24.904
Language Acquisition

Class 19: Quantification

Referential vs. Quantificational Expressions

- **Referring DPs**
  Athulya, the TA of 24.904, the current president of the USA, those workers over there, ...

- **Quantificational DPs**
  every student in 24.904, no adult, most children, ...

Quantifiers

(1) Jill smiled.

(2) a. Every girl smiled.
b. Some girl smiled.
c. No girl smiled.
d. Exactly one girl smiled.
e. Both girls smiled.
f. At most one of the 10 girls smiled.
g. Fewer than 5 girls smiled.
h. Most girls smiled.
i. All but 5 girls smiled.
j. More than 5 but less than 10 girls smiled.
k. More girls than boys smiled.

Quantifiers v. referential terms

- Subset to superset inferences

(1) Jack is a student from France.
Therefore, Jack is from France.

(2) Everybody is a student from France.
Therefore, everybody is from France.

(3) Nobody is a student from France.
Therefore, nobody is from France.

Quantifiers v. referential terms

- Law of contradiction

(1) Jack is under 30 and Jack is over 40.

(2) Somebody is under 30 and somebody is over 40.

(3) Exactly 5 students are under 30 and exactly 5 students are over 40

Quantifiers v. referential terms

- Ambiguities

(1) a. Jack admires Jill.
    b. Everyone admires someone.

Brief primer on compositional semantics

Basic tenets:

- Principle of Compositionality (Frege 1884)
  The meaning of a complex expression is determined by its structure and the meanings of its constituents.

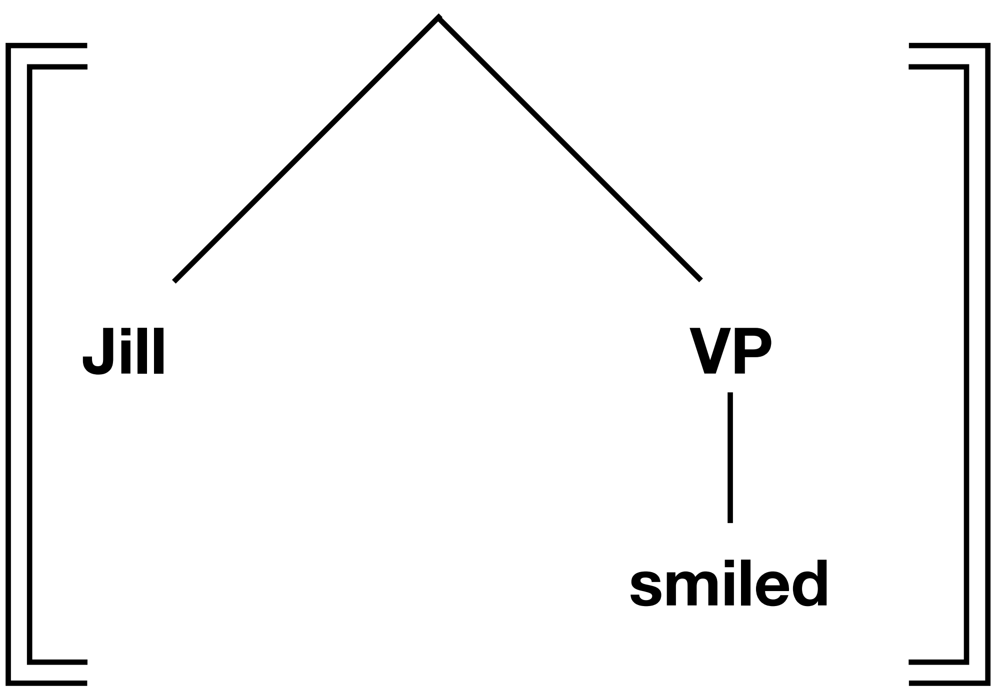
Brief primer on compositional semantics

Basic tenets:

- Truth-conditional semantics
  - the meanings of sentences are truth-conditions, the conditions that must hold in a situation for that sentence to be true
  - Thus: [[Jill smiled]] = TRUE *iff Jill smiled*

