

# **A model of frame and verb compliance in language acquisition**

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## Word learning

- Children learn new words rapidly
- Observe the object or event and associate it with the word
  - Not enough
- Use another source of information, syntax
  - Gleitman (1990)***
    - Correlate syntactic structure with events, objects, and words

## Frame and Verb Compliance

- One way to study the effect of syntax on the acquisition of word meaning is to place familiar words in unfamiliar or incorrect syntactic context
  - Transitive verbs into intransitive frames
  - Intransitive verbs into transitive frames
- If the interpretation is in accordance with the frame, children are said to be *Frame Compliant*; otherwise they are *Verb Compliant*.

## Frame and Verb Compliance

- Subjects: 2.5 to 12 year old children; adults
- Task: Enact scenes described in sentences using wooden toy animals as props
  - *\*The lion puts in the ark*
  - *\*The zebra brings*
  - *\*The elephant comes the giraffe*

***Naigles, Fowler, and Helm (1992); Naigles, Gleitman, and Gleitman (1993)***

- Results
  - Younger children, especially the 2-year-olds, were Frame Compliant. They changed the meaning of the verb to fit the sentence.
  - Older children, especially the adults, were Verb Compliant.
  - Intermediate ages, intermediate levels of compliance

## Overgeneralization

- Children's early verb use is mostly correct
  - *Tomasello (2000)*
- A major exception to this occurs somewhere around age 3
  - *Bowerman (1977; 1982)*
- They sometimes use verbs in incorrect frames
  - \*Don't fall that on me
- They must eventually learn which uses are licensed
  - *sink* can be used either transitively or intransitively
  - *fall* and *go* allow only intransitive, noncausal interpretation
- How to eliminate overgeneralizations?

## Theories of Compliance/Overgeneralization Maturation

- Verbs get organized in *narrow range subclasses* based on semantic criteria
- If one verb alternates (between transitive and intransitive use), other verbs in the same subclass are assumed to alternate too (Frame Compliance)
- Those subclasses for which there has been no evidence of alternation are “closed” at maturation, and no new information is accepted (Verb Compliance)

***Pinker (1989)***

- There are factors other than age that affect compliance behavior
- No across-the-board shift from frame to verb compliance
  - Some verbs elicit more compliance than others; some frames too
  - Timing of the shift varies for different verbs and frames

## Theories of Compliance/Overgeneralization Mutual Exclusivity

- Children will allow only one lexical entry to occupy a semantic niche
- If two words are determined to have similar meanings, one of them is pre-empted and removed from the lexicon
  - Causative (over-generalized) *come* is similar to *bring*
  - When causative *come* is used, *bring* is non-existent
  - When *bring* becomes more frequent, causative *come* declines

***Bowerman (1982); Clark (1987, 1991); Markman (1987)***
- While ME may have some role to play, it does not account for all the data
  - Why some verbs elicit Verb Compliance earlier than others
  - For some verbs, it is difficult to find similar meaning verbs that can preempt their use in the right way

## Theories of Compliance/Overgeneralization Lexical Knowledge

- Children's conjunctures about verb meanings are refined by ongoing events as well as by the structures in which they appear
- At early stages, open-minded children assume that not all structures have yet been heard and therefore certain properties (such as causality) may be unknown (Frame Compliance)
- Older children and adults feel warranted to believe that all relevant information about the meaning has been obtained; a novel structure is ill formed (Verb Compliance)

*Naigles, Gleitman, and Gleitman (1993)*

- Explains many effects in the data well
- Amount of compliance varies for some verbs depending on the frame
- How exactly do children determine if they have enough knowledge of the meaning?

## Theories of Compliance/Overgeneralization Lexical Knowledge and Innate Principles

- “The learning device is asking itself, in effect: Assuming Principles [the Theta Criterion and the Projection Principle], what could be the meaning of the verb now heard, such that these principles projected this observed (surface) structure for it? Such a deductive procedure will be invoked only when the learner does not have secure knowledge of the verb in question.”  
(p. 37)

*Lidz, Gleitman, and Gleitman (2001)*

- Amount of compliance varies for some verbs depending on the frame
- How exactly do children determine if they have “secure” knowledge of the meaning?

