Scalar implicature:

a whirlwind tour with stops in processing, development and disorder

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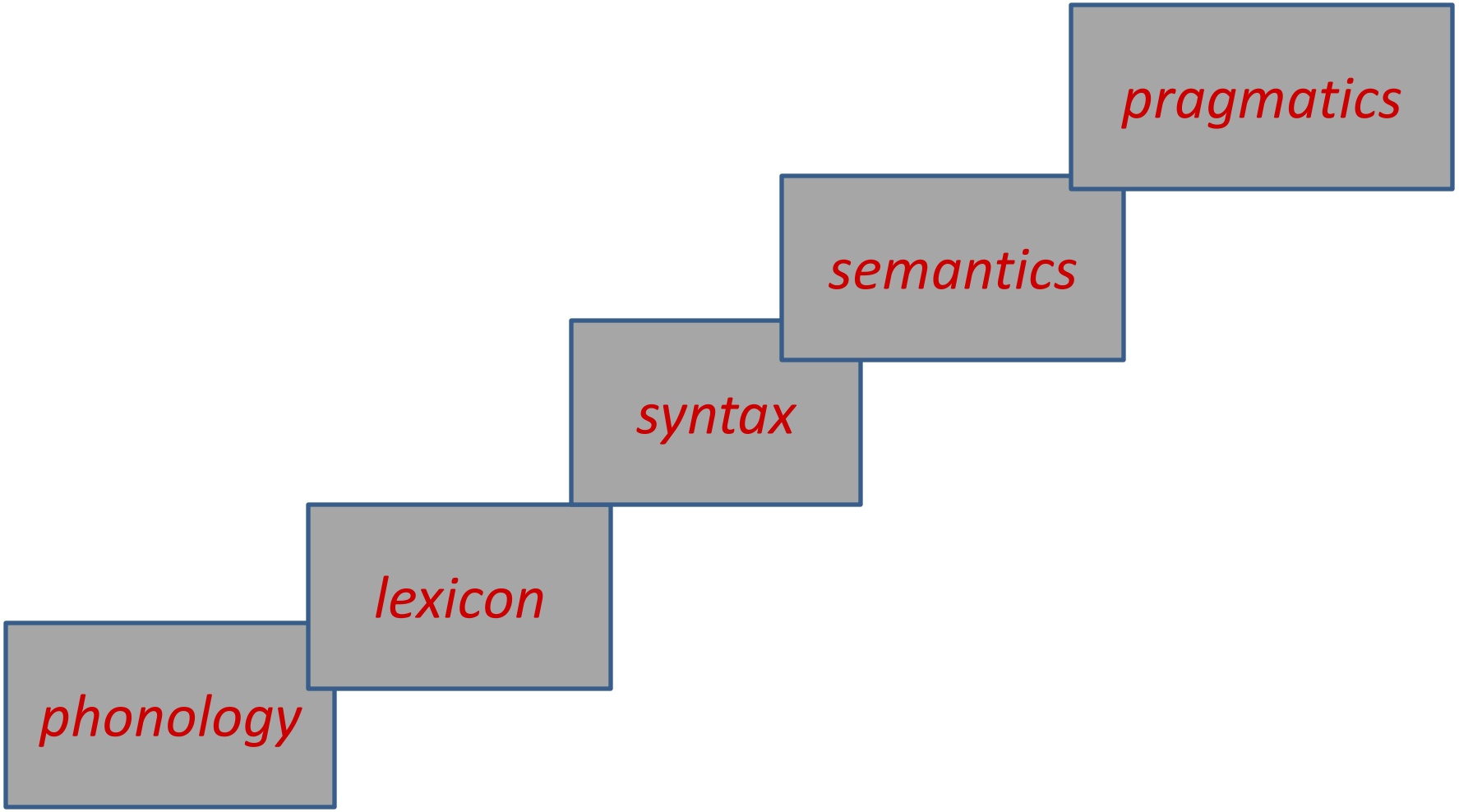
Outline

- Grounding assumptions
- A modest proposal
- The data behind the proposal
  1. Implicature typically takes time and effort
  2. Instant SI's occur only when pre-encoding is plausible
  3. SI proficiency develops slowly
  4. In disordered populations SI patterns with language ability

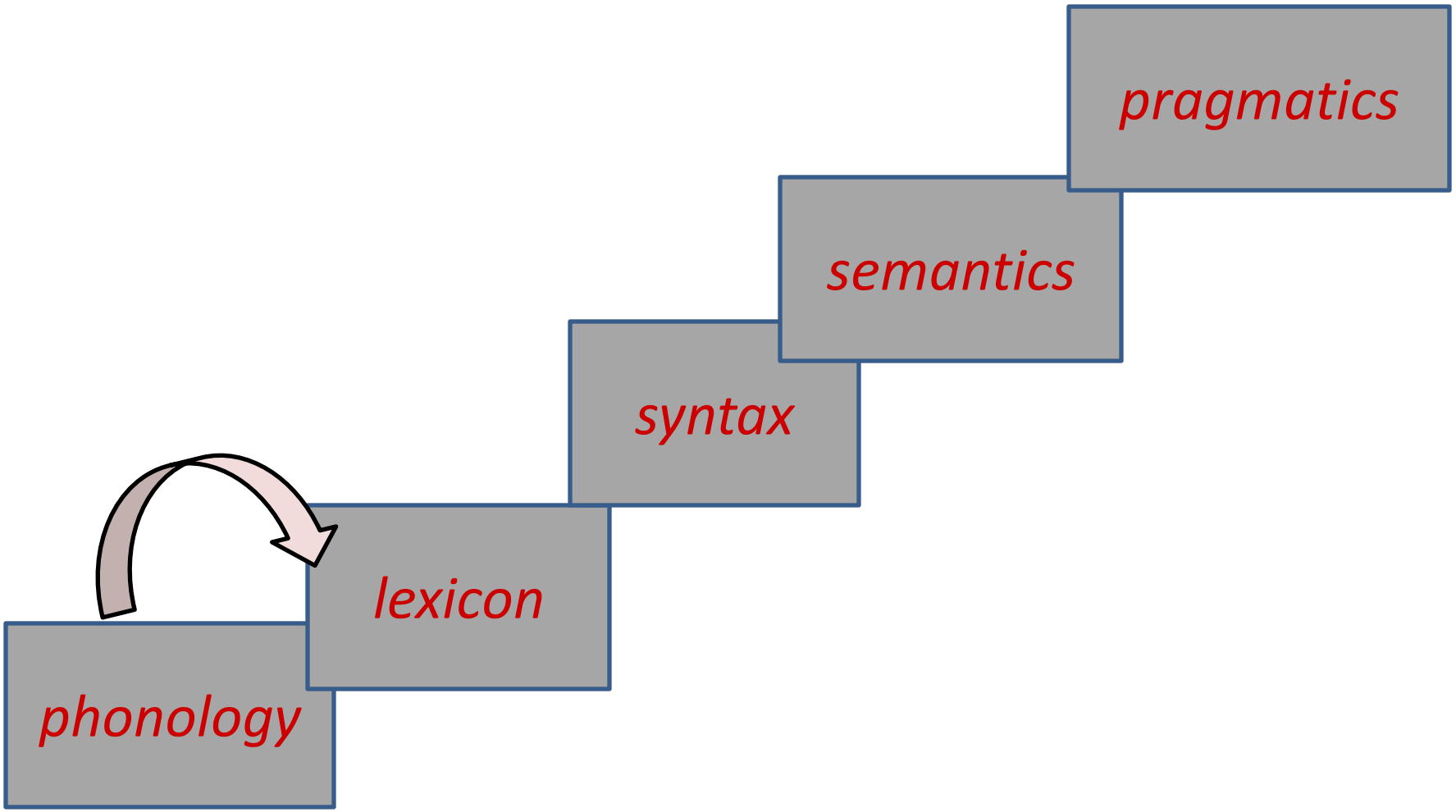
21st century standard model

1. Comprehension builds a partially ordered series of representations



21st century standard model

2. Cascaded processing (incrementality)



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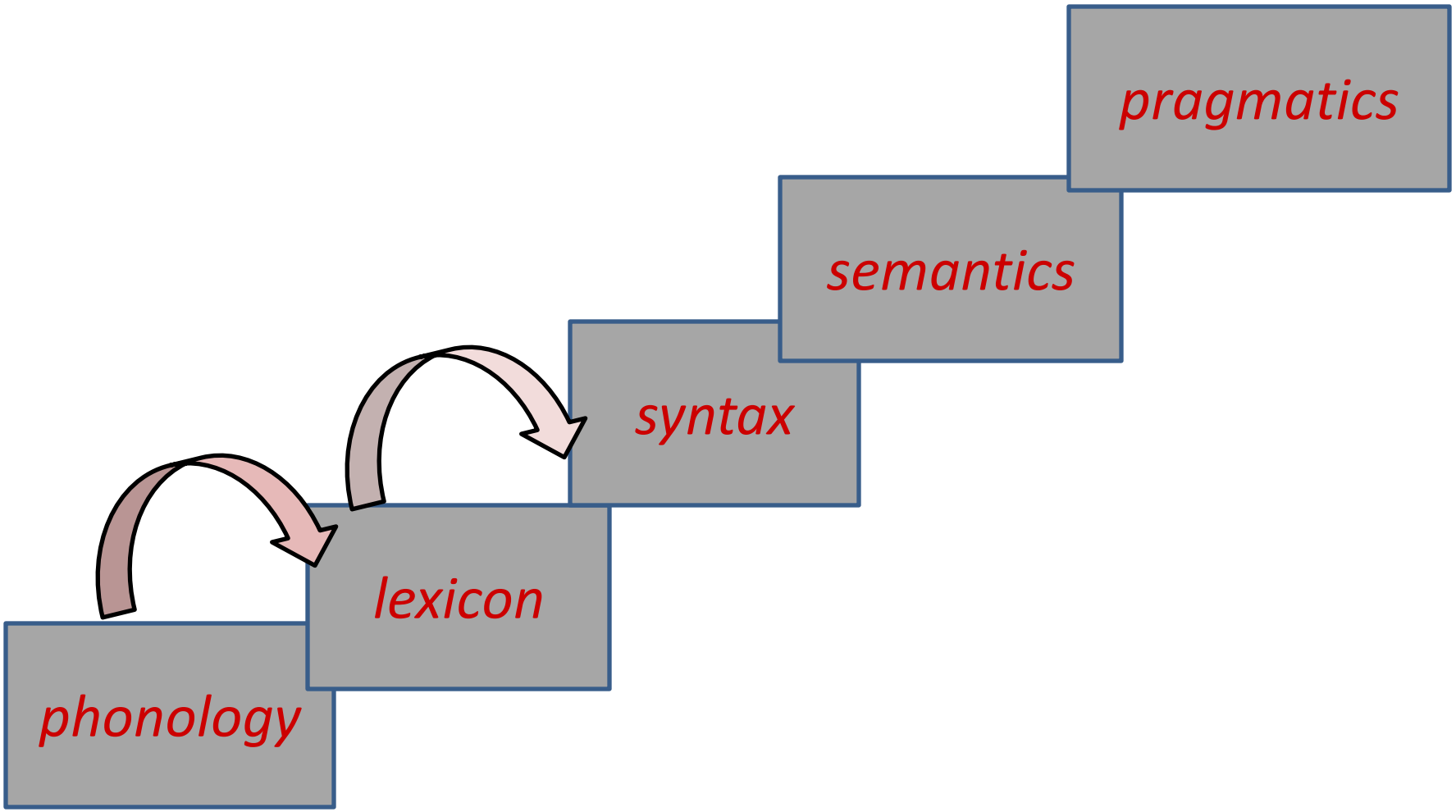

