ACT-R&BIG DATA SYMPOSIUM

CRACKING LANGUAGE WITH ACT-R:

HOW DOES LANGUAGE MIX WITH COGNITION? CHALLENGES FOR THE MODELING COMMUNITY

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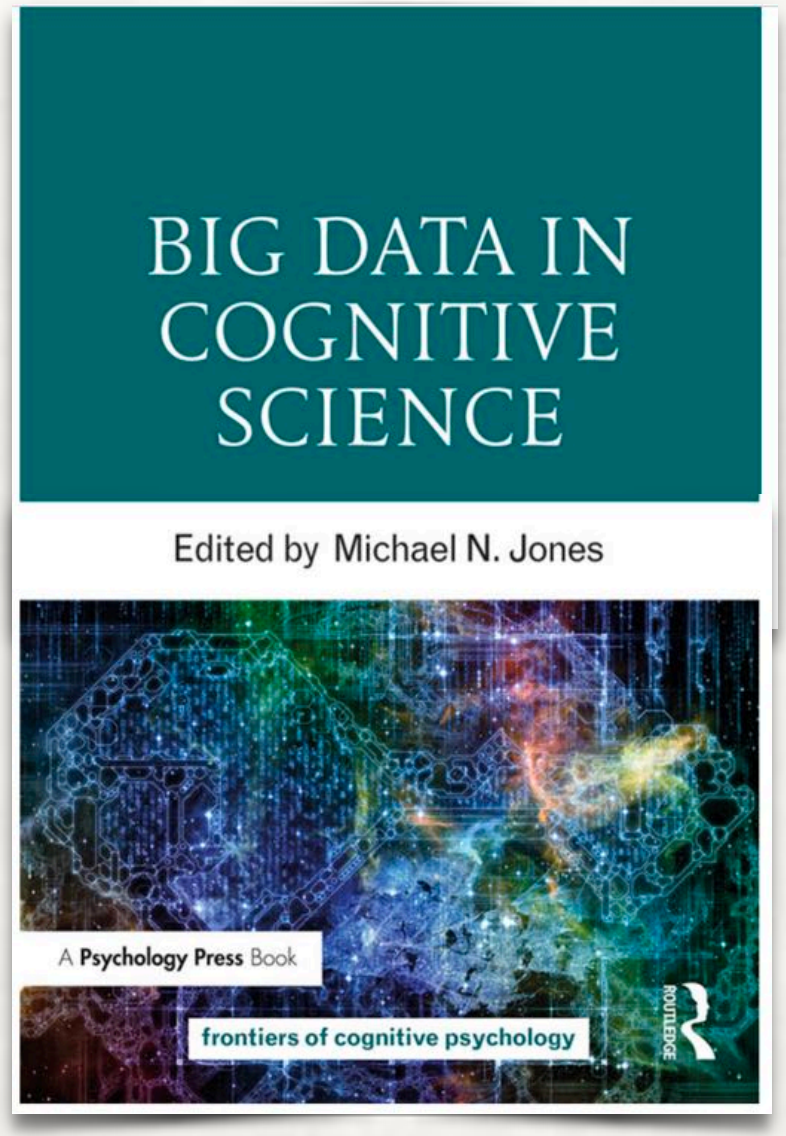
COGNITIVE SCIENCE

COMPUTER SCIENCE

BIG DATA IN COGNITIVE SCIENCE

MICHAEL N. JONES (ED.), ROUTLEDGE, 2017



SOME BIG QUESTIONS

THAT MODELERS MIGHT ADDRESS WITH BIG DATA

- How does cognition give rise to language learning and language processing?
  - What are general, and which are language-specific operations and representations necessary for human language processing?
  - Can we learn, through language, about memory?
- Can language datasets inform our model of (declarative) memory?
  - Decay, spreading activation, and language change
  - Patterns of similarity through distributed representations

