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Online processing of bidirectional optimization

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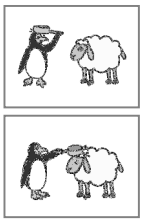
Asymmetry in child language

- Acquisition delay in pronoun *comprehension*
  - Guessing behavior up to 6 years old
- Correct *production* from the age of 4 on

The penguin is hitting himself ⟷

The penguin is hitting him ⟷



(De Villiers, Altreuter, & Cahillane, 2006; Matthews, Lieven, Theakston, & Tomasello, 2009; Spenader, Smits, & Hendriks, 2009)

Why is adult language symmetric?

- Possible explanation:
  - Adults apply bidirectional optimization (and thus coordinate their choices as speakers and hearers)
  - Children are unable to do so
    (Hendriks & Spenader, 2004, 2006; De Hoop & Krämer, 2006)

Question:

- Is bidirectional optimization part of pragmatics, and hence an offline and global process? (Blutner & Zeevat, 2004; Zeevat, 2000)
- Or is bidirectional optimization part of the grammar, and hence an online and local process?

Overview

- Hypothesis
  Bidirectional optimization is online process, constrained by:
  - Linguistic constraints
  - Speed of processing
  - Working memory capacity

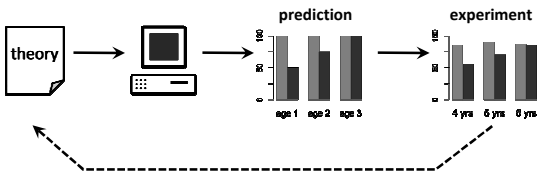
  } Study 1. Object pronouns

  Study 2. Subject pronouns

- Two studies
  - Modeling the acquisition of object pronouns
  - Modeling the acquisition of subject pronouns

Cognitive modeling

- Computational simulations of the cognitive processes involved in a certain task
  - ACT-R (Anderson et al, 2004)
- Goal: generate specific and testable predictions



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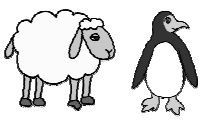
Study 1: Object pronouns



Linguistic constraints

- Implementation of Optimality Theoretic (Prince & Smolensky, 1993/2004) account of pronoun acquisition (Hendriks & Spenader, 2006)
  - **PRINCIPLE A**: reflexives must have a coreferential meaning
  - **REFERENTIAL ECONOMY**: reflexives are more economical than pronouns, and pronouns are more economical than full NPs (cf. Burzio, 1998; Wilson, 2001)
    → only relevant in production
- Constraint ranking: PRINCIPLE A » REFERENTIAL ECONOMY

Explanation of children's performance

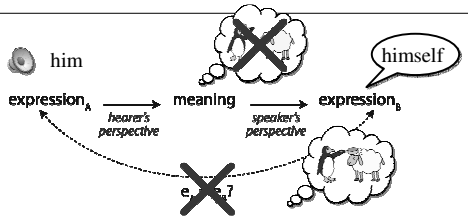
- Non-adult-like comprehension: the interpretation of pronouns is not restricted by the constraints of the grammar

input	output	
reflexive (himself)	coreferential	← **PRINCIPLE A**
pronoun (him)	coreferential / disjoint	← *no constraint*

- Adult-like production:

input	output	
coreferential	reflexive (himself)	← **REF ECONOMY**
disjoint	pronoun (him)	← **PRINCIPLE A**

Explanation of adults' performance

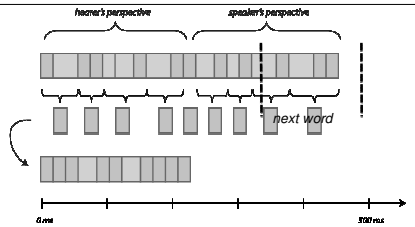


- Adult hearers take into account the speaker's perspective
  - Bidirectional optimization (Blutner, 2000) results in blocking of coreferential meaning for pronoun (Hendriks & Spenader, 2006)

