

Processing Extraposed Structures in English: Grammatical and Processing Factors

Edward Gibson, Ev Fedorenko & Mara Breen (Brain and Cognitive Sciences, MIT)
egibson@mit.edu, evelina9@mit.edu, mbreen@mit.edu

BACKGROUND AND MOTIVATION

It has often been argued that words are combined into phrases and sentences, according to a set of head-dependent context-free rules (e.g., Chomsky, 1957, 1965; Jackendoff, 1972; Pollard, 1983; Pollard & Sag, 1994).

Extraposed structures in English cannot be generated via head-dependent context-free rules of the form:

$$X \rightarrow Y_1 \dots Y_n, \text{ where}$$

(a) $Y_1 \dots Y_n$ are **adjacent (Phrasal Adjacency)**;

(b) one of the right-hand-side categories Y_i is the **head-category** of X ; and

(c) the remaining right-hand-side categories are **semantically dependent** on Y_i .

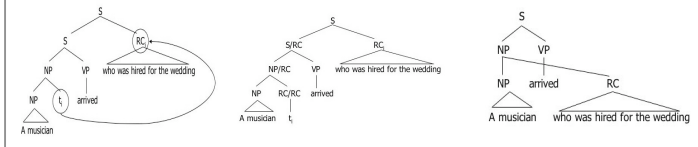
The musician arrived who was hired for the wedding, and all the guests...

The RC "who was hired for the wedding" modifies the noun "the musician" but is not phrasally-adjacent to it.

Hypothesis: There is a processing cost associated with violating the Phrasal Adjacency constraint.

Proposals for representing extraposed structures:

(a) Transformational rules (Chomsky, 1965); (b) Slash categories (Gazdar, 1981); (c) crossed dependencies (e.g., McCawley, 1982)



HYPOTHESES

If there is a cost associated with violating the Phrasal Adjacency constraint: why might extraposed structured (and other structures that cannot be generated via head-dependent context-free rules) be more difficult?

- Hypothesis 1:** More steps are required in deriving non-phrasally-adjacent structures, compared to phrasally-adjacent structures (e.g., the transformational account of grammar (Chomsky, 1965)).
- Hypothesis 2:** Phrasal Adjacency is a grammatical constraint within a constraint-based framework (e.g., MacDonald, Pearlmuter, & Seidenberg, 1994; Pollard & Sag, 1994; Tanenhaus & Trueswell, 1995; Gibson & Pearlmuter, 1998). Non-phrasally-adjacent and phrasally-adjacent structures are generated in the same way, but there is a cost associated with expanding rules over non-adjacent categories.
- Hypothesis 3:** Non-phrasally-adjacent structures require more working memory resources because they involve long-distance dependencies (e.g., Gibson, 1998; McElree et al., 2003, VanDyke & Lewis, 2003; Grodner & Gibson, 2005).

CORPUS STUDY

Methods

- Penn Treebank parsed Brown corpus (Marcus, Santorini, & Marcinkiewicz, 1993);
- Tgrep2 search utility (Rohde, 2001)
- RCs initiated with "who" and "which"

Results

	Extraposed	Non-extraposed	All RCs
RCs initiated by "who"	10	1978	1988
RCs initiated by "which"	32	2268	2300
Total	42	4246	4288

Examples:

Only those story tellers will remain [who can "imitate the style of the virtuous"].
This year several entries from Canada were entered [which made the Junior Class International].

EXPERIMENT 1

Design & Materials

Self-paced word-by-word moving-window reading paradigm (40 participants, 16 items).

Design: 2 x 2

Extrapolation (Extraposed / Non-Extraposed) x Verb-type (Presentative / Non-Presentative)

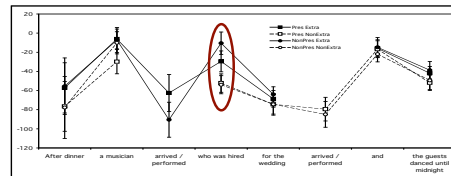
It has been claimed (Givón, 1993) that extrapolation across presentative verbs (verbs that introduce the subject, like "arrived", "appeared", "showed up", etc.) is easier.

