



INSTITUT D'ÉTUDE DE LA COGNITION

Synergies in early language acquisition



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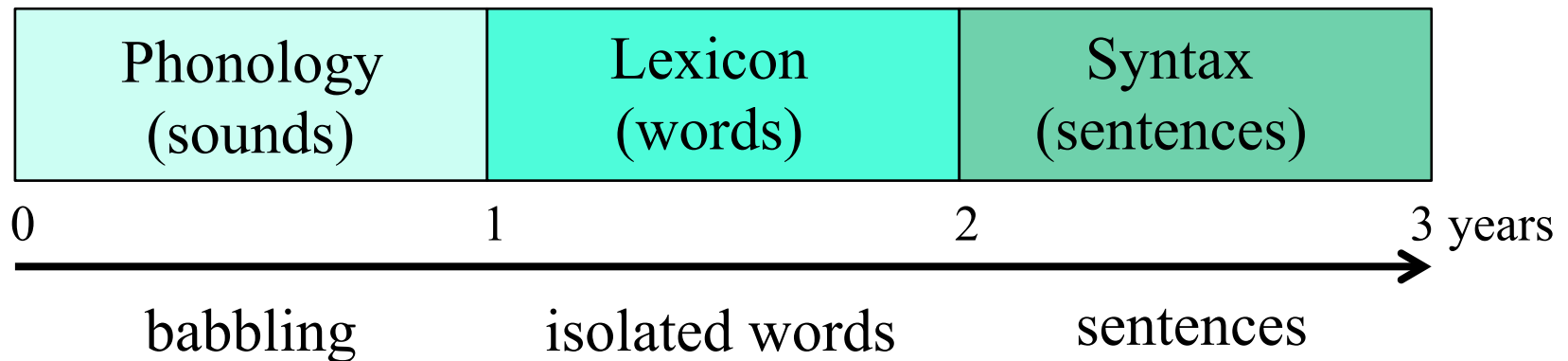
Laboratoire de Sciences Cognitives et Psycholinguistique,
Ecole Normale Supérieure / PSL Research University
CNRS / EHESS.

Rio de Janeiro, 18-19 Mars 2014



Acquiring language

- 'Old' view:



- Implication: you have to acquire phonology before you know many words, learn word meanings before you know syntax, and so on...
but...

Guessing word meanings

- Simple idea: kids learn words because adults point to objects and say the words, e.g. ‘dog, dog’ ...
- Consequence: a child deprived of sensory input should learn more slowly...

Landau & Gleitman (1985) show that the lexical development of a blind child is normal, she even knows the difference between ‘look’ and ‘see’.

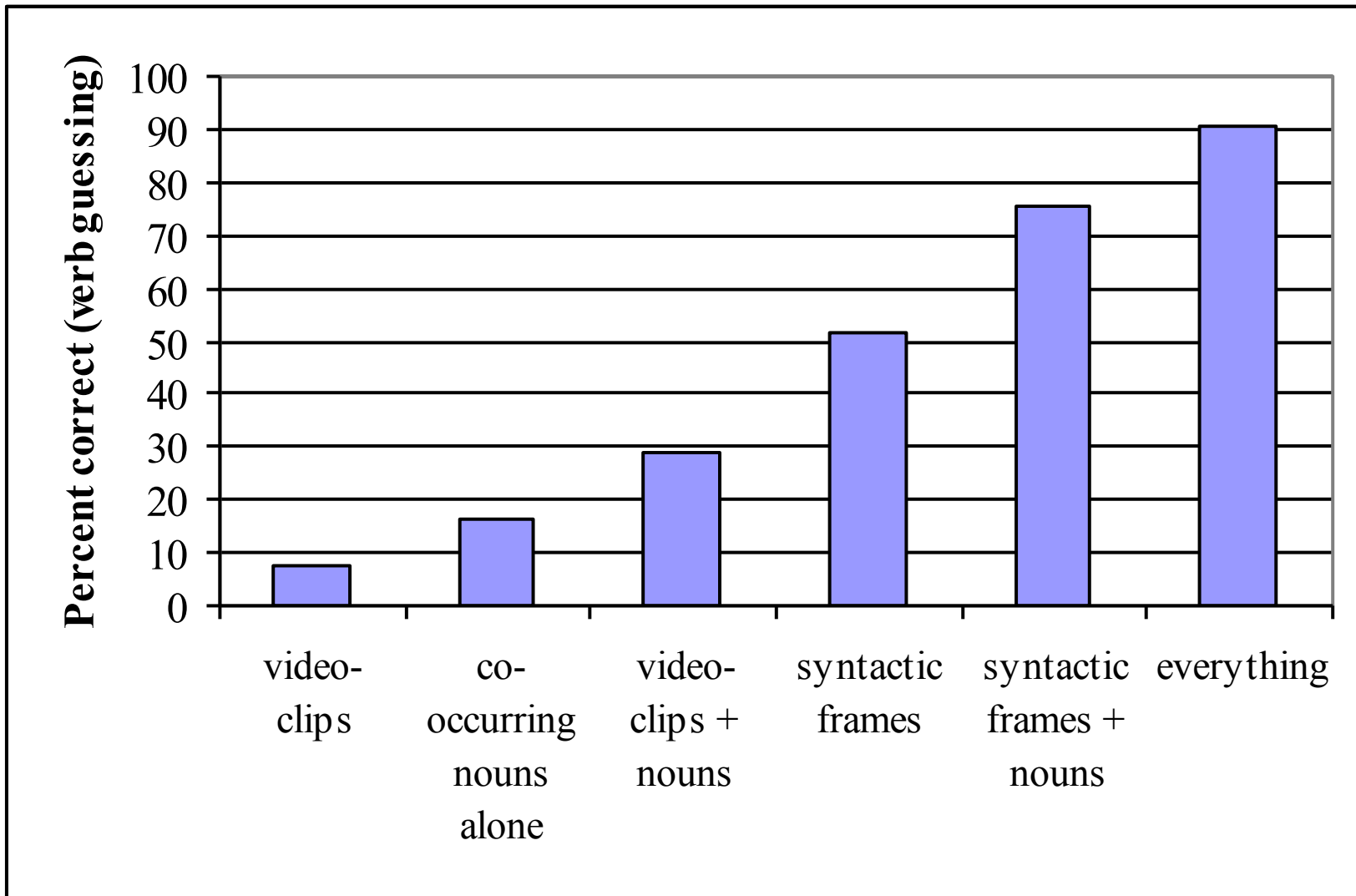
- Hypothesis: *syntactic bootstrapping* (Gleitman, 1990) to learn word meanings (in particular verbs), kids rely on the syntax of sentences

e.g. thought verb: I think that he will come tomorrow

transfer verb: I give a book to John

NOT: *I give that he will come tomorrow, or, *I think a book to John.

Guessing word meanings (verbs)