DETECTING MEMORY EFFECTS IN LANGUAGE

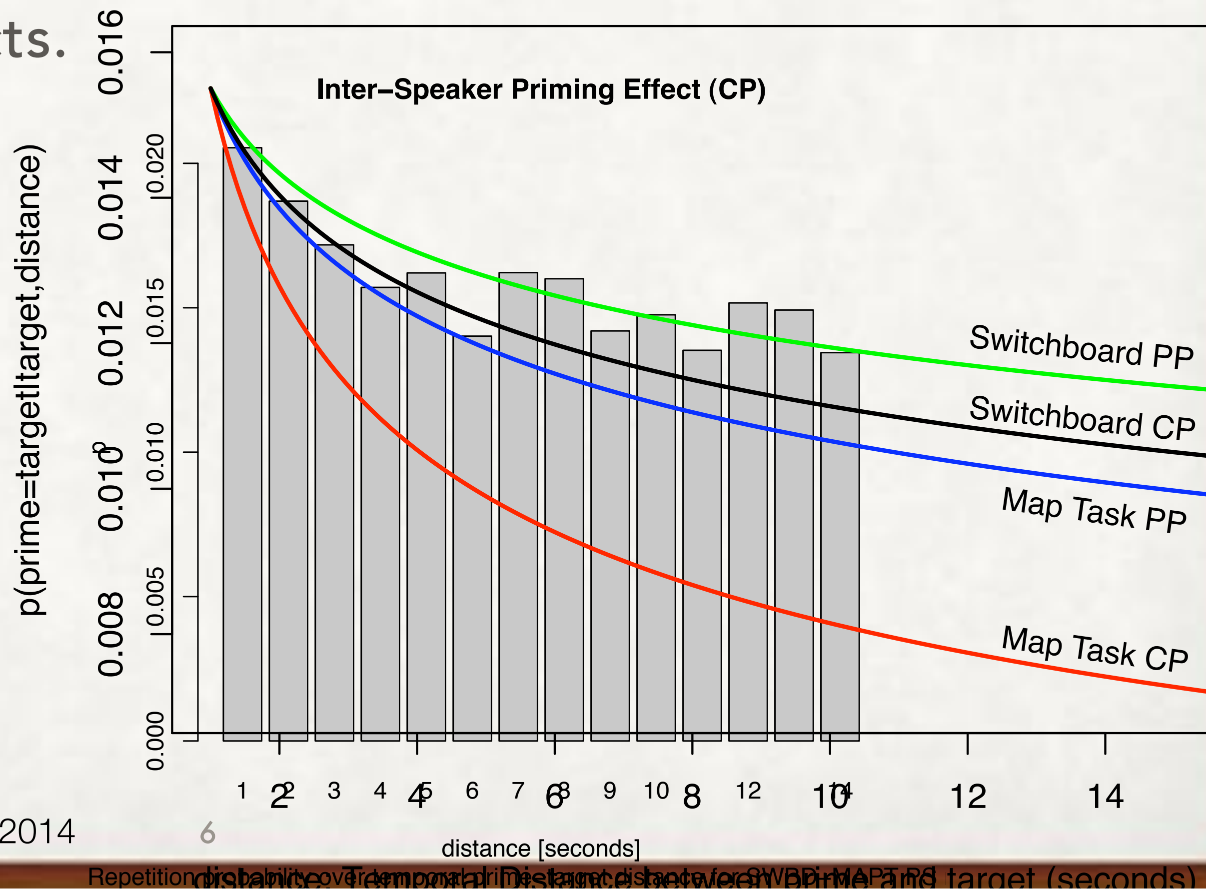
- Sentence structure is influenced by recent context:
  Structural priming causes syntactic choices to be repeated.
  (Bock 1986, Pickering&Branigan 1998, etc.)
- Syntactic repetition is associated with increased task success
  (where the task relies on mutual understanding).
  (Reitter&Moore 2014)
  - This can be seen in small corpora (few MB)

STRUCTURAL PRIMING (SHORT-TERM)

Stronger decay = more priming
in task-oriented dialogue
compared to spontaneous conversation
Compatible with Interactive Alignment Theory

Control for lexical repetition, disfluencies, frequency effects. By-turn analysis.