Brief primer on compositional semantics

- Putting the two together…



=

= [[smiled]]([[Jill]]) = TRUE…

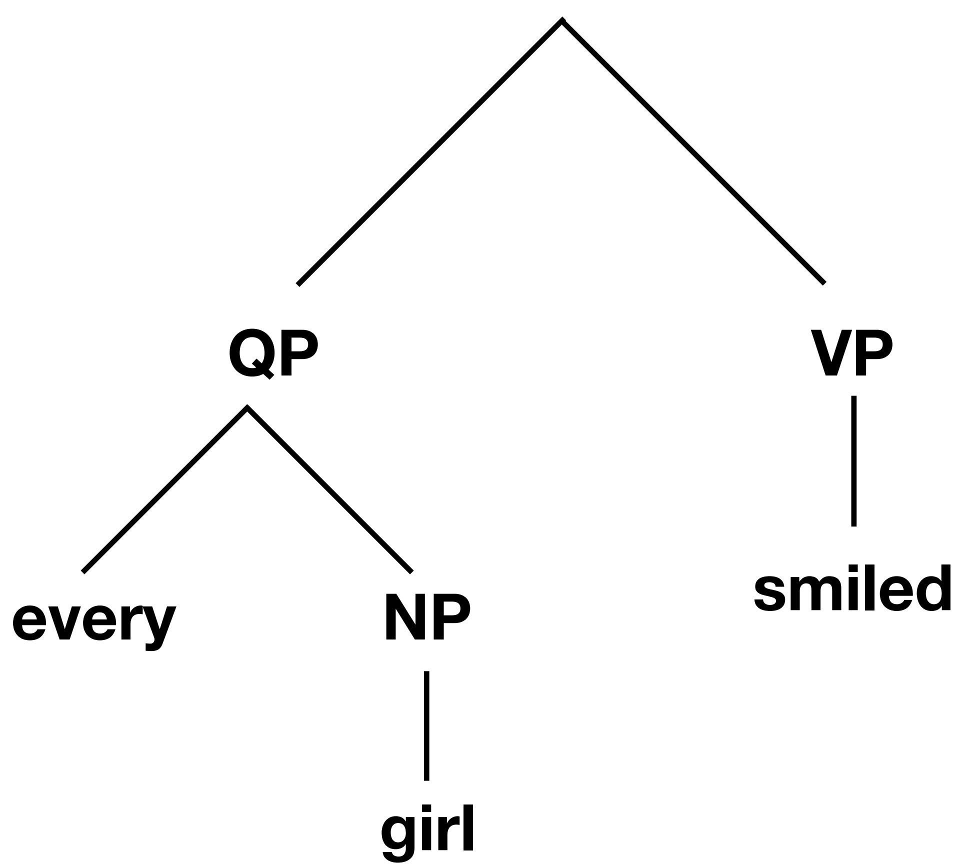
= [[smiled]] () = TRUE…

iff  ∈ {x : x smiled}

Assume [[smiled]] is a set of entities that smiled (or a function characterizing such a set)

