Non-conservative quantifiers are unlearnable
(and what that means for semantic theory)

Tyler Knowlton

University of Pennsylvania

UMass Psycholinguistics Workshop - 10.14.22

Roadmap

Conservativity: a robust & important cross-linguistic universal

➥ Likely has a fundamentally linguistic explanation

Learnability: non-conservative DETs aren't in learners' hypothesis space

➥ Empirical support: mixed / inconclusive

➥ New experiments: evidence for the learnability hypothesis

Relationality: conservativity is a puzzle for the standard, relational view

➥ Amend the standard view or consider a non-relational alternative?

What is “conservativity”?

Intuitively: a **determiner’s** first (NP) argument “sets the scene”

most *frogs are green* ⟵ only frogs matter

every *fish swims* ⟵ only fish matter

Only fish swim ⟵ non-fish matter!

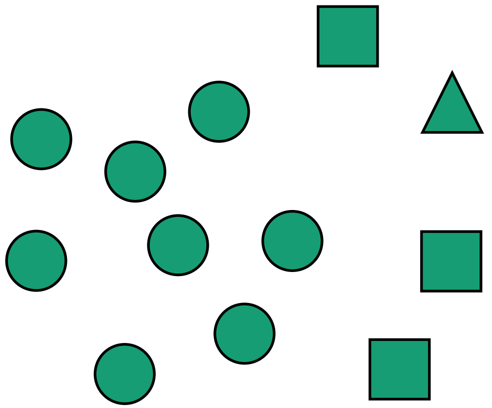
(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

Natural language determiners are "conservative"

A determiner **DET** is conservative iff

(1) [[**DET** NP] PRED] =

(2) [[**DET** NP] [be NP that PRED]]



every *circle is green* (TRUE) =

every *circle is a circle that is green* (TRUE)

(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

Natural language determiners are “conservative”

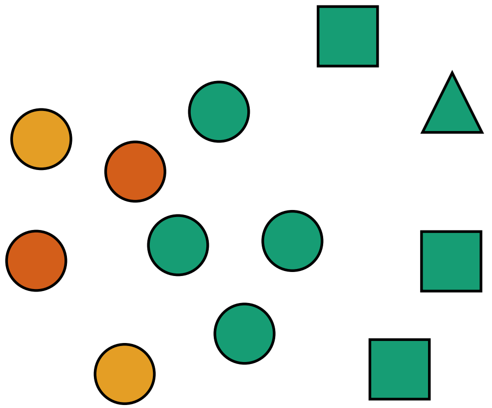
A determiner **DET** is conservative iff

(1) [[**DET** NP] PRED] =

(2) [[**DET** NP] [be NP that PRED]]

every *circle is green* (FALSE) =

every *circle is a circle that is green* (FALSE)



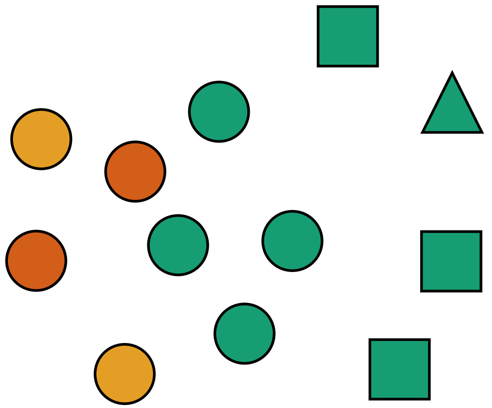
(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

Natural language determiners are “conservative”

A determiner **DET** is conservative iff

(1) [[**DET** NP] PRED] =

(2) [[**DET** NP] [be NP that PRED]]



every *circle is green* (FALSE) =

every *circle is a circle that is green* (FALSE)

Cf.

only circles are green (FALSE) ≠

only circles are circles that are green (TRUE)

(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

We can imagine "non-conservative" determiners

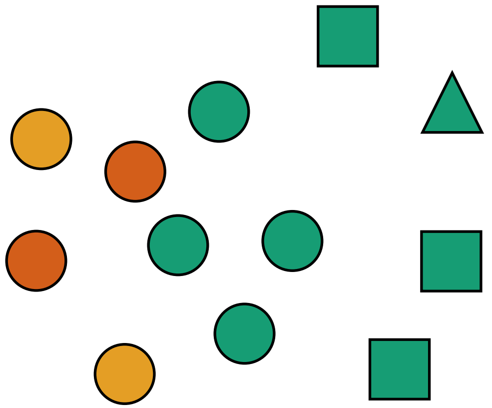
***equi** circles are green*

≈ the circles are equinumerous with
the green things (TRUE; 8=8)

≠

***equi** circles are circles that are green*

≈ the circles are equinumerous with
the circles that are green (FALSE; 8≠4)



We can imagine “non-conservative” determiners

***everynon* *circles* are green**

≈ *all the non-circles are green*

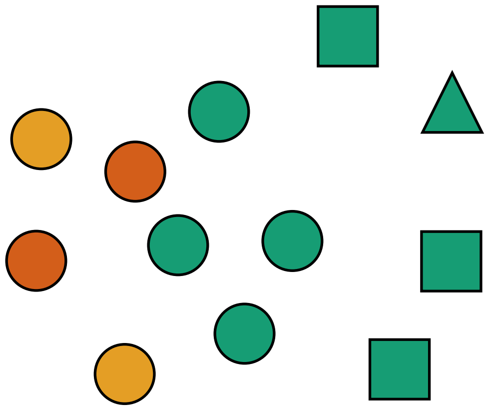
(TRUE; the squares and triangles are)

≠

***everynon* *circles* are *circles* that are green**

≈ *all the non-circles are circles that are green*

(FALSE; the non-circles aren’t circles)



A fundamentally linguistic universal?

“There is no explanation of [conservativity] by means of…

set-theoretic relations

some generic ‘laws of thought’

the psychology of reasoning

facts and theories about pragmatic constraints

efficacy of communication

cultural conventions and the like…

The explanation is exquisitely syntactico-semantic.”

- Massimo Piattelli-Palmarini (2008)

Roadmap

✓**Conservativity**: a robust & important cross-linguistic universal

✓ Likely has a fundamentally linguistic explanation

Learnability: non-conservative DETs aren't in learners' hypothesis space

➥ Empirical support: mixed / inconclusive

➥ New experiments: evidence for the learnability hypothesis

Relationality: conservativity is a puzzle for the standard, relational view

➥ Amend the standard view or consider a non-relational alternative?

Hunter & Lidz (2013): Teaching 5 year-olds novel DETs

5 training items - The puppet likes it when:

Gleeb girls are on the beach

≈*not all of the girls are on the beach* (TRUE)

=*not all of the girls are girls on the beach* (TRUE)

On average, 82% vs. 62% correct
5/10 perfect vs. 1/10 perfect

Gleeb girls are on the beach

≈*not only girls are on the beach* (TRUE)

≠*not only girls are girls on the beach* (FALSE)

Spenader & de Villiers (2019): Attempted replication

5 training items - The puppet likes it when:

Gleeb girls are on the beach

≈*not all of the girls are on the beach* (TRUE)

=*not all of the girls are girls on the beach* (TRUE)

Gleeb girls are on the beach

≈*not only girls are on the beach* (TRUE)

≠*not only girls are girls on the beach* (FALSE)

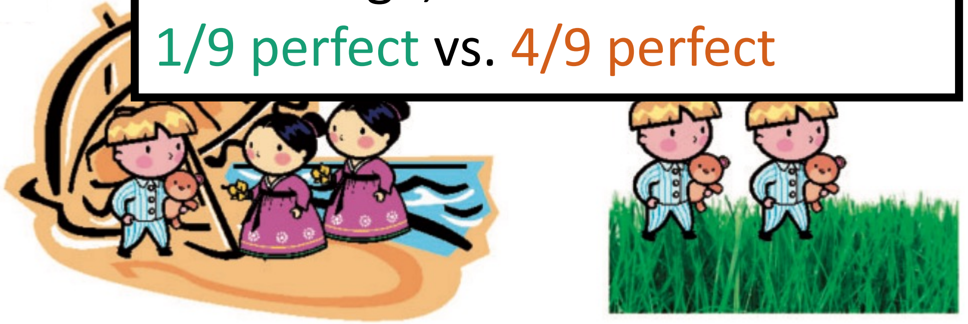
Children

On average, 60% vs. 68% correct

Adults

On average, 56% vs. 69% correct

1/9 perfect vs. 4/9 perfect



Roadmap

✓**Conservativity**: a robust & important cross-linguistic universal

✓ Likely has a fundamentally linguistic explanation

Learnability: non-conservative DETs aren’t in learners’ hypothesis space

✓ Empirical support: mixed / inconclusive

➥ New experiments: evidence for the learnability hypothesis

Relationality: conservativity is a puzzle for the standard, relational view

➥ Amend the standard view or consider a non-relational alternative?

