Special thanks to Douglas Roland

Expectations in comprehension
- We build expectations about upcoming material during comprehension
- Many previous studies demonstrated expectations at the lexical level (e.g., Kutas & Hillyard, 1980)
- Recent studies demonstrated expectations at the syntactic level (*structural prediction*)
  (e.g., Staub & Clifton, 2006; Lau et al., 2006)

Surprisal theory (Hale, 2001; Levy, 2008)
- Expectation is directly linked to cost.
- Expected processing difficulty is proportional to the change in the probability distribution over possible structural options from one word to the next
  \[ \text{difficulty} \propto - \log P(w_i|w_{i-1}, \text{CONTEXT}) \]
- A word that triggers a large change in the distribution is difficult to process
  \[ \Rightarrow \text{Narrowing structural options (i.e., pruning) should be associated with cost} \]

How pruning facilitates subsequent processing

How pruning facilitates subsequent processing

\[ \text{Ueitoresu-ga} \]
\[ \text{waitress-nom} \]

\[ \begin{align*}
\text{Ueitoresu-ga} & \quad \text{okayaku-ni} \\
\text{waitress-nom} & \quad \text{customer-dat} \\
\text{intransitive} & \quad \text{pruned} \\
\text{transitive} & \\
\text{ditransitive} & \\
\text{...} &
\end{align*} \]

→ Since other options but the ditransitive structure are pruned, the probability of the upcoming ditransitive verb is very high
How pruning facilitates subsequent processing

Ueitoresu-ga okyaku-ni hambagaro hakonda
waitress-nom customer-dat hamburger-acc easy

⇒ The cost on actually encountering a ditransitive verb (bring) is very small

What’s still missing

• If the facilitation at the verb was indeed due to early pruning of unlikely structural options, the pruning itself should cause processing cost by the same mechanism

• Such pruning cost has not been documented so far

Konieczny and Döring (2003)

• Contrasted a dative NP with a genitive NP with head-final construction in German

(a) Subject, [that NP-nom NP-dat NP-acc verb], verb ....
(b) Subject, [that NP-nom NP-gen NP-acc verb], verb....

The verb was read faster in (a) than in (b)

• The dative NP, but not the genitive NP, facilitated the processing of the verb (i.e., anti-locality effect)

Cost of pruning

- Pruning cost
- reduced cost

Our study

• Contrasted the dative NP with the genitive NP with Japanese head-final construction (Konieczny & Döring, 2003)

• Investigated whether we observe increased cost at the preverbal constituents (early pruning) and reduced cost at the verb for the sentence with a dative NP

(a) NP-top NP-dat NP-acc verb

(b) NP-top NP-gen NP-acc verb

Estimating the probability of the upcoming ditransitive structure

• We conducted a sentence completion test

• participants produced continuations to the fragments below

(a) NP-top NP-dat......
(b) NP-top NP-gen......

• We also included the fragments with an adjective and noun without case maker

(a’) NP-top NP-dat Adjective Noun......
(b’) NP-top NP-gen Adjective Noun......

• We had 24 items and tested 32 native speakers of Japanese
A significant main effect of NP1 Case (\( p < .001 \))

1. This confirmed participants produced ditransitive structure more with a dative NP than with a genitive NP

A significant interaction between case type and presence/absence adjective + noun (\( p < .001 \))

2. They produced the ditransitive structure even more when an adjective and noun followed the dative NP than when they did not

Our study: Manipulation

- Manipulated case for NP1 (dative vs. genitive)
- Also manipulated case for NP2 (accusative vs. nominative)

NP-top NP1 Case dative \( ni \)
\( vs. \) genitive \( no \)

NP1
\( \rightarrow \)

NP-dat
Adjective

NP-gen

NP2

V1

V2

NP-acc
ditransitive verb

NP-nom
verb (taking nominative object)

- The continuation with the nominative case is very infrequent and unexpected (3.6% in sentence completion), thus violating the expectation of the ditransitive structure

Our prediction I

- We expect to observe cost of early pruning at NP1 (or possibly at NP2 as well)

(a, c) NP-top NP-dat pruning cost

(b, d) NP-top NP-gen no pruning

- If pruning occurs, at the NP-dat, it increases the expectation for ditransitive structure by pruning other structural options

- NP-dat should incur cost related to early pruning

Our Prediction II

- We expect to observe reduced cost at the ditransitive verb (V1) following NP-dat

(a) NP-top NP-dat Adjective V1

(b) NP-top NP-gen Adjective V1

(c) NP-top NP-dat Adjective V1

(d) NP-top NP-gen Adjective V1

(a) < (b)