Quantifiers again

- What are the truth-conditions of *Every girl smiled?*



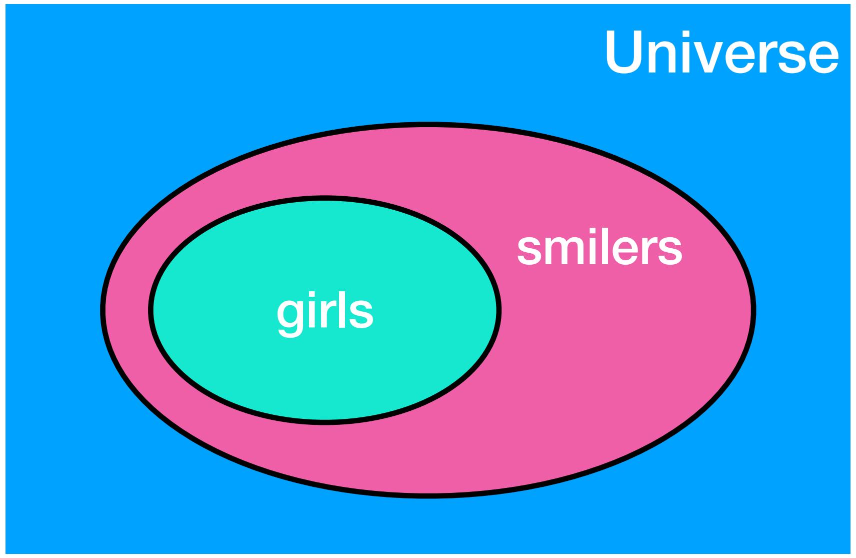
?= [[smiled]]([[every girl]]) = TRUE…

?= [[smiled]] (??) = TRUE…

?= ?? ∈ {x : x smiled}

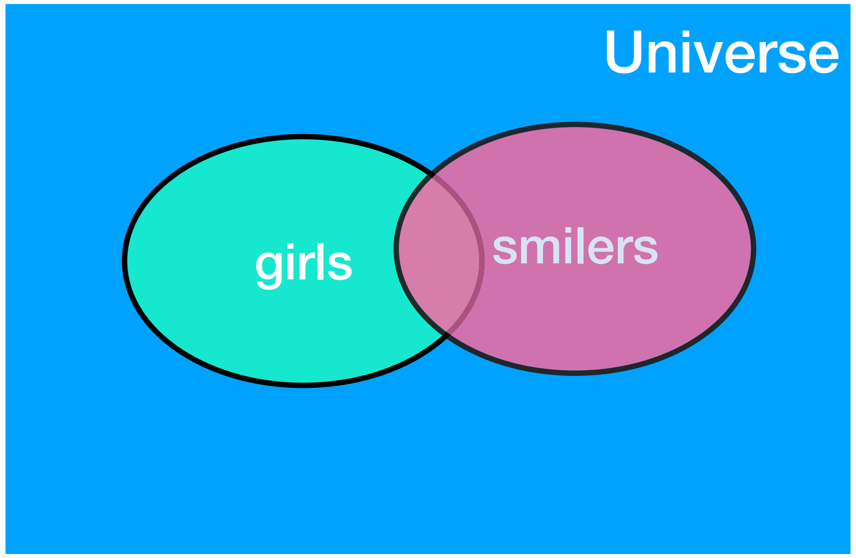
Quantifiers don't refer!

- Quantifiers do not refer to individuals (or groups)
- They are second-order relations between sets
  - [[every girl smiled]] = T iff
  - [[**every**]]([[girl]])([[smiled]]) = T iff
  - {x: x is a girl} ⊆ {y: y smiled}



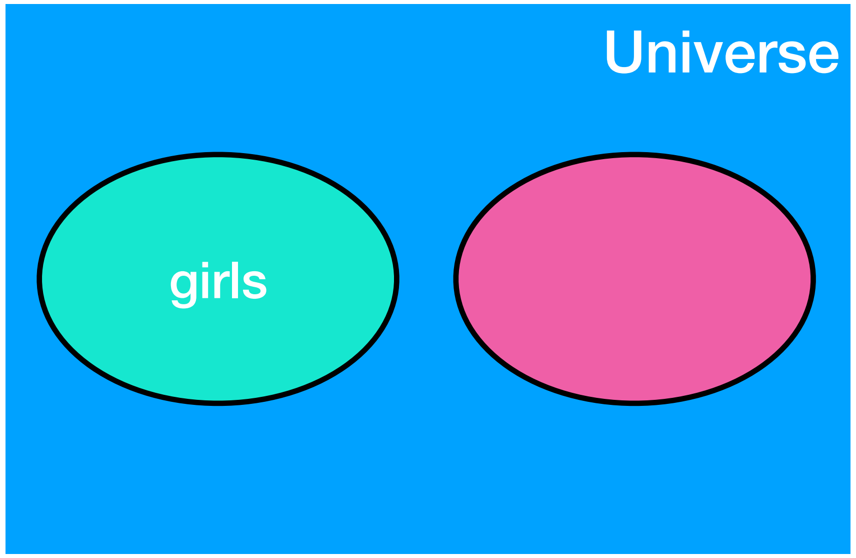
Quantifiers don't refer!

- Quantifiers do not refer to individuals (or groups)
- They are second-order relations between sets
  - [[some girl smiled]] = T iff
  - [[**some**]] ([[girl]])([[smiled]]) = T iff
  - {x: x is a girl} ∩ {y: y smiled} ≠ 0



Quantifiers don't refer!

- Quantifiers do not refer to individuals (or groups)
- They are second-order relations between sets
    - [[no girl smiled]] = T iff
    - [[**no**]] ([[girl]])([[smiled]]) = T iff
    - {x: x is a girl} ∩ {y: y smiled} = 0



Learning quantifiers

- Determiner quantifiers differ in meaning from referential expressions but the two kinds of DPs have largely overlapping syntactic distributions
    - the learner has to identify the Qs in their language and learn their meanings

NB: Other quantificational expressions

- adverbial quantifiers (always, sometimes)
- modals (must, can)
- typically not examined in acquisition (in the case of adverbial qs), or treated as unrelated to quantification (modals, conditionals)
- Today we will focus on quantificational noun phrases, a bit too much perhaps on universal quantifiers

Constraining quantifier meanings

- Let Q be the set of possible quantifier meanings and assume a universe of discourse U that contains all individuals under consideration, then
  - the number of possible subsets over U is $|\{X: X \subseteq U\}| = 2^{|U|}$
  - the number of possible ordered pairs of subsets of U is $|\{X: X \subseteq U\}|^{\wedge 2} = 2^{|U|} * 2^{|U|}$
  - the number of possible sets of such pairs, i.e. $|Q| = 2^{4^{|U|}}$
- Let $|U| = 2$, then there are $2^{16} = 65536$ different possible quantifier meanings

Constraining quantifier meanings

Conservativity:

- A relation Q is conservative iff for any A, B, Q(A)(B) = Q(A)(A∩B)
  - i.e. the truth of a quantificational statement depends only on the members of the first argument

    (1) Every girl smiled = Every girl is a girl who smiled

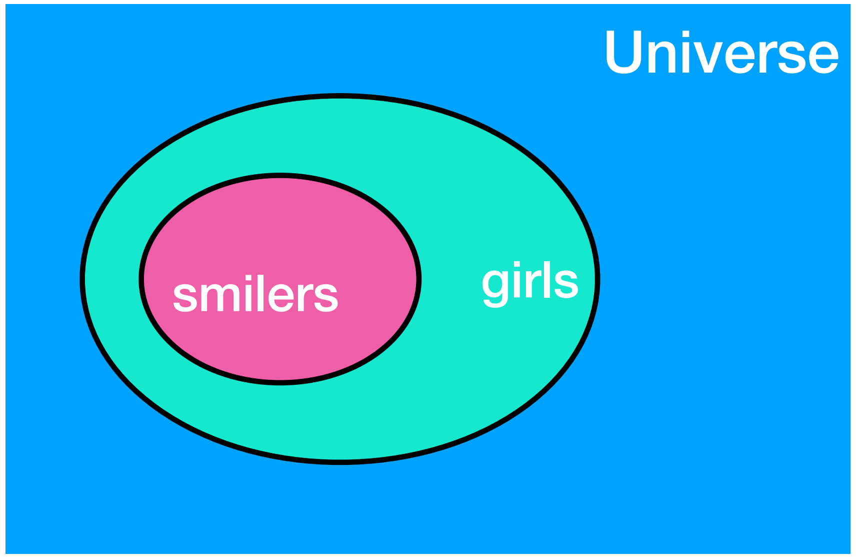
  Conservativity Universal (Barwise&Cooper 1981, etc.)
  All quantifiers in natural language are conservative

- $|Q\_CONS| = 2^{3^{|U|}}$

- Let |U| = 2, then there are now 512 different possible conservative quantifier meanings

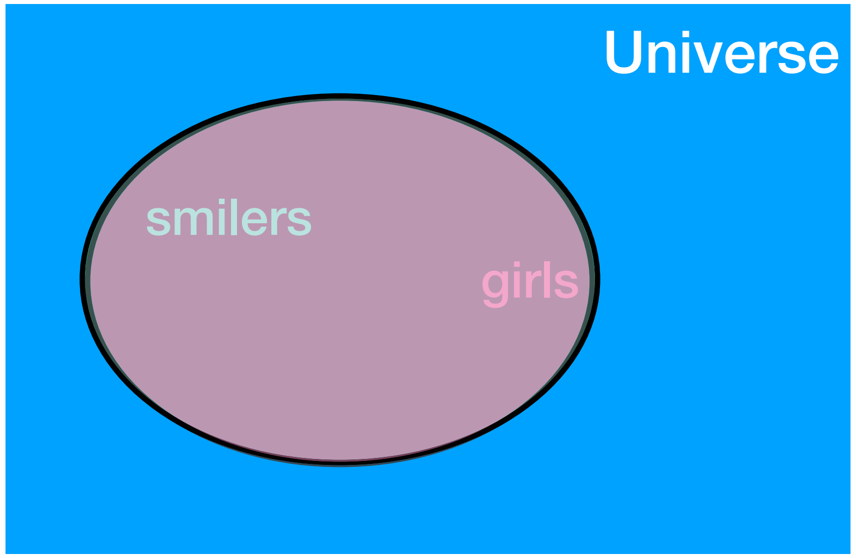
Non-conservative quantifiers

- Only girls smiled =/= Only girls are girls who smiled (if *only* was a quantifier like *every*)



