HuMaze – Testing Hungarian relative clause processing in the Maze-task

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Relative clause processing asymmetry

Subject relative clause (Subject RC)

The engineer [who annoyed the analyst] wrote a report about the project.

Object relative clause (Object RC)

The engineer [who the analyst annoyed] wrote a report about the project.

Object RC is harder to process

(i.a., Gibson, 1998, 2000; King & Just, 1991; Staub, 2010; Staub et al., 2017; Traxler et al., 2002)

Reaction time at RC verb annoyed

Reading time

- Subject RC
- Object RC
Two families of accounts

1. **Expectation**-based accounts (i.a., Hale, 2001; Levy, 2008)

Evidence: i.a., Carreiras et al., 2010; Holmes & O’Regan, 1981; Cohen & Mehler, 1996; Hsiao & Gibson, 2003; Gibson & Wu, 2013

2. **Memory**-based accounts (i.a., Gibson, 1998; Lewis & Vasishth, 2005)

Evidence: i.a., Vasishth & Lewis, 2006; Konieczny, 2000; Levy & Keller, 2013; Nakatani & Gibson, 2008; Ueno & Garnsey, 2008; Kwon et al., 2010; Jäger et al., 2015; Wu et al., 2017
Expectation-based account

Comprehenders predict upcoming structure based on previous experience.

The more expected a word is in its context, the easier it is to process.

$$\text{difficulty} \propto -\log P(w_i|w_{1:i-1}, \text{CONTEXT})$$

Estimated based on corpus frequencies.

English Subject RCs are more frequent than Object RCs → captures processing asymmetry.
Memory-based account

Syntactic structure is built incrementally
Integrating new words requires working memory resources

Subject RC: The engineer [who annoyed the analyst] wrote a report.

Object RC: The engineer [who the analyst annoyed] wrote a report.

Object RC requires a longer dependency → captures processing asymmetry

Cost: retrieval, storage, integration, similarity-based interference
Converging predictions in English

Memory- and expectation-based accounts both capture the English asymmetry

Subject RC: shorter dependency, more frequent
Object RC: longer dependency, less frequent
Hungarian: flexible word order

Subject RCs with short and long dependencies

A mérnök [aki idegesítette az elemzőt ] beszámolt a projektről.
The engineer [who.nom annoyed the analyst.acc ] reported the project-on

A mérnök [aki az elemzőt idegesítette ] beszámolt a projektről.
The engineer [who.nom the analyst.acc annoyed ] reported the project-on

Both: ‘The engineer who annoyed the analyst wrote a report about the project.’
Hungarian: flexible word order

Object RCs with short and long dependencies

A mérnök [akit idegesített az elemző] beszámolt a projektről.
The engineer [who.acc annoyed the analyst.nom] reported the project-on

A mérnök [akit az elemző idegesített] beszámolt a projektről.
The engineer [who.acc the analyst.nom annoyed] reported the project-on

Both: ‘The engineer who the analyst annoyed wrote a report about the project.’
Disentangling predictions in Hungarian

Subject RC:
- Shorter dependency
  - Less frequent

Object RC:
- Shorter dependency
  - Less frequent

Longer dependency
- More frequent

Frequencies extracted from the Hungarian National Corpus
(Oravecz et al. 2014)
More fine-grained predictions

Memory accounts
longer dependencies harder
local < non-local

Expectation accounts
less frequent harder
non-local < local

Location: RC Verb
- place of verb-argument integration
- anti-locality effect

(as reported by Ronai & Xiang, 2023)
More fine-grained predictions

Relative pronoun case marking signals RC structure (aki vs. akit)

Expectation accounts
SRCs globally more frequent than ORCs
Easier processing for SRMs at Rel. Pronoun

Memory accounts
No difference at Rel. Pronoun
Prior work using self-paced reading

Ronai & Xiang’s (2023) SPR experiments:

RelPr (who)

RCV (annoyed)

no effect at RelPr

local advantage at RCV

⟶ memory account
Russian RCs in SPR vs. eye-tracking

**Russian RCs** have very similar properties:
- Case-marking disambiguates SRC vs. ORC at relative pronoun
- Word order flexibility

**Relative pronoun**: SRC < ORC prediction
- No clear effect found in SPR (Levy et al., 2013; Price & Witzel, 2017)
- **Confirmed in eye-tracking** while reading (Price & Witzel, 2017)
Lexical Maze-task

Sentence presented as *series of lexical decisions*

**Effect localization & web reliability**

Boyce, Futrell & Levy 2020; Vani, Wilcox & Levy 2021

**Replicates** results found in *other methodologies*

Boyce, Futrell & Levy 2020; Forster, Guerra & Elliot 2009; Witzel, Witzel & Forster 2009
Creating L-maze for Hungarian

Custom language extension for Wuggy (Python Version)
Keuleers & Brysbaert 2010; https://github.com/WuggyCode/wuggy

Cleaned Hungarian Webcorpus
Halácsy et al., 2004; Kornai et al., 2006

Automated naïve syllable structures

Deployed in PCibex
Boyce, Futrell & Levy 2020; Zehr & Schwarz 2022
Experimental manipulation

2-by-2 design: RC type (SRC vs. ORC) x word order (local vs. non-local)

(Levy et al., 2013; Ronai & Xiang, 2023)

(3) a. SRC, VO (local)
A mérnök, aki idegesítette az elemzőt...
the engineer.NOM who.NOM annoyed the analyst.ACC

b. SRC, OV (non-local)
A mérnök, aki az elemzőt idegesítette...
the engineer.NOM who.NOM the analyst.ACC annoyed
Both: ‘The engineer who annoyed the analyst... (wrote a report...).

(4) a. ORC, VS (local)
A mérnök, akit idegesített az elemző...
the engineer.NOM who.ACC annoyed the analyst.NOM

b. ORC, SV (non-local)
A mérnök, akit az elemző idegesített...
the engineer.NOM who.ACC the analyst.NOM annoyed
Both: ‘The engineer who the analyst annoyed... (wrote a report...).’

SRC (local): I mulnád, epi reedenítálye éz elegült náp súl áze, bagyágort ö kroluktród.

ORC (non-local): I mulnád, epit éz elegül reedenítály náp súl áze, bagyágort ö kroluktród.
## Recap of predictions

<table>
<thead>
<tr>
<th>RC Verb Position</th>
<th>Rel. Pronoun</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Memory</strong></td>
<td><strong>Memory</strong></td>
</tr>
<tr>
<td>local &lt; non-local</td>
<td>No differences</td>
</tr>
<tr>
<td><strong>Expectation</strong></td>
<td><strong>Expectation</strong></td>
</tr>
<tr>
<td>non-local &lt; local</td>
<td>SRCs &lt; ORCs</td>
</tr>
</tbody>
</table>
Results

Region by Region Maze Response Time (N=46)

Response Time (ms)

Rel. Pro  RC Verb

A mem'k  aki  az  elemzett idegesitette  az  elemzett  már  sok  éve  beszámolt  a  projektről

p<0.001  p<0.05

Local
- Local
- Non-Local

SRC
- ORC
- SRC
Conclusion

Adaptation of maze-task to a language understudied in psycholinguistics

Captured predicted effects:

- **RC verb** $\rightarrow$ favors **memory** accounts
  - Replication of previous results from Hungarian SPR

- **Relative pronoun** $\rightarrow$ favors **expectation** accounts
  - Evidence for effect that has not been detected with Hungarian SPR
  - Lexical Maze can be useful method for capturing elusive effects
Thank you!
Selected references

Price & Witzel. 2017. Sources of relative clause processing difficulty: evidence from Russian. JML.