Let the Eyes Speak
Processing of Object Relative Clauses in Young Children

FLAVIA ADANI
DEPARTMENT OF LINGUISTICS
UNIVERSITY OF POTSDAM

LANGUAGE SPRING SCHOOL @ MILANO-BICOCCA – May 27-29, 2015
Why studying sentence processing in children?

By age four or five, children have:
- Mastered the basics of their native language;
- Ammassed an impressive vocabulary

👍
Why studying sentence processing in children?

By age four or five, children have:
- Mastered the basics of their native language;
- Ammassed an impressive vocabulary

But how children employ this knowledge while they are listening?
- Are they as rapid as adults?
- Do they arrive at the same final interpretation?
- How do children deal with (temporary) linguistic ambiguity?
Constraints on the study of sentence processing in children

In adults,

◦ use of reading times allows a very precise identification of processing load at different points in an utterance

In children,

◦ these effects are preferably studied with spoken sentences (instead of written)
Constraints on the study of sentence processing in children

In adults,
- use of reading times allows a very precise identification of processing load at different points in an utterance
- use of a secondary task

In children,
- these effects are preferably studied with spoken sentences (instead of written)
- often, without a secondary task
Talk structure

- Eye gazes as a way to study sentence processing in young children
- The complexity of relative clauses
- Study 1: Comparing implicit and explicit measures of relative clause comprehension (Adani & Fritzsche, 2015)
- Study 2: Individual differences in children’s processing of object relative clauses (Haendler, Kliegl & Adani, under review)
- Final remarks
Eye movements
Studying Children’s Eye-Gazes

Cf. Same method described yesterday in Falk’s talk
The Visual World Paradigm
The gradual emergence of complex syntax

The mastery of complex syntax is a milestone in typical language acquisition, usually argued to be accomplished around 6 years of age.

Complex syntax: passive sentences, questions, topicalized sentences, relative clauses ...

Sources of difficulty:
- computation of movement operations
- non-canonical word order
- difficulty in assigning theta roles
- limited memory resources

Cf. Naama’s talk from yesterday
The complexity of relative clauses

Subject relative clause

**SRC**  Where is the cow that *<the cow>* is chasing the dog?

Object relative clause

**ORC**  Where is the cow that the dog is chasing *<the cow>*?

**Subject-object asymmetry**: Object relative clauses are harder than subject relative clause
Object relative clauses are hard...

**Adult processing:** Frazier, 1978; Gibson, 1998; Gordon et al. 2001, 2004; Reali & Christiansen, 2007; Fox & Thompson, 1990, De Vincenzi, 1990; Traxler et al. 2002; Mak et al. 2002 & 2006; a.o.;

**Language breakdown:** Caramazza & Zurif, 1978; Crain et al., 2001; Burchert et al., 2003; Garraffa & Grillo, 2007, Grillo, 2008 & 2009, a.o.;

**Language acquisition:** Goodluck & Tavakolian, 1982; Hamburger & Crain, 1982; de Villiers et al., 1979; Correa, 1995; Kidd & Bavin, 2002; Arnon, 2005 & 2009; Friedmann et al., 2009; Arosio et al. 2009; Belletti & Contemori, 2010; Kidd et al., 2007, a.o.

**Developmental disorders:** Friedmann & Novrogodsky, 2004; Novrogodsky & Friedmann, 2006; Hakansson & Hansson, 2000; Stavrakaki, 2001, 2002; Grant et al. 2002; Zukowski, 2009; Contemori & Garraffa, 2010; Jensen de Lopez et al., 2012
...but they can become easy!

**Adult processing:** Gordon et al. 2001, 2004; Reali & Christiansen, 2007; Mak et al. 2002 & 2006; Traxler et al. 2002;

**Language breakdown:** Burchert et al. 2003;

**Language acquisition:** Arnon, 2009; Friedmann et al., 2009; Kidd et al. 2007; Brandt et al., 2009; Adani et al. 2010; Adani, 2011; Belletti et al., 2012; Contemori & Marinis, 2014; Handler, Kliegel, Adani, 2015;

**Developmental disorders:** Adani et al., 2014
Explicit and implicit measures of language development

Explicit responses (e.g., picture pointing, acting out) reflect the outcome of several extra-linguistic processes e.g., goal selection, action planning and cognitive load.

Arguably, these responses do not tap on the linguistic abilities that children may have.