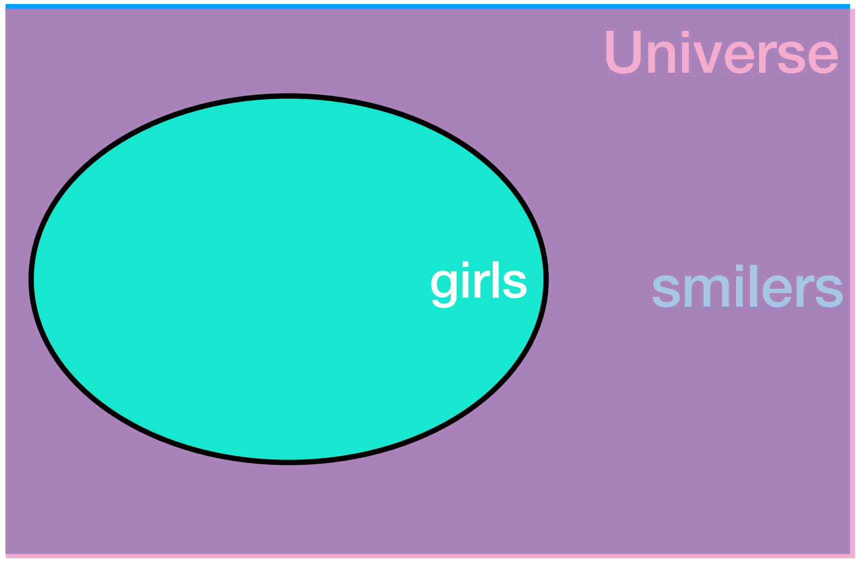
Made up non-conservative quantifiers

- **Equi** girls smiled ≈ the girls are the smilers



Made up non-conservative quantifiers

- **Allnon** girls smiled ≈ the non-girls are smilers



Constraints on quantifier meanings and learnability

A good question and a bad study…

- Hunter & Lidz (2013):
  - Are non-conservative quantifiers harder to learn?
  - If yes, might be indication that such Qs are never even part of the hypothesis space

Hunter & Lidz 2013

- Two novel quantifiers
  - $Gleeb_1$: conservative, *nevery* meaning

    (1) ‘$Gleeb_1$ girls are on the beach’ is true iff
    GIRL $\nsubseteq$ BEACH-GOERS

  - $Gleeb_2$: non-conservative, *nonly* meaning

    (2) ‘$Gleeb_2$ girls are on the beach’ is true iff
    BEACH-GOERS $\nsubseteq$ GIRLS

Hunter & Lidz 2013

- Participants:
  - 20 children, aged 4;5 to 5;6 (M=5;0), randomly assigned to conservative or non-conservative conditions (10 per group)

Hunter & Lidz 2013

- “Picky Puppet Task”
  - “One experimenter controls a ‘picky puppet’, who likes some cards but not others. The second experimenter places the cards that the puppet likes in one pile, and the cards that the puppet does not like in a second pile. The child’s task is to make a generalization about what kinds of cards the puppet likes, and subsequently ‘help’ the second experimenter by placing cards into the appropriate piles.”
  - “Liking criteria”: puppet likes it when e.g. ‘gleeb X are Y’

Hunter & Lidz 2013

Figure 1:
Gleeb=*Not all*: True
Gleeb=*Not only*: False

Figure 2:
Gleeb=*Not all*: False
Gleeb=*Not only*: True

Hunter & Lidz 2013

Card	beach		grass		'gleeb girls are on the beach'	'gleeb′ girls are on the beach'
	boys	girls	boys	girls		
Train 1	2	0	1	2	true	true
Train 2	0	2	3	0	false	false
Train 3	0	1	2	3	true	false
Train 4	2	3	0	0	false	true
Train 5	2	1	1	2	true	true
Test 1	3	0	0	2	true	true
Test 2	0	3	3	0	false	false
Test 3	2	3	0	2	true	true
Test 4	1	2	2	0	false	true
Test 5	1	2	0	2	true	true

Table 1 The distribution of girls and boys on each card in the experiment

Hunter & Lidz 2013

Condition	Conservative	Non-conservative
Cards correctly sorted (out of 5)	mean 4.1 (above chance, $p<0.0001$)	mean 3.1 (not above chance, $p>0.2488$)
Subjects with "perfect" accuracy	50%	10%

