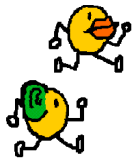
# Asymmetries in grammar



Day 4: Learning to optimize bidirectionally

Petra Hendriks, LOT Winter School 2009

## Learning to optimize bidirectionally

- Why are children unable to optimize bidirectionally?
- Theory of Mind, working memory, speed of processing
- Competence vs. performance
- Cognitive models of language

## Bidirectional OT

Hearers are also speakers (and vice versa):

Speaker: Intention ➔ Utterance ➔ Hearer: Interpretation

Hearers check whether selected meaning corresponds to uttered form.

Speakers check whether selected form corresponds to intended meaning.

## Speakers and hearers

- Task speaker:
  Meaning ➔ Form ➔ Meaning'
  m' = m ?
  Guarantees recoverability
- Task hearer:
  Form ➔ Meaning ➔ Form'
  f' = f ?
  Guarantees compositionality

## Task of a hearer

- **Step 1**: Select optimal meaning for heard form (unidirectional optimization).
- **Step 2**: Select optimal form for selected meaning (unidirectional optimization in opposite direction).
- **Step 3**: Check whether optimal form is identical to heard form.
- **Step 4a**: If yes, selected meaning is bidirectionally optimal.
- **Step 4b**: If no, inhibit selected meaning and select another meaning for heard form.

## Bidirectional optimization

Why are children unable to optimize bidirectionally?

1. Underdeveloped Theory of Mind (ToM)
2. Limited working memory capacity (cf. Reinhart, 2006)
3. Insufficient speed of sentence processing
4. ???

## Bidirectional optimization

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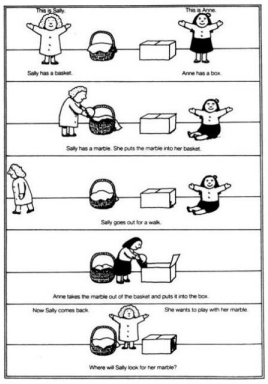
## 1. Theory of Mind

- Most children pass first-order false belief tests at age 4 (Wimmer & Perner, 1983).




The Sally-Anne test (Baron-Cohen, Leslie & Frith, 1985):

Where will Sally look for her marble?

## 1. Theory of Mind

- Most children pass first-order false belief tests at age 4 (Wimmer & Perner, 1983).
- So underdeveloped first-order ToM cannot explain children's inability to optimize bidirectionally.
- Exception: Children with Autism Spectrum Disorders.
- How would children with ASD perform on the tasks discussed so far?

## Pragmatic problems in autism

Children with autism have difficulty interpreting non-literal language:

- Detecting violations of Gricean maxims (Surian, Baron-Cohen & van der Lely, 1996)
- Interpreting metaphors and irony, but not synonyms (Happé, 1993).
- Interpreting indirect speech acts (Bara, Bosco & Bucciarelli, 1999; Frith, 1989).

## Second-order ToM

- Is first-order ToM sufficient for bidirectional optimization, or do we need second-order ToM?

## Flobbe, Verbrugge, Hendriks & Krämer (2008)

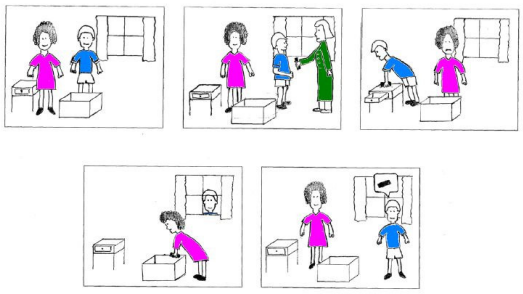
- Second-order false belief task:
  - Birthday Puppy Story (Tager-Flusberg & Sullivan,1994)
  - Chocolate Bar Story (based on first-order story by Hogrefe and Wimmer, 1986)
- Second-order strategic reasoning task
- Sentence comprehension task requiring bidirectional optimization (indefinite subjects, cf. Termeer, 2002; Vrieling, 2006)