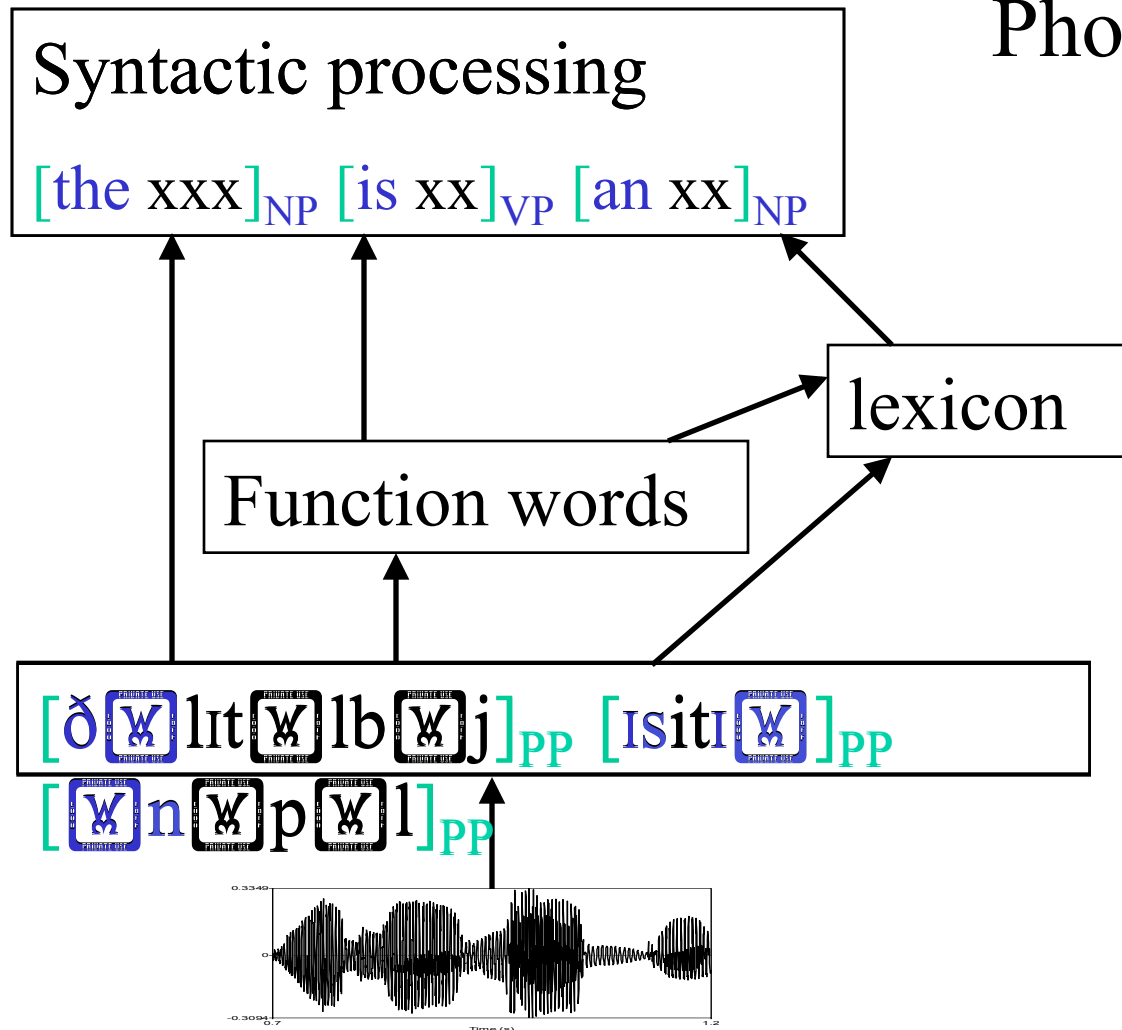
Synergies in language acquisition

To acquire the beginnings of syntactic structure:

Find sources of information that can be available to infants early on and through a relatively uninformed analysis of the speech signal:

Phrasal prosody }
Function words } => *syntactic skeleton*

Model of processing and acquisition



Phonological phrases
and function words
= *syntactic skeleton*

*Phonological and
prosodic representation*

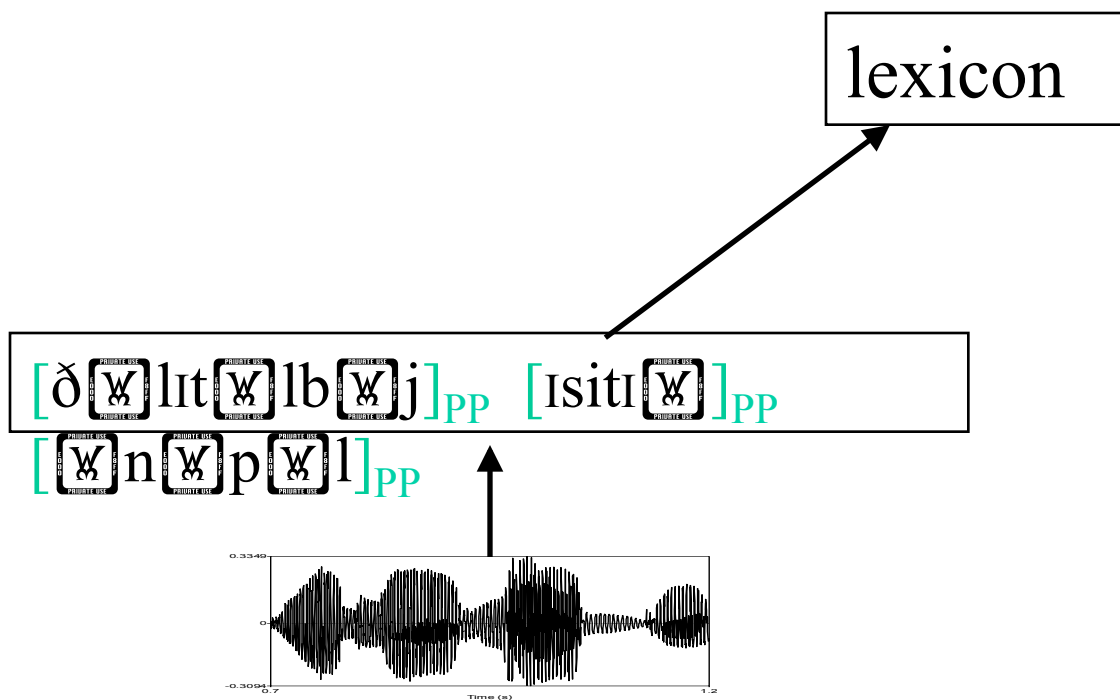
Speech signal

"the little boy is eating an apple"

Phrasal prosody is acquired early:

- Many experiments show that young infants react to the disruption of prosodic units:
 - 4.5-month-olds perceive intonational phrase boundaries, e.g. Kemler-Nelson, Hirsh-Pasek, Jusczyk & Cassidy, 1989; ...
 - 9-month-olds perceive phonological phrase boundaries, e.g. Gerken, Jusczyk, & Mandel, 1994;
- Well-formed prosodic units also enhance memorization:
 - Nazzi, Nelson, Jusczyk & Jusczyk, 2000;
Soderstrom, Seidl, Kemler Nelson & Jusczyk, 2003...

Phonological phrase boundaries constrain lexical access.