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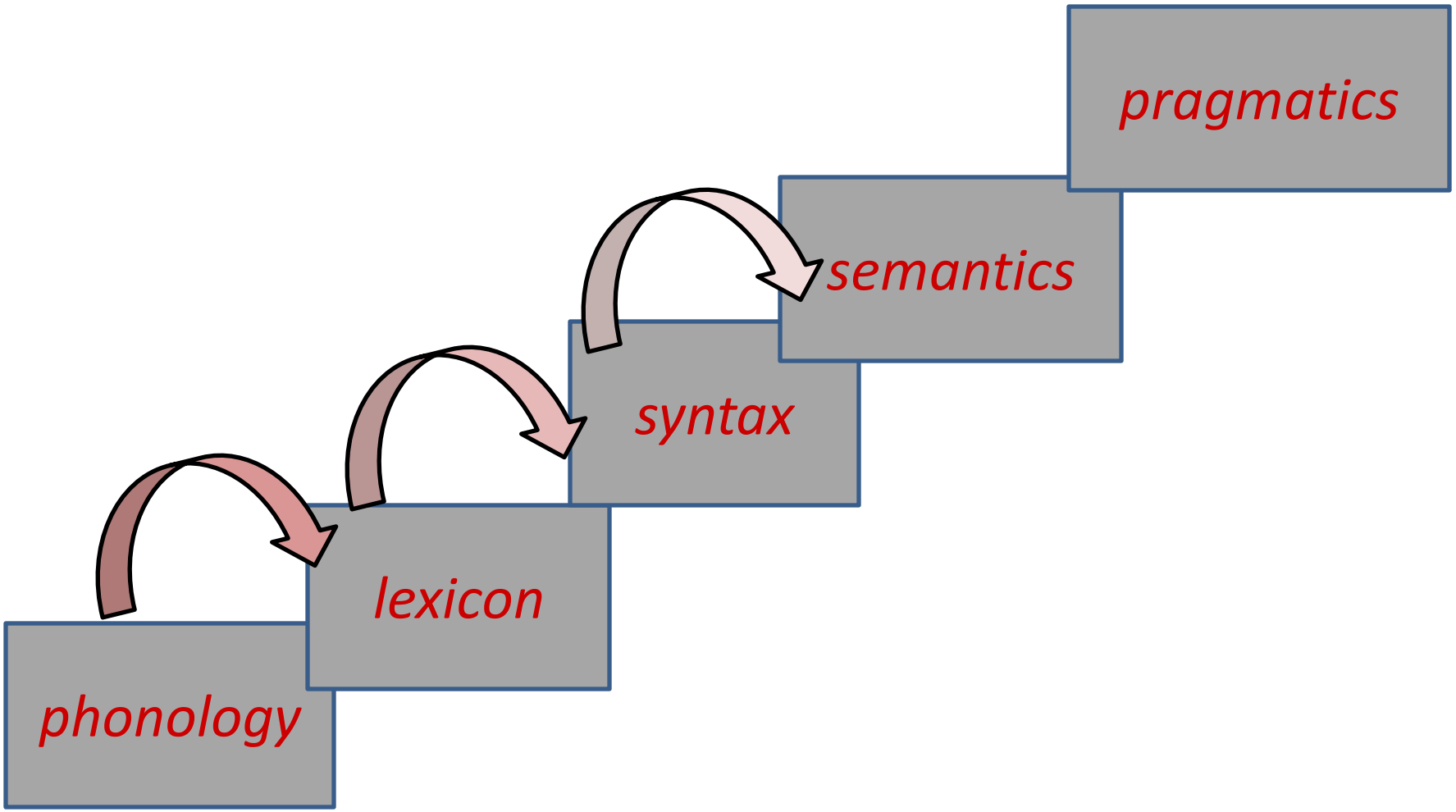

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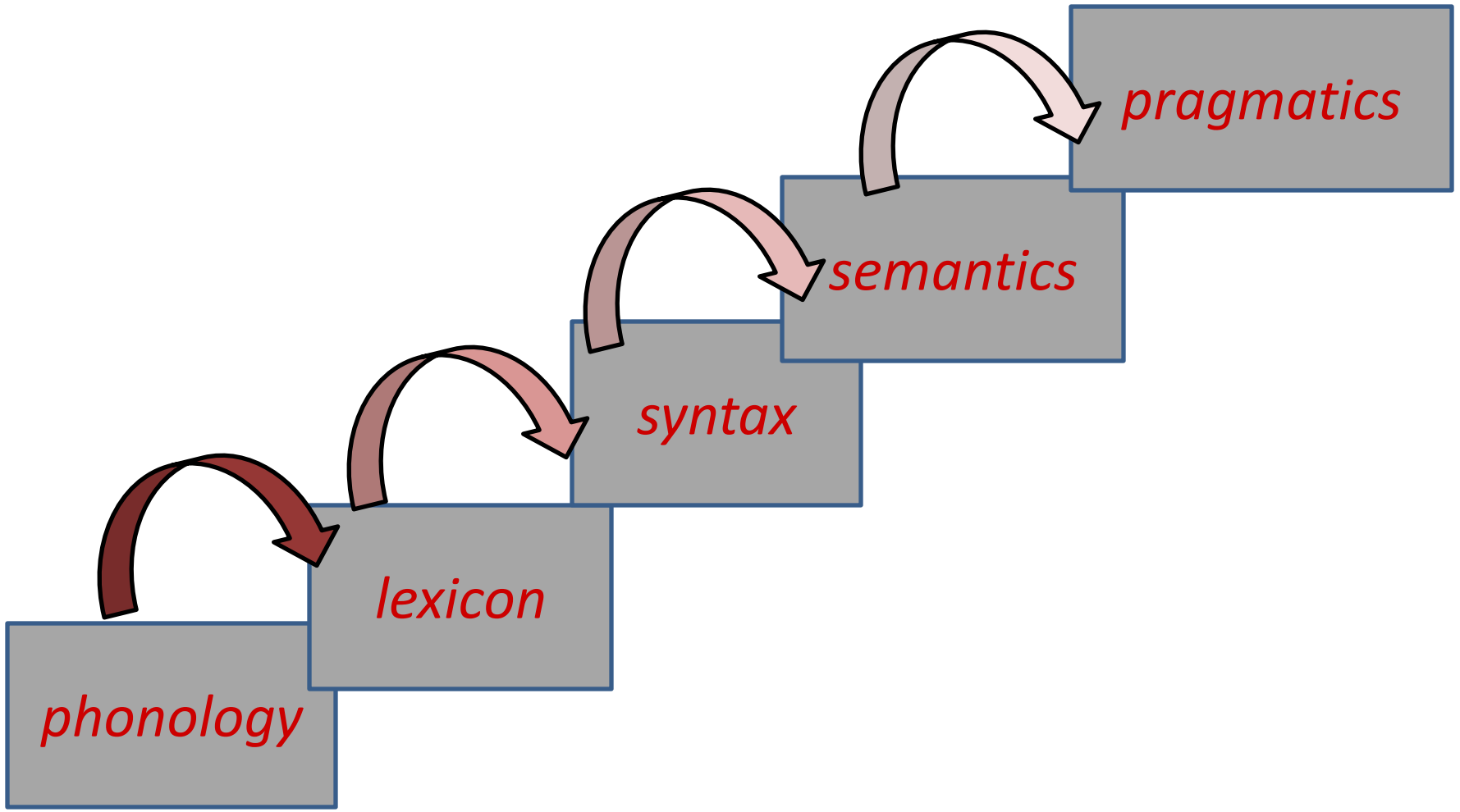
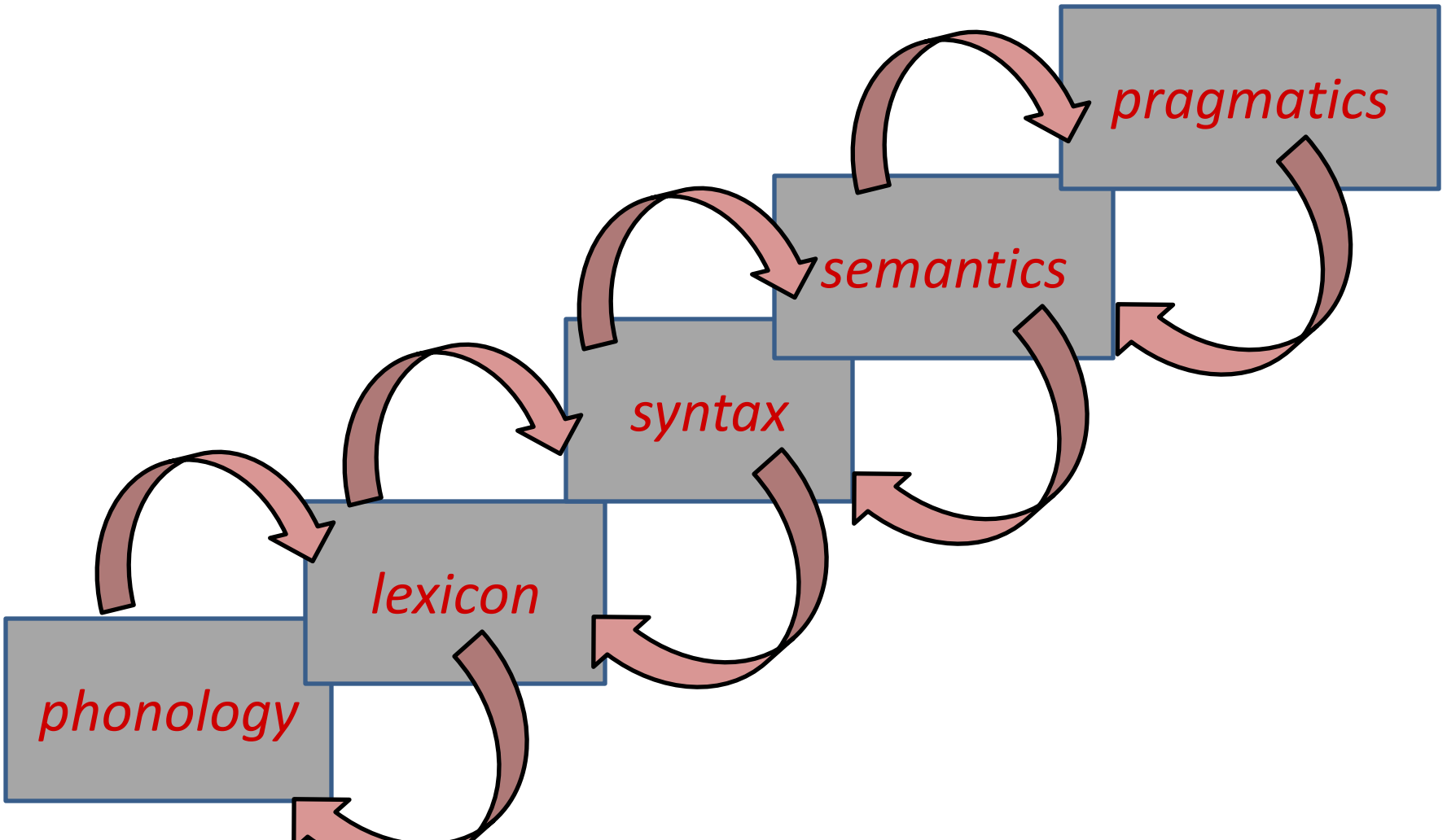


21st century standard model

3. Processing is interactive: both directions

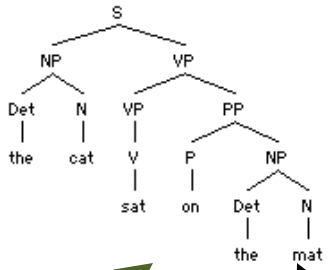


3. Interactivity: many inputs

pragmatic interpretation

semantics

$\exists$ x [cat (x) $\wedge$ on mat (x)]
$\wedge \forall$ y [cat (y) $\wedge$ on mat (y)] x=y



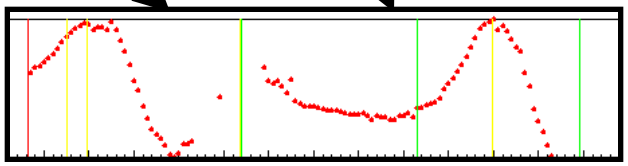
syntax

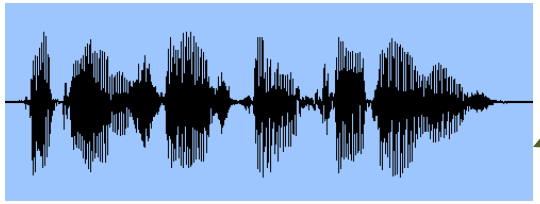
lexicon

/kæt/: noun, singular, animate
/sæt/: verb, past, intransitive
/mæt/: noun, singular, inanimate