## Flobbe, Verbrugge, Hendriks & Krämer (2008)

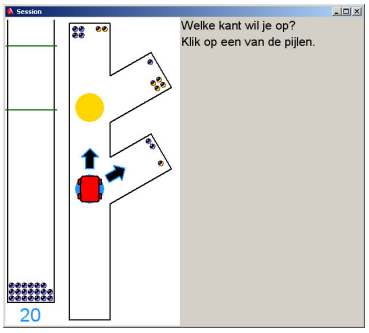
Participants:

- 40 children (age 8;4 - 10;3, mean age 9;2)
- 27 adults (age 18 - 26, mean age 20)

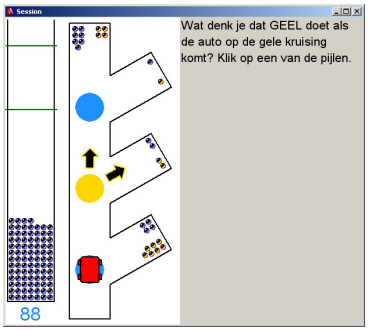
## Second-order false belief task



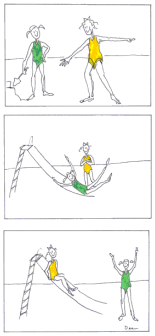
## First-order reasoning




## Second-order reasoning task




## Indefinite subject task



1. Twee meisjes gaan een dagje naar het strand. Kijk, hier zie je ze op het strand.
   'two girls are going to the beach for a day. Look, here you see them on the beach'
2. Als eerste gaan ze naar de glijbaan. Het meisje met het groene badpak gaat als eerste van de glijbaan af.
   'first they go to the slide. The girl with the green bathing suit goes down the slide first'
3. Daarna gaat het meisje met het gele badpak van de glijbaan af.
   'then the girl with the yellow bathing suit goes down the slide'

A: Een meisje ging twee keer van de glijbaan af.
'a (particular) girl went down the slide twice'

B: Er ging twee keer een meisje van de glijbaan af.
'twice a girl went down the slide'

## Indefinite subjects in bi-OT

| | C1: Subjects get a referential interpretation.<br>C2: Indefinite NPs get a non-referential interpretation.<br>C3: Indefinite subjects are in sentence-initial position. | MARK C1 | MARK C2 | MARK C3 |
|---|---|---|---|---|
| ✌ | <sentence-initial, referential> | | | |
| | <sentence-initial, non-referential> | * | * | |
| | <sentence-internal, referential> | | | * |
| ✌ | <sentence-internal, non-referential> | * | * | * |

*Tableau 1*: de Hoop & Krämer's (2005/6) account of indefinite subjects in sentence-initial (A) or sentence-internal (B) position.

## Results Flobbe et al.

- Second-order false belief task:
  - Most children (72% + 92%) responded correctly to second-order false belief question.
- Reasoning task:
  - Most children (77%) were capable of making first-order predictions, but only 57.2% of making second-order predictions (adults: 97% + 75.5%).
- Sentence comprehension task:
  - Most children (60%) preferred non-adult referential reading for existential sentence B.

## Correlations between tasks

- Passing a second-order false belief task may be a necessary condition for second-order strategic reasoning and adult sentence comprehension.
- No correlation between children's behavior on strategic reasoning task and their behavior on sentence comprehension task.

## Bidirectional optimization

Why are children unable to optimize bidirectionally?

1. Underdeveloped Theory of Mind (ToM)
2. **Limited working memory capacity** (cf. Reinhart, 2006)
3. Insufficient speed of sentence processing

## 2. Working memory

Wubs, Hendriks, Hoeks & Koster (in press):

- Production task based on 4 picture stories eliciting topic shift
- Comprehension task based on 8 pre-recorded stories (4 topic shift, 4 non-topic shift)
- Auditory memory task (taken from Schlichting test)

## Earlier study of anaphoric subjects

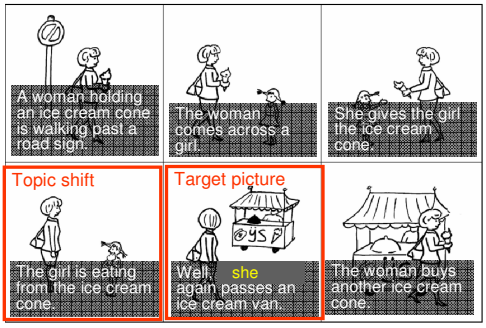
Hendriks, Englert, Wubs & Hoeks (2008):