Effect of Prime-Target Distance

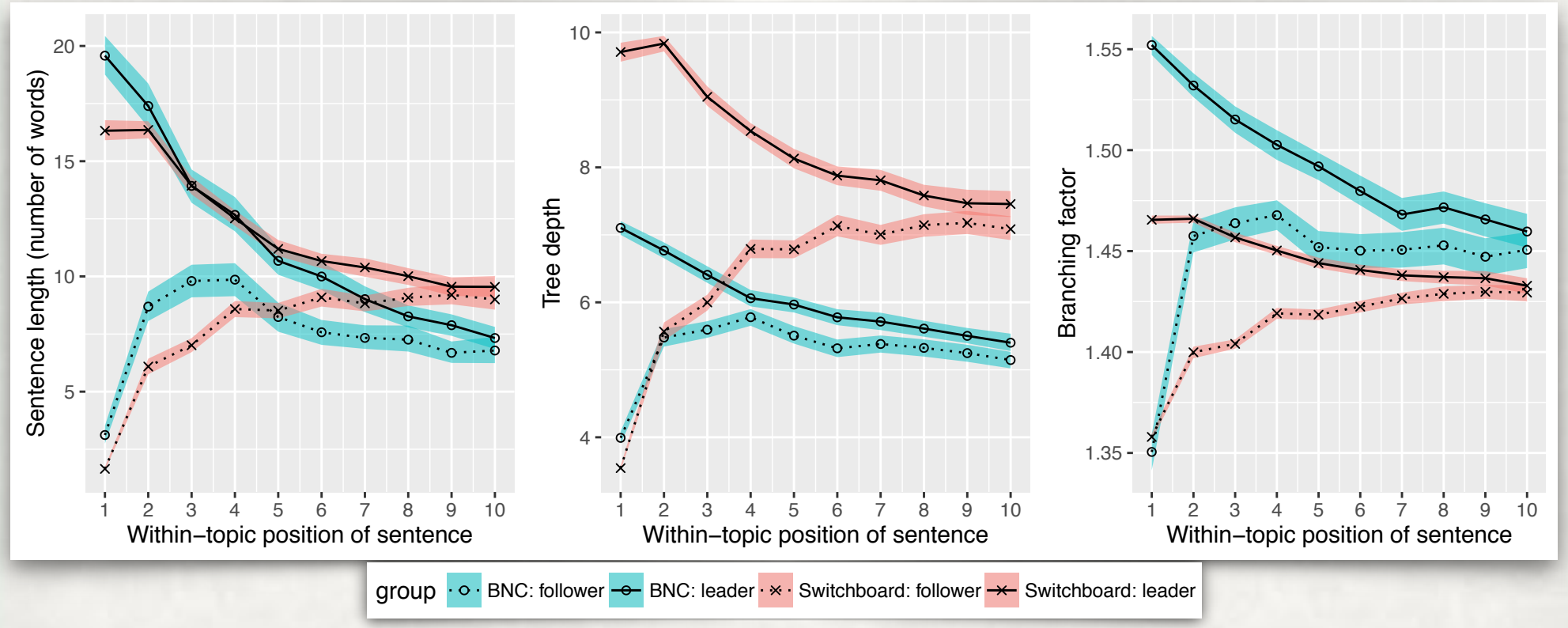


Reiter & Moore, Journal of Memory and Language, 2014

SYNTACTIC COMPLEXITY CONVERGES

XU & REITTER, ACL, 2016

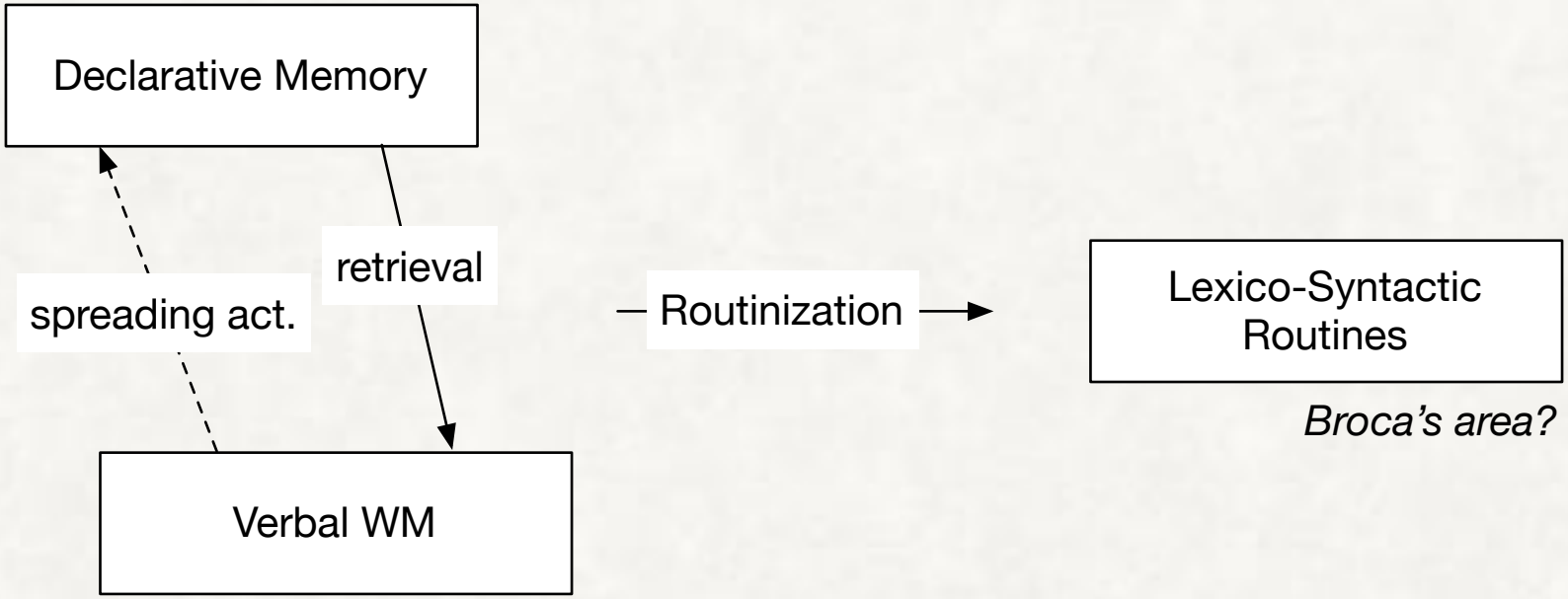
- Adaptation or accommodation appears to be strategic, at certain levels: syntactic complexity converges towards that of one's conversation partner (X&R 2016)
  - Seen in large corpora of written dialogue (100s MB)



CHALLENGE: HOW DOES LANGUAGE EXISTS IN THE MIND?

GENERAL COGNITION AND PSYCHOLINGUISTICS