To date, very few studies have looked at the processing of relative clauses online, collecting an implicit response, only with school-aged children (Contemori & Marinis, 2014; Love, 2007)
Study 1: Combining implicit and explicit responses of relative clause comprehension

Looking-while-listening eye-tracking experiment to test subject and object relative clauses in German-speaking 4-year-olds and compare them to adults:

- Implicit measure: eye gazes
- Explicit measure: pointing accuracy in a referent identification task

Participants were assigned to one of two tasks:

- Looking only
- Looking + Pointing to the correct RC head referent, while eye gazes are recorded
# Participants

<table>
<thead>
<tr>
<th>Condition</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUP 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking only</td>
<td>N (female/male)</td>
<td>32 (13/19)</td>
</tr>
<tr>
<td>Mean Age (range)</td>
<td>4;4.22 (4;1.0–4;11.11)</td>
<td>23.5 (20–33)</td>
</tr>
<tr>
<td><strong>GROUP 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking and Pointing</td>
<td>N (female/male)</td>
<td>31 (14/17)</td>
</tr>
<tr>
<td>Mean Age (range)</td>
<td>4;5.2 (4;0.2–4;11.20)</td>
<td>25.9 (19–44)</td>
</tr>
</tbody>
</table>

All monolingual speakers of German, with no history of linguistic, hearing or cognitive disorder.
Spoken stimuli

Subject relative clauses (SRC)
Wo ist die Kuh, die den Hund jagt?
Where is the cow that the ACC dog chases
*Where is the cow that is chasing the dog?*

Object relative clauses (ORC)
Wo ist die Kuh, die der Hund nass spritzt?
Where is the cow that the NOM dog wet splashes
*Where is the cow that the dog is splashing?*

Filler condition
Wo ist die Kuh?
*Where is the cow*
Visual stimuli

Pragmatically adequate context

- Referents are introduced one after another
Visual stimuli

Pragmatically adequate context

- Referents are introduced one after another

- set of (two) potential head referents, which is restricted by the RC (Adani, 2011; Hamburger & Crain, 1982; Heim & Kratzer, 1998).
Here is a cow.
Here is another cow.
And here is a dog.

Where is the cow who theNOM/ACC dog is chasing?

Can you see it?

Pointing (optional, time variable)
Predictions

Pointing responses (children)
- SRC > ORC
  - Higher accuracy scores for SRC vs. ORCs
- At or below chance performance in ORC

Looks (children & adults)
- Increase in target looks after hearing the embedded DP for both SRC and ORC
- SRC > ORC: target in SRC is fixated earlier than in ORC

If there is a Task interferes:
- reduced target looks with a pointing task
Results: Pointing data

Adults
- Ceiling effects
- No differences between conditions

Children
- All conditions differ in accuracy
- SRC/ORC asymmetry: SRC: above chance ORC: below chance
Results: Eye Gaze data
Results: Eye Gaze data
Children’s response asymmetries

**Performance pattern**

Explicit responses (pointing)

- SRC > chance (= adults)
- ORC < chance (≠ adults)

**Knowledge of ORC?**
Children’s response asymmetries

Performance pattern

Explicit responses (pointing)

- SRC > chance (= adults)
- ORC < chance (≠ adults)

Knowledge of ORC?

- Not present
Children’s response asymmetries

**Performance pattern**

Explicit responses (pointing)
- SRC > chance (= adults)
- ORC < chance (≠ adults)

Implicit responses (eye-gazes)
- SRC, ORC: target looks increase (= adults)
- Faster increase in SRC (= adults)

**Knowledge of ORC?**
- Not present
Children’s response asymmetries

**Performance pattern**

Explicit responses (pointing)

- SRC > chance (= adults)
- ORC < chance (≠ adults)

Implicit responses (eye-gazes)

- SRC, ORC: target looks increase (= adults)
- Faster increase in SRC (= adults)

**Knowledge of ORC?**

- Not present

- Present and qualitatively similar to adults (= subject-object asymmetry)
Pronoun effects in object relative clause comprehension

Object relative clauses with embedded pronominal subjects are easier than object relative clauses with two full nominal constituents:

**OR+2DP** Where is the cow that **the dog** is chasing <the cow>?  
**OR+pro** Where is the cow that the **you** are chasing <the cow>?  

(adults: Gordon et al., 2001; Warren & Gibson, 2002; 2005; children: Friedmann et al., 2009; Arnon, 2010; Brandt et al., 2009; Kidd et al., 2007)

However, to date, the effect of different pronouns has not been tested within the same experiment (with exception of Warren & Gibson, 2002, 2005)
Pronouns differ in their referential properties

Recanati, 1993; Erteschik-Shir, 1997; Ariel, 2001; Heim, 1991; Legendre & Smolensky, 2012
Pronouns differ in their pace of acquisition and processing

1st/2nd person pronouns preceed 3rd person pronouns in acquisition (e.g., Legendre & Smolensky, 2012)

Adults process 1st/2nd person pronouns at ease compared to 3rd person pronouns, in different sentential contexts (e.g., Warren & Gibson, 2002, 2005: Carminati, 2005)

Sentence processing effects are (often) explained in terms of memory resources that are necessary to process and interpret various pronouns (e.g., Warren & Gibson, 2002, 2005: Gordon et al., 2001)
Individual differences in children’s processing of object relative clauses

Looking-while-listening eye-tracking experiment to test object relative clauses with different referring expressions as embedded subjects in German-speaking 5-year-olds and the impact of language and/or memory development
Individual differences in children’s processing of object relative clauses

Looking-while-listening eye-tracking experiment to test object relative clauses with different referring expressions as embedded subjects in German-speaking 5-year-olds and the impact of language and/or memory development.

Do different pronoun types determine different effect in object relative clause processing?