phonology

əkætsætmæt



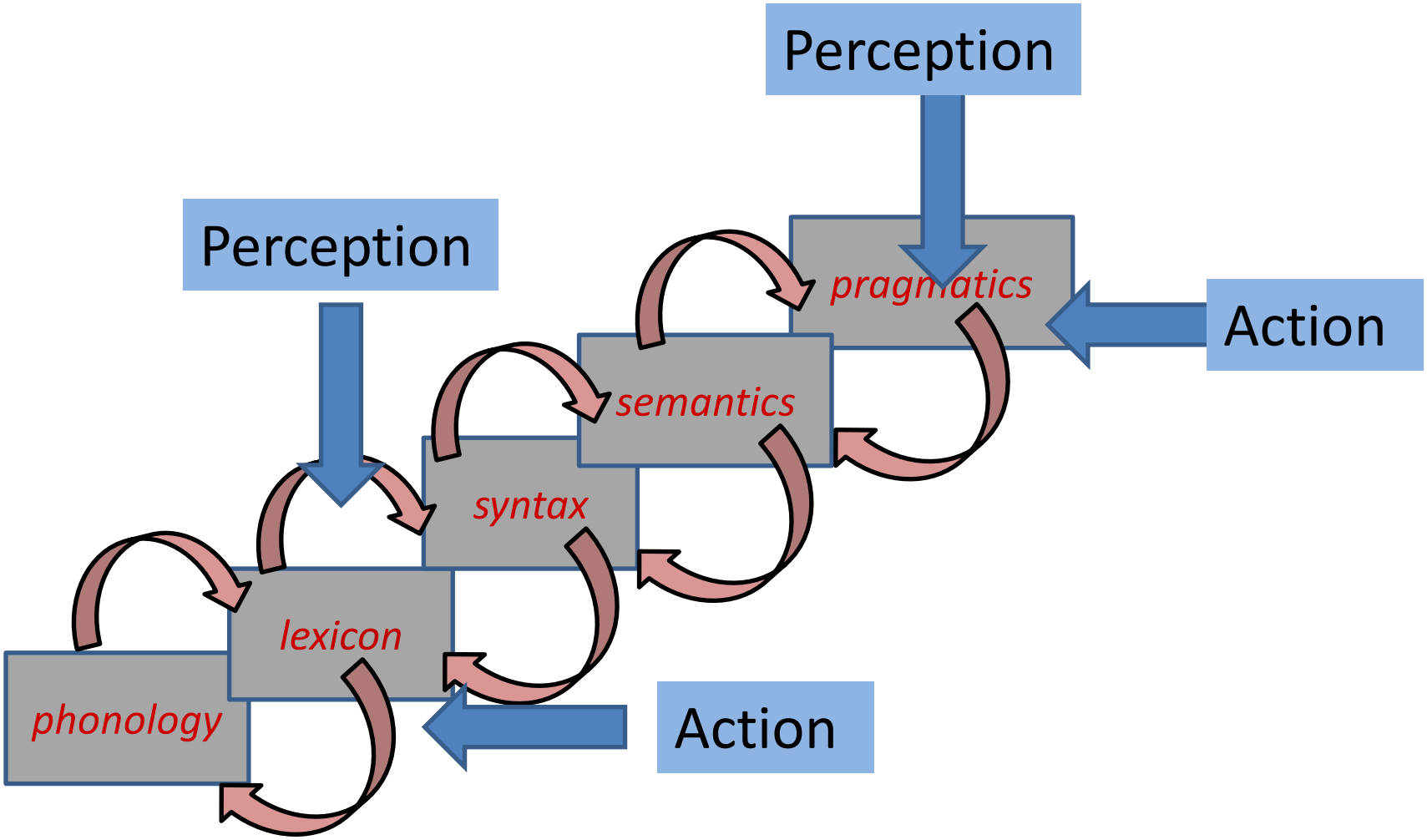


acoustic processing

prosody

21st century standard model

4. No walls around language



21st Century Standard Model

1. Levels of representation
2. Incremental
3. Interactive
   - Corollary: under many circumstances processing will be predictive
4. In contact with perception and action
   - Corollary: introduces the possibility of top-down prediction of speech

- Does this mean that all natural inferences are made instantly, with no delay?
- Of course not, cognitive operations unfold over time
  - Can be done ahead of time
  - Can be stored
  - But they are not atemporal

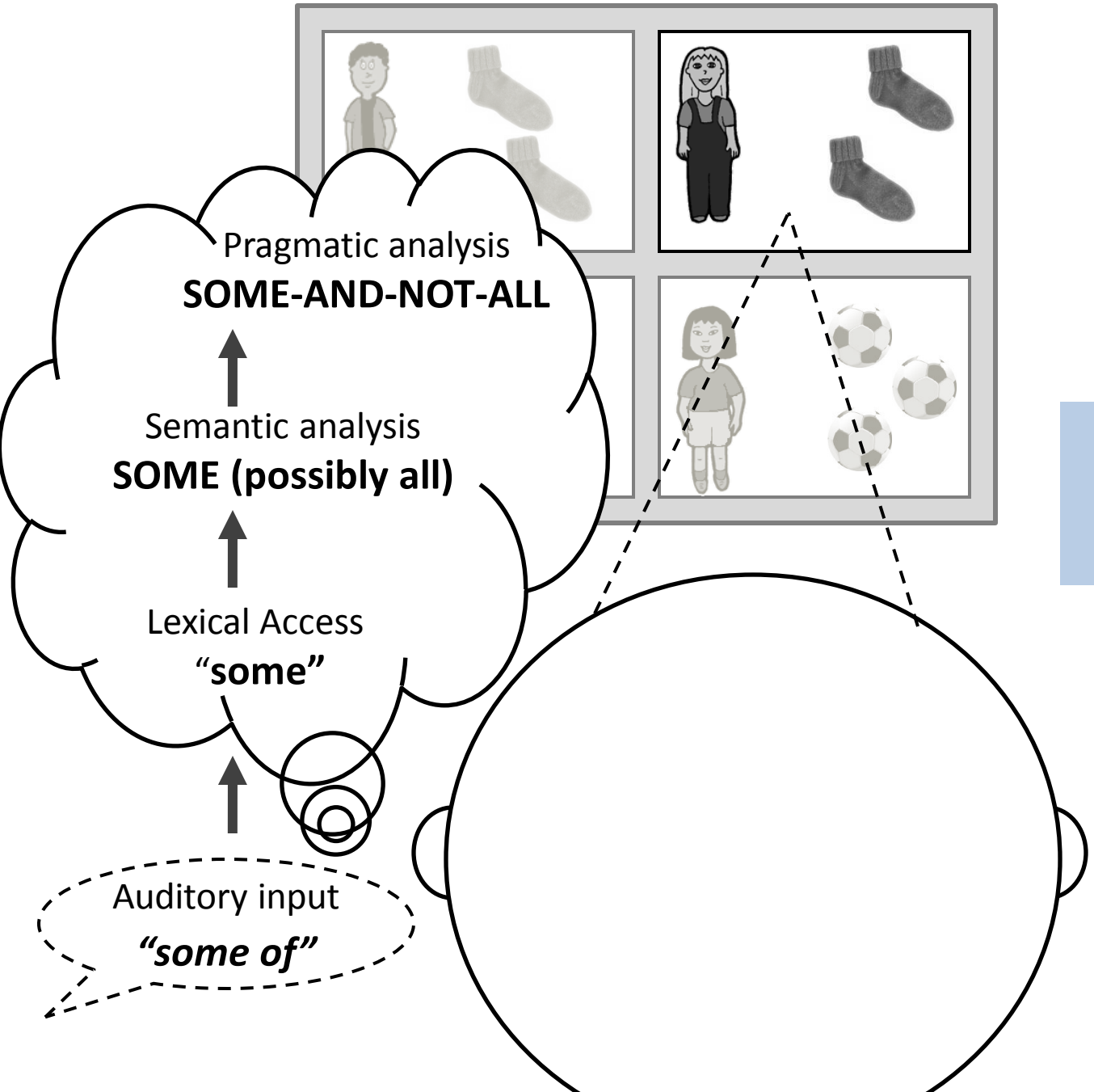
How are scalar implicatures calculated?

Bottom-up

- Hear “some”
- Retrieve its meaning
- Activate stronger alternative (*all*)
- Construct enriched meaning
- Evaluate / link to context

Dependent on context!

Remember, this is incremental and interactive
(we reject the “2-stage” label)

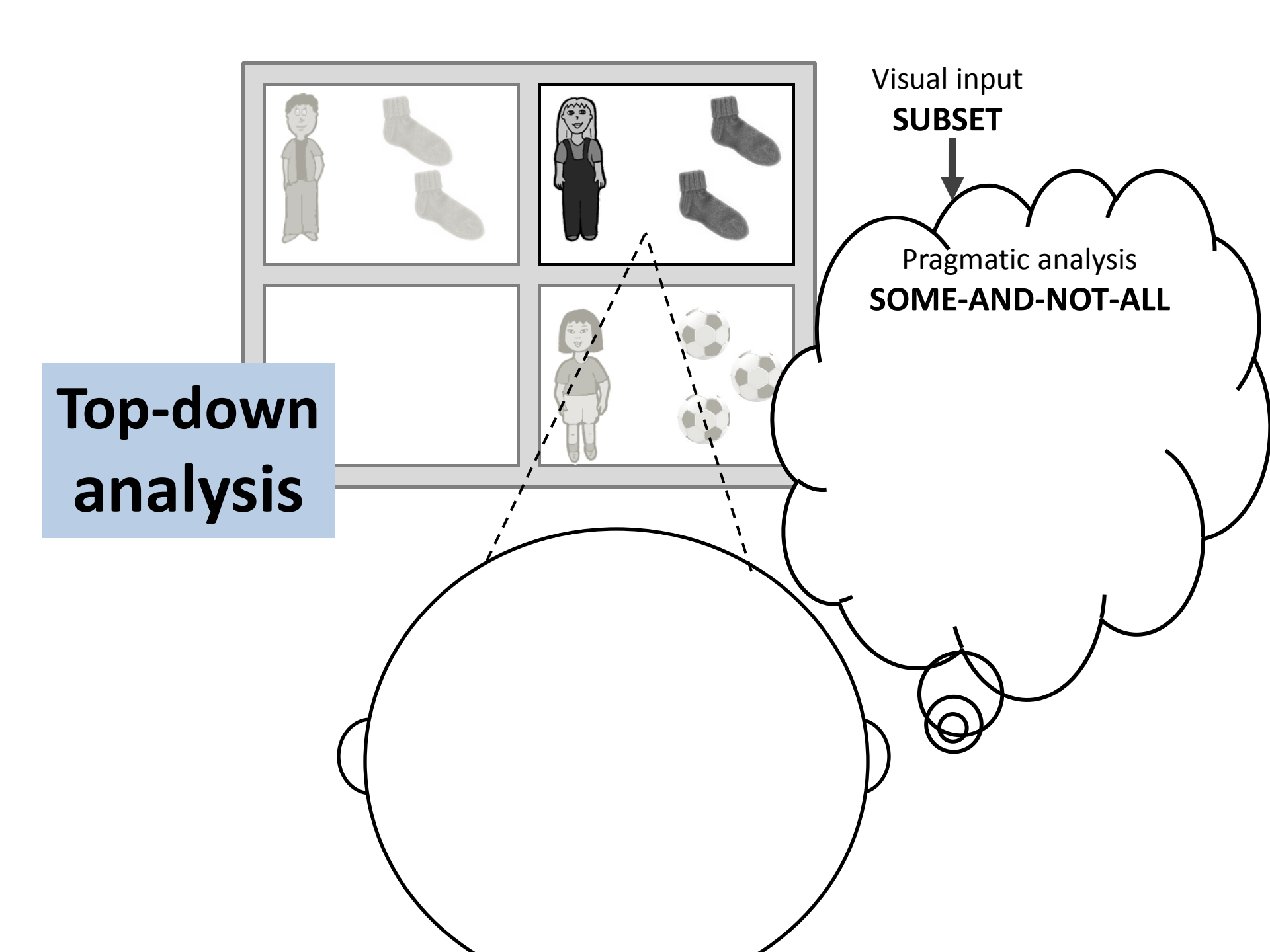


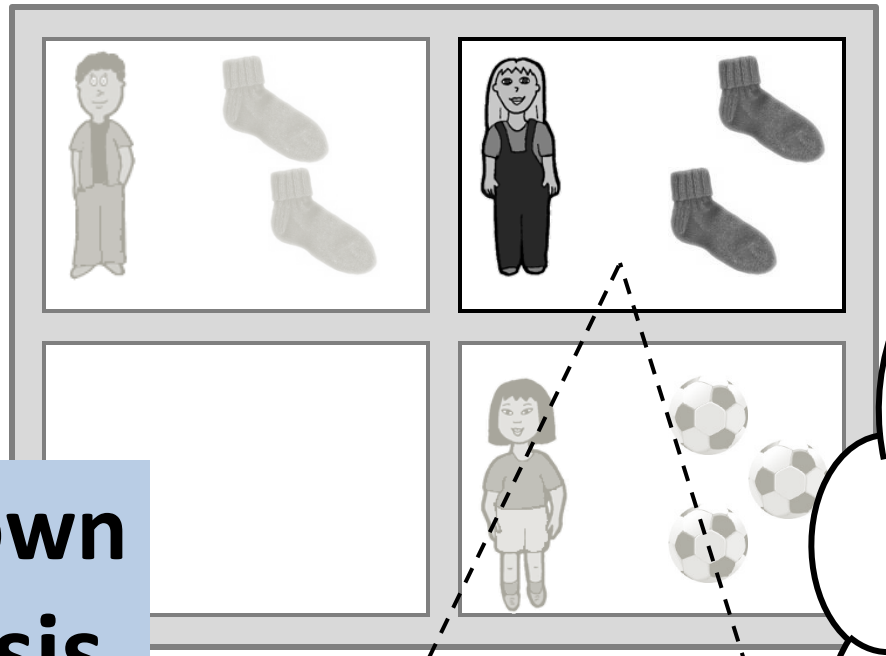
Bottom-up analysis

How are scalar implicatures calculated?