Implicit Processes in Language Production and Comprehension



Reitter, Keller & Moore 2011 (ACT-R)

Cole & Reitter, ICCM 2017

Kelly, Reitter, & West, ICCM 2017

Chang, Dell, Bock 2006 (Connectionist)

ACT-R MODEL OF LANGUAGE PRODUCTION

COLE&REITTER, ICCM 2017

Automatic generation of semantic representation from corpus sentences.

Learning of syntactic rules (DM, productions) necessary to process these sentences.

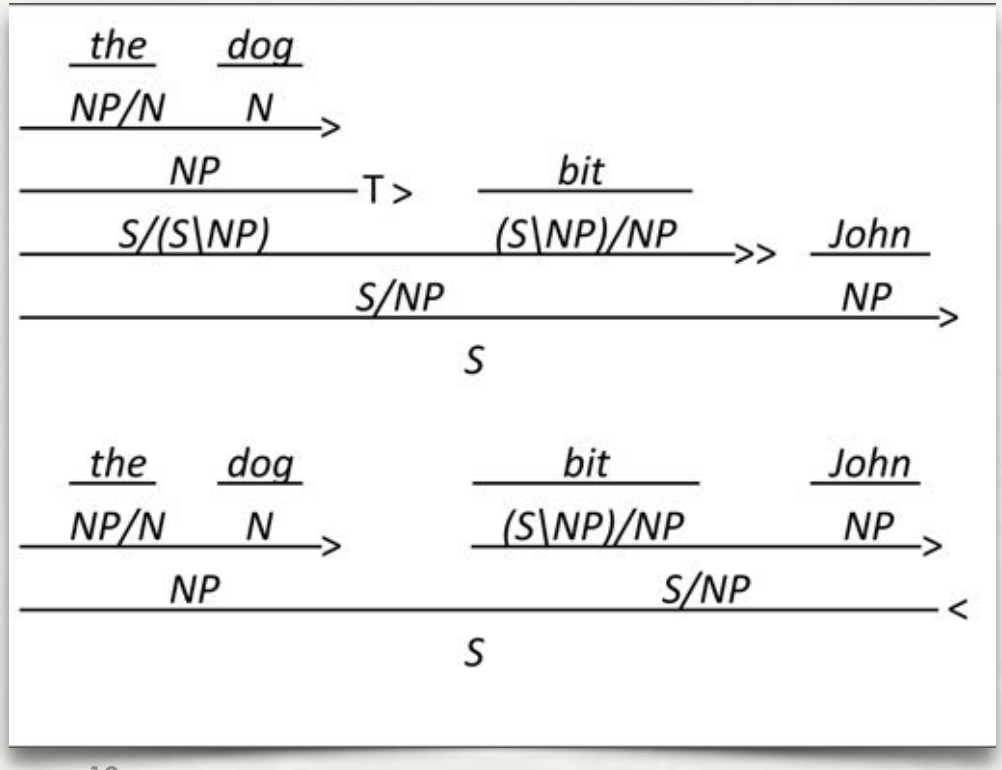
How well can a model recover the corpus sentences?