Table 2 Summary of results

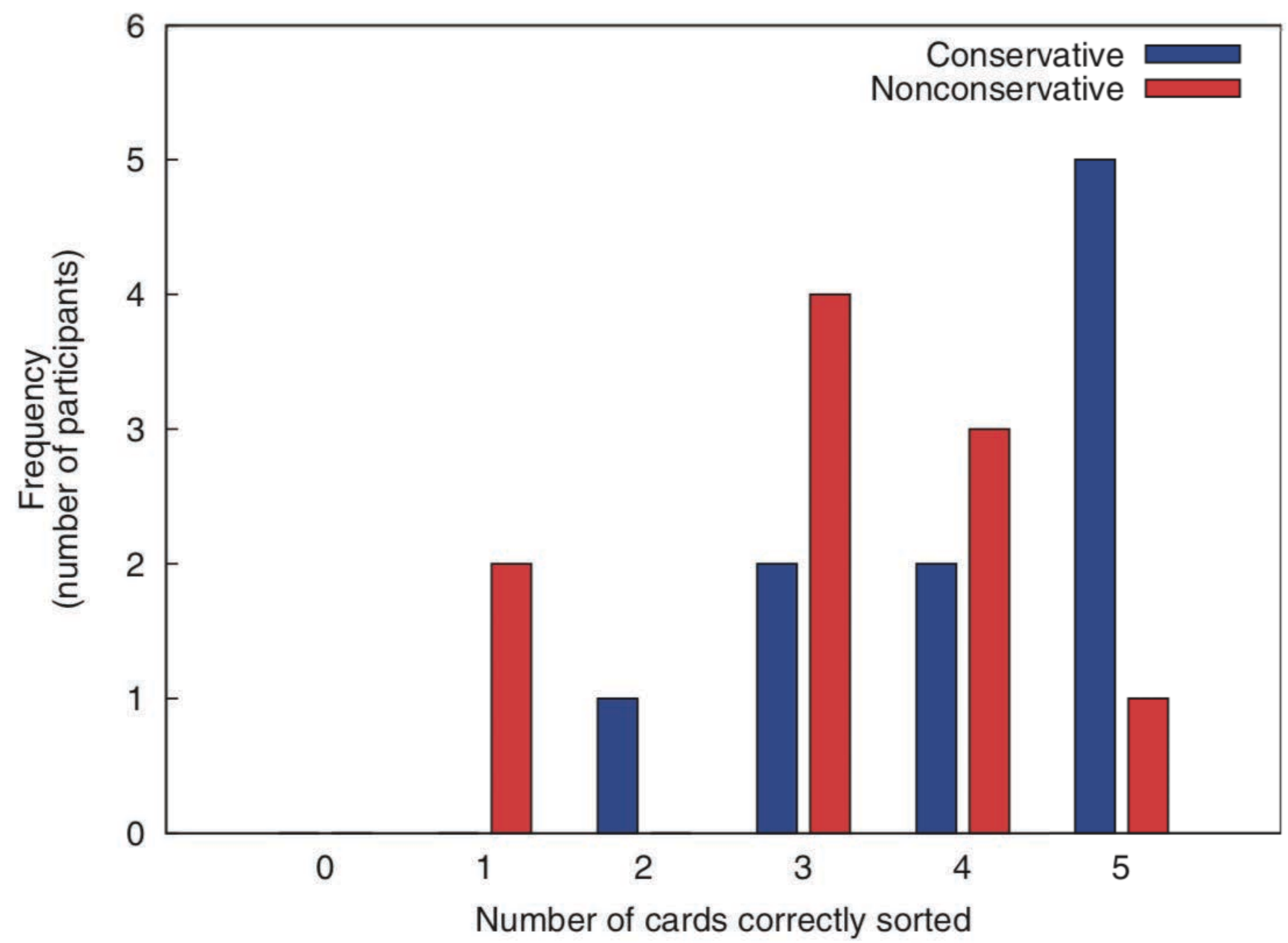


Figure 2 Distribution of participants in each condition according to how many cards were correctly sorted.

Failures to replicate

Spenader & de Villiers 2019

- Experiment 1:
  - Adults (N=18; 9 per group)
  - Same materials as H&L13
  - 56% success on conservative; 69% non-conservative, not statistically different
  - NB: post-hoc review of justifications indicated that some adults succeeded by treating “gleeb2 girls” as “non-girls" s.t. if boys were on the beach, they say yes.

Failures to replicate

Spenader & de Villiers 2019

- 20 children (10 per group) trained on exactly the same materials as HL13, + 6 extra items

- 60% success for conservative; 68% for non-conservative gleeb
  - 3.0 cons vs. 3.4 ncons for the first 5 items
  - 6.0 cons vs. 7.2 ncons for the total 11 items

Methodological morals

- More careful experimentation
  - counterbalance aspects of the task that might lead to artifactual results (e.g. presentation order)
  - statistical power
- More careful reviewing and citation practices
  - at some point in the review process, both (i) and (ii) above should have been raised as concerns

Non-conservativity in child quantifier meanings?

Is every rabbit riding an elephant?

Non-conservativity in child quantifier meanings?

Is every rabbit riding an elephant?