## The Model

- Task: comprehension
- Input: utterances generated by a grammar, one word at a time
- Output: Representation of a “scene” described by the sentence
  - One or two objects and an action
  - Predict entire scene after each word
  - The representation of an action includes four units encoding causality (1100  $\Rightarrow$  causal event; 0011  $\Rightarrow$  noncausal event)



## Grammar

$S \rightarrow NP \mid NP1 \mid NP \text{ is } IV \mid NP1 \text{ are } IV \mid NP \text{ is } TV \ NP$

$NP \rightarrow DET \ N \mid DET \ SIZE \ N$

$NP1 \rightarrow NP \text{ and } NP$

$N \rightarrow \text{boy} \mid \text{girl} \mid \text{dog} \mid \text{mouse} \mid \dots$

$SIZE \rightarrow \text{large} \mid \text{small}$

$IV \rightarrow \text{jumping} \mid \text{dancing} \mid \text{running} \mid \dots$

$TV \rightarrow \text{pushing} \mid \text{holding} \mid \text{hugging} \mid \dots$

$DET \rightarrow a$

- *a boy* (N)
- *a small dog and a girl* (NN)
- *a boy is jumping* (NV)
- *a mouse and a large frog are jumping* (NNV)
- *a small boy is pushing a large dog* (NVN)

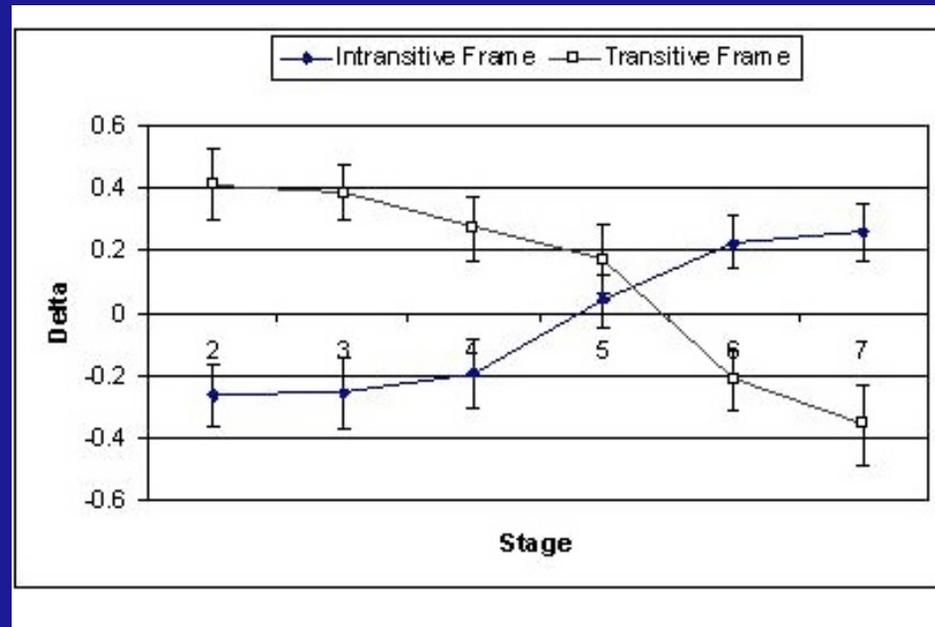
## Comprehension

- Utterances probabilistically divided into training and testing set
- Differing probabilities for different sentence types based on frequency; about 1/3 in the training set overall
- Close to 100% accuracy on the training set, about 96% on the test set

## Modeling Compliance

- The network trained in stages with increasing vocabulary
- Two transitive and two intransitive verbs constant all all stages
- The number of nouns increased gradually; trained to 100% accuracy at each stage
- Tested at each stage using the utterances containing the words seen at that stage for generalization
- Test for compliance: insert incompatible verbs in transitive and intransitive frames with novel nouns
  - *a xxx is dancing a yyy*
- Define a “causality index”  $\delta$ 
  - $\delta = \text{mean activation of the first two units} - \text{mean activation of the last two units}$
  - Positive  $\delta \Rightarrow$  causal/transitive; negative  $\delta \Rightarrow$  noncausal/intransitive interpretation