- Production task based on 8 picture stories eliciting topic shift
- Comprehension task based on 8 written stories
- Auditory memory task (WAIS digit span test)

Participants:

- 25 elderly people (age 62 - 94, mean 81;7)
- 25 controls (age 19 - 31, mean 23;2)

## Production task

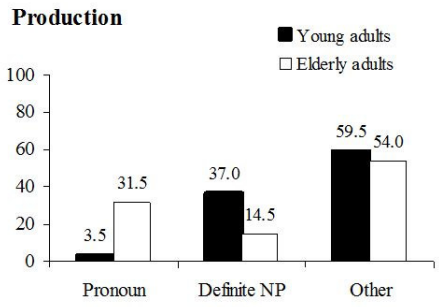



## Differences with Wubs et al.

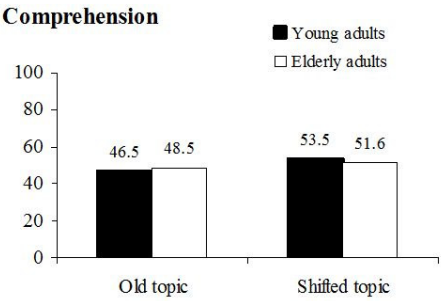
In later study by Wubs et al. (in press):

1. Second referent was established as the topic in two subsequent pictures/ utterances.
2. The production and comprehension stories were construed as parallel.
3. In comprehension, a topic shift condition as well as a non-topic shift condition was included.

## Elderly adults




## Elderly adults




## Effects of working memory

Wubs et al. (in press):

- Children: Significant correlation between WM and proportion Full NPs ($r = .42$; $p<.05$), and WM and proportion Other Response ($r = -.36$; $p=.05$)
- Adults: No correlations with WM.

Hendriks et al. (2008):

- Elderly/young adults: Strong positive correlation between group scores on WM and proportion Full NPs (Pearson $r(48)=.51$, $p<.001$).

## Bidirectional optimization

Why are children unable to optimize bidirectionally?

1. Underdeveloped Theory of Mind (ToM)
2. Limited working memory capacity (cf. Reinhart, 2006)
3. **Insufficient speed of sentence processing**

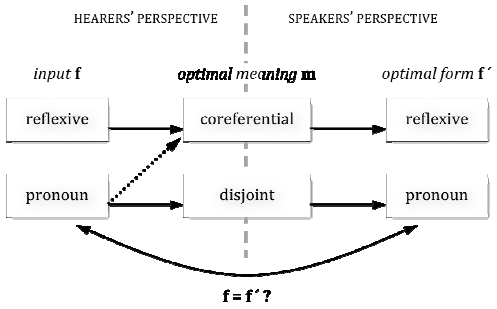
## 3. Speed of processing

Delay of Principle B Effect (DPBE):

- Here you see an elephant and an alligator. The elephant is hitting himself.
  - Correct performance from 3 years on (Principle A).

- Here you see an elephant and an alligator. The elephant is hitting him.
  - Performance at chance level up to 6;6 years old (Principle B).

## Hearers take into account the perspective of the speaker




## ACT-R (Anderson et al., 2004)

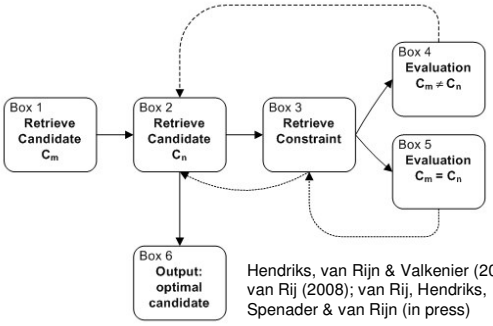
Hendriks, van Rijn & Valkenier (2007) built OT account of DPBE in ACT-R:

- ACT-R is architecture of cognition based on plausible assumptions about retrieval, storage and processing of information.
- ACT-R is computational modeling environment.
- ACT-R provides estimates of durations of cognitive processes.

