Bootstrapping into Filler-Gap: An Acquisition Story

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Introduction

Analyses of filler-gap dependencies usually involve complex syntactic rules or heuristics; however recent results suggest that filler-gap comprehension begins earlier than seemingly simpler constructions such as ditransitives or passives. Therefore, this work models filler-gap acquisition as a byproduct of learning word orderings (e.g. SVO vs OSV), which must be done at a very young age to extract meaning from language.
This approach learns role assignment in filler-gap constructions in a manner consistent with current developmental findings and is extremely robust to initialization variance. Additionally, this model is shown to be able to account for a characteristic error made by learners during this period (*A and B gorped* interpreted as *A gorped B*).

What is Filler-Gap?

- Argument appears outside canonical position
- Content questions and relative clauses:
  - [What]$_i$ did the boy eat t$_i$?
  - That is [the apple]$_i$ that the boy ate t$_i$.
- Categorized by which argument appears outside canonical position:
  Subject: [the boy]$_i$ that t$_i$ ate the apple
  Object: [the apple]$_i$ that the boy ate t$_i$

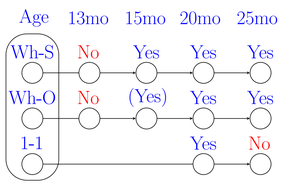
What is 1-1 Role Bias?

- Children assign a unique role to each noun
- Leads to characteristic interpretation error:

John and Mary gorped
interpreted as
John gorped Mary

[Gertner and Fisher, 2012]

Timeline



- Developmental timelines
  Wh-S: Non-canonical subject comprehension
  Wh-O: Non-canonical object comprehension
  1-1: 1-1 role bias errors
- Parentheses indicate weak comprehension
- Nodes correspond to findings

[Seidl et al., 2003, Gagliardi et al., 2014]
[Gertner and Fisher, 2012]

The Model

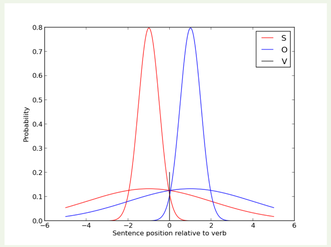
Learn word orderings to process filler-gap dependencies:

- Assign SUBJECT and OBJECT roles to NPs
  - Assumption: Only one S and one O per sentence
  - Replace all nouns with nominal heads

Input	Susan said John gave the girl a book
Output	**Susan** said **John** gave **girl book**
	-3 -2 -1 0 1 2

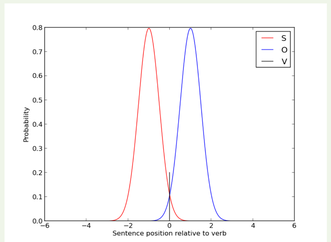
Nominal heads of noun chunks are in bold

- Model describes probable positions for each role
  - Relative to the (final) main verb
  - Only generalize up to two roles [Bello, 2012]
  - Separate parameters for canonical and noncanonical positions



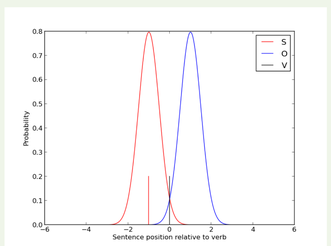
Initial gaussians without priors

- Expectations of canonical positions are strong
- Expectations of noncanonical positions are weak



Initial model expectations (with priors)

- Roles may be skipped (at a penalty)

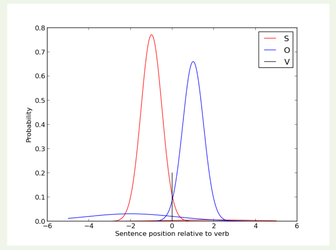


Role assignments: What$_o$ did John$_s$ **eat**?