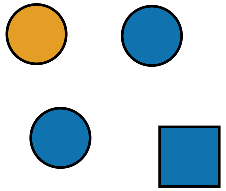
A better pair than *notAll* vs. *notOnly*?

Gleeb of the circles are blue

≈*all but 1 of the circles are blue* (TRUE)

=*all but 1 of the circles are blue circles* (TRUE)

|X|- 1 = |X & Y|

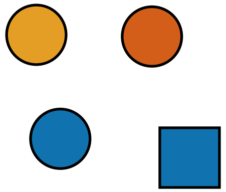


Gleeb of the circles are blue

≈*the circles outnumber by 1 the blue things* (TRUE)

≠*the circles outnumber by 1 the blue circles* (FALSE)

|X| - 1 =|Y|



Improving on the task

<u>Hunter & Lidz</u>

$X \not\subseteq Y$ vs. $X \not\supseteq Y$

“Gleeb girls are on the beach”

Picky puppet task

Kids & adults

<u>Current study</u>

$|X| - 1 = |X \& Y|$ vs. $|X| - 1 = |Y|$

“Gleeb **of the** circles are blue”

Word learning task

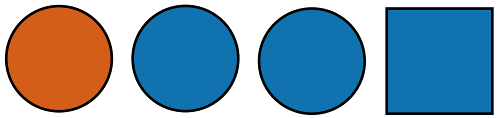
Focus on adults

Experiment 1: Learning by example

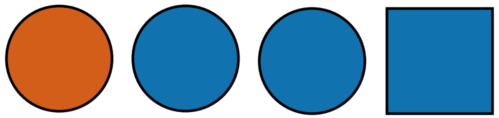
Conservative condition	**Non-conservative** condition
$\|x: circle(x)\| - 1 =$ $\|x: circle(x) \& blue(x)\|$	$\|x: circle(x)\| - 1 =$ $\|x: blue(x)\|$

Training
(16 trials)

There are three circles.
There are three blue shapes.
Gleeb of the circles are blue.



There are three circles.
There are three blue shapes.
It's not the case that
gleeb of the circles are blue.

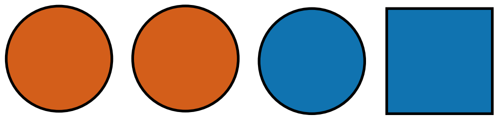


Experiment 1: Learning by example

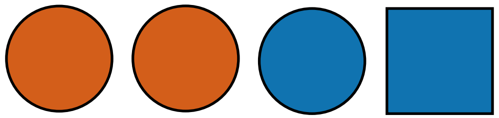
Conservative condition	**Non-conservative condition**
|x: circle(x)| - 1 = |x: circle(x) & blue(x)|	|x: circle(x)|-1 = |x: blue(x)|

Training
(16 trials)

There are three circles.
There are two blue shapes.
It's not the case that
gleeb of the circles are blue.

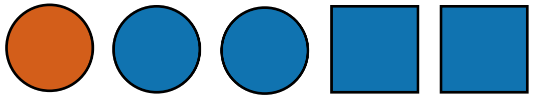


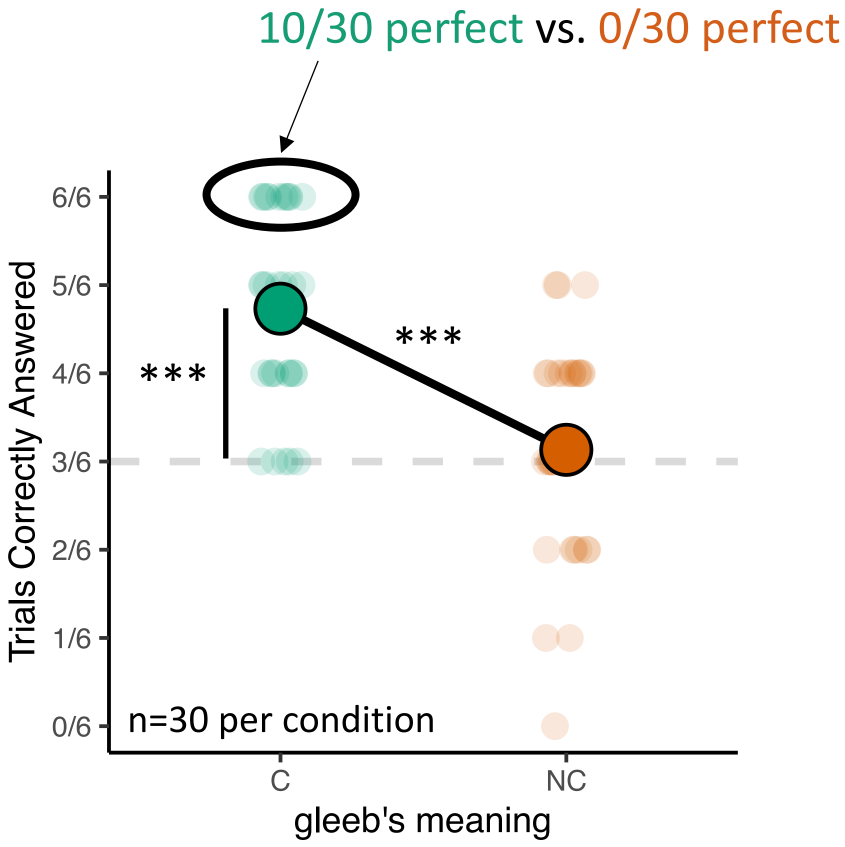
There are three circles.
There are two blue shapes.
Gleeb of the circles are blue.



Test
(6 trials)

There are three circles.
There are four blue shapes.
Is it true that
gleeb of the circles are blue?



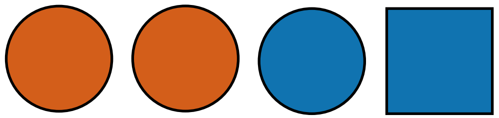


Experiment 2: Generalizing to a new predicate

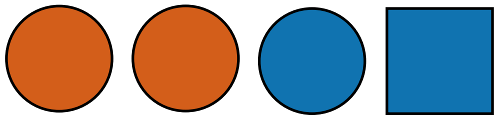
Conservative condition	**Non-conservative** condition
|x: circle(x)| - 1 = |x: circle(x) & blue(x)|	|x: circle(x)|-1 = |x: blue(x)|

Training
(16 trials)

There are three circles.
There are two blue shapes.
It’s not the case that
gleeb of the circles are blue.