Cognitive constraints

- Why don't children use bidirectional optimization?
- Cognitive (ACT-R) model to simulate the acquisition of bidirectional optimization
  - Assumptions:
    1. Bidirectional optimization is implemented as two serial processes
    2. Time for interpretation is limited
  - Explanation: Children have insufficient processing speed to take into account the speaker's perspective as a hearer

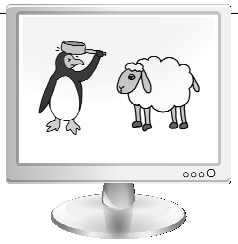
Simulation of acquisition



- Gradually, the processes become more efficient as a result of a proceduralization mechanism (Taatgen & Anderson, 2002)
- **Prediction**: Children can complete bidirectional optimization more often if provided with more time for interpretation.

Picture Verification Task

- Is the sentence a correct description of the picture?
- Crucially: Pronoun occurs mid-sentence; time for interpretation is limited by presentation of next word



De pinguin slaat hem/zichzelf met een pan.

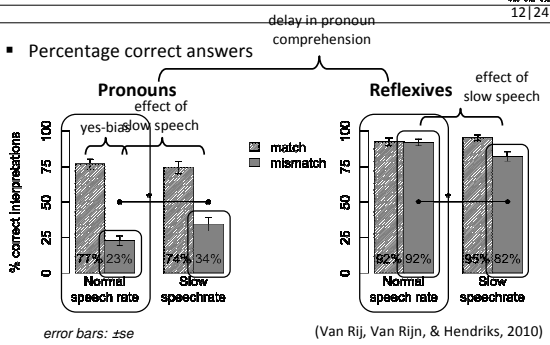
'The penguin is hitting him/himself with a pan.'

Experiment

- Conditions:
  - Normal speech rate
  - Slow speech rate: 2/3 of normal rate
- Participants: 62 Dutch children (age 4;1-6;2, mean 5;1)
  - *At normal speech rate,* 43 children showed incorrect comprehension of pronouns, but correct interpretation of reflexives

Experimental results

- Percentage correct answers



error bars: ±se

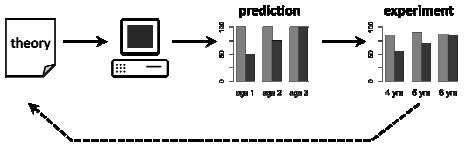
(Van Rij, Van Rijn, & Hendriks, 2010)

Summary Study 1

- Use of object pronouns (and hence bidirectional optimization) is constrained by:
  - Linguistic constraints
    - Direction-sensitive constraints cause asymmetry between comprehension and production in children
  - Cognitive constraints
    - Sufficient speed of processing is necessary to overcome this asymmetry by using bidirectional optimization
- Bidirectional optimization seems to apply online and locally:
  - Effects occur mid-sentence during sentence comprehension

Refining the cognitive model

- Can the same cognitive model be used to generate predictions about the acquisition of *subject* pronouns?



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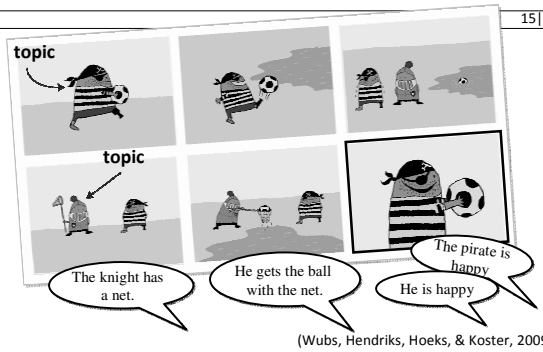
Study 2: Subject pronouns

Storybook task: elicited production

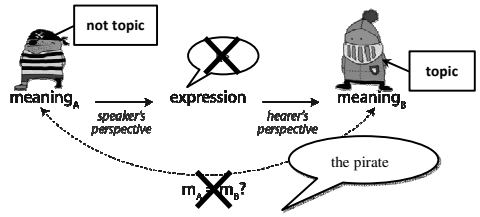


(Wubs, Hendriks, Hoeks, & Koster, 2009)