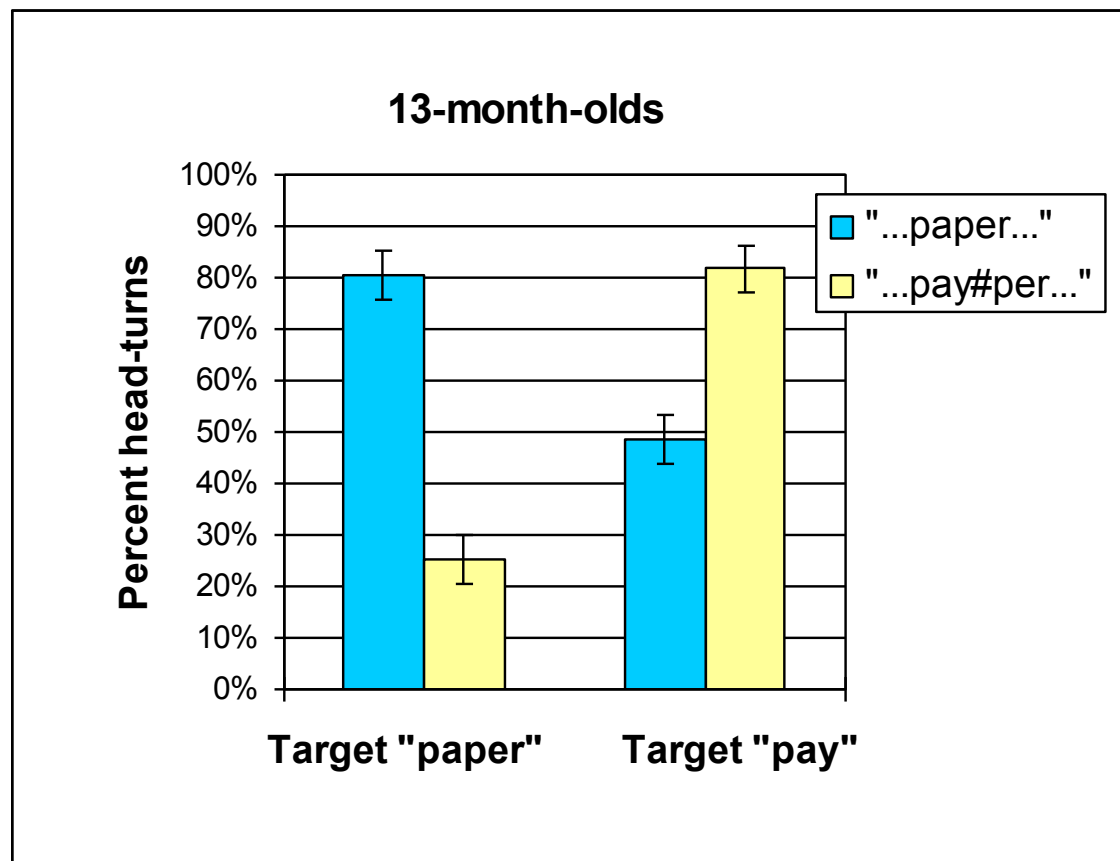


Phonological and prosodic representation

Speech signal


"the little boy is eating an apple"


Phonological phrase boundaries constrain lexical access:



American 13-month-olds.

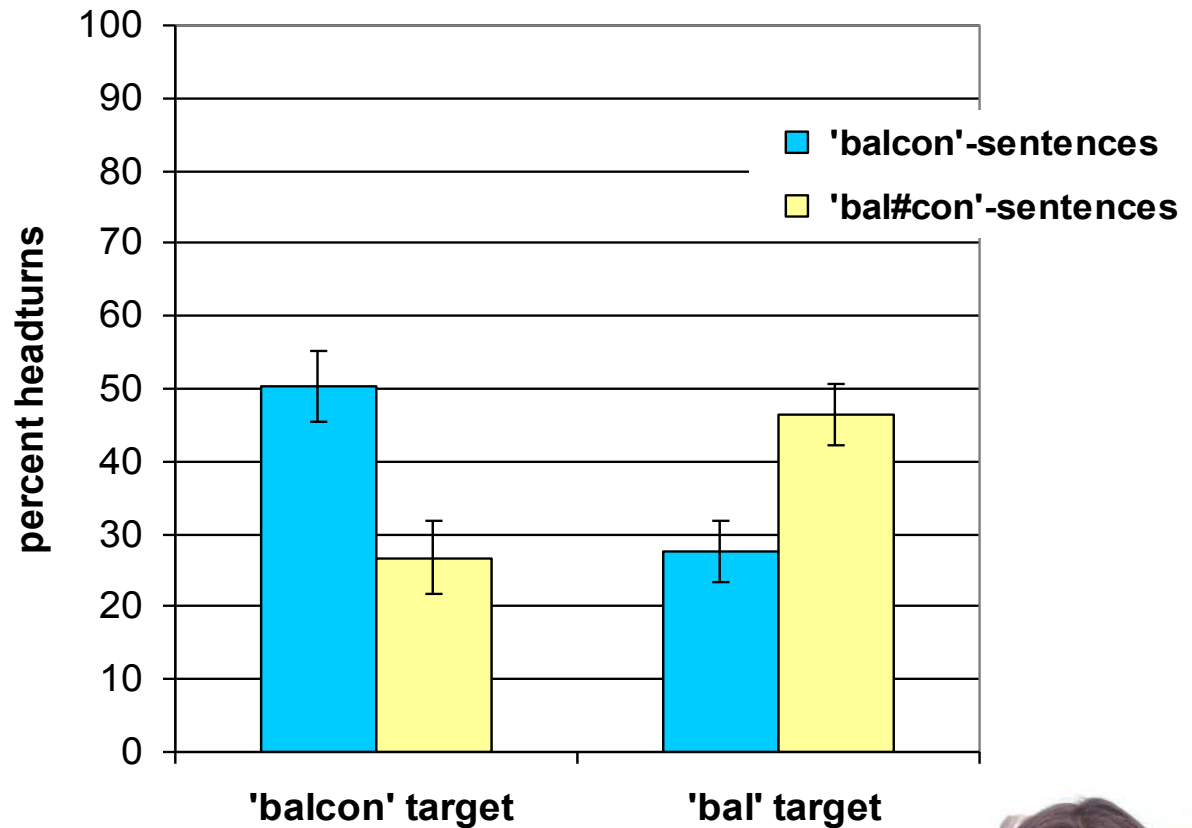
Method:
Word detection,
variant of
conditioned
head-turning.

[The church] [with the most *paper* spires] [is heavenly]. 

[The man] [with the least *pay*] [*perspires* constantly]. 

Phonological phrase boundaries constrain lexical access:

Word detection,
French
16-month-olds.



[La rangée de *balcons*] [fait face au cloître] [du monastère] 

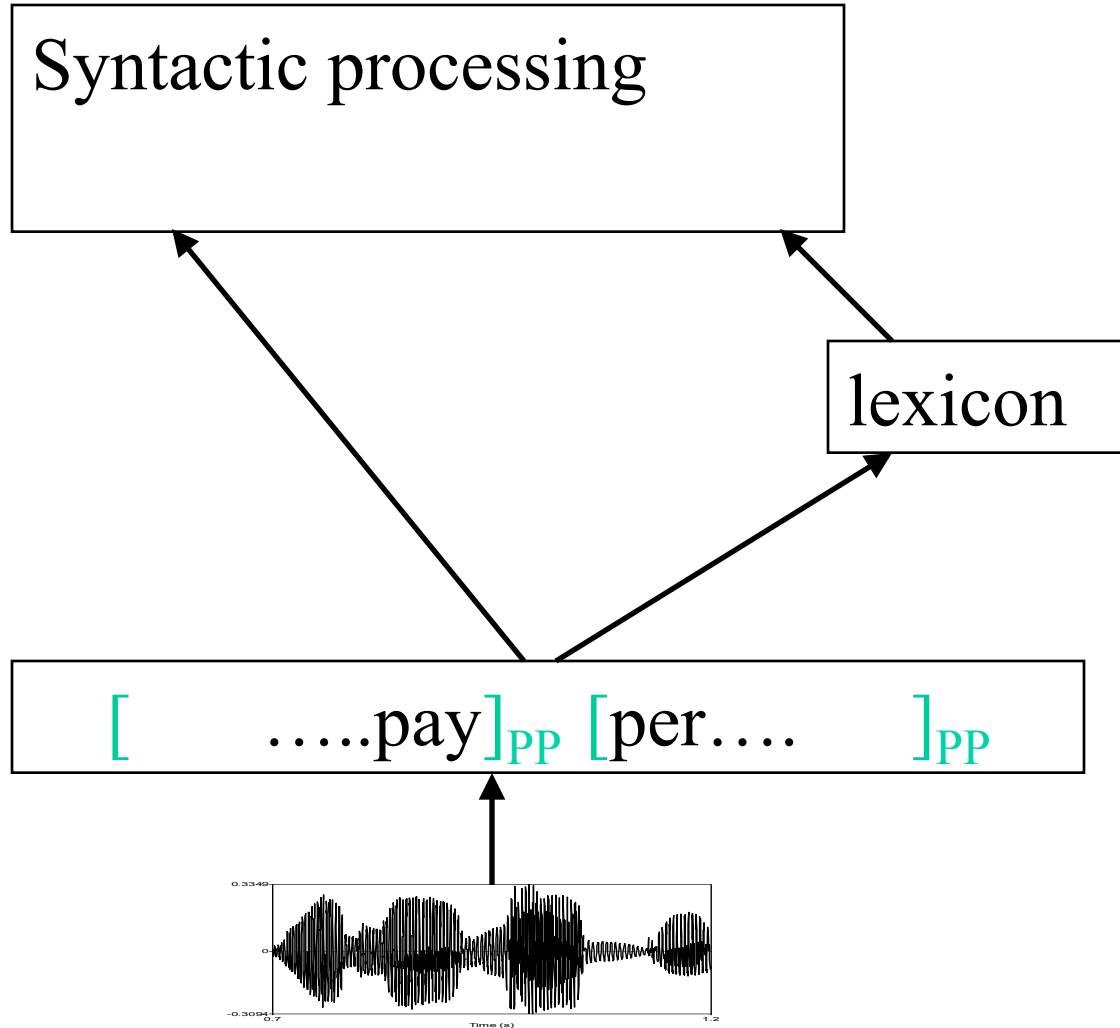
[La grande salle de *bal*] [*confère* un air solennel] [au château]. 