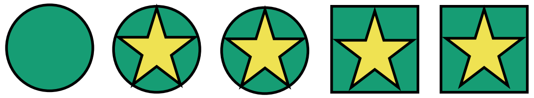


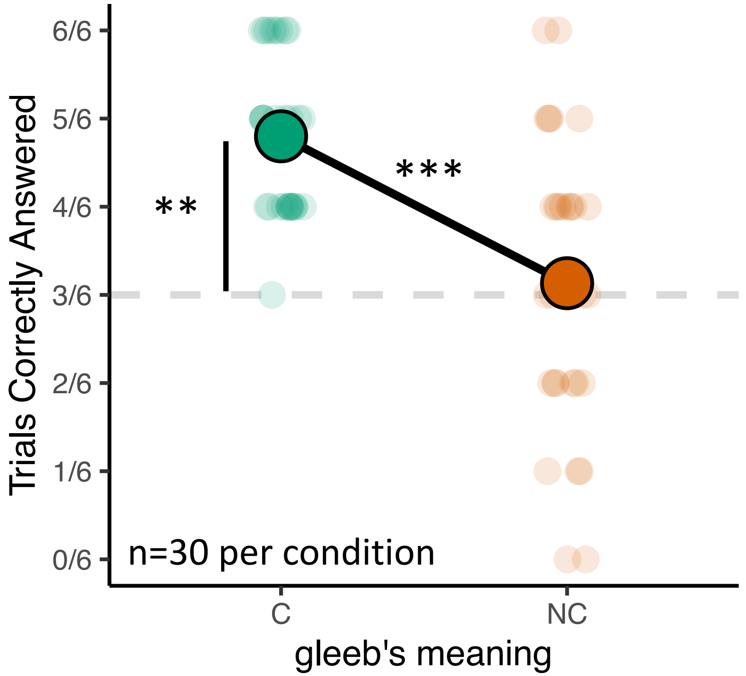
There are three circles.
There are two blue shapes.
Gleeb of the circles are blue.



Test
(6 trials)

Is it true that
gleeb of the circles have stars?





Experiment 3: Explicit teaching

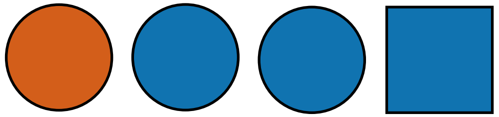
Teaching

‘Gleeb of the Xs are Y’ means:
The number of Xs minus 1
is the number of Xs that are Y.

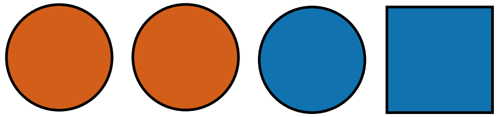
'Gleeb of the Xs are Y’ means:
The number of Xs minus 1
is the number of Ys.

Training
(8 trials)

Here, gleeb of the circles are blue because there are 3 circles and 2 blue circles. 3-2=1.

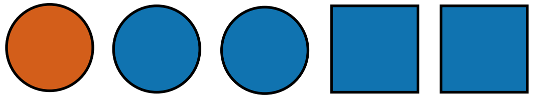


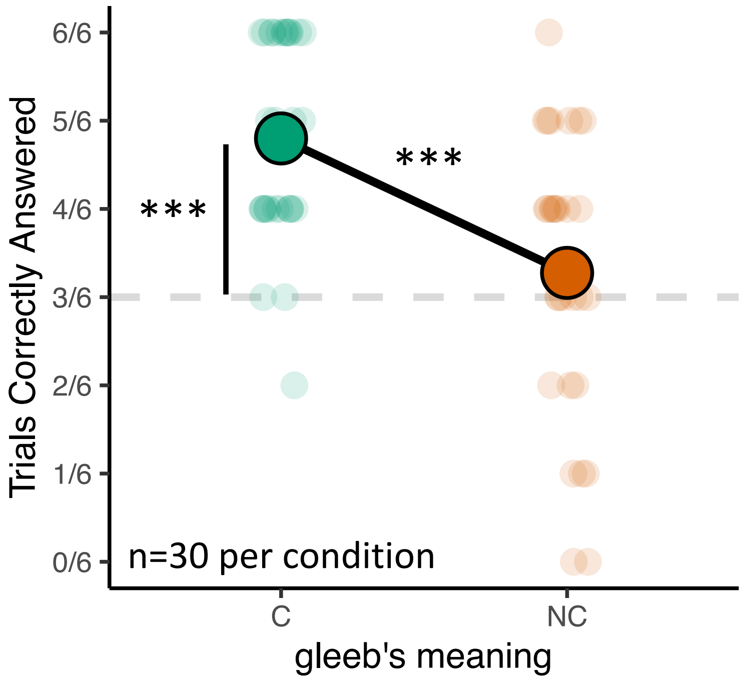
Here, gleeb of the circles are blue because there are 3 circles and 2 blue things. 3-2=1.



Test
(6 trials)

Fill in the blank:
___ of the circles are blue



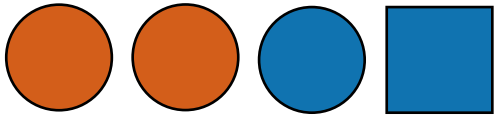


Experiment 4: Teaching a non-conservative **verb**

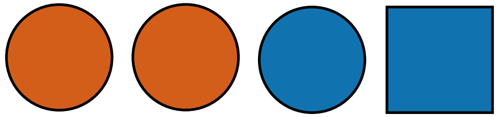
Conservative condition	**Non-conservative** condition
|x: circle(x)| - 1 = |x: circle(x) & blue(x)|	|x: circle(x)|-1 = |x: blue(x)|

Training (16 trials)

There are three circles.
There are two blue shapes.
It's not the case that the circles gleeb the blue circles.

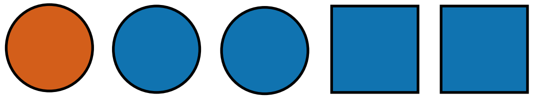


There are three circles.
There are two blue shapes.
The circles gleeb the blue shapes.

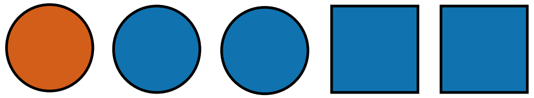


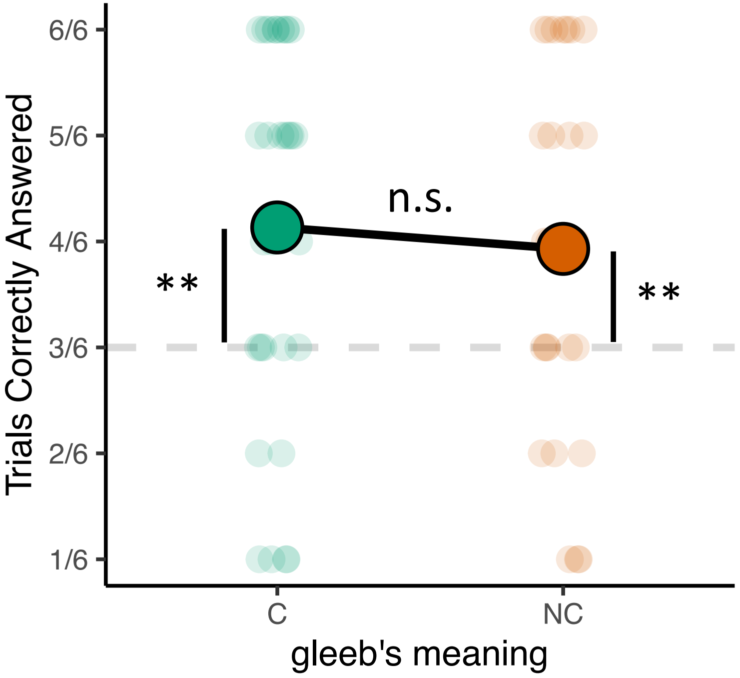
Test (6 trials)

There are three circles.
There are four blue shapes.
Is it true that the circles gleeb the blue circles?



There are three circles.
There are four blue shapes.
Is it true that the circles gleeb the blue shapes?



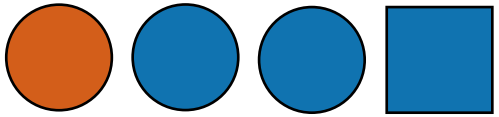


Experiment 5: Another non-conservative determiner

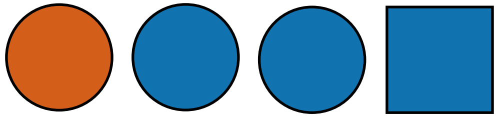
Conservative (*every*)	**Non-conservative** (*equi*)
|x: circle(x)| = |x: circle(x) & blue(x)|	|x: circle(x)| = |x: blue(x)|

Training
(16 trials)

Here, it’s not the case that
gleeb of the circles are blue.

