the food. Now that	none of the male spotted rats loved the food. Now that
of spotted rats $ ightarrow$	they knew that SOME of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats
IDENTICAL \rightarrow	Some of the spotted rats loved the food. Now that they knew that Some of	not all of the spotted rats loved the food. Now that they knew that not all of	all of the spotted rats loved the food. Now that they knew that all of the	none of the spotted rats loved the food. Now that they knew that none of
to spotted rats →	the spotted rats	the spotted rats	spotted rats	the spotted rats
${\tt SUPERSET} \rightarrow$	SOME of the rats loved the food. Now that	not all of the rats loved the food. Now that	all of the rats loved the food. Now that	none of the rats loved the food. Now that
of spotted rats $ ightarrow$	they knew that SOMe of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats

- trivially entailed
- entailed
- not entailed

Evidence of accurate logical reasoning in online sentence
comprehension
Experiment 2
Methods
Lexperiment 2 conditions, full

	SOME	NOT ALL	ALL	NONE
SUBSET →	note your mole spotted rots had to find the day toy have the SOTHE of the spotted rots.	male spotted rats	- cli you made spotted rate that the first the that the same the clif of the spotted rate.	male spotted ro may be seen to the seen to provide the seen to the
IDENTICAL →	apotted rots too fee fee fee my less too 32 ft/d / m spotted rots	spotted rots spotted rots see the feet the rise reported rots	aported rots sported rots see the plat the see aported rots	spotted rets
SUPERSET →	- SO THE AT ANY FORE local the final line she they know the SO/THE AT IN ADDITION TO S.	not all year rats had be just become to be seen for all y	they have the \$60 of the	note you not to you you you you you you you you you yo

Here, you can see the twelve conditions schematized.

	SOME	NOT ALL	ALL	NONE
$\overline{\text{SUBSET}} \rightarrow$	some of the male spotted rats loved the food. Now that	loved the food. Now that	all of the male spotted rats loved the food. Now that	none of the male spotted rat. loved the food. Now tha
of spotted rats \rightarrow	they knew that SOME of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats
$\overline{IDENTICAL} o$	Some of the spotted rats loved the food. Now that they knew that SOME of	not all of the spotted rats loved the food. Now that they knew that not all of	all of the spotted rats loved the food. Now that they knew that all of the	none of the spotted rats loved the food. Now that they knew that none of
to spotted rats \rightarrow	the spotted rats	the spotted rats	spotted rats	the spotted rats
$ ext{SUPERSET} ightarrow$	some of the rats loved the food. Now that	not all of the rats loved the food. Now that	all of the rats loved the food. Now that	none of the rats loved the food. Now that
of spotted rats \rightarrow	they knew that SOME of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats

- trivially entailed
- entailed
- not entailed

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Methods

experiment 2 conditions, full



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.

	SOME	NOT ALL	ALL	NONE
SUBSET $ ightarrow$	some of the male spotted rats loved the food. Now that	not all of the male spotted rats loved the food. Now that	all of the male spotted rats loved the food. Now that	none of the male spotted rat loved the food. Now tha
of spotted rats \rightarrow	they knew that SOMe of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats
$\begin{array}{c} IDENTICAL \to \\ to \ spotted \ rats \to \end{array}$	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 $ ightarrow$	SOMe of the rats loved the food. Now that they knew that SOMe of	not all of the rats loved the food. Now that they knew that not all of	all of the rats loved the food. Now that they knew that all of the	none of the rats loved the food. Now that they knew that none of
of spotted rats \rightarrow	the spotted rats	the spotted rats	spotted rats	the spotted rats

- trivially entailed
- entailed
- not entailed

Evidence of accurate logical reasoning in online sentence comprehension 2021-05-29 Experiment 2 -Methods experiment 2 conditions, full

	SOME	NOT ALL	ALL	NONE
SUBSET → of sported rate →	male spotted rats that to feet the the try has the BOTH of the spotted rats.	not all you male spotted rats to fine the fine that the second rats of the spotted rats.	male spotted rate in the true in the part the first true in part to spotted rate.	male spotted ra
IDENTICAL →	to the first flow that	spotted rots spotted rots see the feet the rise reported rots	aported rots sported rots see the plat the see aported rots	spotted rets
SUPERSET → of sported cars →	- SO THE of the FORE STATE OF THE STATE OF THE SOUTH OF THE SOU	not all you rets that the first the first that the first that the first all you reported rets.	eats summarished the standard stay they then the standard apostsed rate.	nate in feet from the third the state of the plant from the poor of the poor o
ental	ly entailed led stalled			

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

	SOME	NOT ALL	ALL	NONE
extstyle ext	some of the male spotted rats loved the food. Now that	not all of the male spotted rats loved the food. Now that	all of the male spotted rats loved the food. Now that	none of the male spotted rat loved the food. Now tha
of spotted rats \rightarrow	they knew that Some of the Spotted rats		they knew that all of the spotted rats	they knew that none of the spotted rats
IDENTICAL \rightarrow to spotted rats \rightarrow	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
	SOMe of the rats loved the food. Now that	not all of the rats loved the food. Now that	all of the rats	none of the rats
of spotted rats \rightarrow	they knew that SOME of the Spotted rats	they knew that not all of the spotted rats	they knew that all of the spotted rats	they knew that none of the spotted rats