Séverine Millotte

Millotte, Morgan, Margules, Bernal, Dutat & Christophe (2010)
Journal of Portuguese Linguistics

Phonological phrase boundaries constrain lexical access ... and syntactic processing



- a phonological phrase boundary is interpreted on-line as a word boundary.

Phonological and prosodic representation

Speech signal

"The man with the least *pay* *perspires* constantly"

Phonological phrase boundaries constrain on-line syntactic processing -- in adults

- Locally ambiguous sentences

- Verb :

[le petit chien]_{NP} [**mord** la laisse]_{VP} [qui le retient]...
(*the little dog **bites** the leash that restrains it*)

- Adjective :

[le petit chien **mort**]_{NP} [sera enterré demain]_{VP}...
(*the little **dead** dog will be buried tomorrow...*)

→ Sentence completion task:
listen to sentence beginning, freely complete sentence

Prosody:

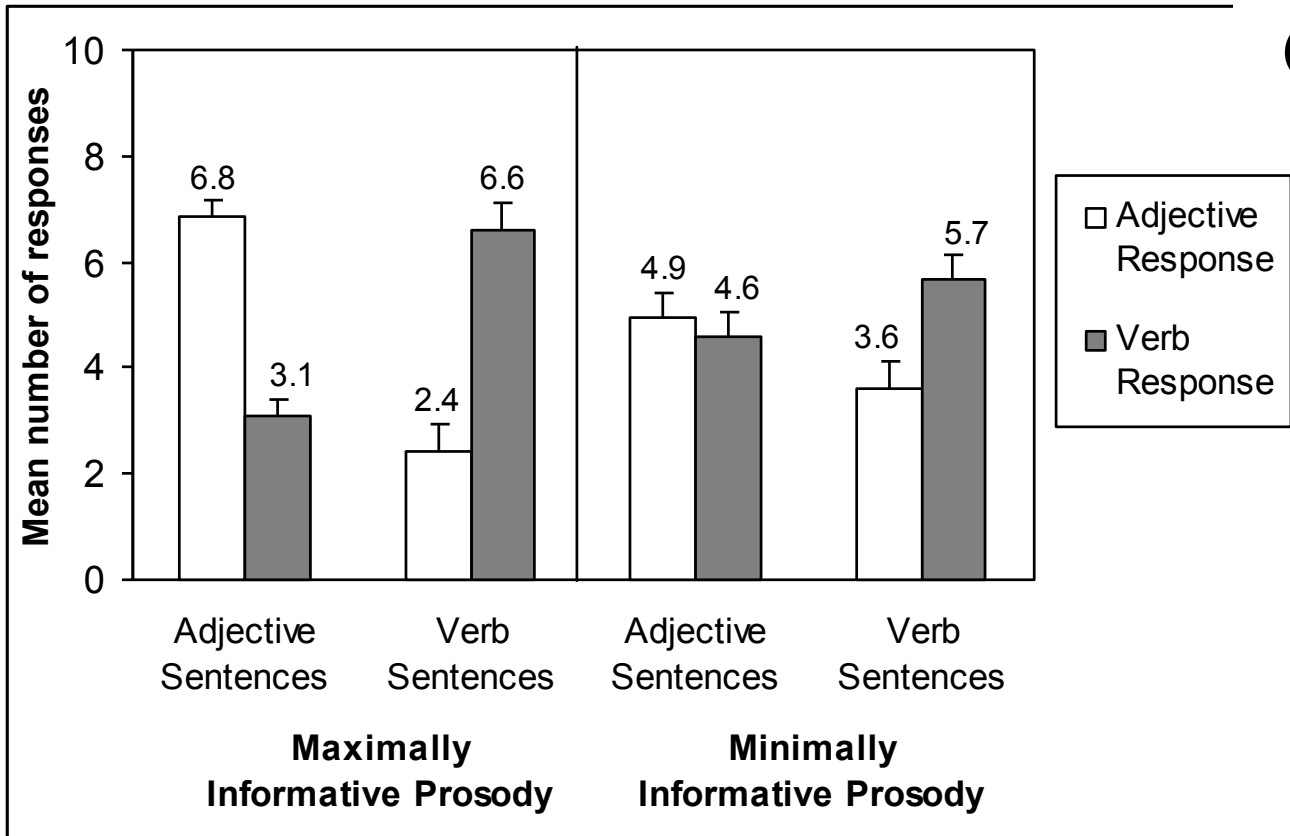
Max

Min



Séverine Millotte

Completion task



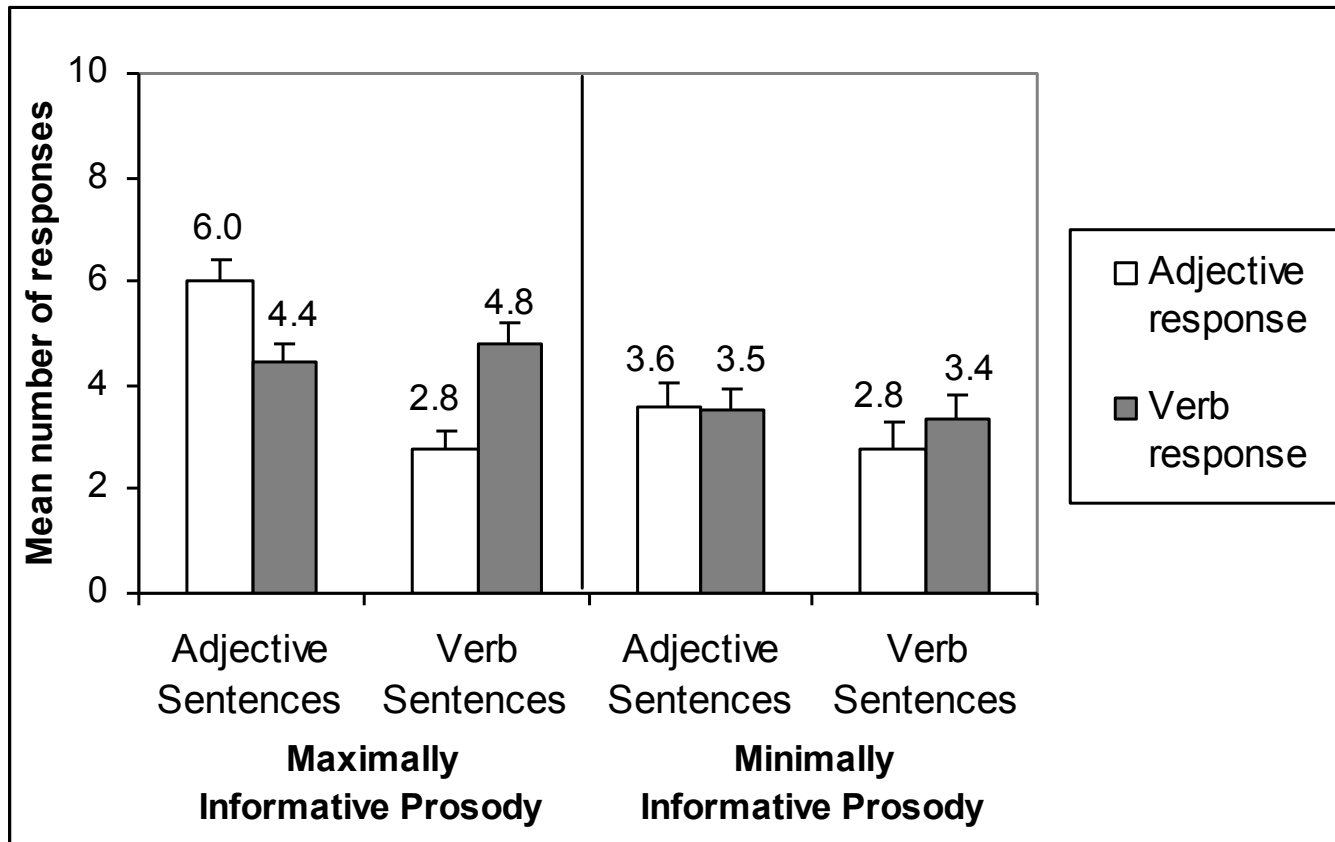
Séverine Millotte

Conclusion: when prosodic cues are well-marked, adults exploit them to constrain their syntactic analysis of sentences.