BIG-DATA ACT-R MODEL OF LANGUAGE PRODUCTION

Grammatical Encoding: words are combined into sentences. Lexical Retrieval: Words are retrieved (and thus, enter working memory). How do constraints on working memory affect this process?

incremental model:

Non-incremental model:



*less effective than incremental ****

*also: more WM <-> more effective ****

WHAT OUR ACT-R MODEL CAN DO (TODAY)

1000 sentences

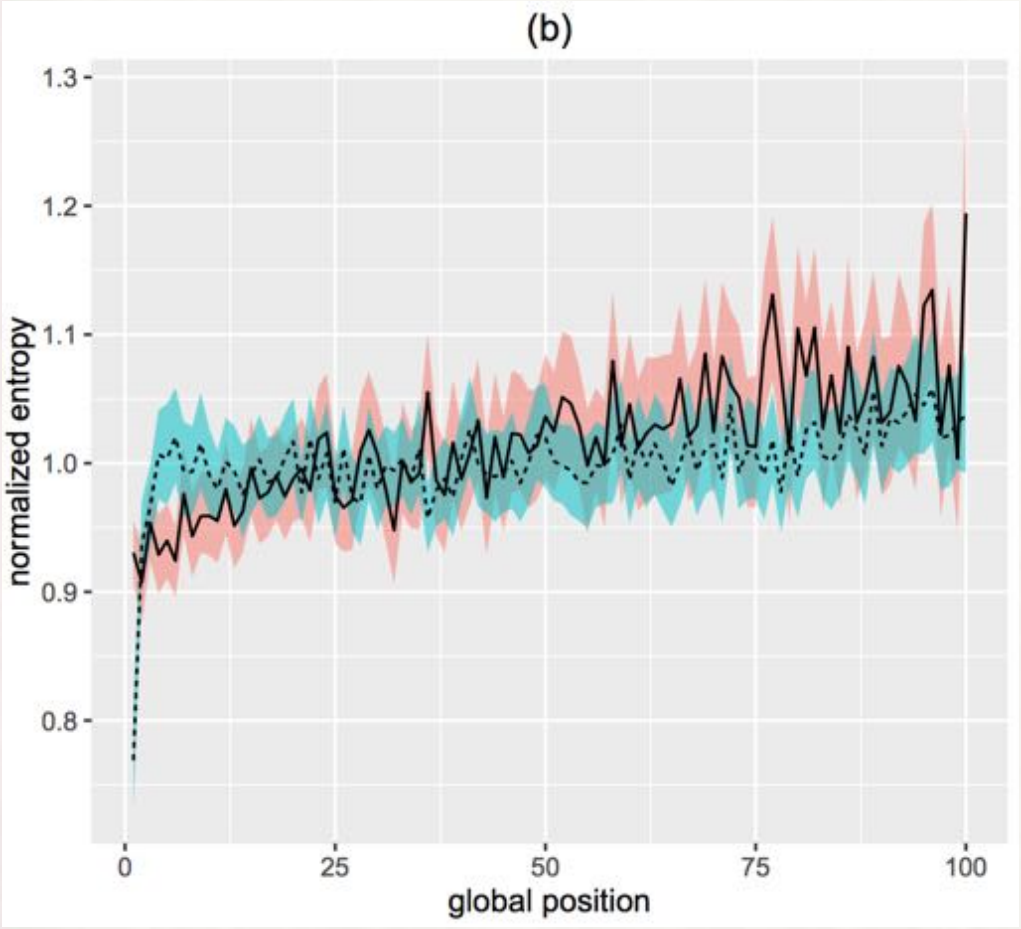
Contrast different model variants (high/low WM, decay, incrementality)