Top-down

- Listener sees display (knows the situation)
- Encodes a “message level” representation of possible referents (GIRL + SUBSET OF X’S)
- Begins to link to lower levels of representation (semantic, maybe even lexical)


Visual input
SUBSET
Pragmatic analysis
SOME-AND-NOT-ALL
Top-down analysis



Visual input

SUBSET

Pragmatic analysis

SOME-AND-NOT-ALL

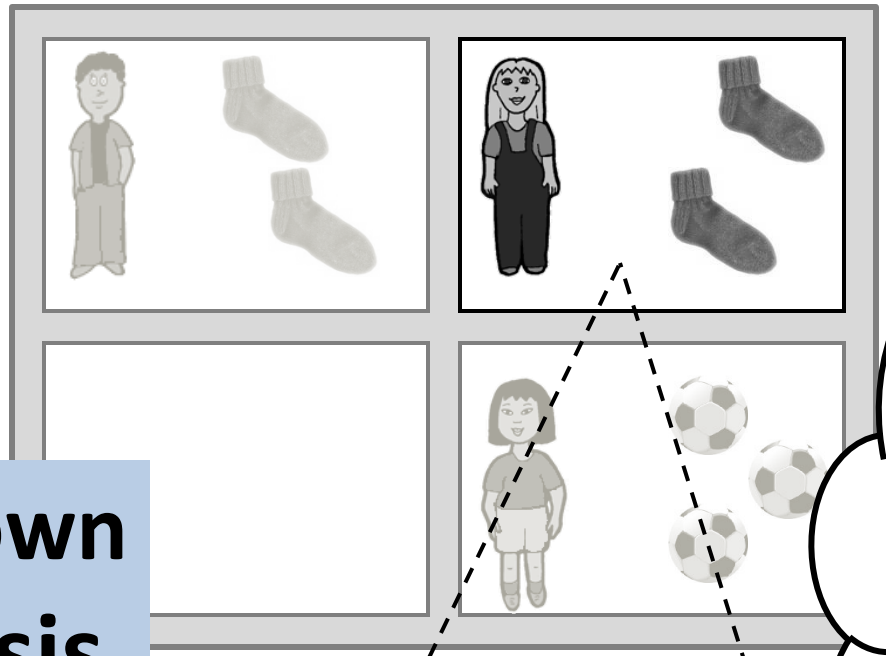
Semantic Analysis

SOME

Lexical access

“**some**”

Top-down analysis



Visual input
SUBSET

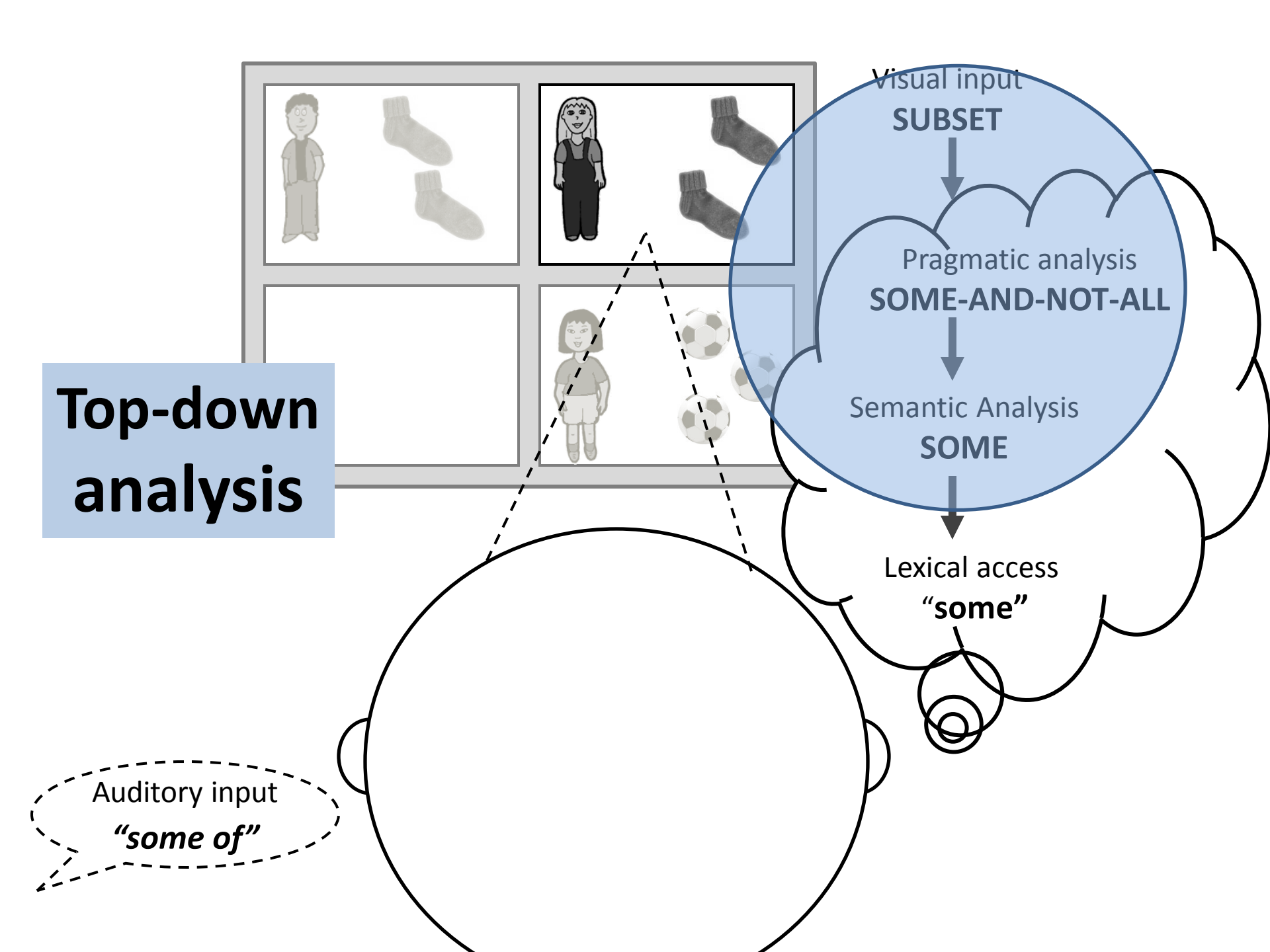
Pragmatic analysis
SOME-AND-NOT-ALL

Semantic Analysis
SOME

Lexical access
“**some**”

Top-down analysis

Auditory input
“some of”


Top-down analysis
Visual input
SUBSET
Pragmatic analysis
SOME-AND-NOT-ALL
Semantic Analysis
SOME
Lexical access
"some"
Auditory input
"some of"

Predictions

- Bottom-up
  - Scalar upper bound delayed relative to lexically encoded upper and lower bounds
  - Occurs when verbal encoding is difficult
    - Messages more unpredictable to comprehender
    - Multiple construals of given referent
- Top-down
  - Scalar upper bound guide reference resolution as rapidly as lexical bounds
  - Occurs when a verbal encoding is easy
    - Facts already known to listener (visual world)
    - Single salient construal of each referent in task

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SI's typically require time and effort

1. Sentence judgment studies

   Bott & Noveck, 2004; Bott, Bailey & Grodner, 2012; Marty & Chemla, 2011

2. Dual-task studies

   DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty & Chemla, 2011

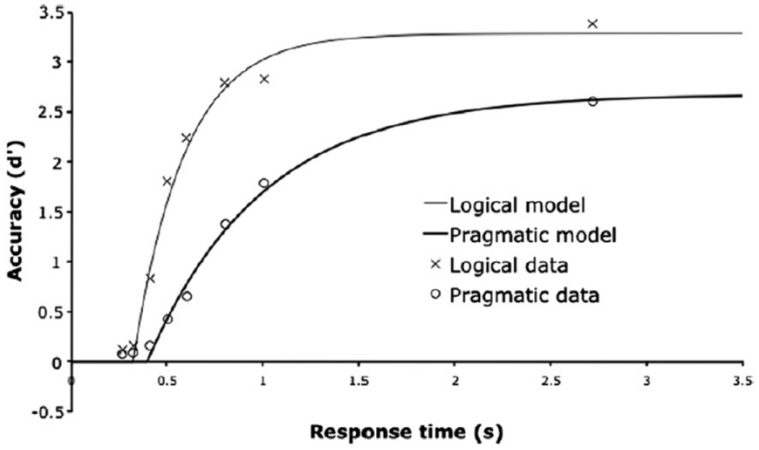
3. Reading studies

   Breheny, Katsos & Williams, 2006; Bergen & Grodner, 2010; Hartshorne & Snedeker, still under review; Nieuwland, Dittman & Kuperberg , 2010

Judgment tasks:
Bott, Bailey & Grodner (2012)

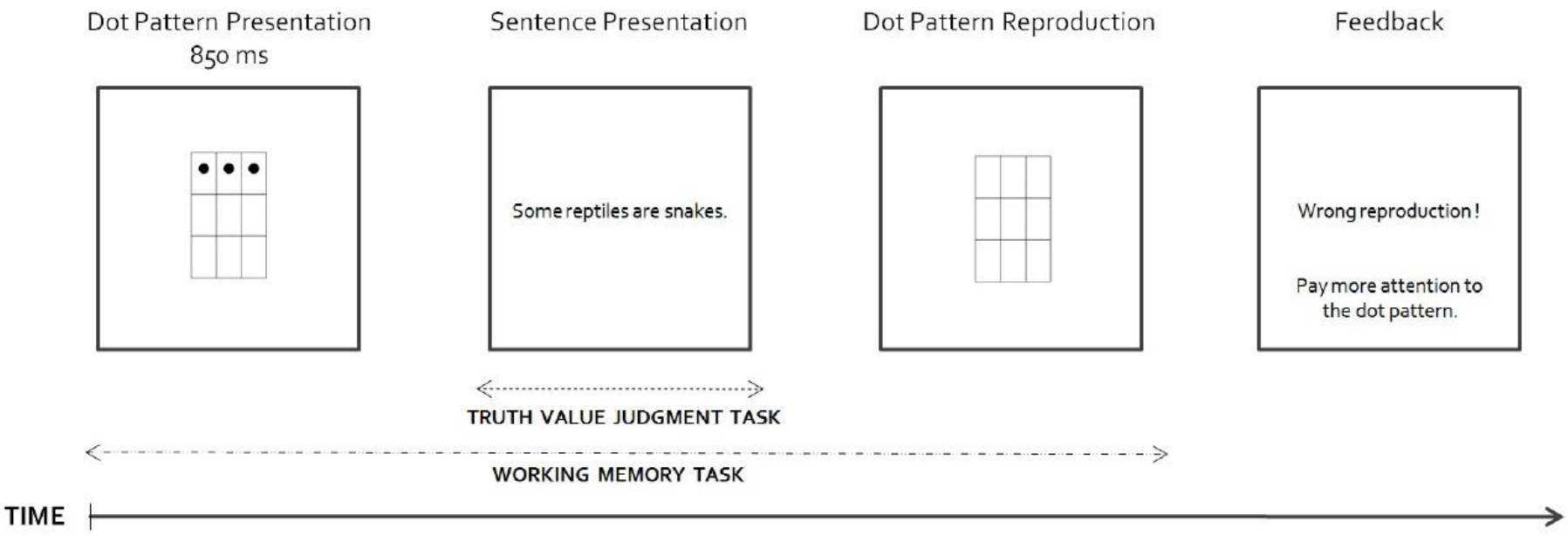
- Speeded verification of underinformative sentences (SAT task)
- Delay for calculating SI
- Not due to speed accuracy tradeoff: shift in starting point and slope
- Not merely verification: pragmatic “some” slower than “only some”

“Some elephants are mammals”



Dual-task paradigm

- Cognitive load reduces calculation of scalar implicatures (DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty, Chemla & Spector, 2011)



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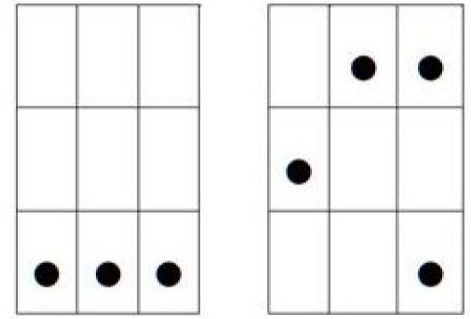
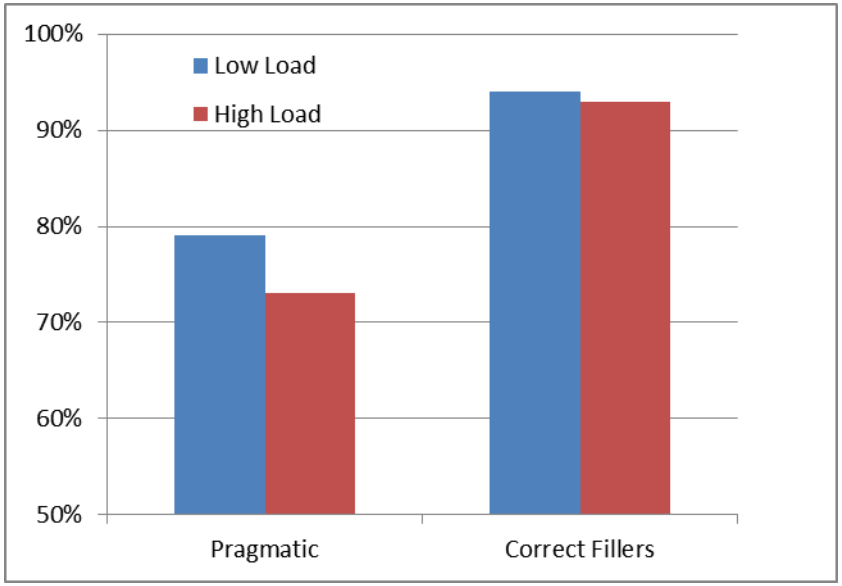


Low load High load



Data from: DeNeys & Schaeken (2007)