- are these cues exploited on-line?
- are they produced spontaneously by naïve speakers?

Are prosodic cues exploited on-line? Yes

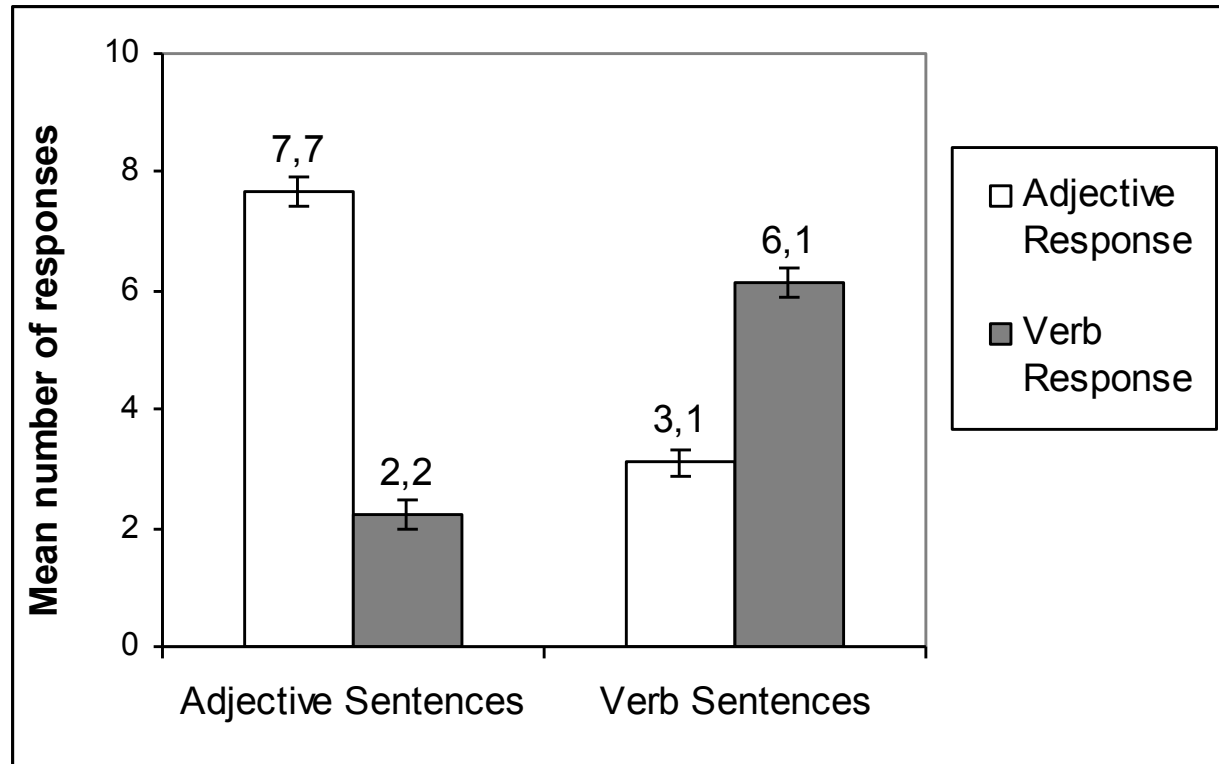
Task: abstract word detection; e.g. 'mordre' (to bite): respond to verb sentences, refrain from responding to adjective sentences.



Séverine Millotte

Results: fast responses only (given at the end of the ambiguous word)

Are prosodic cues spontaneously produced by naïve speakers? Yes



Séverine Millotte

Six naïve speakers produced the ambiguous sentences: they are perceived as unambiguous by listeners...

How about kids?

Ferme: **Noun** / **Verb**

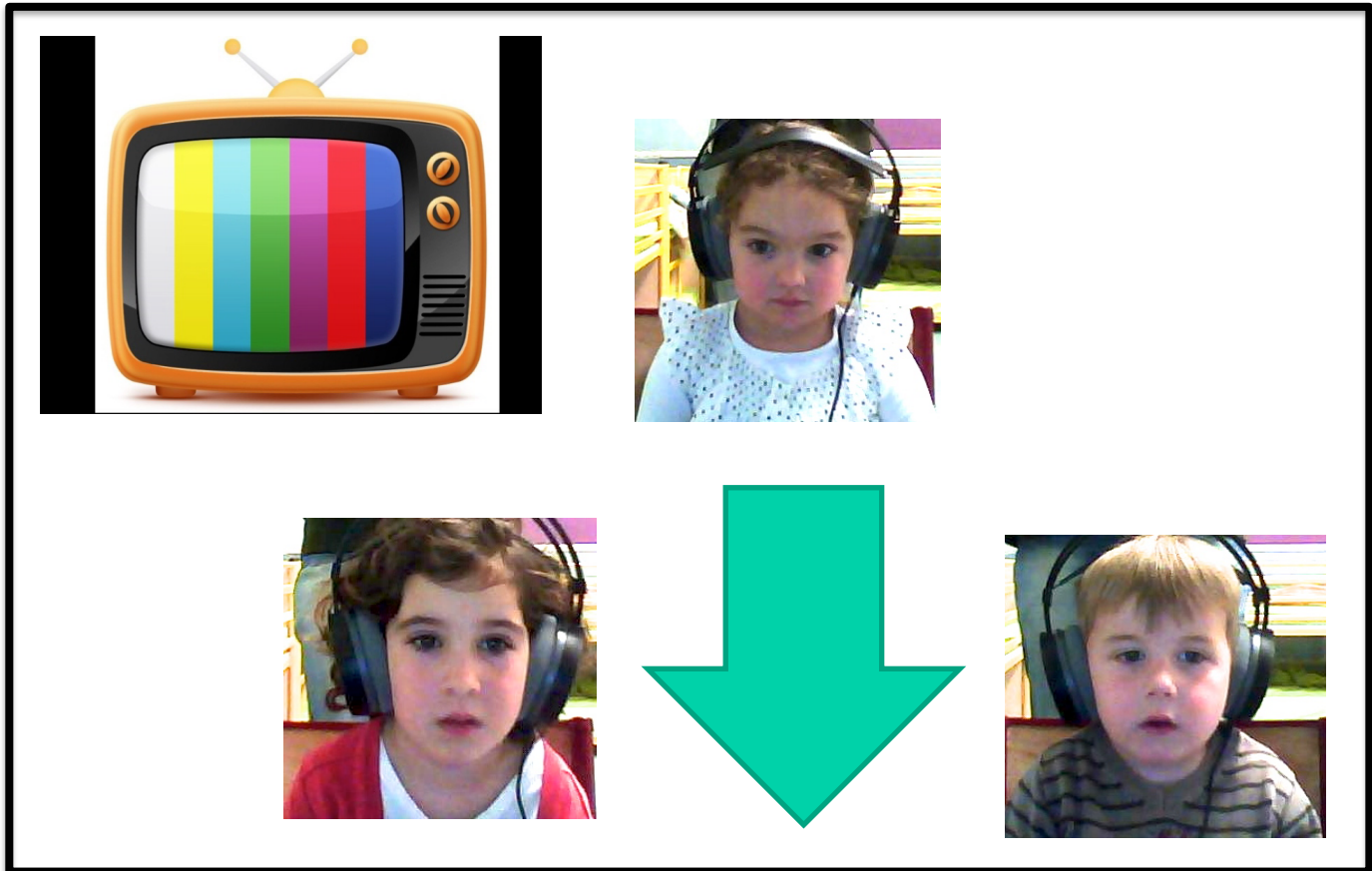
[La petite_A ferme_N] [lui plait beaucoup]
[The little farm] [pleases him a lot]