## ACT-R/OT model

- Bidirectional optimization is computationally modeled as two serial processes of unidirectional optimization.
- Initially, the model cannot use bidirectional optimization because this takes too much time.
- When constraints are applied more often, the speed of processing will increase.
- ➔ The chance of succeeding in bidirectional optimization will also increase.

## Structure of ACT-R/OT model

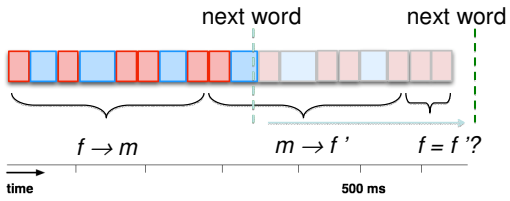



Hendriks, van Rijn & Valkenier (2007); van Rij (2008); van Rij, Hendriks, Spenader & van Rijn (in press)

## Predictions for DPBE

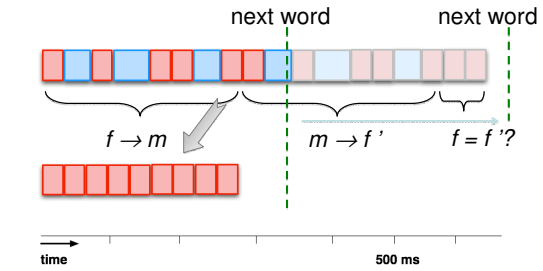
Time for interpretation is limited:

➔ Initially the model cannot use bidirectional optimization because this takes too much time.



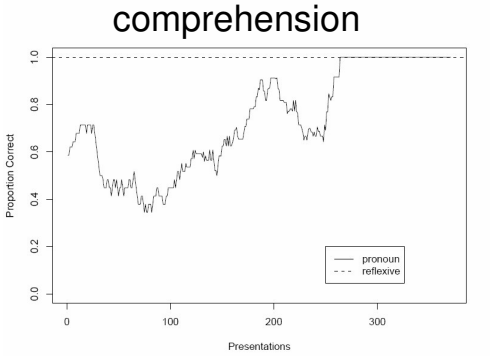
# Learning in ACT-R

Production compilation:

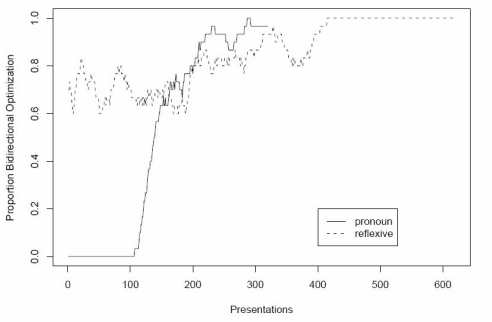



E.g., Taatgen & Anderson (2002)

# Performance of model on comprehension




# Performance of model on bidirectional optimization




# Competence vs. performance

- OT:
  - Constraints are applied in parallel.
  - Candidate set is infinite.
- ACT-R/OT model:
  - Constraints are applied one by one.
  - Only two candidates are evaluated at a time.
- OT defines input-output relations.
- ACT-R/OT model specifies process by which these relations come about.

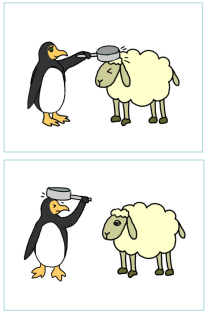
# Testing ACT-R/OT model

Van Rij, Hendriks, Spenader & van Rijn (in press):

- Children will perform better on pronoun interpretation if they have more time for comprehension.
- Children will have more time for comprehension if speech rate is slowed down.

# Speech rate

- Task: TVJT in Dutch
- Normal speech rate (4.1 syll/sec):
  - Look, a penguin and a sheep are on the pavement. The penguin is hitting him/himself with a pan.
- Slow speech rate (2/3 normal = 2.7 syll/sec)



## When children show DPBE:

- Slowed-down speech is predicted to significantly increase performance on pronoun comprehension
  - Because children will now have sufficient time to optimize bidirectionally in a higher proportion of trials.
- Slowed-down speech is predicted to show no significant effect on performance on reflexive comprehension
  - Because unidirectional optimization already yields the adult interpretation.