Dual-task paradigm

- Cognitive load reduces calculation of scalar implicatures (DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty & Chemla, 2011)
- Load does not reliably interfere with semantic upper bounds ("only some") (Marty & Chemla, 2011)
- Opposite effect for numbers (Marty, Chemla & Spector, 2011)

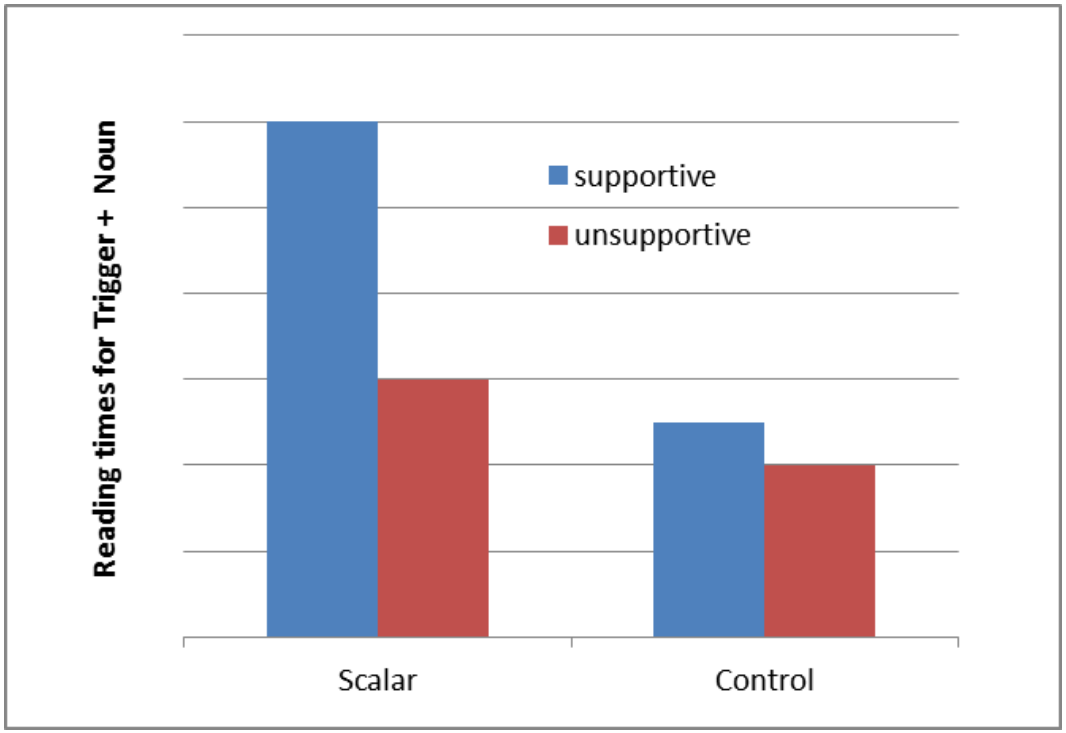
Reading time experiments

Recipe (from Breheny et al., 2006, illustrated with Bergen & Groder, 2012)

- Contexts
  - Supportive: “Before the hurricane landed, I checked every house in town.”
  - Non-supportive: “Before the hurricane landed, I volunteered to help out in town.”
- Trigger
  - Scalar: “Some of the residents had evacuated”
  - Control: “Only some of the residents had evacuated”
- Anaphor (probes upper bound)
  - “The rest stayed home and foolishly risked their lives”

Reading time experiments

- Slow down at trigger for Scalar in supportive contexts*



Data from Bergen & Grodner

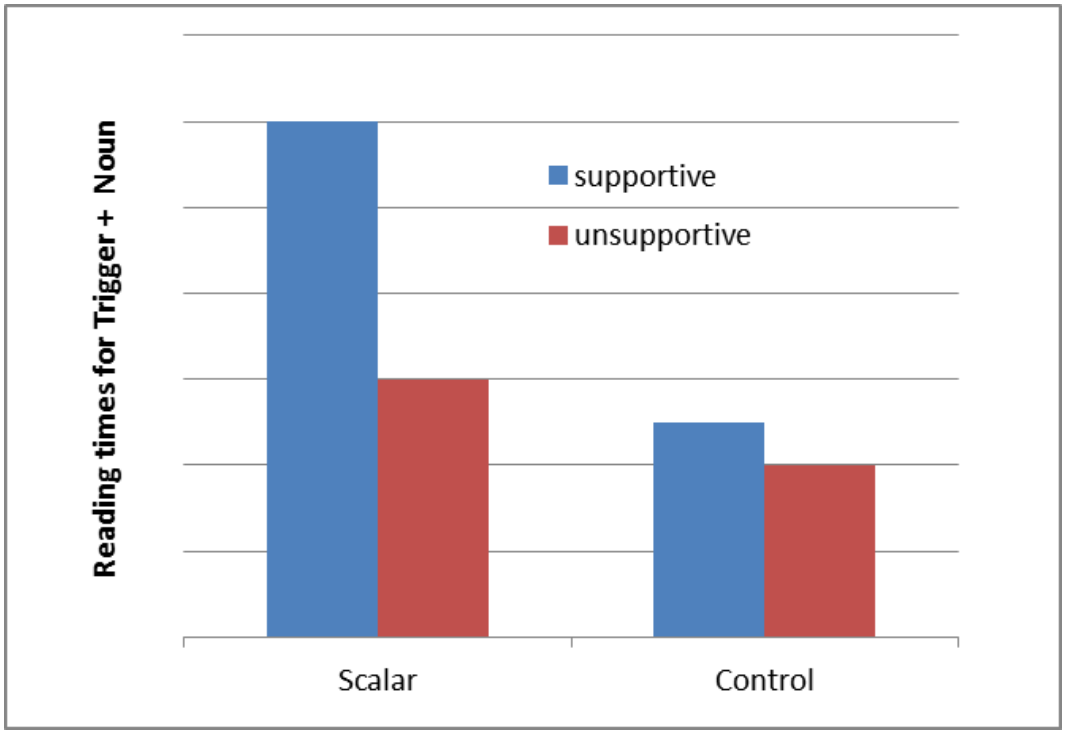
* But see Hartshorne & Snedeker for caveats

Reading time experiments

- Slow down at trigger for Scalar in supportive contexts*

Interpretation:

- SI takes effort
- Effort begins immediately
- But only when context calls it up



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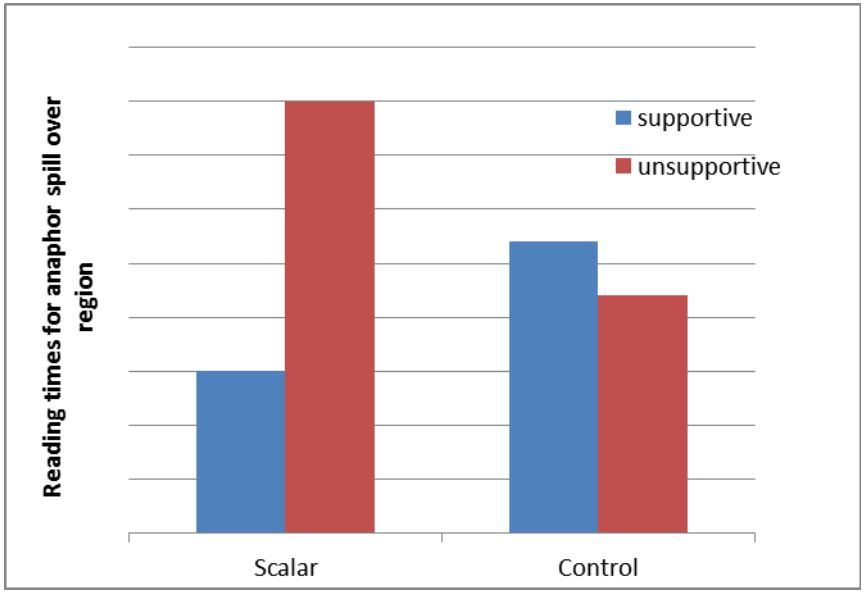
- Slow down after anaphor for scalars in unsupportive contexts



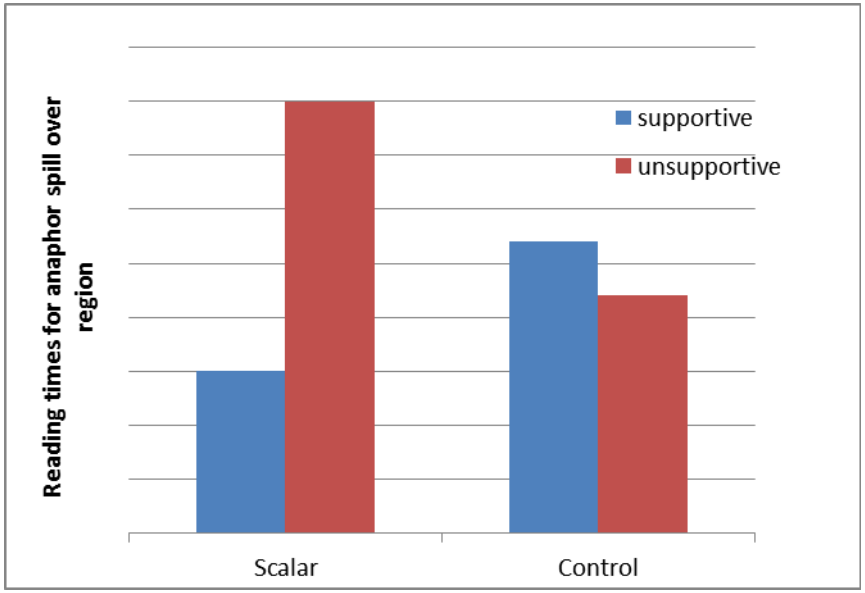
Data from Bergen & Grodner

Reading time experiments

- Slow down after anaphor for scalars in unsupportive contexts

Interpretation:

- Upper bound calculated in supportive contexts and controls
- Not in unsupportive contexts



Data from Bergen & Grodner

Reading time experiments

- How fast is that upper bound calculated?
- Mean time from trigger to anaphor effect
  - Bergen & Grodner: ~2,400 ms
  - Breheny et al: ~2000 ms
  - Nieuwland et al: ~1700 ms

Reading time experiments

- How fast is that upper bound calculated?
- Mean time from trigger to anaphor effect
  - Bergen & Grodner: ~2,400 ms
  - Breheny et al: ~2000 ms
  - Nieuwland et al: ~1700 ms
- Hartshorne & Snedeker manipulate distance
  - No anaphor effect at 1500 ms
  - Robust anaphor effect at 3000 ms
  - Adding upper bound takes time

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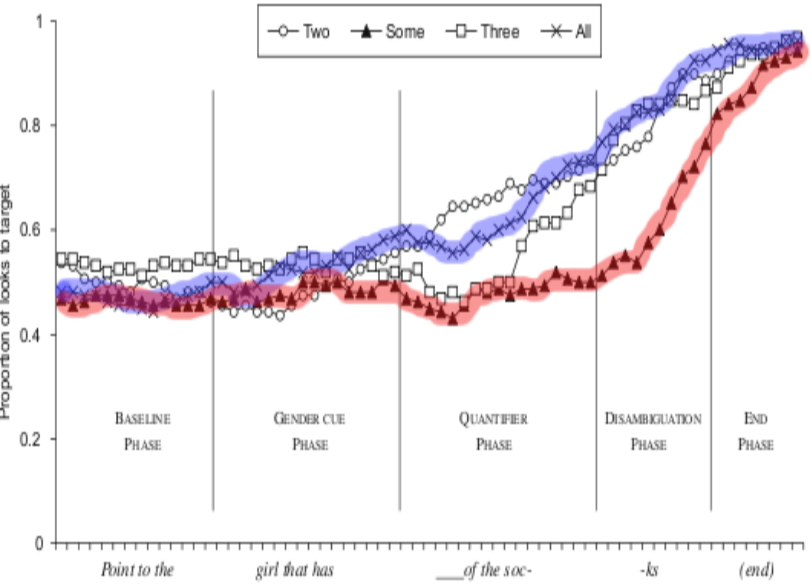
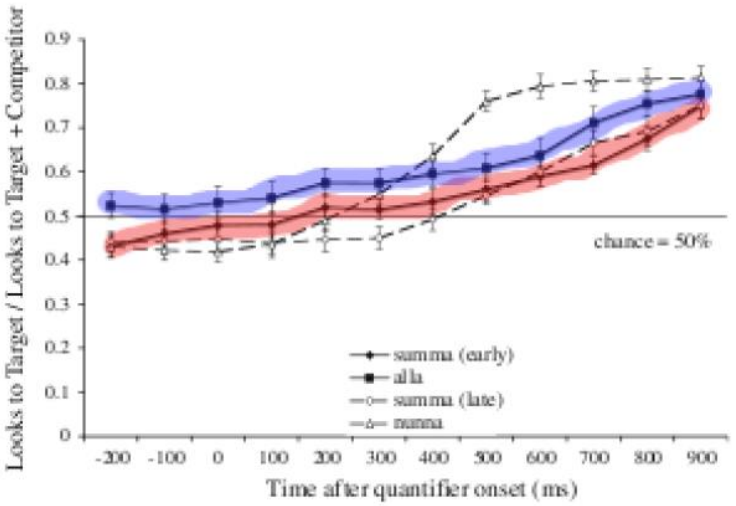
Divergent Findings in Visual World Paradigm