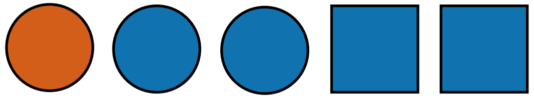


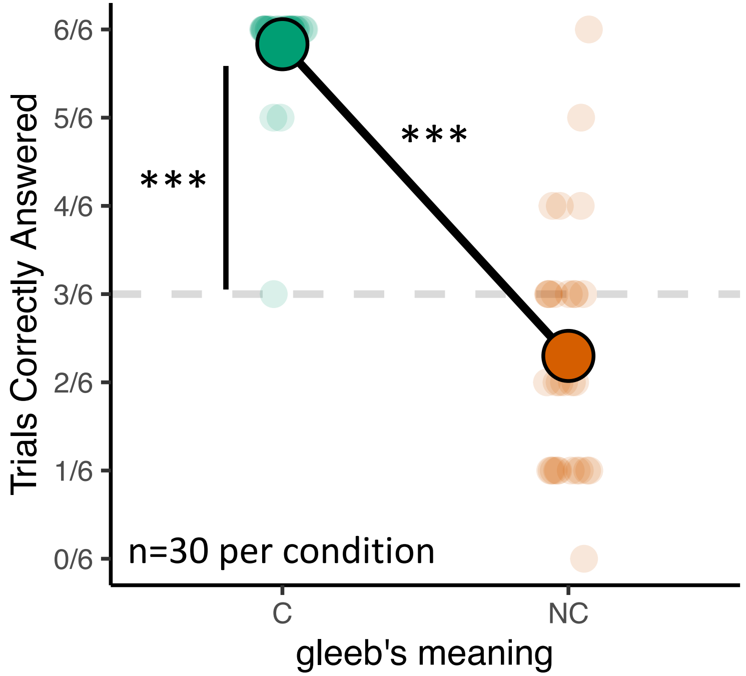
Here,
gleeb of the circles are blue.



Test
(6 trials)

Is it true that
gleeb of the circles are blue?





Roadmap

✓**Conservativity**: a robust & important cross-linguistic universal

✓ Likely has a fundamentally linguistic explanation

✓ **Learnability**: non-conservative DETs aren't in learners' hypothesis space

✓ Empirical support: mixed / inconclusive

✓ New experiments: evidence for the learnability hypothesis

Relationality: conservativity is a puzzle for the standard, relational view

➥ Amend the standard view or consider a non-relational alternative?

“Conservativity” is puzzling on the standard view

If determiners express <u>relations between two independent sets</u>,

then what rules out all the non-conservative relations?

✓

$|CIRCLES \cap GREEN| > |CIRCLES - GREEN|$

≈most circles are green

$CIRCLES \subseteq GREEN$

≈every circle is green

✗

$|CIRCLES| = |GREEN|$

$|CIRCLES| > |GREEN|$

$CIRCLES \supseteq GREEN$

≈only circles are green

“Conservativity” is entailed on a non-relational view

If determiners are tools for creating restricted quantifiers,

then non-conservative meanings are not stateable!

Devices that specify, relative to a restricted domain, how many things a predicate applies to

Relative to the circles, *is green* applies to

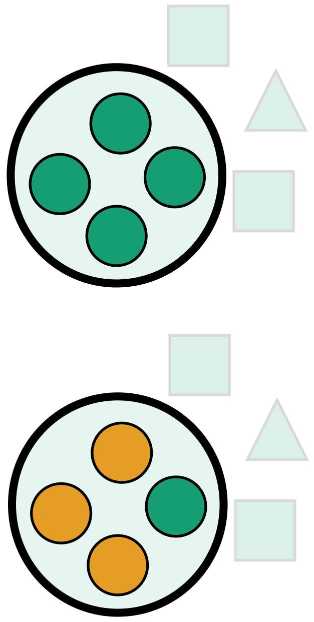
…all things

…most things

…at least 2 & at most 4 things

…??? things

(intended: |CIRCLES| = |GREEN|)



(Pietroski 2005, 2018; Westerståhl 2019; Knowlton et al. 2021; Lasersohn 2021; Ludlow & Živanović 2022)

A way of retaining relationality

⟦**Every** circle is green⟧

$=_{LF}$ [**every** circle [~~**every** circle~~ is green]] (QR & Trace conversion)

≈ CIRCLES ⊆ CIRCLES ∩ GREEN-THINGS

⟦**Equi** circles are green⟧

≈ |CIRCLES| = |CIRCLES ∩ GREEN-THINGS|

$_{TC}$= *every*!

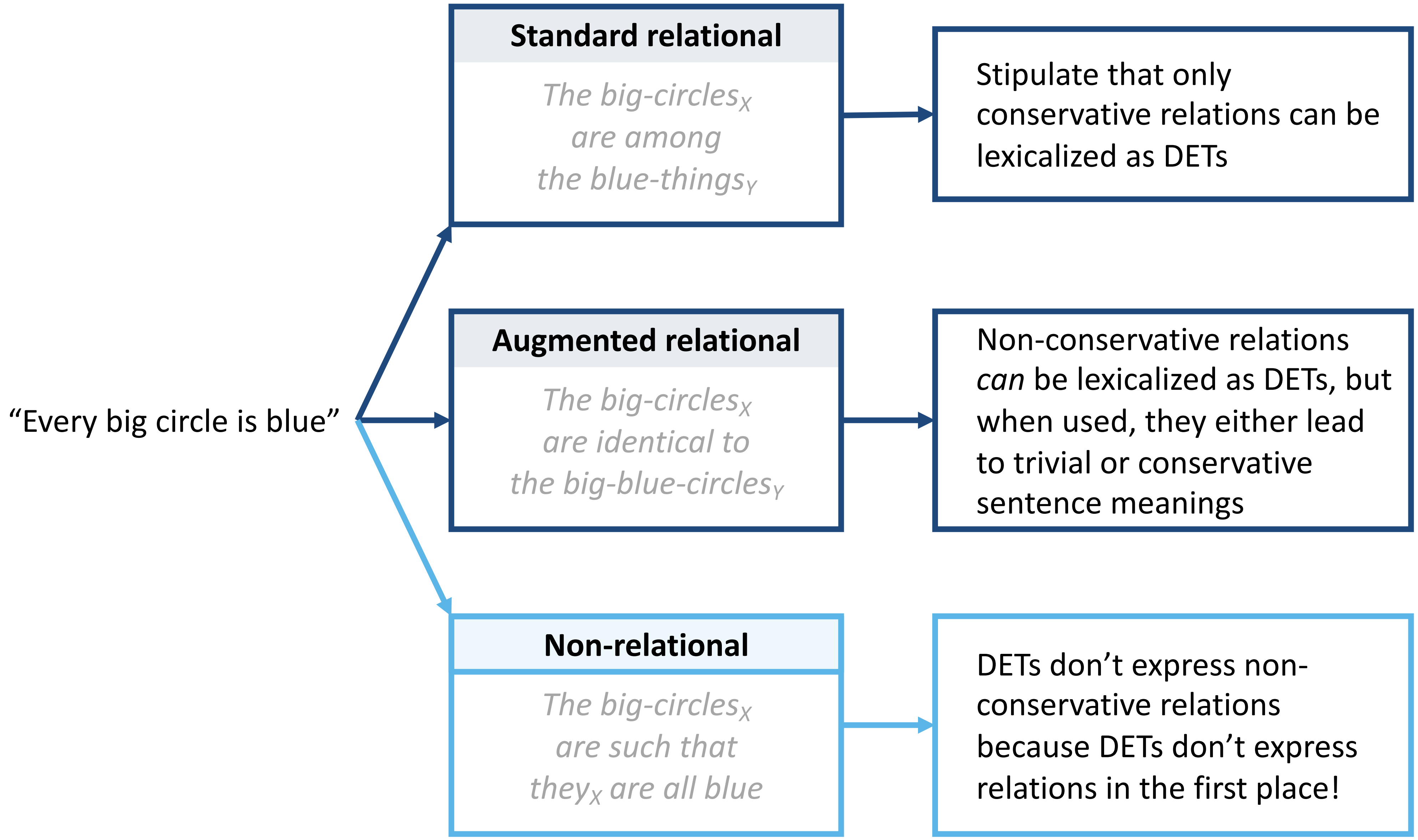
⟦**Yreve** circle is green⟧ (aka *only* as a DET)