Do participant’s individual differences (language, memory) modulate these effects?
Participants

47 5-year-olds (24 girls; age range: 5;0-5;11; mean age: 5;5)

All monolingual speakers of German, with no history of linguistic, hearing or cognitive disorder.
Spoken stimuli

**OR+2DP**

Welche Farbe hat der Hase *den* das Pferd *jagt*?
Which color has the bunny who_{ACC} the horse *chases*

*Which color is the bunny that the horse is chasing?*

**OR+1pro**

Welche Farbe hat der Hase *den* ich *jage*?
Which color has the bunny who_{ACC} I *chase*

*Which color is the bunny that I am chasing?*

**OR+3pro**

Welche Farbe hat der Hase *den* es/sie *jagt*?
Which color has the bunny who_{ACC} it/she *chases*

*Which color is the bunny that it/she is chasing?*

**Filler**

Welche Farbe hat der Hase mit *dem Hut*?
Which color has the bunny with the *hat*

*Which color is the bunny with the hat?*

---

Temporal ambiguity until the head noun

Case morphology on the relative pronoun disambiguates
Visual stimuli

Preamble*: Here are two bunnies. The one bunny is yellow and the other bunny is green. And here is their friend the horse. The horse is purple.

Test sentence: Look! What color has the bunny that the horse is chasing?

* The preamble was adapted to introduce each experimental condition in a pragmatic appropriate way
INTRO1: Here are two bunnies, one is green and the other is yellow.

INTRO2: And here is their friend, the horse. The horse is purple.

TEST: What color is the bunny who the horse is chasing? I am chasing? she is chasing?

SILENCE: 2 seconds

COLOR NAMING: Time variable
Language Measures

3 subtests from TSVK battery (Siegmüller et al., 2010):

1) Topicalized sentences (SVO vs. OVS)
2) Various types of relative clauses
3) Sentences with reflexive and anaphoric pronouns

A composite score was calculated as the average of the three subtests and fitted into the model as a continuous covariate.
Memory Measures

Forward and Backward span test with letters and digits (adapted from Grob et al., 2009)

A composite score was calculated as the average of Forward + Backward spans and fitted into the model as a continuous covariate.
Results: Correct color naming

- OR + 1pro: ceiling performance (not analyzed)
- OR + 2DP = OR + 3pro
- NO main effect or interaction with memory
- Main effect of Language: High Language > Low language
- Interaction with Language: High language: OR + 2DP > OR + 3pro
Results: Eye-tracking data

Critical time window 2800 ms: from 200 ms from the off-set of the relative pronoun until 2 sec of silence after the end of the sentence.

OR+2DP is used as a baseline

Analysis of correct and incorrect trials
Results: Eye-tracking data

Proportion of target looks: OR+1pro > OR+2DP > OR+3pro

OR+1pro: no Lang/Mem effect

OR+2DP and OR+3pro
No evidence of accurate processing in low language

High language: differences between high vs low memory in OR+2DP and OR+3pro
Pronouns *per se* do not facilitate

The comparison of different referring expressions revealed a gradient of difficulty: $\text{OR} + 1\text{pro} < \text{OR} + 2\text{DPs} < \text{OR} + 3\text{pro}$

These effects can be explained in terms of different processing to access the referent in the discourse model:

**1st person pronoun**: direct mapping between the pronoun and the speaker

**Noun phrase**: direct mapping between the linguistic expression and the referent in the discourse

**3rd person pronoun**: indirect mapping, via an antecedent in the discourse
Individual differences in accurate processing

Language and memory have independent, additive effects that vary in relation to the experimental conditions

<table>
<thead>
<tr>
<th></th>
<th>OR+1pro</th>
<th>OR+2DP</th>
<th>OR+3pro</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Language</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-memory</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Low-memory</td>
<td>✔️</td>
<td>✔️ But late!</td>
<td>✗</td>
</tr>
<tr>
<td>Low-Language</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-memory</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Low-memory</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Assumption: referring expressions whose discourse referent is accessed directly overload memory resources to a lesser extent than referring expressions whose referent is accessed indirectly.
Individual differences impact processing

Memory capacity appears to be the crucial factor in accessing discourse referents, but only when the language skills are sufficiently strong:

- Low-language performers: no accurate processing, no memory effects
- High language performers: different effects depending on memory
  - 2DP condition (=direct access): even low-memory performers eventually look at the target, although they are delayed
  - 3pro condition (=indirect access): no evidence that low-memory performers process the structure accurately
Summary Study 1

When sentence processing abilities are measured implicitly:

Four-year olds are able to use their grammatical knowledge while processing relative clauses on-line

Children resolve temporal ambiguity locally (like adults)

Continuity in the parsing mechanisms employed by children and adults
Summary Study 2

Different referring expressions affect object relative clause processing differently.

There is no pronoun facilitation *per se*.

There appear to be a direct link between memory capacity and the ability to access discourse referents of referring expressions.

However, having developed language abilities seems to be a pre-requisite for the emergence of memory individual differences.
Acknowledgements

All participants and their families for the kind collaboration.

http://www.uni-potsdam.de/aladdin/