Linguistic constraints

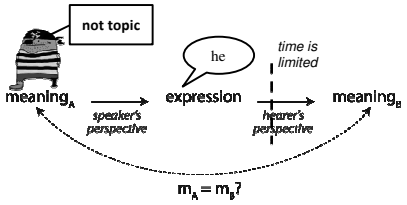
- Linguistic constraints (Hendriks, Englert, Wubs, & Hoeks, 2008):
  - **PRINCIPLE A**: reflexives must have a co-referential meaning
  - **REFERENTIAL ECONOMY**: pronouns are more economical than full NPs, and reflexives are more economical than pronouns (cf. Burzio, 1998; Wilson, 2001)
    - → only relevant in production
  - **PROTOP**: pronouns refer to the discourse topic (cf. Beaver, 2004; Grosz, Weinstein, & Joshi, 1995)
- Constraint ranking: REFERENTIAL ECONOMY » PROTOP
- As a result of this constraint ranking, children prefer to use subject pronouns in production

Explanation of adults' performance



- Adult speakers take into account the hearer's perspective
  - Bidirectional optimization (Blutner, 2000) results in blocking of use of pronouns for non-topic referents (Hendriks et al, 2008)

Speed of processing



- Similar assumption: time for production is limited
- The model overuses pronouns because processing speed is not sufficient to take into account the hearer's perspective

Something is missing from the model

- The constraint PROTOP assumes knowledge about the discourse status of the referent
  - How does the model determine what is the current topic?
- Topic is considered to be the most salient element in the current discourse
  - Implemention: All discourse representations in memory have a certain amount of activation, reflecting saliency/accessibility

Working Memory

- In the cognitive model, the activation of discourse elements relies on the amount of working memory (WM) capacity (cf. Daily, Lovett, & Reder, 2001)
  - Low amount of WM capacity:
    - Activation determined by frequency and recency of mentioning in the current discourse
  - High amount of WM capacity:
    - Activation determined by goal-relevant information, such as grammatical role in previous sentence
- Both production *and* comprehension rely on sufficient WM capacity to determine the current discourse topic

Predictions for comprehension

- Children determine topic on the basis of frequency and recency, whereas adults use extra information, such as the grammatical role of the referents.
- Adults will perform *child-like* if they do not have sufficient WM capacity available

5x reference to the pirate

3x reference to the knight

Story without topic shift

1.The pirate is on the beach.

2.He is playing with a ball.

3.He tells **a knight** that the ball is in the water.

4.The pirate asks to borrow the net of **the knight**.

5.The pirate finally catches the ball with the net of **the knight**.

6.He is happy.

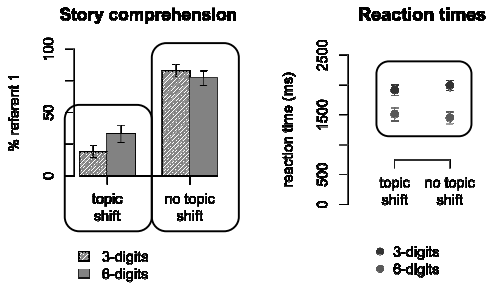
Question: **Who** is happy?

(Wubs et al, 2009)

Experiment

- Participants: Dutch adults
- Dual-task experiment
  - Memory task: remember 3 or 6 digits
  - Self-paced reading task, followed by comprehension question:
    - Short stories *with* a topic shift or *without* a topic shift
- Prediction: When performing the 6-digit task, participants are more likely to ignore a topic shift than in the 3-digit task

Preliminary results (n=9)



Conclusions

- Bidirectional optimization is constrained by:
  - Linguistic constraints
    - Direction-sensitive constraints cause asymmetry in children
  - Cognitive constraints
    - Sufficient speed of processing is necessary to overcome this asymmetry by using bidirectional optimization
    - Sufficient WM capacity is necessary to determine the discourse topic correctly
- Bidirectional optimization seems to be online and local process:
  - Children become adult-like when given sufficient time
  - Adults may become child-like when their memory is taxed