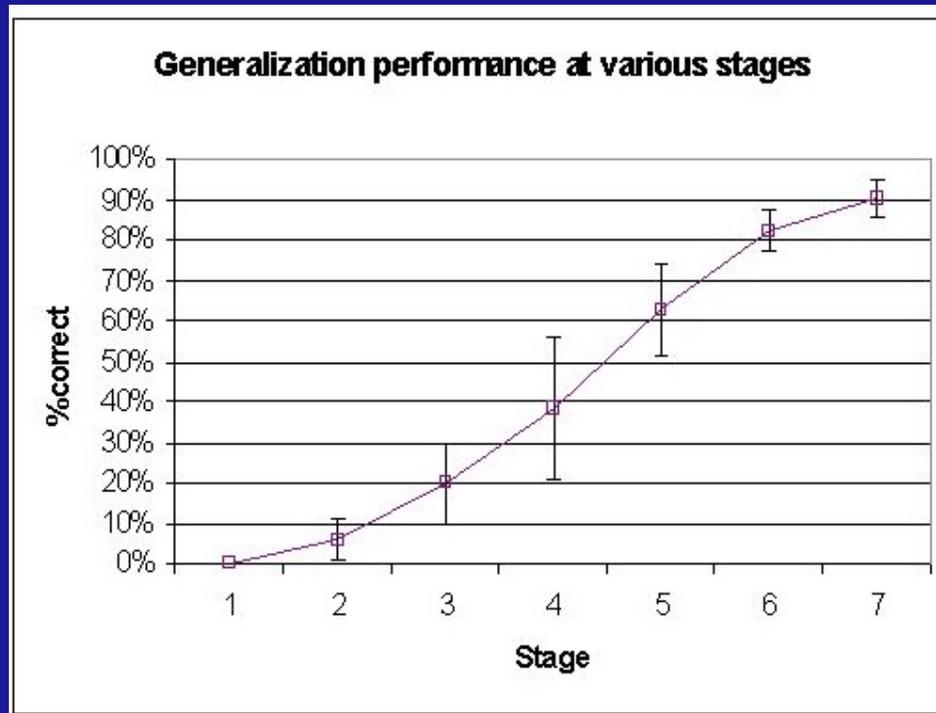
## $\delta$ across various stages



- Early stages
  - Rote-learning
  - “Item-based” or context-bound representations
  - Predicts poor generalization
  - Stronger form-form correlations
- Later stages
  - Categorical, context-free representations
  - Predicts good generalization
  - Stronger form-meaning correlations

- What is nature of representations in the network?
- What is nature of representations in children?

## Generalization across various stages

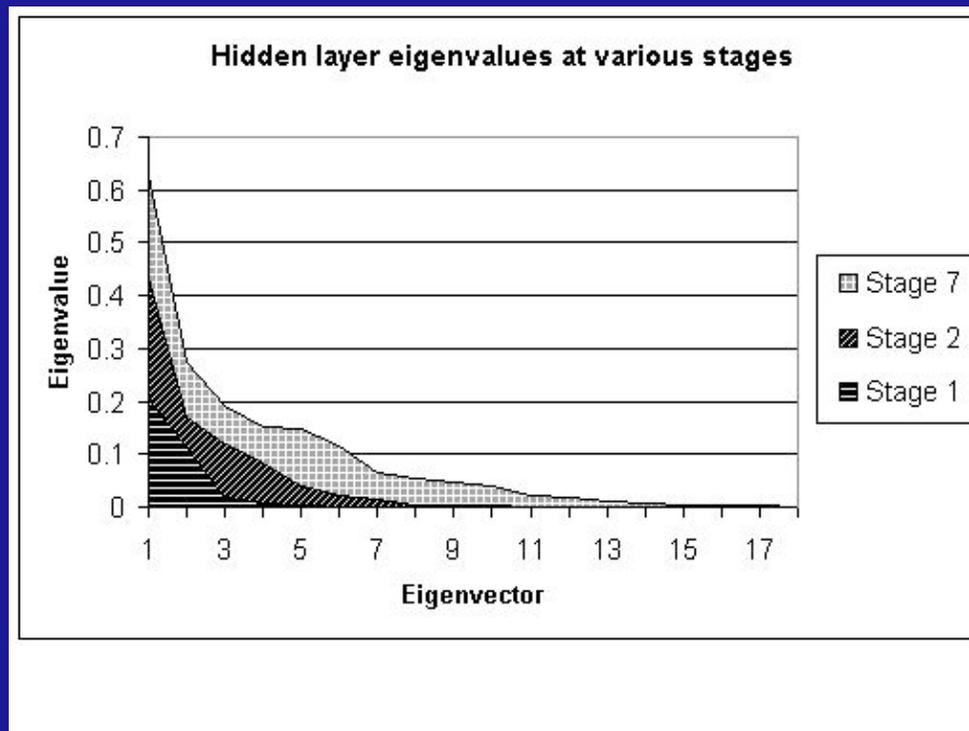


- The performance on the training set at each stage is ~100%

## Principal Components

- The utterances used at the first stage are passed through the network, and hidden unit activations recorded after each word at each stage
- If the network is using a simple strategy (such as the presence or absence of a single feature) to recognize utterances, there would be few underlying dimensions of variation; few principal components required
- For more complex processing, the representations would change gradually as new information is taken into account as the utterance is processed; more principal components required