Delayed Upper Bound for “Some”



Huang & Snedeker (2009)

Instant Upper Bound for “Some”

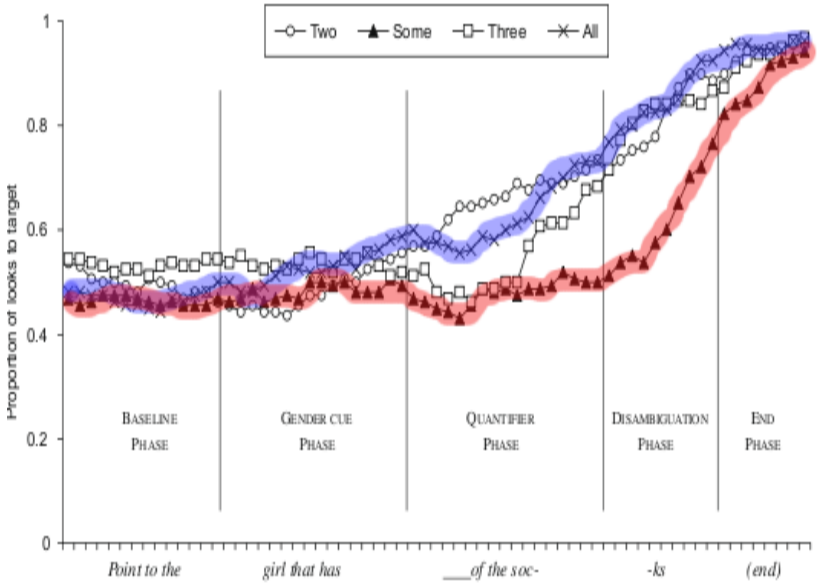


Grodner et al. (2010)

Methodological differences

- Pronunciation “summa” vs. some of
- Embedded in stories vs. not
- Length of experiment
- Number trials (Huang, Hahn & Snedeker; Degen & Tanenhaus)

Huang & Snedeker (2009)



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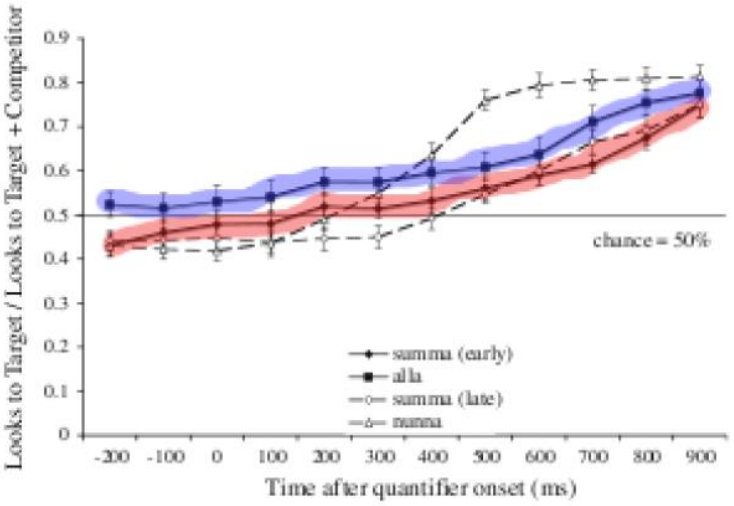
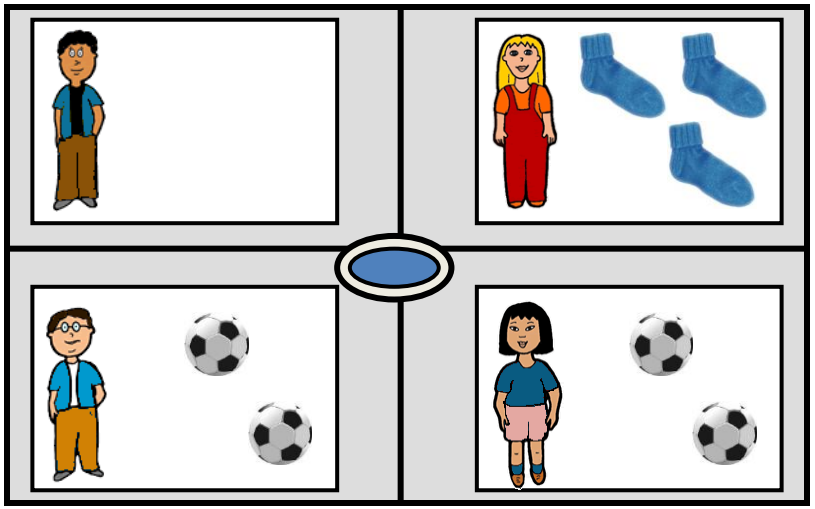


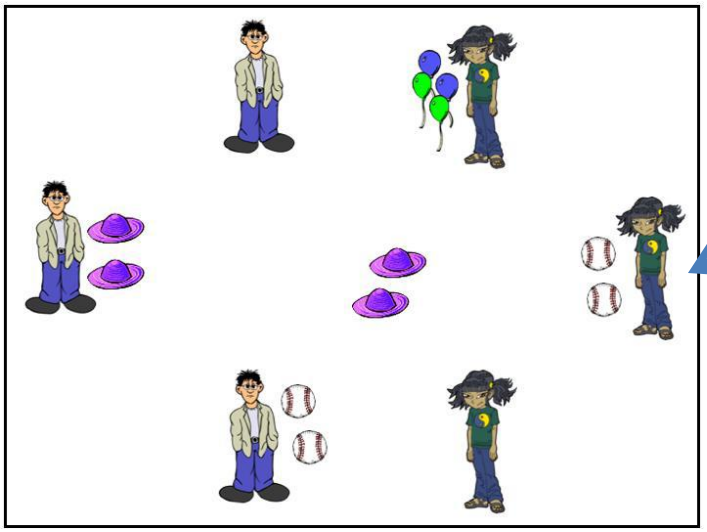
Comparison of studies



Dual Encoding:

The girl with some of the soccer balls
The girl with two of the soccer balls.

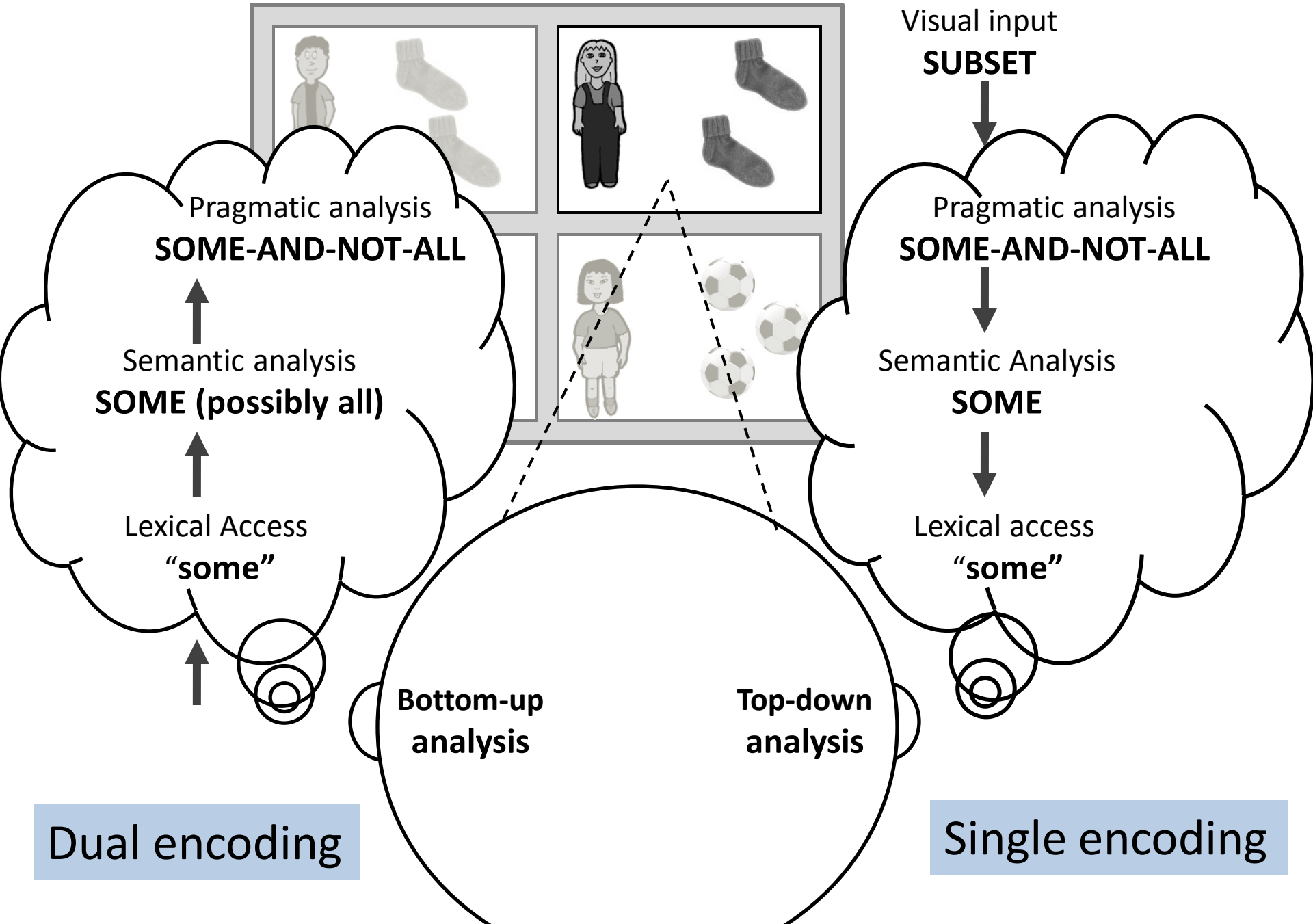
SI delayed



Single Encoding:

The girl with some of the balls

Immediate SI


Visual input
SUBSET
Pragmatic analysis
SOME-AND-NOT-ALL
Semantic analysis
SOME (possibly all)
Lexical Access
"some"
Pragmatic analysis
SOME-AND-NOT-ALL
Semantic Analysis
SOME
Lexical access
"some"
Bottom-up analysis
Top-down analysis
Dual encoding
Single encoding

Robust generalization across experiments

Red: slow SI, fast semantic; Green: both fast

Dual Encoding

- H&S, 2009
- H&S, 2011
- Panizza, Huang, Chierchia & Snedeker (2009)
- Huang, Hahn & Snedeker
- Degen & Tanenhaus
- Hartshorne et al

Single Encoding

- Grodner et al., 2010
- Breheny, Ferguson & Katsos, (2012)
- Breheny, Ferguson & Katsos (2013)
- Huang, Hahn & Snedeker
- Degen & Tanenhaus
- Hartshorne et al.
- Huang (*most*, *start*, pc)

Underlined studies manipulated encoding

Alternative proposal

- Including numbers makes “some” less natural
  - By what mechanism does naturalness influence processing?
  - Depending on answer this may be the same account….
  - In Degen & Tanenhaus (eyetracking) naturalness doesn’t predict speed of reference resolution
  - Naturalness ratings for sentences embedded in our story task do not support (some = two)
- Bayesian proposal
  - May describe what gets computed
  - But doesn’t provide a clear story of how

Bayes Theorem

Meanings $M = \{m_0, m_1, m_2, \ldots, m_\forall\}$
Utterances $U = \{u_{\text{some}}, u_{\text{all}}, u_{\text{none}}, u_{\text{number}}\}$
QUD $Q = \{\text{qud}_{\text{all?}}, \text{qud}_{\text{any?}}\}$

$$P_{\text{listener}}(M|U, Q) \propto P_{\text{speaker}}(U|M, Q)P(M)$$

Bayes Theorem

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$$P_{\text{listener}}(M|U, Q) \propto P_{\text{speaker}}(U|M, Q)P(M)$$

Awesome, how does the listener get that?

Option 1: ask 100 people on AMT?

Option 2: use stored knowledge (of Bill & Judy and the soccer balls?)