- Model correctly 'detects' a filler-gap dependency...
  - By labeling filler NP with correct SUBJ/OBJ role
- 1-1 role bias ensures canonical roles are preferred
- Use Viterbi EM to infer best parameters:
  E: Current gaussians label observed arguments
  M: Update gaussians to maximize chosen labels
- Using noncanonical roles increases expectation

Results

Final model expectations:



- CHILDES role annotations determine accuracy
- Collapse all non-agent roles to 'object' role
  (children do not seem to generalize ditransitives)

Overall Accuracy

	Eve (n = 4820)			Adam (n = 4461)		
	P	R	F	P	R	F
Initial	.54	.64	.59	.53	.60	.56
Trained	.52	.69	.59*	.51	.65	.57*
Initial$_c$	.56	.66	.60	.55	.62	.58
Trained$_c$	.54	.71	.61*	.53	.67	.59*

$^*p << .01$

Top: Raw accuracies
Bottom: Non-agent roles collapsed to a single role

- Improvements slight since filler-gap is uncommon

Filler-Gap Accuracy

	Eve (n = 1345)			Adam (n = 1287)		
	P	R	F	P	R	F
Initial$_c$	.53	.57	.55	.53	.52	.52
Trained$_c$	.55	.67	.61*	.54	.63	.58*

$^*p << .01$

Filler-gap accuracy when non-agent roles are collapsed

1-1 Role Bias Error

	Error rate
Initial (given 2 args)	.66
Trained (given 2 args)	.13
Connor et al. 2009	.73

Frequency of labelling an NNV sentence SOV

- Compared to previous model of 1-1 role bias
- Before training, model is comparable to previous work
- After training, 1-1 role bias error is infrequent

Subject/Object Accuracy

	P	R	F	P	R	F
Eve	Subj (n = 691)			Obj (n = 654)		
Initial$_c$	.66	.83	.74	.35	.31	.33
Trained$_c$	.64	.84	.72†	.45	.52	.48*
Adam	Subj (n = 886)			Obj (n = 1050)		
Initial$_c$	.69	.81	.74	.33	.27	.30
Trained$_c$	.66	.81	.73	.44	.48	.46*

$^\dagger p < .02$ $^*p << .01$

- Major improvement on noncanonical objects
- Minor decline on noncanonical subjects

That/Wh- Accuracy

	P	R	F	P	R	F
Eve	Wh- (n = 689)			That (n = 125)		
Initial$_c$	.63	.45	.53	.43	.48	.45
Trained$_c$	.73	.75	.74*	.44	.57	.50†
Adam	Wh- (n = 748)			That (n = 189)		
Initial$_c$	.50	.37	.42	.50	.50	.50
Trained$_c$	.61	.65	.63*	.47	.56	.51†

$^\dagger p < .02$ $^*p << .01$

- Model is slower to acquire *that*-relatives than *wh*-relatives
- Children are too [Gagliardi and Lidz, 2010]

Summary

- Model accounts for subject/object asymmetry
- Model accounts for that/wh- asymmetry
- Model accounts for 1-1 role bias error trajectory

Conclusions

- Filler-gap comprehension does not require hierarchical structure
- Filler-gap comprehension may be learned as a byproduct of learning word orderings

References

[Bello, 2012] Bello, S. (2012). Identifying indirect objects in French: An elicitation task. In *Proc. CLA 2012*.

[Connor et al., 2009] Connor, M., Gertner, Y., Fisher, C., and Roth, D. (2009). Minimally supervised model of early language acquisition. In *Proc. CoNLL 2009*.

[Gagliardi and Lidz, 2010] Gagliardi, A. and Lidz, J. (2010). Morphosyntactic cues impact filler-gap dependency resolution in 20- and 30-month-olds. In *Poster session of BUCLD35*.

[Gagliardi et al., 2014] Gagliardi, A., Mease, T. M., and Lidz, J. (2014). Discontinuous development in the acquisition of filler-gap dependencies: Evidence from 15- and 20-month-olds. Harvard unpublished manuscript: http://www.people.fas.harvard.edu/∼gagliardi.

[Gertner and Fisher, 2012] Gertner, Y. and Fisher, C. (2012). Predicted errors in children's early sentence comprehension. *Cognition*, 124.

[Seidl et al., 2003] Seidl, A., Hollich, G., and Jusczyk, P. W. (2003). Early understanding of subject and object wh-questions. *Infancy*, 4(3).