- trivially entailed
- entailed
- not entailed

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

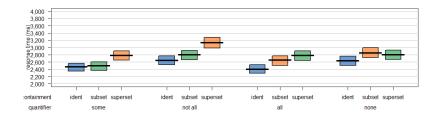
Methods

experiment 2 conditions, full

	SOME	NOT ALL	ALL	NONE
SUBSET → of sported cars →	BOTH class male spotted rats lead to find the the toy have the BOTH of the Spotted rats.	not all you male spotted rats inserted for the day inserted for all your spotted rats	call your made spotted rate has been been the majorited rate.	mole spotted ret male spotted ret may have the BODE of my spotted nats.
IDENTICAL →	spotted rots insert the free, line that they have vise \$2.000 of my spotted nats.	not all you spotted rate and for fact law the deplete rate flot all you spotted rate .	apotted rats spotted rats that the that the past the fill apotted rats.	aported rots institute per per per per per per per per per pe
SUPERSET → of sported rate →	- BOTH y/or note had by find the due by how the BOTH y/ or Spotted rots.	not all you rets may be just the for top how the flot all of to spotted rets.	ests in the post that the star that the post that the star that the spotted rots.	. Agent of the Agent Agent The State
ental	ly entailed ed stailed			

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

experiment 2 results



trivialontailed

entailednot entailed

subset: male spotted rats ≺ spotted rats
ident: spotted rats ≺ spotted rats
superset: rats ≺ spotted rats

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Results

-experiment 2 results

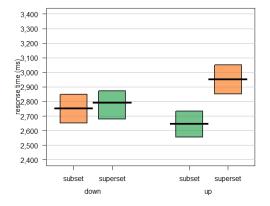


In the results of Experiment 2, the twelve conditions are grouped by quantifiers.

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.

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experiment 2 results, quantifiers grouped by entailment



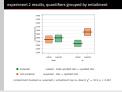
entailed subset: male spotted rats \prec spotted rats not entailed superset: rats \prec spotted rats containment (subset vs. superset) \times entailment (up vs. down): $\chi^2 = 10.9$, p < 0.001

Evidence of accurate logical reasoning in online sentence comprehension

Experiment 2

Results

experiment 2 results, quantifiers grouped by



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

language involves accurate and spontaneous logical computations

Evidence of accurate logical reasoning in online sentence comprehension

Discussion

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- Isograps incolves accurate and spontaneous logical competitions

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.

- 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)

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Discussion

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Language involves accurate and operationeous logical complexations — and the process theories of cognition in a comment peoples' instance logical horositedge emerges from a lammonity consist in which hop principles have shown practical to accommission of the hop principles have shown practical to accommission (2019). (In News and Pennycolic (2019).

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

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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)

Evidence of accurate logical reasoning in online sentence comprehension

Discussion

- language involves acrustas and spontaneous logical computations of differ from dual suprocess thereiars of cagotion it is estimated that people's naturals begord shooledge it is estimated that people's naturals begord shooledge periodical from commonscipt of the people periodical from commonscipt or the people periodical from the people periodical from the people peop

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

- 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?

Evidence of accurate logical reasoning in online sentence comprehension

Discussion

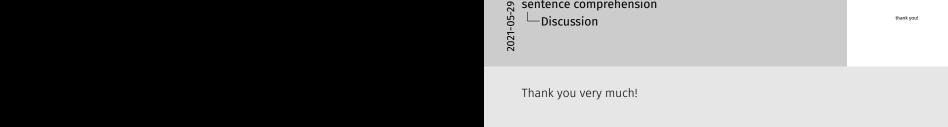
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Thus, we conclude the compositionality of language and at least *some* inferential thought may both derive from the same cognitive mechanisms.



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sentence comprehension

thank you!

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.

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Discussion

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Braine, Martin D. S. and David P. O'Brien (1998). Mentol logic.

Cheng, Patricia W. and Keith J. Holyoak (1985). "Pragmatic Reasoning Schemas". In: Cognitive Psychology 174, pp. 391–416.

Cheng, Patricia W. and Keith J. Holyoak (1989). "On the natural selection of reasoning theories". In: Cognition.

Cheng, Patricia W, Köhi H, Holyauk, Richard E, Nisbett, and Lindsay M. Oliver (1986). "Pragmatic versus syntactic approaches to training deductive reasoning". In: Cognitive Psychology 18.3, nn 293-338.

IDE 2007/326. Wilm 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.

Evidence of accurate logical reasoning in online sentence comprehension Discussion

-references

Evans, Ionathan St. B. T. and Keith E. Stanovich (2013), "Dual-process theories of higher cognition: Advancing the debate". in:

Galewski, Ion (2002), "L-analyticity and natural language", Manuscrip

Kahneman, Daniel (2011). Thinking, Fost and Slow, Farrar, Straus and

Wason, Peter C. (1968). "Reasoning about a rule". In: Quarterly Journal

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