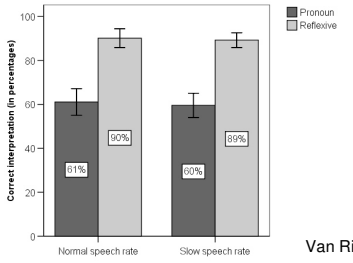
## Design experiment

Within-subjects design:

- Normal speech rate condition: 16 sentences (8 pronouns, 8 reflexive)
- Slow speech rate condition: 16 sentences (8 pronouns, 8 reflexive)
- Results of 62 children used for statistical analysis (age 4;1 - 6;2, mean 5;1); 13 children were excluded from analysis.

## General results

- All participants: No effects of speech rate

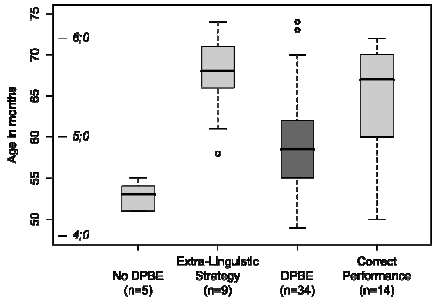



Van Rij (2008)

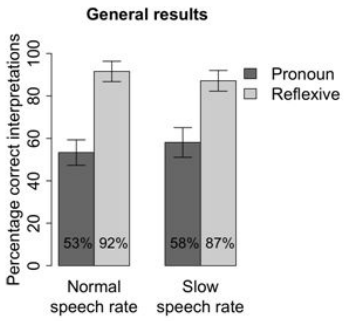
## Selection of target group

- No DPBE group:
  - Many errors with reflexives and pronouns (n=5)
- Extra-Linguistic Strategy group:
  - Reflexives (almost) correct (80% or more), say “yes” to all pronouns (n=9)
- DPBE group:
  - Reflexives (almost) correct, errors with pronouns (n=34)
- Correct Performance group:
  - Both reflexives and pronouns (almost) correct (n=14)

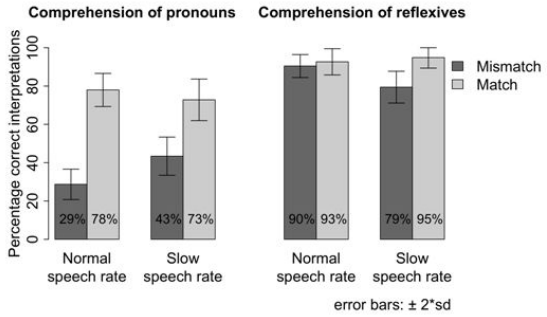
## Ages of the groups




## Results DPBE group



## DPBE group: Match vs. mismatch




## Effects of slow speech rate

DPBE group:

- Slow speech has significant positive effect on comprehension of pronouns,
- But significant negative effect on comprehension of reflexives (experimental artifact?).

Correct Performance group:

- Slow speech has significant negative effect on comprehension of pronouns (experimental artifact?).

## Selective effects

- So slow speech has a positive effect on comprehension, but only if the child displays the DPBE.
- These results are in line with bidirectional optimization account of DPBE.

## Alternative explanations of DPBE

- Lack of relevant pragmatic knowledge:
  - Unclear how slowed-down speech would provide children with necessary pragmatic skills.
- Experimental artifact:
  - Because slowing down speech was shown to increase performance in same participants, DPBE must be real effect.

## Alternative explanations of DPBE

- Insufficient working memory capacity:
  - If slowed-down speech places greater burden on WM (Small, Andersen, & Kempler, 1997), then slowed-down speech should decrease, rather than increase, performance.

## Cognitive modeling of language

- ACT-R/OT model: Theory of linguistic competence embedded in cognitive architecture.
- This allows for the generation of detailed and testable predictions with respect to linguistic performance.

## Today's conclusions

Why are children unable to optimize bidirectionally?

- ToM may be a necessary condition, but does not seem to be a sufficient condition.
- Bidirectionally optimal responses are correlated with working memory capacity.
- Bidirectional optimization requires sufficient speed of processing.