(\( a \)) \((c) = (d)\)
Method

- Measured eye-movements during reading using EyeLink II (SR Research)
- Created 24 items
- N=32 native speakers of Japanese (One participant excluded due to low comprehension question accuracy)

Data analysis

- We focus on the following measures
  - First pass \( (fp) = 1 + 2 \)
  - Regression path \( (rp) = 1 + 2 + 3 + 4 \)
  - Second pass \( (sp) = 8 \)
- Reading times were analyzed using Linear Mixed-Effects (LME) models
- The best-fit model with the optimal random slope structure was selected using a backward selection approach

Regions of our interest

We report the results for the following regions

<table>
<thead>
<tr>
<th>Subject</th>
<th>NP1</th>
<th>Adjective</th>
<th>NP2</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>That school girl top</td>
<td>the designer</td>
<td>unique</td>
<td>earring</td>
<td>ordered</td>
<td>want</td>
</tr>
</tbody>
</table>

| NP1 Region |

<table>
<thead>
<tr>
<th>Subject</th>
<th>NP1</th>
<th>Adjective</th>
<th>NP2</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>That school girl</td>
<td>the designer</td>
<td>unique</td>
<td>earring</td>
<td>ordered</td>
<td>want</td>
</tr>
</tbody>
</table>

| Adjective Region |

<table>
<thead>
<tr>
<th>Subject</th>
<th>NP1</th>
<th>Adjective</th>
<th>NP2</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>That school girl top</td>
<td>the designer</td>
<td>unique</td>
<td>earring</td>
<td>ordered</td>
<td>want</td>
</tr>
</tbody>
</table>

| Corpus frequency |

- Bigram frequency can affect reading times (McDonald & Shillcock, 2003)
- But N + dative is more frequent than N + genitive (in Kyoto University Text Corpus)
  - In general: dative 28,700 and genitive 2,665
  - Restricted to personal names: dative 251 and genitive 58
- Slowdown at Adjective after NP-dat is not caused by the difference in frequency
**Summary of results**

1. The adjective following the NP·dat was read more slowly than the one following the NP·gen → Increased cost due to early pruning before the verb

2. The verb following the NP·dat was read faster than the one following the NP·gen when NP2 was accusative → Reduced cost at the verb following the early pruning
Further Analysis I
Probability for ditransitive structure and reading time data

- We calculated the probability for the ditransitive structure for each item.
- In LME model, we entered the item-by-item probabilities for the ditransitive structure and tested whether these probabilities can account for reading times (first pass no regression) at the Adjective region.

<table>
<thead>
<tr>
<th>Fragment type</th>
<th>Probability for ditransitive structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) NP-top NP-dat</td>
<td>43%</td>
</tr>
<tr>
<td>(b) NP-top NP-gen</td>
<td>3%</td>
</tr>
</tbody>
</table>

*The result showed no effect (p>.1)*

Further Analysis I
Results

- We first entered the item-by-item probabilities estimated for the fragment up to NP1.

Further Analysis II
Link between early pruning cost and late reduced cost

- All the previous analyses examined reading times in each region separately.
- We still do not know whether the slower reading times at Adjective were indeed paired with the faster reading times at V1 in individual trials.
- We paired the first pass no regression times at Adjective with second pass times at V1 from the same trial and calculated their log-ratio.

Further Analysis II
Link between early pruning cost and late reduced cost

- A significant interaction between NP1 Case and NP2 Case (p<.05).
- The same pattern of interaction in total times at V1 (p<.05).

Log-ratio = \[ \log(\frac{\text{first pass no regression times at Adjective}}{\text{second pass times at V1}}) \]
Further Analysis II
Link between early pruning cost and late reduced cost

The ratio in dative-accusative condition was higher than genitive-accusative condition (dative: 3.22; genitive: 2.42; \( p < .05 \)).

There was no difference between dative-nominative condition and genitive-nominative (\( p > .1 \)).

→ Reading times at the Adjective region and those at V1 region are directly linked.

Conclusions
- Confirmed two predictions based on surprisal
  1. early increased cost
     - Two preverbal arguments pruned structural options, causing early pruning cost
  2. late reduced cost
     - The cost at the ditransitive verb was reduced due to early pruning

- Further analyses confirmed that early pruning cost indeed reflected the probabilities for individual items, and resulted in late reduced cost at the verb at the level of individual trials

Summary of further analyses
- NP-dat increases the probabilities for the ditransitive structure
- It is further increased by a following adjective + noun
- Our analysis suggested that reading times in the adjective region reflected the probability with adjective + noun
- Longer reading times at Adjective and faster reading times at V1 in the “NP-dat NP-acc” were paired at the level of individual trials

Thank you for listening!!