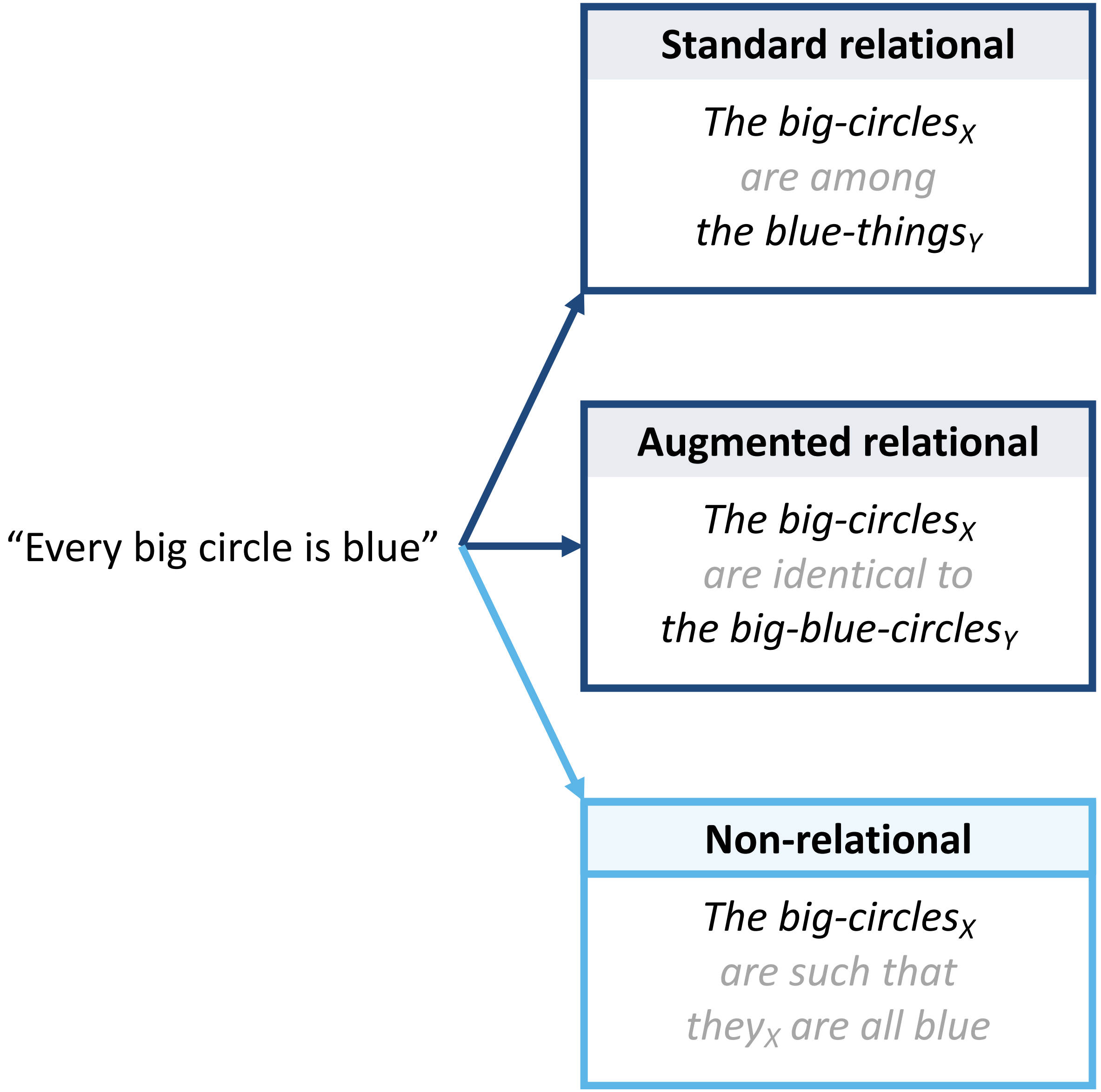
≈ CIRCLES ⊇ CIRCLES ∩ GREEN-THINGS

(always TRUE)

* Trivial meanings

(Romoli 2015, building on Chierchia 1995; Fox 2002; Sportiche 2005)


"Every big circle is blue"
Standard relational
The big-circles$_X$ are among the blue-things$_Y$
Stipulate that only conservative relations can be lexicalized as DETs
Augmented relational
The big-circles$_X$ are identical to the big-blue-circles$_Y$
Non-conservative relations *can* be lexicalized as DETs, but when used, they either lead to trivial or conservative sentence meanings
Non-relational
The big-circles$_X$ are such that they$_X$ are all blue
DETs don't express non-conservative relations because DETs don't express relations in the first place!



How do people actually understand *every*?

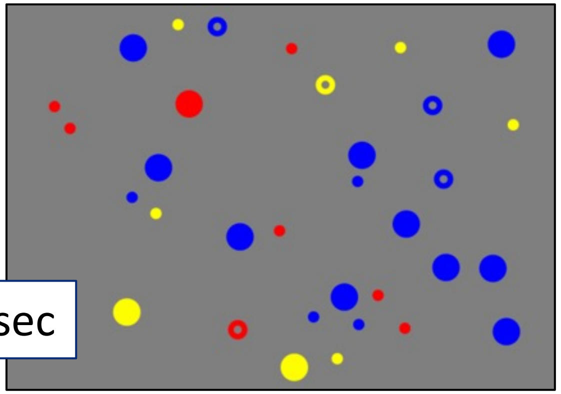
Knowlton, Pietroski, Williams, Halberda & Lidz 2021 *SALT proceedings*

Every <u>big</u> circle is <u>blue</u>

TRUE FALSE

Standard relational

The big-circles$_X$
are among
the blue-things$_Y$



1 sec

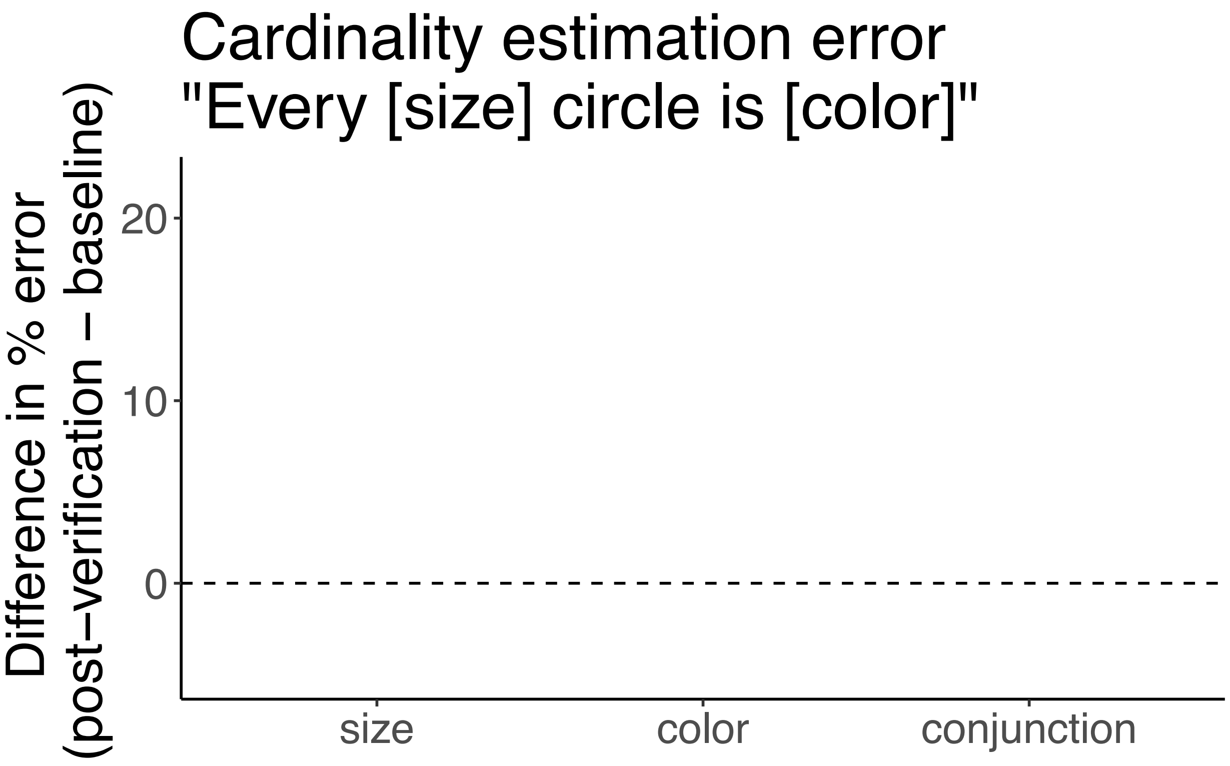
Augmented relational

The big-circles$_X$
are identical to
the big-blue-circles$_Y$

How many {<u>big/blue/big blue</u>} circles were there?