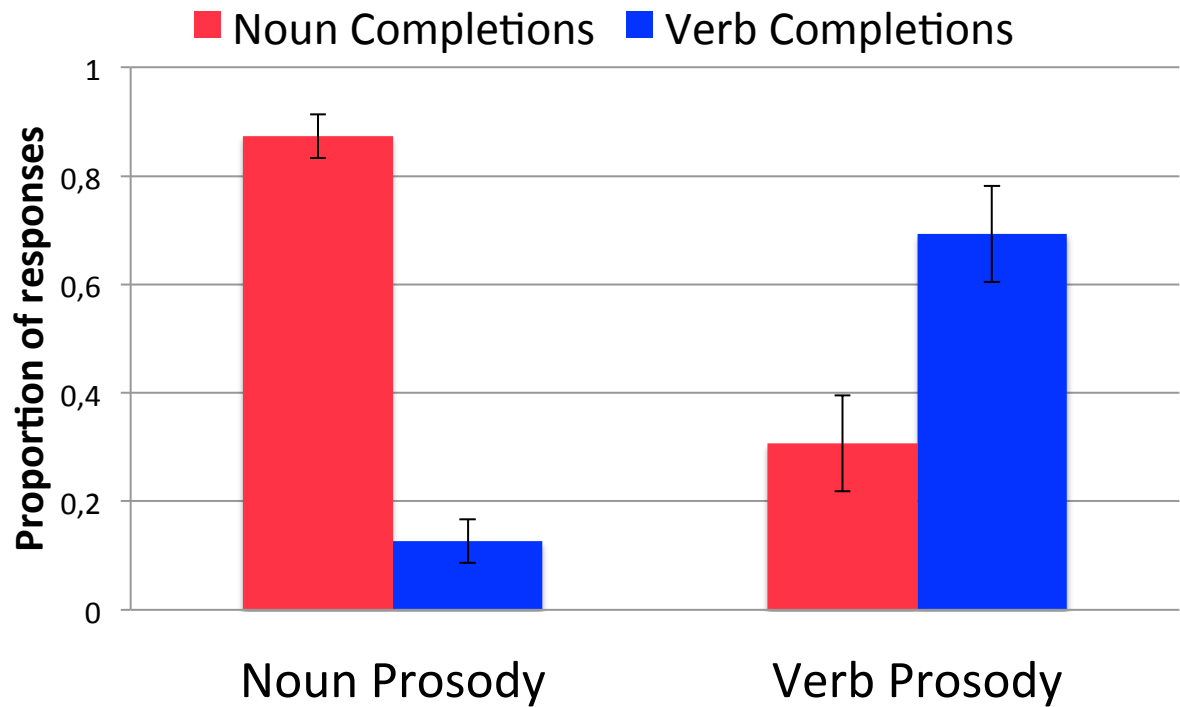
[La petite_N] [ferme_V] [le coffre à jouets]
[The little (girl)] [closes] [the toy box]

Completion task



Alex de Carvalho





4.5 year-olds

2-7 training sentences;

8 test sentences:

mouche: N: a fly V: to blow somebody's nose

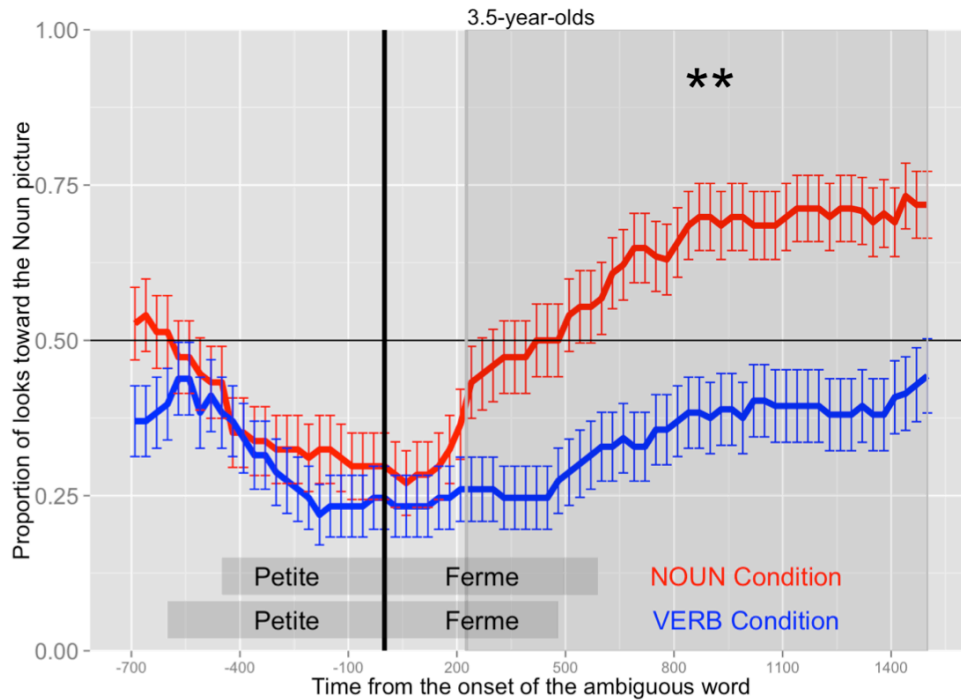
porte: N: a door V: to carry



What about on-line processing?

3.5-year-olds

[ferme] (noun/verb)



Noun

[La petite_A ferme_N] lui plait beaucoup
[The little farm] pleases him a lot

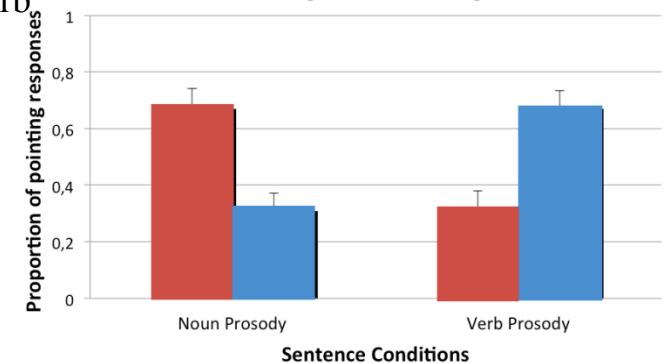


Verb

[La petite_N] [ferme_V] [le coffre à jouets]
[The little (girl)] [closes] [the toy box]

Experiment 2: Pointing responses
(3.5-year-olds)