Option 3: run a production simulation (our proposal)

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The primary observation

Children often accept under informative scalar terms in judgment tasks

- Accept “might be” in context of MUST BE (Noveck, 2001)
- Accept “started” for FINISHED (Papafragou & Musolino, 2003)

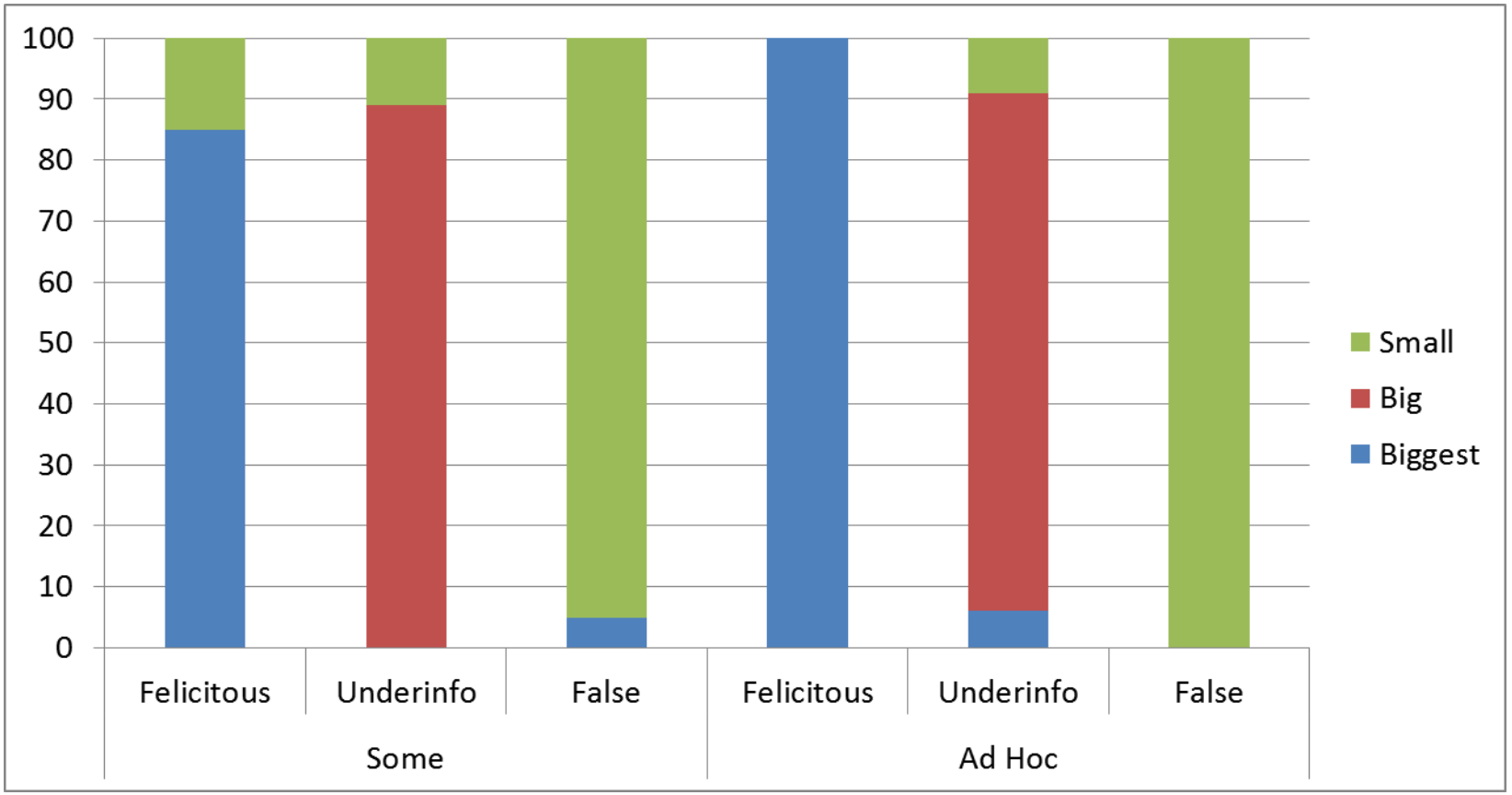
Possibility 1: Children must acquire a single discrete skill (implicature)

Non-starter: there is too much variation

- Performance heavily task dependent (Papafragou & Tantalou, 2004; Pouscoulous, Noveck, Politzer, Bastide, 2007)
- Instructions matter (Papafragou & Musolino, 2003 i.a.)
- Variation across scalar terms
- Age range success ~3-10

Possibility 2: Children are simply tolerant
(Katsos & Bishop, 2011)

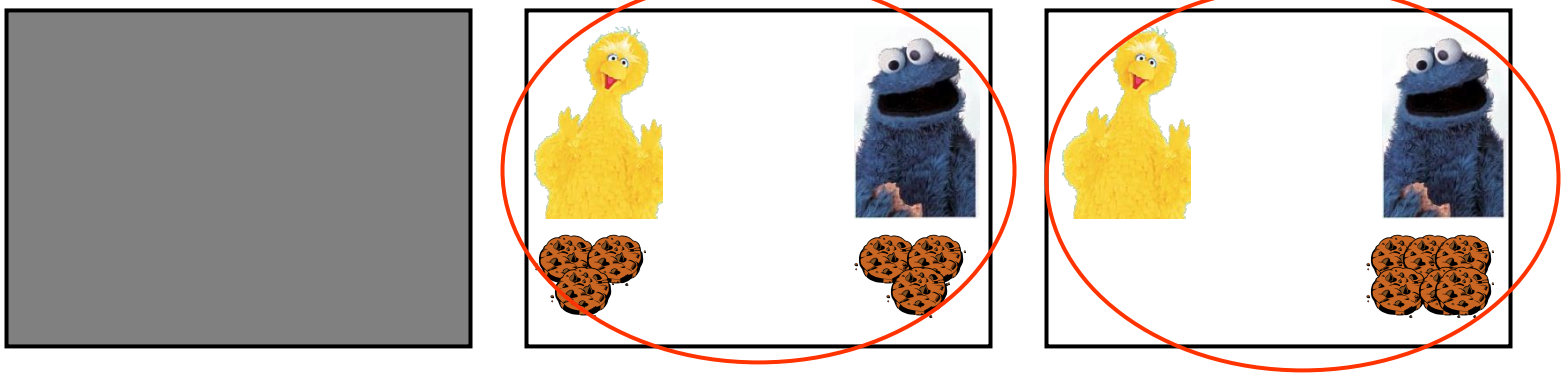
- 5 year olds succeed with 3 point scale



Tolerance can’t explain it all

- Younger children fail at selection tasks
  - Huang, Spelke, & Snedeker 2013 (2;6-4:0)
  - *“Can you give me the box where Cookie Monster has some of the cookies?”*

kids pick either one



See also Hurewitz et al., 2006

Tolerance can't explain it all

- Generic bias (Leslie & Gelman, 2012)
  - Adults and children misremember universal statements as generics (all dogs → dogs)
  - 3 yr olds *also* misremember "some" statements as generics (some dogs → dogs)
  - Suggests they aren't generating implicature
- Processing failure (Huang & Snedeker, 2009, Dev Psych)
  - Adults slower to interpret underinformative *some* than felicitous *some*
  - Children are not!

Possibility 3: processing account

- Computing SI without pre-encoding is effortful
  - See above
  - Children fail to pre-encode in contexts where adults do (Huang, data)
- Children have difficulty retrieving scales (Barner, Brooks & Bale, 2012)
- Children have difficulty using top-down cues (Snedeker, 2013)
  - SI may involve generating higher-level information to enrich interpretation
  - Such loops unfold over time (see Dell, 1986)
  - Slower processing = fewer time steps….
- As they become faster more efficient processors, they may be able to calculate SI's more often

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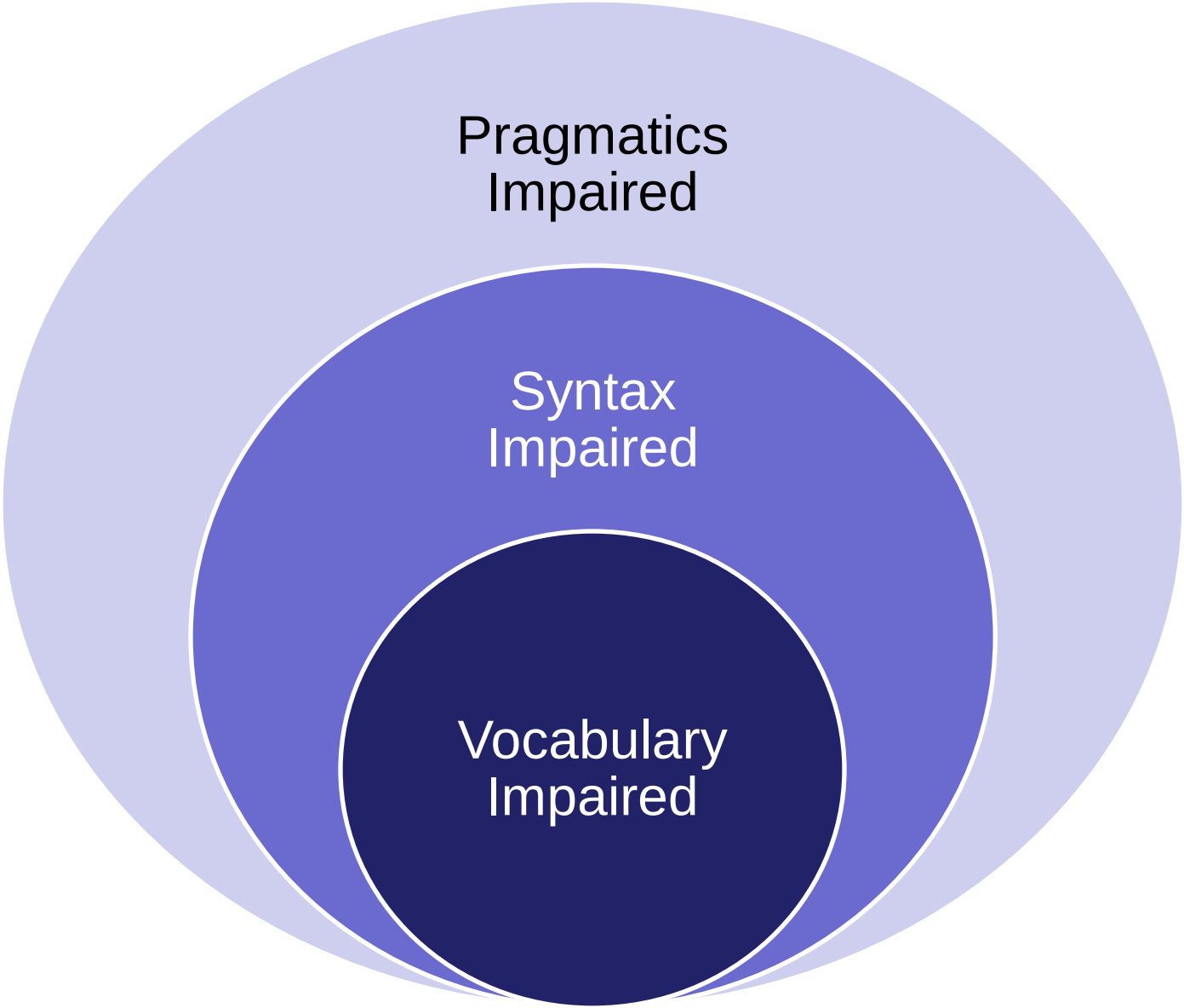
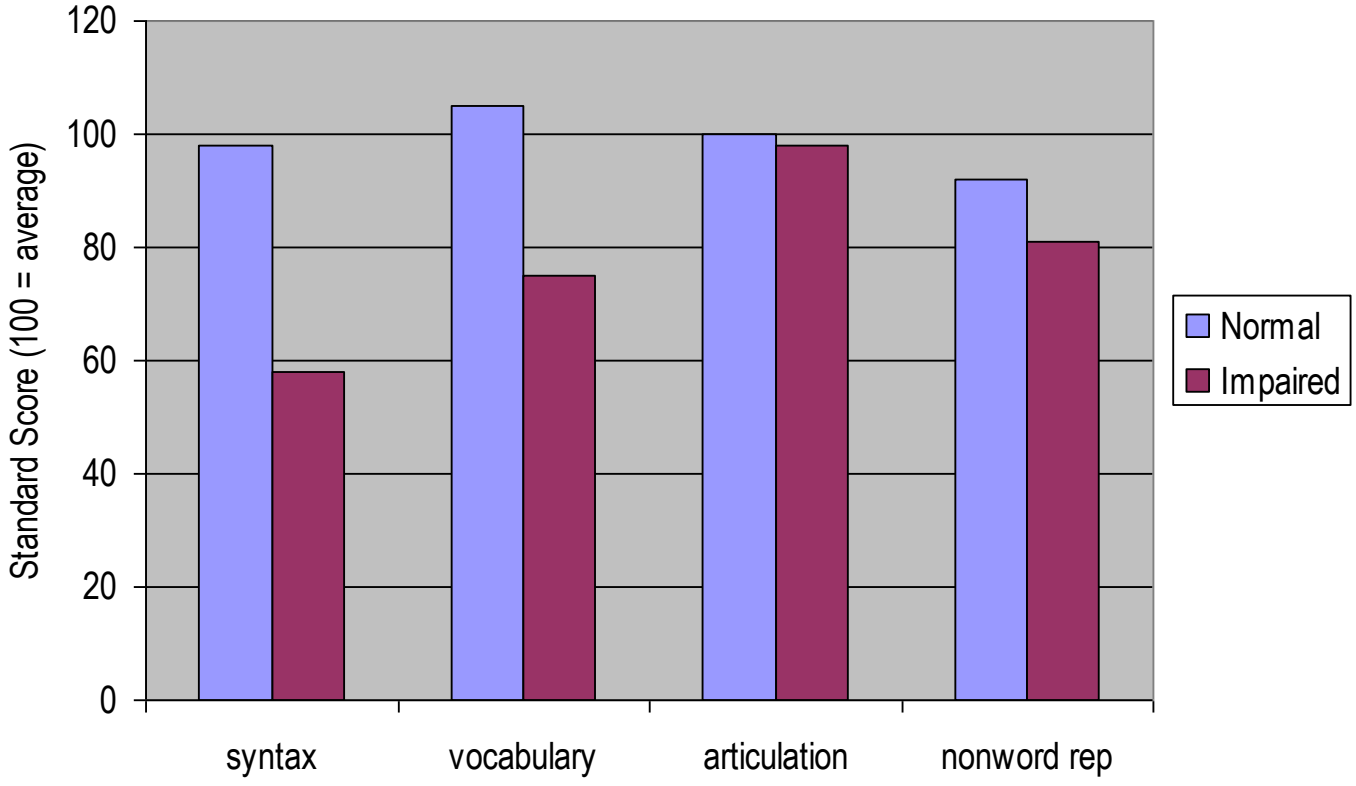
  4. In disordered populations SI patterns with language ability