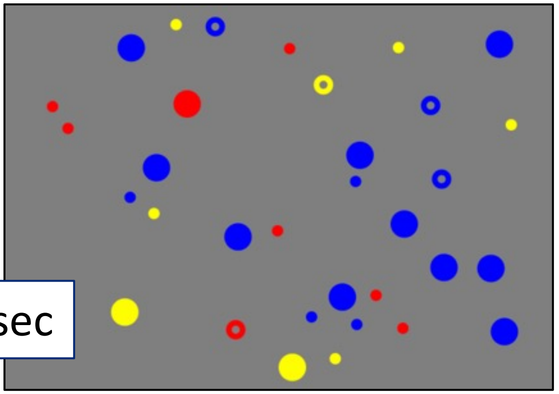
Non-relational

The big-circles$_X$
are such that
they$_X$ are all blue



Every big circle is blue

TRUE FALSE



1 sec

How many {big/blue/big blue} circles were there?

Standard relational

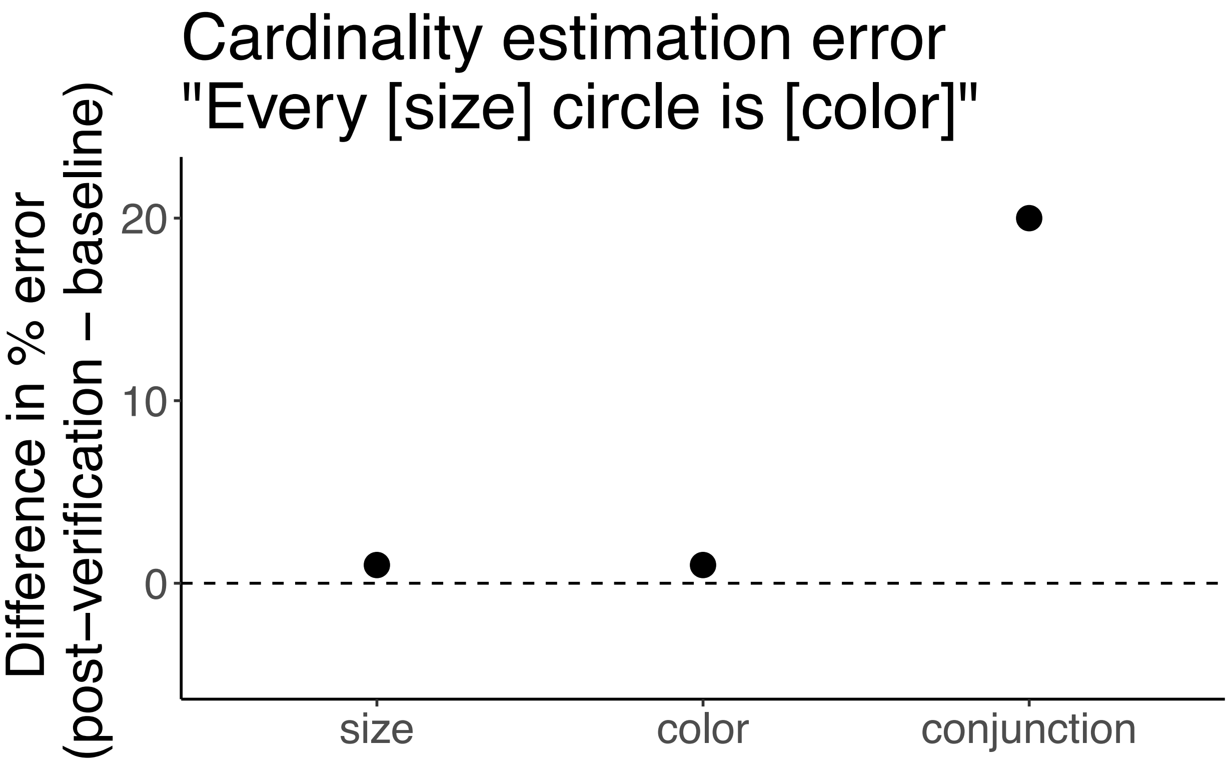
The big-circles$_X$ are among the blue-things$_Y$