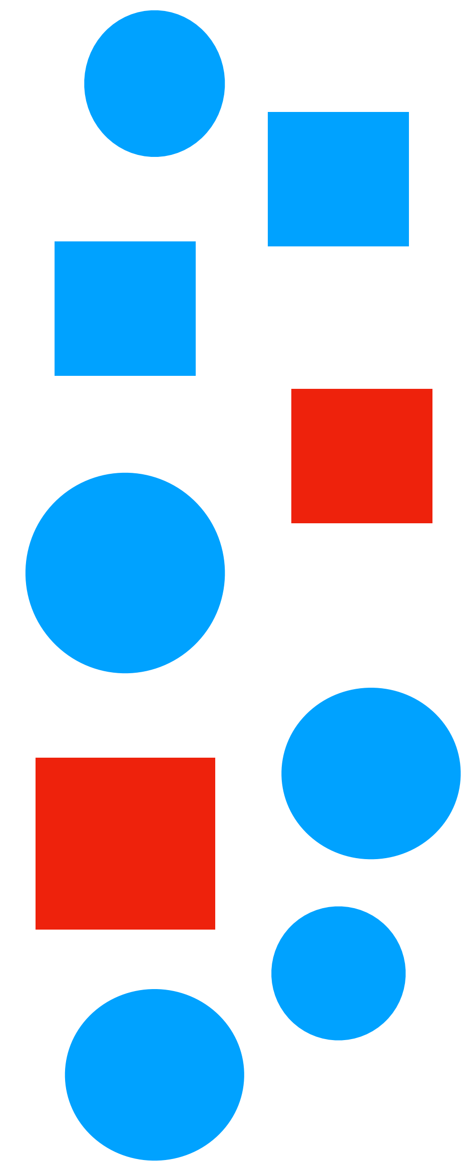
Adults: Yes

4-6-year-olds: No

Why? extra elephant

Inhelder & Piaget 1958, 1964

- Class inclusion task—an assessment of children's ability to classify objects on the basis of common features
- E.g. child might be shown a set of counters comprising five blue circles, two blue squares, and two red squares
- When asked "Are all the circles blue?" children say "no" and point to the blue squares as justification



Donaldson & Lloyd 1974

- Fourteen preschool children (3-to 5-year-olds)
- Array of 4 garages and a set of either 3 or 5 cars, with the cars arranged in partial one-to-one correspondence with the garages.
- When there were 4 garages and 3 cars, children tended to evaluate the statement "All the cars are in the garages” as wrong, often justifying their answer by noting the emptiness of the fourth garage.
- Similarly, where they saw 4 garages and 5 cars, they rejected “The garages have all got cars in them” justifying their answer by pointing to the ungaraged car.

One-to-one correspondence

- Inhelder & Piaget: “It looks as if the child’s thinking is conditioned by a need of symmetry: the extension of the predicate blue must be the same as that of the subject round… **[Our subjects] substitute equivalence (A = B) for class inclusion (A > B or B > A)**”

- But this is precisely the kind of quantifier meaning that natural language disallows!

Two error types

- Overexhaustive search
- Underexhaustive search

Is every circle above a star?

Overexhaustive vs. Underexhaustive Search

Table 1: % of children who make over- and under-exhaustive search errors

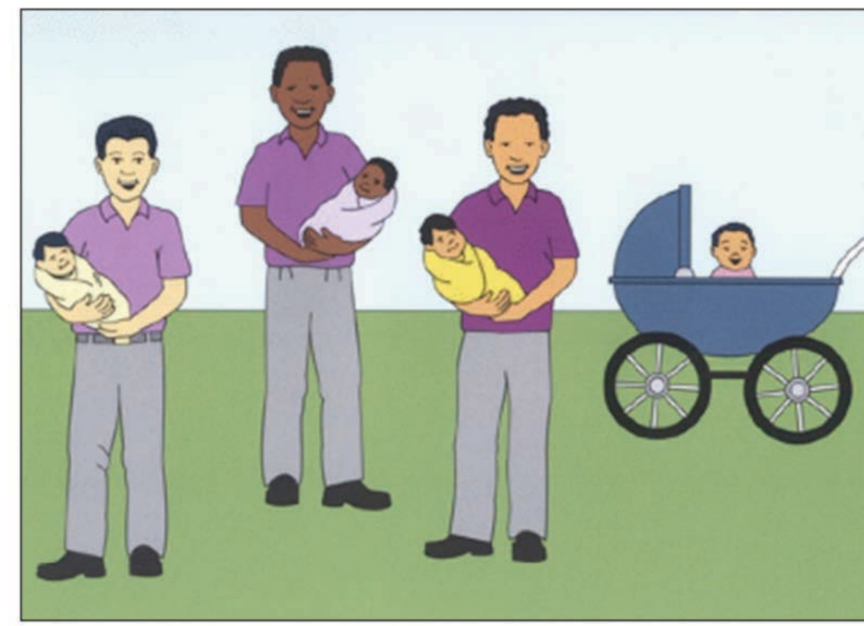
Language	Avg. Age	Over-exhaustive	Under-exhaustive	Other
English (6 studies)	4;7	80%	18%	2%
Japanese (2 studies)	5;1	62%	38%	0%
Dutch	6;6	57%	12%	31%
French	5;9	43%	44%	13%
Spanish	5;6	42%	43%	15%
Norwegian	6;2	40%	55%	5%

Meta-analysis from Philip 2011

Relation between the errors

- Aravind et al. 2017
- Longitudinal study, 140 English-acquiring children tested 4 times
- Mean age, T1 = 4.22; Mean age, T4 = 6.73
- 2 questions each of (i) over-exhaustive vs. (ii) under-exhaustive scenarios

Is every man holding a baby?