language processing vs. general cognition

large-scale routinization of syntactic/semantic knowledge possible (in the future)

AN INFORMATION-THEORETIC ACCOUNT OF DIALOGUE

Yang Xu
ACL 2016
Xu&Reitter, Cognition (to appear)



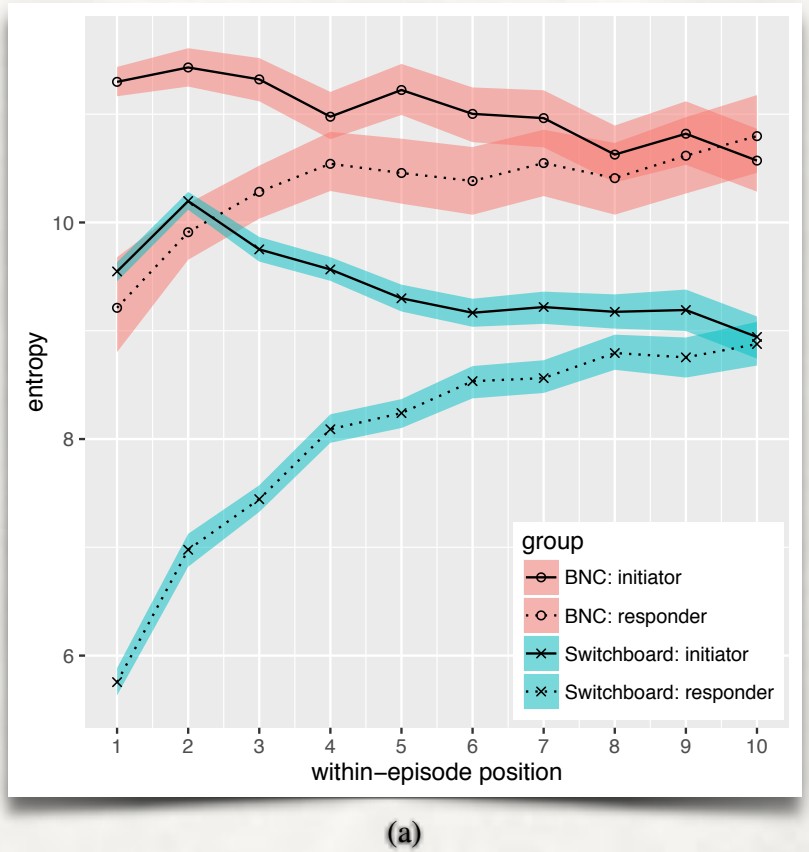
$$H(w_1 \dots w_n) = -\frac{1}{n} \sum_{w_i \in W} \log P(w_i | w_1 \dots w_{i-1})$$

- Entropy approximates information content: the more predictable language is, the more lower its entropy
- Information increases within documents, paragraphs (Genzel&Charniak, 2002; Keller, 2004)
- Speakers may strive to compensate for high-information content in one part of a sentence (o turn) by reducing it elsewhere ("Uniform Information Density", Levy&Jaeger, 2007): The average entropy (entropy rate) tends to be constant.

CHALLENGE: INFORMATION DENSITY

WHY AND HOW DO WE DISTRIBUTE INFORMATION?

- Entropy: indicates un-predictability of an unseen message
  (Prediction here does not use immediate preceding context)
  - Proxy for **information density**
- **Normally increases over time**
- But pattern is converging among speakers in dialogue
- Language seems to be distributed to equalize information density (**Uniform Information Density, Jaeger&Levy 2007**)
  - Hypothesis: Behavior in general is also distributed to avoid spikes in information load
  - Why?



(a)

Yang Xu, ACL 2016
Xu&Reitter, Cognition (to appear)