Augmented relational

The big-circles$_X$ are identical to the big-blue-circles$_Y$

Non-relational

The big-circles$_X$ are such that they$_X$ are all blue

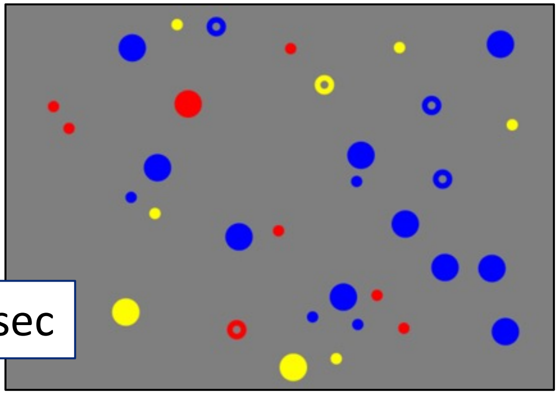


Every big circle is blue

TRUE FALSE

Standard relational

The big-circles$_X$
are among
the blue-things$_Y$



1 sec

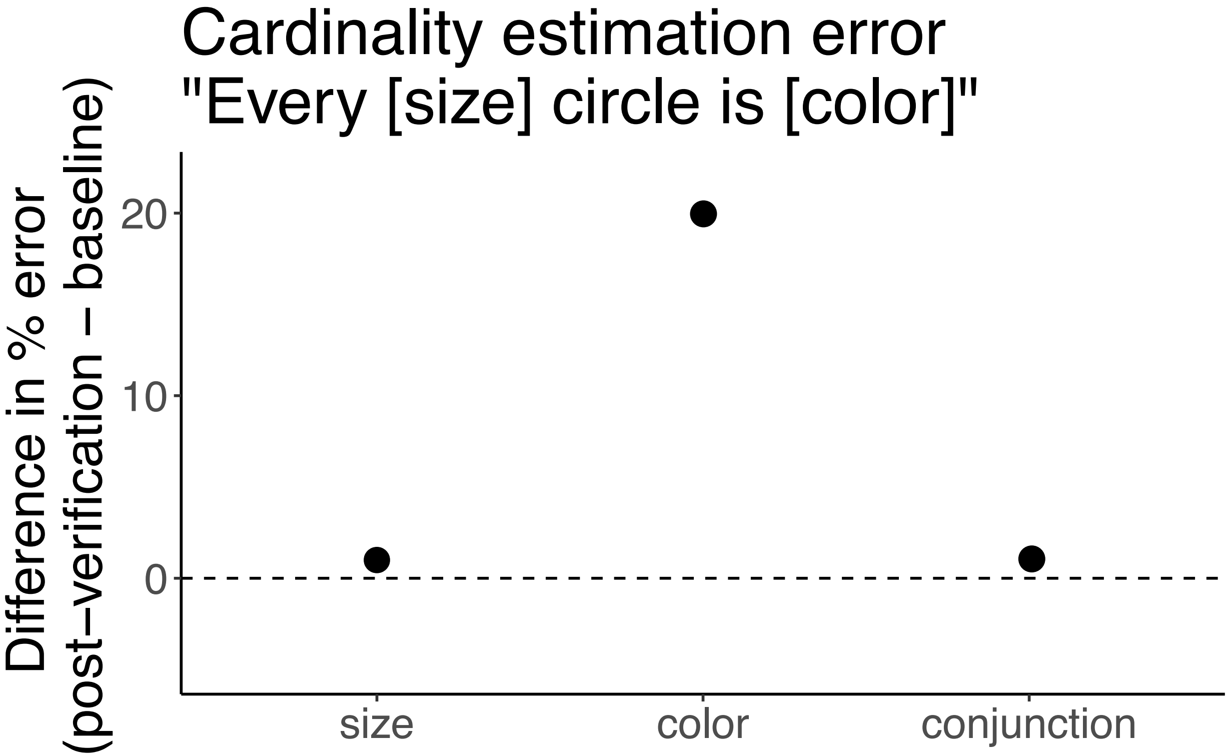
Augmented relational

The big-circles$_X$
are identical to
the big-blue-circles$_Y$

How many
{big/blue/big blue}
circles were there?

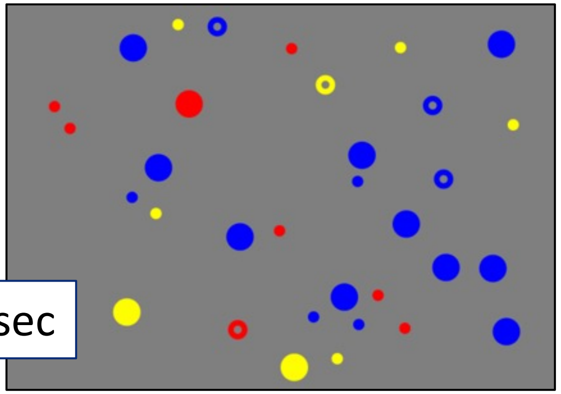
Non-relational

The big-circles$_X$
are such that
they$_X$ are all blue



Every big circle is blue

TRUE FALSE



1 sec

How many {big/blue/big blue} circles were there?

Standard relational

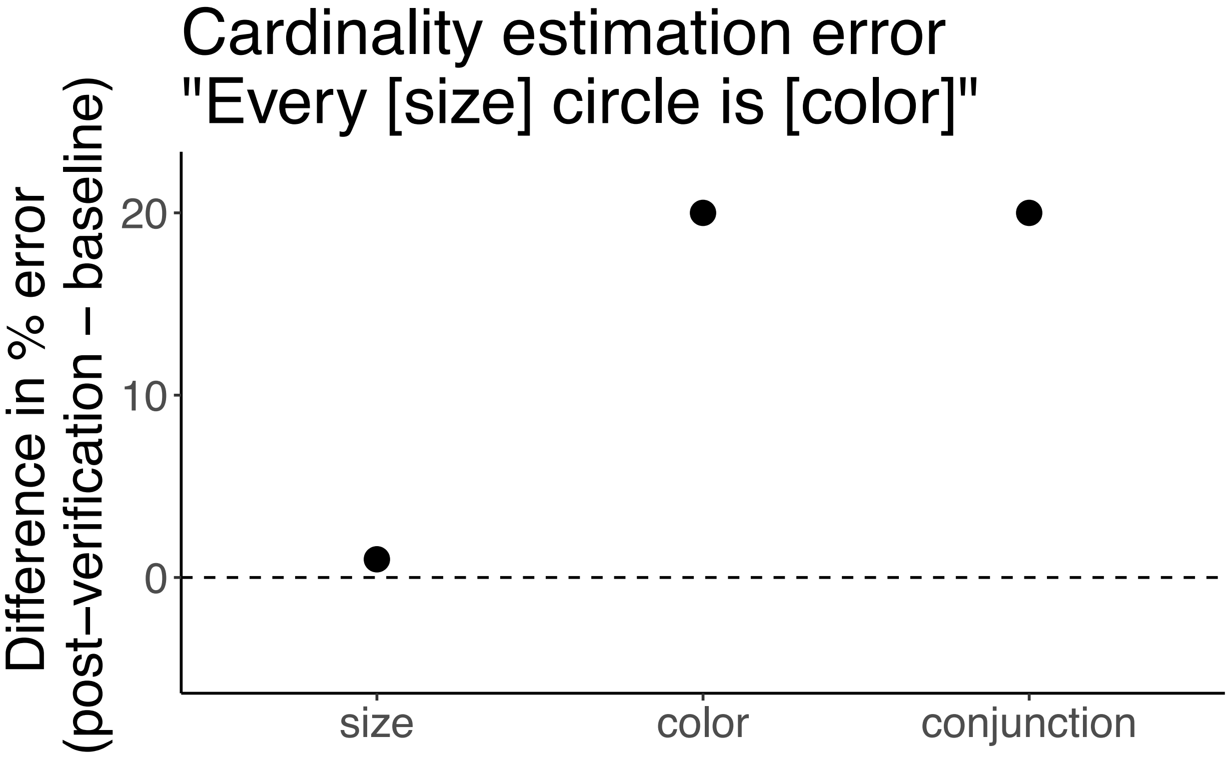
The big-circles$_X$ are among the blue-things$_Y$

Augmented relational

The big-circles$_X$ are identical to the big-blue-circles$_Y$

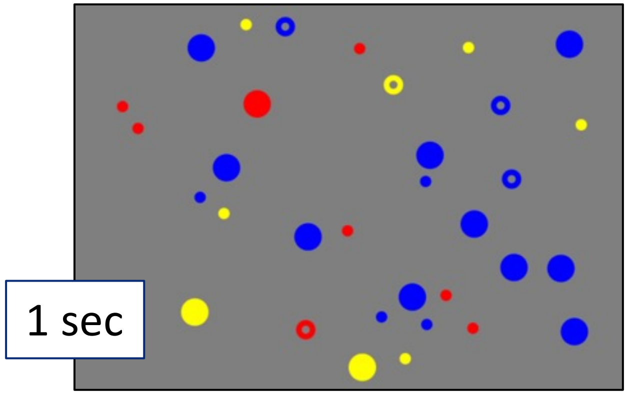
Non-relational

The big-circles$_X$ are such that they$_X$ are all blue



Every <u>big</u> circle is <u>blue</u>

TRUE FALSE



How many {<u>big/blue/big blue</u>} circles were there?

