Background & Motivation

- Big picture: processing complexity based on some combination of... 
- Memory storage & retrieval operations (Gibson 1998, 2000; Lewis 1996; Gordon et al., 2001, 2004; Lewis & Vasishth, 2005; Lewis et al., 2006)
- Gibson & Breen (2003) concluded from a series of self-paced reading studies that there was evidence for complexity associated with processing discontinuous dependencies: 
- Extraposition of a relative clause (RC) from subject across a verb (G&B exp 2): 
- Extraposition of RC from object across a PP (G&B exps 3 & 4): 
- G&B exps 3&4 suggest that this difficulty is unlikely to be reducible to dependency locality or retrieval interference 
- The results could be due to... 
- Derivational complexity of the extraposed structure—more transformational steps (Fodor, Bever & Garrett 1974)
- A constraint-based cost (MacDonald, Pearlmutter & Seidenberg 1994) for the extraposed RC rule higher than that of the unextraposed RC 
- Here, we will refine the interpretation of these results by suggesting that the processing cost of these discontinuous dependencies is derived from probabilistic expectations over upcoming structure 

Expectations and extraposition

- Extraposed RCs are rare in corpora, and unexpected in the contexts of the above experiments (estimated from parsed Brown corpus): 
  - VP
  - NP
  - RC
  - PP
  - VP
  - NP
  - PP
  - RC

- We crossed RC expectation (low/high) with RC extraposition (extraposed/unextraposed) 
- Example sentence: The chairman consulted... 

Method

- Word-by-word self-paced reading 
- 36 native English-speaking members of the MIT community participated 
- This prediction depends on the assumption that high RC expectation from premodifiers is not (strongly) negatively correlated with extraposition.

Conclusions

- Syntactic expectations are not limited to the continuous-constituent/dependency domain (a novel finding) 
- Strong expectations for an RC can facilitate extraposed RC processing 
- The processing constraint associated with phrasal adjacency seems to be entirely reducible to syntactic expectations 
- Probabilistic expectations at many levels of representation play a broader role than previously realized 
- Broader outlook: couple expectation-based comprehension with a theory of weight effects in production (Wasow, 2002) to explain distribution & processing of discontinuous dependencies 

Manipulating extraposed RC expectations

- If extraposed RCs are hard because they’re unexpected... 
- ...then making them more expected should make them easier 
- Recent work (Wasow et al., 2005; Jaeger, 2006; Levy & Jaeger, 2007) has found that premodifier type can affect expectation for (in-situ) RCs 
  - low RC expectation 
  - higher RC expectation 
  - very high RC expectation 
- If premodifier-induced expectations are carried over past the continuous NP domain, we may be able to manipulate extraposed RC expectations the same way* 

Experiment Design

- We crossed RC expectation (low/high) with RC extraposition (extraposed/unextraposed) 
- Example sentence: The chairman consulted... 

Results

- The differences across conditions show up in the RC onset: 
- The interaction is significant (all p’s < 0.05) at the disambiguating verb (was/were) and also at the next region (making) 
- When an RC is less expected, there is a processing penalty for the extraposed variant 
- When an RC is more expected, the extraposed variant is easier 
- Equivalently, increasing expectation for an RC facilitates processing of that RC despite its extraposition 

• After dinner, a musician was hired for the wedding arrived 
  - easy 
  - harder 

• The chair consulted the executive of the companies who was making lots of $ 
  - easy 
  - harder 

• G&B exps 3&4 suggest that this difficulty is unlikely to be reducible to dependency locality or retrieval interference 

• The results could be due to... 
  - Derivational complexity of the extraposed structure—more transformational steps (Fodor, Bever & Garrett 1974) 
  - A constraint-based cost (MacDonald, Pearlmutter & Seidenberg 1994) for the extraposed RC rule higher than that of the unextraposed RC 
  - Here, we will refine the interpretation of these results by suggesting that the processing cost of these discontinuous dependencies is derived from probabilistic expectations over upcoming structure 
  
• Extraposed RCs are rare in corpora, and unexpected in the contexts of the above experiments (estimated from parsed Brown corpus): 
  - VP
  - NP
  - RC
  - PP
  - VP
  - NP
  - PP
  - RC

• We disambiguate the RC attachment weakly through the relative pronoun, and completely at the auxiliary verb (number marking on was/were; balanced across items) 

• We predict an interactive effect: high RC expectation (“only those”) will facilitate RC reading, but only in the extraposed condition 

• We don’t have enough annotated corpus data to test this explicitly 

• But there is no reason to expect such a correlation 

• The interaction is significant (all p’s < 0.05) at the disambiguating verb (was/were) and also at the next region (making) 

• When an RC is less expected, there is a processing penalty for the extraposed variant 

• When an RC is more expected, the extraposed variant is easier 

• Equivalently, increasing expectation for an RC facilitates processing of that RC despite its extraposition 

• Syntactic expectations are not limited to the continuous-constituent/dependency domain (a novel finding) 

• Strong expectations for an RC can facilitate extraposed RC processing 

• The processing constraint associated with phrasal adjacency seems to be entirely reducible to syntactic expectations 

• Probabilistic expectations at many levels of representation play a broader role than previously realized 

• Broader outlook: couple expectation-based comprehension with a theory of weight effects in production (Wasow, 2002) to explain distribution & processing of discontinuous dependencies