Is every woman sailing a boat?

Trajectory

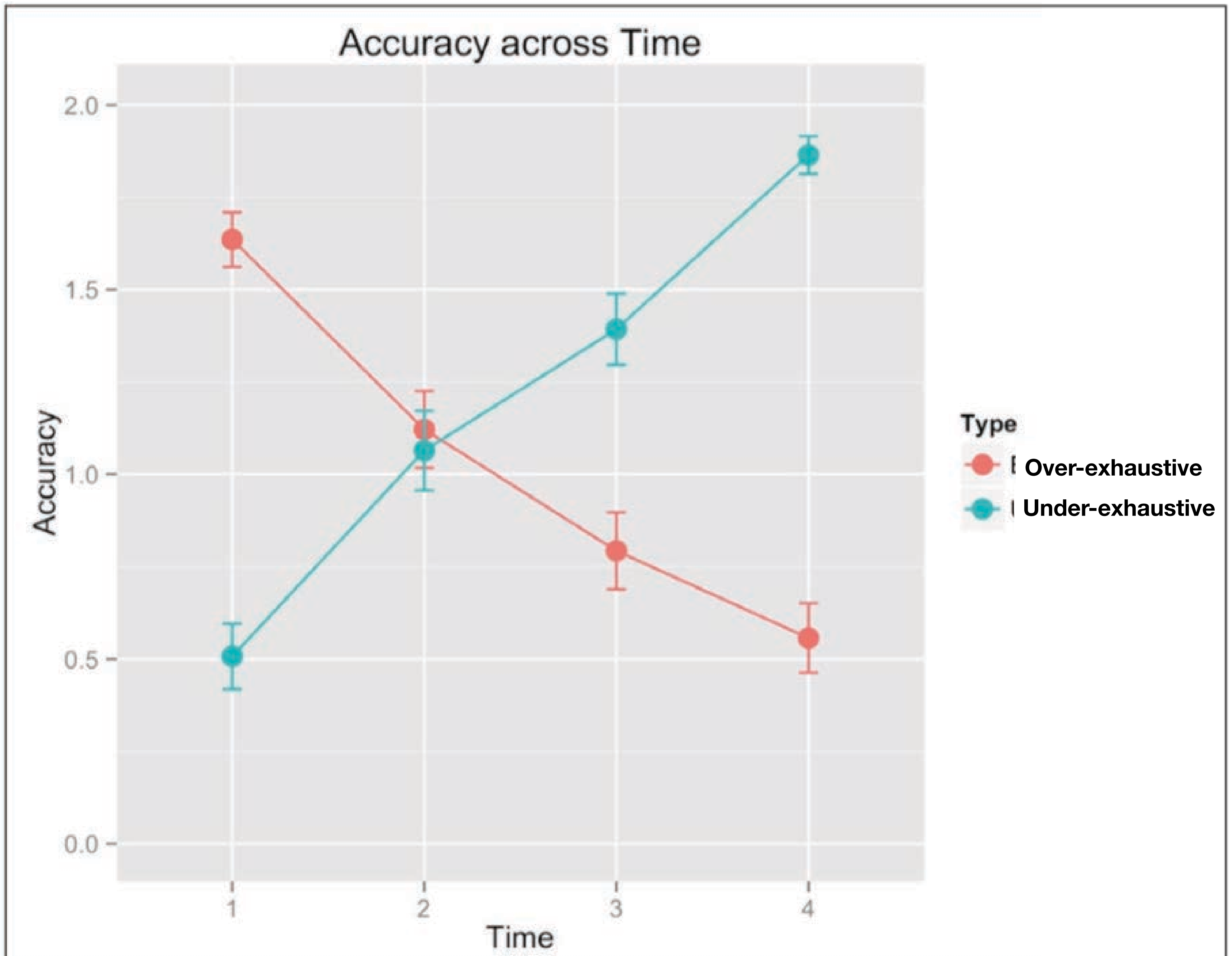


Figure 3: Mean accuracy for the two types across time.

Upshot

- Inverse relationship in development between Overexhaustive errors and Underexhaustive errors
- Not compatible with the idea that the error derives from an initial non-conservative “one-to-one” meaning for the quantifier
- The interesting case is the over-exhaustive errors: it seems *progressive* in nature
- What’s going on?

Next time

- Continue discussion of over-exhaustive errors
- Readings: Guasti Ch.9, an extra reading by Keenan 2002 for those interested in quantifier meanings