Forward vs. Backward Processing of Subject-Verb Agreement in Comprehension

Eric S. Solomon and Neal J. Pearlmutter
Northeastern University

INTRODUCTION

How are number agreement features tracked during comprehension?

Hypotheses

Forward-checking: Features processed during parser's forward movement through a sentence. Verbs always checked for agreement with subject NP.

Backward-checking: Features processed by a backtracking mechanism. Verbs checked for agreement only when explicitly marked for number.

Nicol, Forster, & Veres (1997): Propose a backward-checking mechanism.

The author of the speech will be well rewarded.
The author of the speeches will be well rewarded.

— No head-local noun mismatch effect in whole-sentence reading times.

— Suggests that non-number-marked verbs are not checked for head noun agreement.

Pearlmutter, Garnsey, & Bock (1999): Suggest a backward-checking mechanism.

— Based on efficiency considerations: Less than 25% of all English verb tokens (in Brown Corpus) are number-marked.

Probabilistic and Constraint-based comprehension systems

— Singular-marked verbs (e.g., *was*) nearly always agree with subject NPs.

— Prediction from constraint-based lexical models (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994): Even verbs which are *not* overtly number-marked (e.g., modals) might be associated with a lexically-represented probability of being singular versus plural, which would influence agreement-checking.

MARKING BIAS FOR MODAL VERBS

— Counts obtained from text corpora to determine marking biases for modal verbs.

— One hundred tokens from each of 3-4 different locations counted in each corpus for each verb.

Singular Marking Biases (%) for Modals

Modal	*WSJ*	*CSPAE*	*Reuters*	Mean
could	69	57	72	66
may	69	59	71	66
might	77	50	76	68
will	72	62	70	68
would	74	71	75	73
mean	72	56	73	67
can	53	39	50	47
must	56	52	51	53
mean	55	46	51	50

EXPERIMENT 1

Do readers keep track of marking biases on modal verbs?

— Pure singular verb (*was*) vs. singular-biased modals vs. equibiased modals

— Singular vs. plural local nouns; head noun always singular

Method

Pure singular
The key to the cabinet was rusty from years of disuse. (singular local noun)
The key to the cabinets was rusty from years of disuse. (plural local noun)

Singular-biased
The key to the cabinet might be rusty from years of disuse. (singular local noun)
The key to the cabinets might be rusty from years of disuse. (plural local noun)

Equibiased
The key to the cabinet must be rusty from years of disuse. (singular local noun)
The key to the cabinets must be rusty from years of disuse. (plural local noun)

64 participants
36 critical items, 84 fillers (40 ungrammatical)

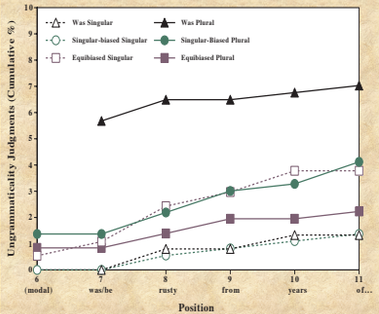
— Self-paced moving window paradigm with continuous grammaticality judgments and yes/no comprehension questions

Results

— Backward-checking predicts same mismatch effect for singular-biased as for equibiased modals.

— Forward-checking predicts larger mismatch effect for singular-biased relative to equibiased modals.

— Head-local mismatch effect should be largest for pure singular cases.



— Significant bias by number interactions at each Position from Position 7 to Position 11

— Largest mismatch effect for *was*, intermediate mismatch effect for singular-biased modal, no significant effect for equibiased modals

— Evidence for a forward-checking account of number agreement processing, at least when grammaticality judgment is required

EXPERIMENT 2

Is information about marking biases on modals used during normal comprehension?

— Singular-biased modals vs. equibiased modals (no pure singular condition)

— Subject NP either strongly singular or strongly plural

Method

Singular-biased
The key to the cabinet might rust from the moisture near the window. (strongly singular)
The keys to the cabinets might rust from the moisture near the window. (strongly plural)

Equibiased
The key to the cabinet can rust from the moisture near the window. (strongly singular)
The keys to the cabinets can rust from the moisture near the window. (strongly plural)

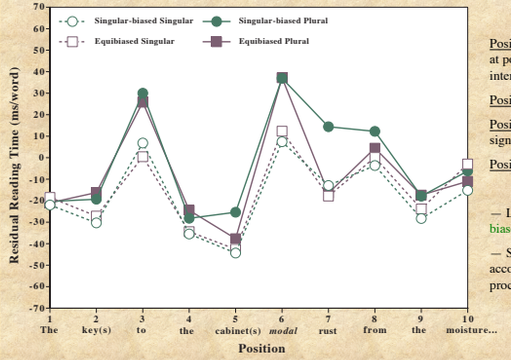
91 participants
36 critical items, 64 fillers (all grammatical)
One critical item dropped from analysis (stimulus was ungrammatical)

— Self-paced moving window with yes/no comprehension questions; no grammaticality judgments

Results

— Backward-checking predicts the same subject NP number effect for singular-biased as for equibiased modals.

— Forward-checking predicts larger NP number effect for singular-biased relative to equibiased modals.



Positions 1-5: Effect of number starting at position 2; no bias effects or interactions

Position 6: Effect of number

Position 7: Effects of number and bias; significant interaction

Positions 8-9: Effects of number

— Larger number effect for singular-biased modals (Position 7 interaction)

— Supports a forward-checking account of number agreement processing

CONCLUSIONS

Readers can use marking biases of non-overtly-marked verbs.

— Ungrammaticality judgments show largest local noun number mismatch effect for *was*, smaller effect for singular-biased modals, and no effect for equibiased modals.

— Preliminary evidence for a forward-checking processing mechanism.

Agreement is checked in a forward process during normal comprehension .

— Subject NP number computed as the subject NP is processed.

— Verb number unified with subject NP number by activating verb number feature even for non-overtly-marked verbs.

— Equibiased modals: Singular and plural subject NPs are equally compatible, because singular and plural verb features are equally likely.

— Singular-biased modals: Singular subject NPs are more compatible than plural subject NPs, because singular verb features are more likely.

— Effect of marking bias on non-overtly-marked verbs during normal comprehension is not compatible with backward-checking.

REFERENCES

ACL Data Collection Initiative [CD-ROM]. (1993). Philadelphia, PA: University of Pennsylvania Linguistic Data Consortium (www.ldc.upenn.edu).

Corpus of Spoken Professional American English [CD-ROM]. (2000). Houston, TX: Michael Barlow [Producer], Athelstan (www.athel.com) [Distributor].

MacDonald, M.C., Pearlmutter, N.J., & Seidenberg, M.S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, **101**, 676-703.

Nicol, J.L., Forster, K.I., & Veres, C. (1997). Subject-verb agreement processes in comprehension. *Journal of Memory and Language*, **36**, 569-587.

Pearlmutter, N.J., Garnsey, S.M., & Bock, K. (1999). Agreement processes in comprehension. *Journal of Memory and Language*, **41**, 427-456.

Reuters Corpus Volume 1 (English Language, 1996-08-20 to 1997-08-19) [CD-ROM]. (2000). London: Reuters.

Trueswell, J.C. & Tanenhaus, M.K. (1994). Towards a lexicalist framework of constraint-based syntactic ambiguity resolution. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentences processing* (pp. 155-179). Hillsdale, NJ: Erlbaum.

ACKNOWLEDGEMENTS

This research was supported by the National Science Foundation (Grant BCS-9729007) and the National Institute on Deafness and Other Communication Disorders (NIH Grant 1 R01 DC05237-01).