Materials:

Extraposed: *After dinner, a musician arrived/performed who was hired for the wedding, and...*

Non-Extraposed: *After dinner, a musician who was hired for the wedding arrived/performed, and...*

Results



Main Effect of Extraposition:
F(1,39)=10.18; MSE=4293; p<.05
F(2,115)=26.24; p<.05

EXPERIMENT 2

Design & Materials

Self-paced word-by-word moving-window reading paradigm (48 participants, 32 items; one item was excluded because of the error in the number of words per region, relative to all the other items).

Design: 2 x 4: Extrapolation (Extraposed / Non-Extraposed) x Length of the RC (Short RC / Medium RC / Long RC additional PP / Long RC additional RC):

SHORT RC:

Extraposed: *After the dinner, a musician arrived who was hired yesterday, and...*

Non-Extraposed: *After the dinner, a musician who was hired yesterday arrived, and...*

MEDIUM RC:

Extraposed: *After the dinner, a musician arrived who was hired yesterday for the wedding, and...*

Non-Extraposed: *After the dinner, a musician who was hired yesterday for the wedding arrived, and...*

LONG RC additional PP:

Extraposed: *After the dinner, a musician arrived who was hired yesterday for the wedding at the famous French castle, and...*

Non-Extraposed: *After the dinner, a musician who was hired yesterday for the wedding at the famous French castle arrived, and...*

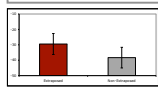
LONG RC additional RC:

Extrap: *After the dinner, a musician arrived who was hired yesterday for the wedding where many celebrities were invited, and...*

Non-Extrap: *After the dinner, a musician who was hired yesterday for the wedding where many celebrities were invited arrived, and...*

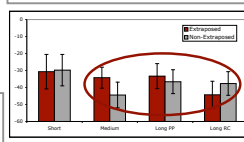
Results

RTs during the RC region



Main Effect of Extraposition:
• F(1,47)=4.85; MSE=1880; p<.05
• F(2,130)=3.87; MSE=1160; p=.06

RTs during the Verb and the RC region



Interaction between Extraposition and Length (Medium / Long RC):

F(1,47)=3.94; MSE=3390; p=.053
F(2,130)=4.88; MSE=2612; p<.05
Medium (pairwise comparison):
F(1,47)=2.93; MSE=2498; p=.09
F(2,130)=2.80; MSE=1692; p=.11
Long RC (pairwise comparison):
F(1,47)=1.94; MSE=1047; p=.17
F(2,130)=1.59; MSE=970; p=.22

EXPERIMENT 3

Design & Materials

Self-paced word-by-word moving-window reading paradigm (15 participants, 24 items; one item was excluded because of the error in the number of words per region, relative to all the other items).

Design: 2 x 2: Extrapolation (Extraposed / Non-Extraposed) x Type of the RC (Long RC additional PP / Long RC additional RC; minimal contrast pairs):

LONG RC additional PP:

Extraposed: *After the dinner, a musician arrived who was hired yesterday for the wedding at the famous French castle, and...*

Non-Extraposed: *After the dinner, a musician who was hired yesterday for the wedding at the famous French castle arrived, and...*

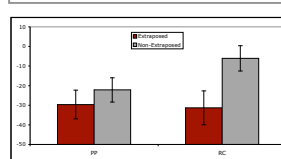
LONG RC additional RC:

Extraposed: *After the dinner, a musician arrived who was hired yesterday for the wedding which took place at the famous French castle, and...*

Non-Extraposed: *After the dinner, a musician who was hired yesterday for the wedding which took place at the famous French castle arrived, and...*

Results

RTs at the critical region: the Verb and the RC



Interaction between Extraposition and Type of RC:

F(1,14)=6.71; MSE=1185; p<.05
F(2,122)=2.63; MSE=1924; p=.12

RC-conditions (pairwise comparison):

F(1,14)=14.91; MSE=4772; p<.005
F(2,122)=5.15; MSE=6356; p<.05

PP-conditions (pairwise comparison):

Fs<2

SUMMARY AND CONCLUSIONS

Summary:

- When the extraposed RC is relatively short, there is a cost associated with violating the Phrasal Adjacency constraint.
- When the extraposed RC is long, the cost associated with violating the Phrasal Adjacency constraint is swamped by the cost associated with violating the working memory constraint (minimizing dependency lengths) (c.f. Bever, 1970; Hawkins, 1994, 2005; Stallings et al., 1998).

Conclusions:

- Two competing constraints affect the processing of extraposed structures:
- the Phrasal Adjacency constraint (a grammatical constraint);
 - the working memory constraint.