Communicative deficits in autism



Autism with, and without, language impairment



Kjelgaard & Tager-Flusberg (2001)

Autism and scalar implicature

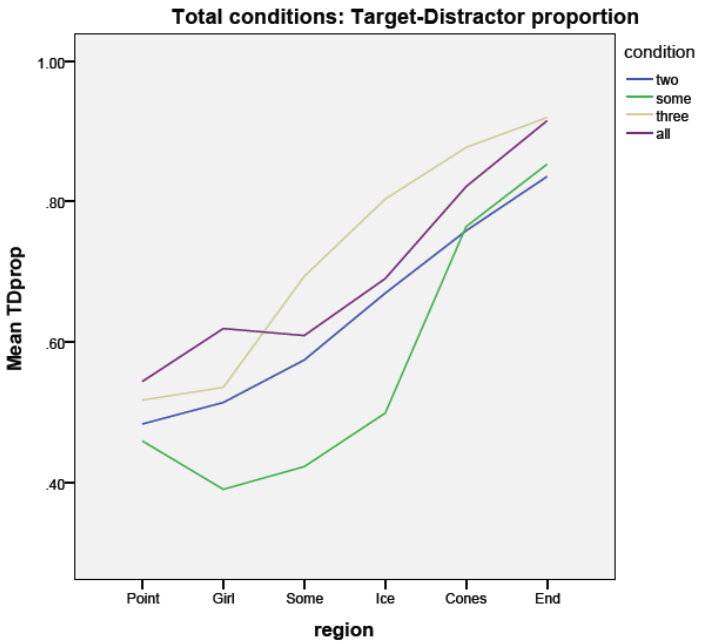
- Adults and teens with autism make SI's as often as language-matched controls (Pijnaker et al., 2008; Chevallier et al., 2010).
- Early deficit could disappear by 13
  - Deficits in Theory of Mind task only present until verbal mental age of 6-7 (Happe, 1995)
  - SI improves from 4 to 10 years
- Do persons with autism use the same process?

Our study

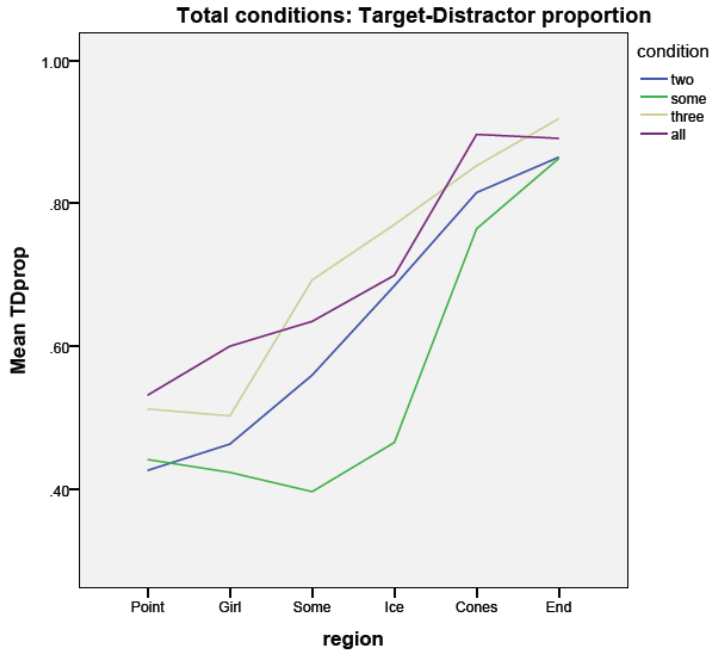
(Hahn, Huang & Snedeker, in prep)

- Goals
  - Assess likelihood of calculating scalar implicature at an age where it is rapidly changing (box task)
  - Determine whether mechanisms of comprehension are similar (visual world task)
- 6-9 year olds children
  - 40 with High Functioning Autism
  - 40 Typically Developing
  - Matched on: age, gender, CELF syntax scores

Same online processing profile



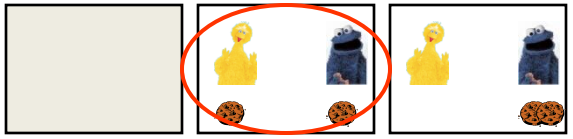
Typically Developing



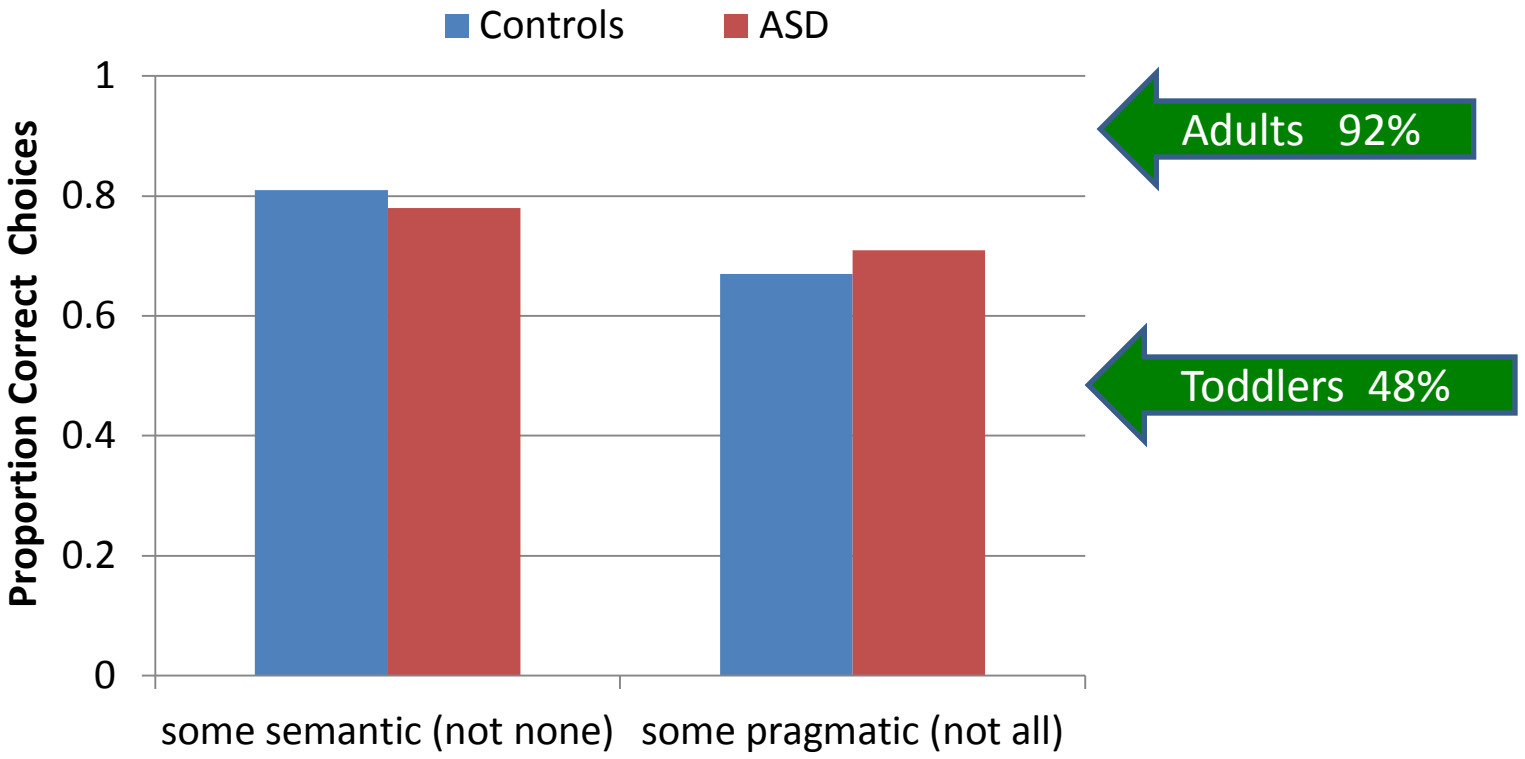
Highly Verbal ASD

Some -------

Hahn, Huang & Snedeker, in prep

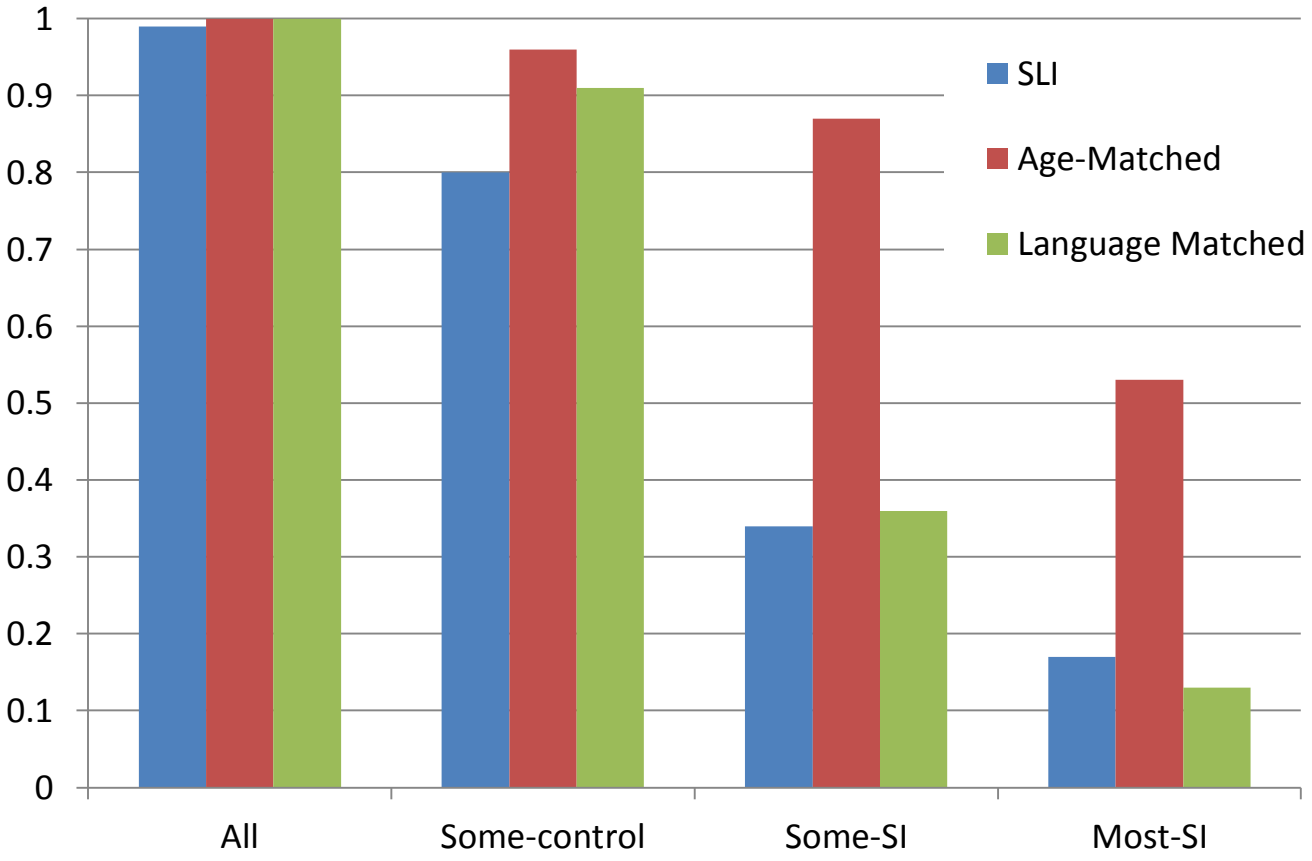


During the period where SI is developing children with ASD perform as well as controls



SI is linked to emerging language skills

Katsos, Roqueta, Clemente & Cummins (2011)



The only evidence that SI is linked to ASD….

- Nieuwland, Dittman & Kuperberg (2010)
  - "Some people have lungs/pets"
  - N400 at *pets*
  - Correlates with AQ communication scale (not social scale)

- My suspicion:
  - In college students, communication scale may capture differences in language skills

In sum

1. Implicature takes some work (bottom up)
2. But the work can be done ahead of time
   - When the conceptual encoding for each message is unambiguous
   - Listener as speaker
3. Thus SI proficiency develops gradually as children become more effective processors
4. Thus SI breaks down with language skills
   - Consistent with a distinction btw grammatical/social inferences or explicatures/implicatures?

Thank you!

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