## The values of Principal Components at various stages



## Representations in children

- Many recent studies suggest that much of children's early competence is rote learned or item-based
  - Organized around concrete linguistic items, phrases, words, not based on system-wide syntactic categories and schemas

*Tomasello (2000)*

- Lieven et al. (1997) : 12 children, 2-3 years age
  - Virtually all verbs and predicative terms were used in only 1 sentence frame
  - 92% of all utterances were from 25 lexically based patterns (different for different children)
- Pine and Lieven (1997)
  - When children started to use 'a' and 'the' they did it for almost totally different set of nouns
  - No abstract category for the determiner

## Representations in children

- Tomasello (1992): Verb islands
  - Some verbs were used in only one sentence frame (Cut \_\_\_) some were used in more complex frames (Draw \_\_\_, Draw \_\_\_ on \_\_\_, etc.)
  - Morphological markings were uneven across verbs
  - The best predictor of a child's use of a given verb was not her use of other verbs, but the use the same verb preceding days
  - No transfer of structure across verbs
- Dabrowska (2000):

<u>Age</u>	<u>%Formulaic</u>
1;6-1;11	94.8
2;0-2;5	91.2
2;6-2;11	77.6
3;0-3;9	63.5

## Cross-linguistic evidence

- Italian (*Pizutto & Caselli, 1994*) : 47% of verbs were used in only one frame, another 40% were used in 2 or 3 frames
- Portuguese (Brazilian) (*Rubino & Pine, 1998*) : Verb use corresponded to high-freq. patterns in the input
- Hebrew (*Berman, & Armon-Lotem, 1995*) First 20 verbs were rote-learned and morphologically unanalyzed
- Also, Hungarian, German, Dutch, Spanish, Russian, Inuktitut, Catalan

## What about the input?

- The shift from Frame to Verb compliance in the network depends on the changing input
  - Increasingly combinatorial input with increasing vocabulary
- Is this, in any way, similar to what children experience? Isn't changing the input to your model bad?

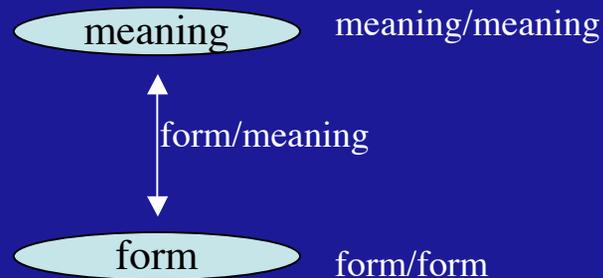
## The nature of input to children

- First, even if children live in a constant linguistic environment, with time they necessarily sample more and more utterances from it
  - More words, more word combinations experienced with time
- Second, the linguistic environment of children changes with time
  - When talking to young children, the words used by caregivers are less diverse
  - Child-directed speech (CDS) is syntactically and semantically simplified
  - The type-token ratio in CDS decreases with age
  - Caregivers are sensitive to the child's comprehension level; not so much to their production

*Cameron-Faulkner and Tomasello (2003); Chapman (1981); Cross 1977); Hu (1994); Pine (1994)*

## Summary and conclusions

- The shift in the model's behavior emerges from a shift in the underlying representations, which in turn is caused by a change in the input
  - Initially, context-bound, item-based, rote-learned; components undifferentiated
  - Later, context-free, categorical, or referential; individual components separated



## Summary and conclusions

- No explicit decision making, no specialized principles
- “open-mindedness” in early stages and “secure knowledge” of the meaning in later stages can be explained as relative strengths of form/form and form/meaning correlations
- Shift in compliance emerges from the nature of input, the task, and characteristics of the network
- Specialized-looking behaviors such as Frame and Verb compliance can be understood as cases of pattern completion, a ubiquitous phenomenon

## When pattern completion is not used



Wait! Wait! ...Cancel that, I guess it says ‘helf’.