Standard relational

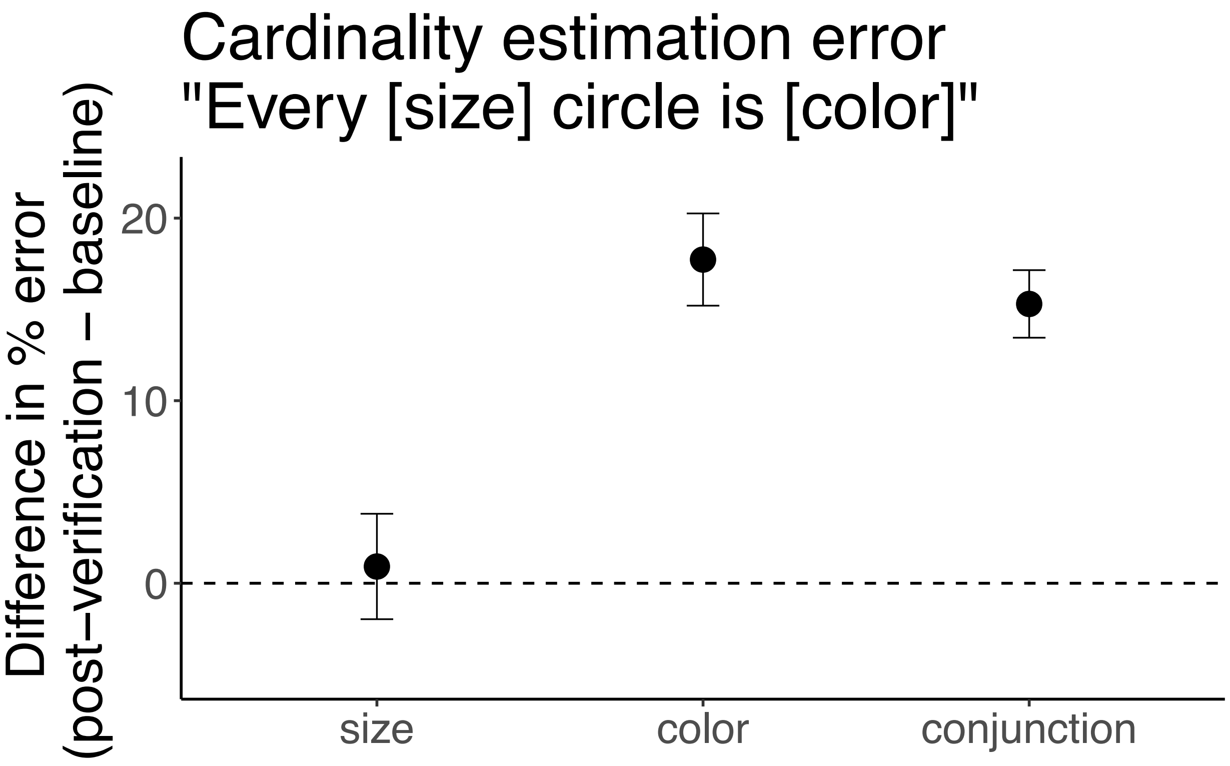
The big-circles$_X$ are among the blue-things$_Y$

Augmented relational

The big-circles$_X$ are identical to the big-blue-circles$_Y$

Non-relational

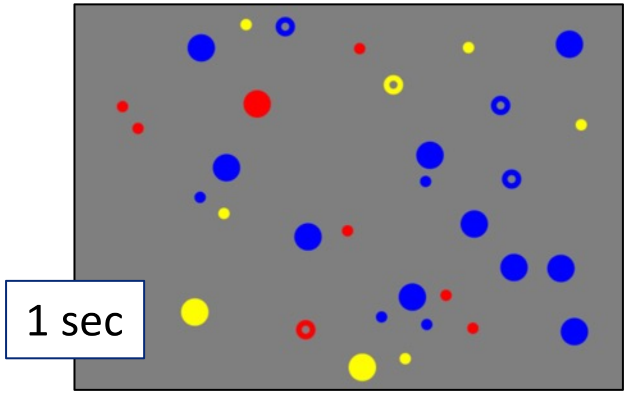
The big-circles$_X$ are such that they$_X$ are all blue



n = 48

Every <u>big</u> circle is <u>blue</u>

TRUE FALSE



How many {<u>big/blue/big blue</u>} circles were there?

Standard relational

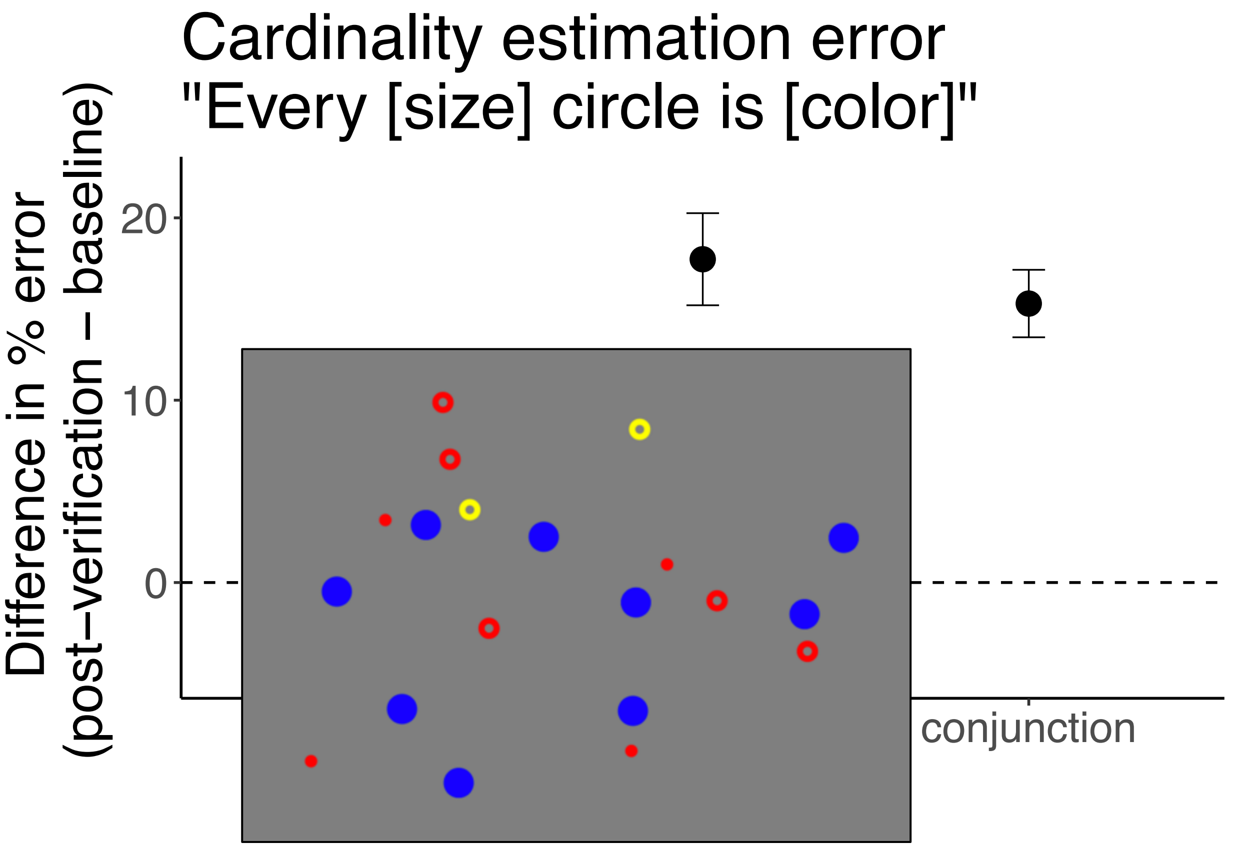
The big-circles$_X$
are among
the blue-things$_Y$

Augmented relational

The big-circles$_X$
are identical to
the big-blue-circles$_Y$

Non-relational

The big-circles$_X$
are such that
they$_X$ are all blue



|BIG|=|BIG & BLUE|

n = 48

Roadmap

✓**Conservativity**: a robust & important cross-linguistic universal

- ✓ Likely has a fundamentally linguistic explanation

✓ **Learnability**: non-conservative DETs aren't in learners' hypothesis space

- ✓ Empirical support: mixed / inconclusive
- ✓ New experiments: evidence for the learnability hypothesis

✓ **Relationality**: conservativity is a puzzle for the standard, relational view

- ✓ Amend the standard view or consider a non-relational alternative?

Conclusion

Non-conservative determiners are unlearnable

➥ because determiner conservativity is a fundamental feature of the Language Faculty

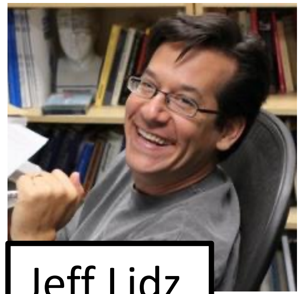
➥ which supports semantic theories that treat conservativity as a cornerstone

Thanks!

Collaborators on presented work:

Anna Papafragou

John Trueswell



Jeff Lidz

Paul Pietroski

Justin Halberda

Alexander Williams

Special thanks also to:

Florian Schwarz
Alexis Wellwood
Nico Arlotti
Zoe Ovans
Valentine Hacquard
Norbert Hornstein
& Simon Chervenak

University of Maryland 1856

Language at Maryland

Penn University of Pennsylvania

mindCORE Center for Outreach, Research, and Education

NSF NRT-1449815 & NSF BCS-2017525