- Pointing toward Noun image
- Pointing toward Verb image



3.5-year-olds

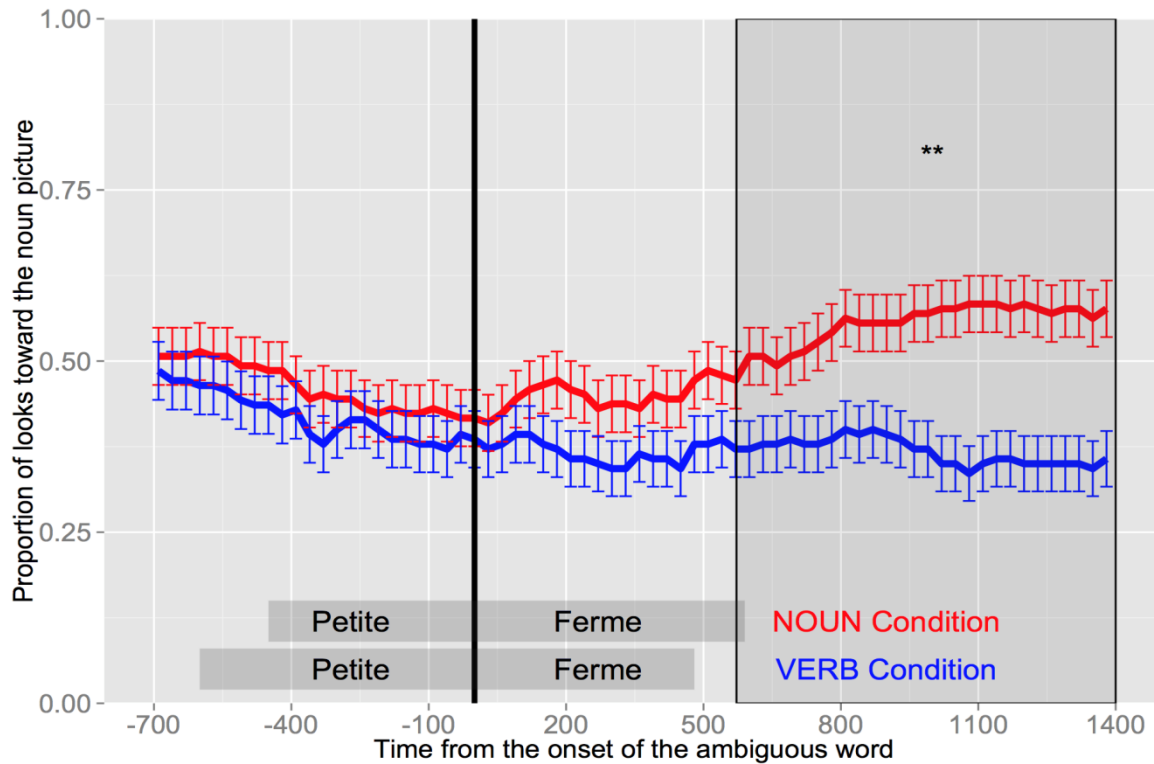


Alex de Carvalho



Isabelle Dautriche

Phonological phrase boundaries constrain syntactic processing: 28-month-olds



Condition
— Noun prosody
— Verb prosody

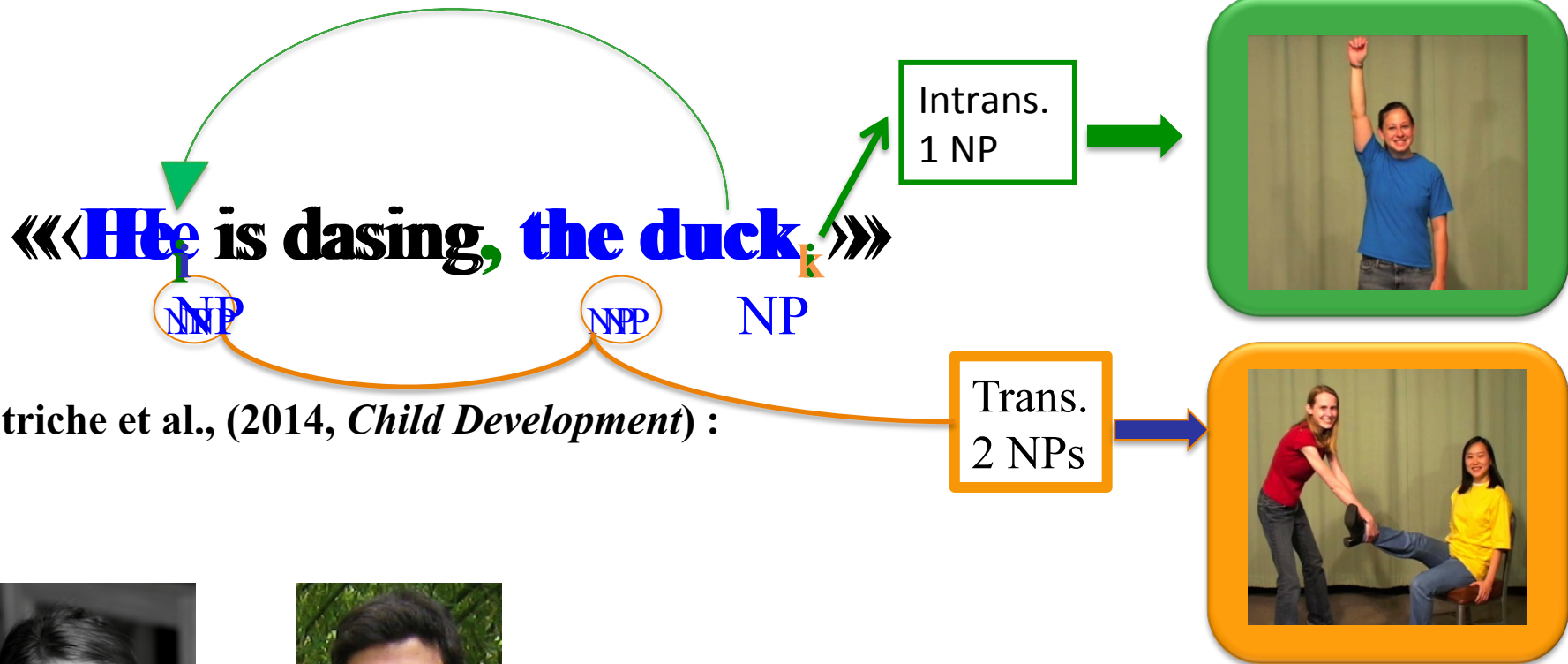


Alex de Carvalho



Isabelle Dautriche

Phrasal prosody impacts syntactic processing: right-dislocation in French



Dautriche et al., (2014, *Child Development*) :



Isabelle Dautriche



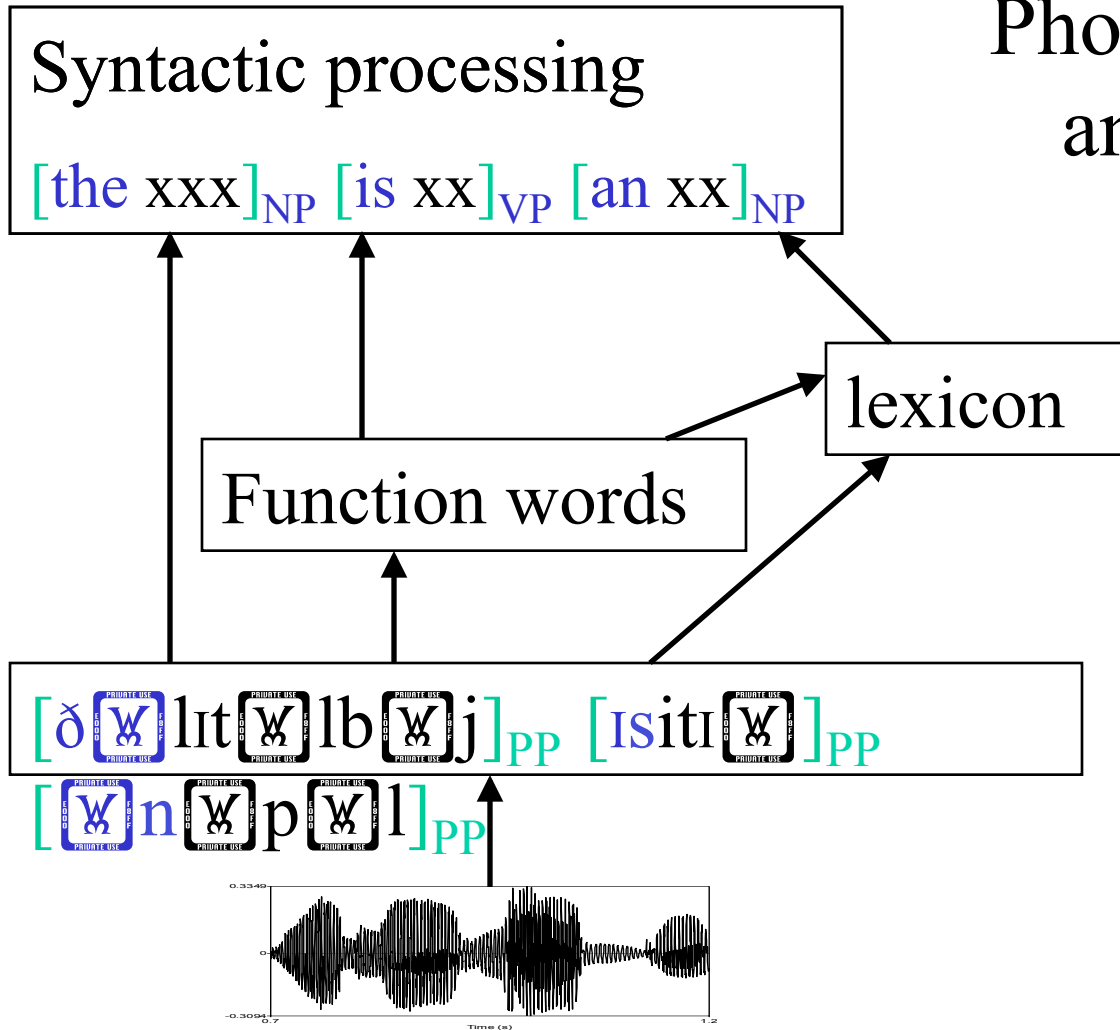
Alex de Carvalho

To hear about these two studies, go listen to the talk by Alex de Carvalho tomorrow at 3pm

de Carvalho (2014) Master thesis
de Carvalho, Dautriche & Christophe (in preparation)

Special role for function words

Phonological phrases
and function words



*Phonological and
prosodic representation*

Speech signal

"the little boy is eating an apple"

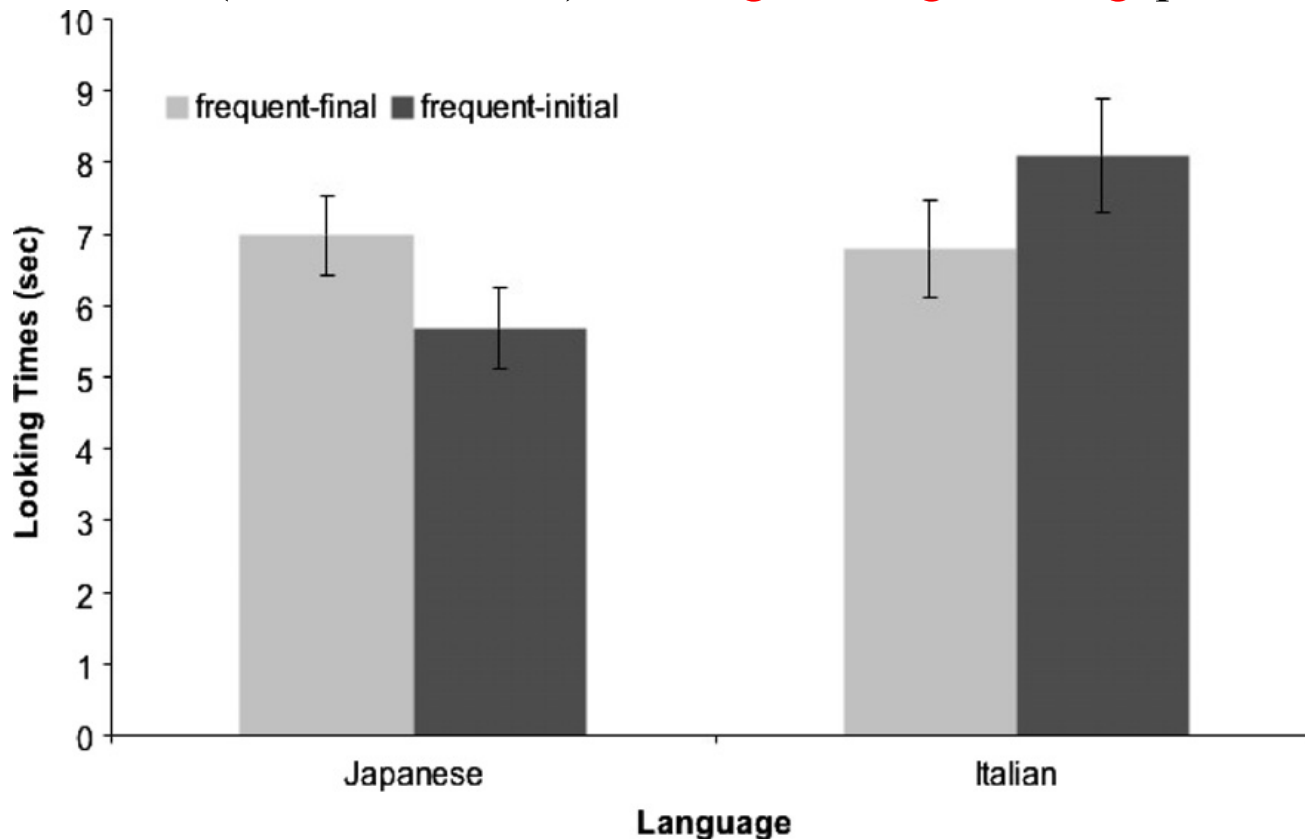
Function words:

- Can be acquired through a distributional analysis: extremely frequent, short, located at prosodic unit edges. e.g. Morgan, Shi & Allopenna (1996), Shi, Morgan & Allopenna, P. (1998).
- Are acquired early :
 - > 8- to 11-month-olds already know the most frequent function words of their language (Gerken, Landau, & Remez, (1990), Shafer, Shucard, Shucard & Gerken (1998), Shi & Gauthier, 2005, Shi, Werker & Cutler 2006), even though they may not have a fully detailed representation yet (Shi, Cutler, Werker & Cruickshank (2006))
 - > Infants exploit function words to find content words: Hallé, Durand & de Boysson-Bardies (2008) ; Shi & LePage (2008); e.g., after being familiarized with ‘des preuves’, look longer towards ‘preuves’ at test, but not after being familiarized with ‘ké preuves’ where ‘ké’ is not a function word in French.

Function words:

- Young infants know whether they cluster at the beginning or end of syntactic units:

e.g. Gervain et al. 2008: 8-month-olds are familiarized with a stream of syllables containing highly frequent elements ('function words') and much less frequent ones ('content words'), ex: ...**ge**lo**fi**bu**ge**de**fi**ko**ge**pa**fi**moge...



Frequent-initial:
fifoge**bu**

Frequent-final:
ba**ge**bo**fi**

Function words:

- Young infants know that they don't carry meaning – content words do (Hochmann 2010, 2013).

Familiarization Phase

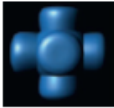
Experiment 1 : ...davofigibuvodegisivo...

Experiment 2: ...damu~~fin~~abumu~~dena~~simu...

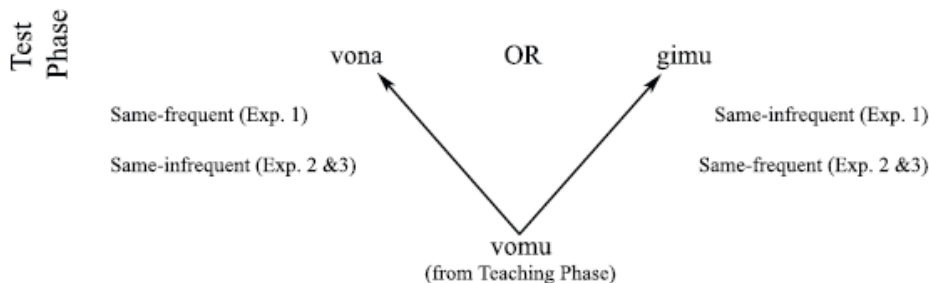
Experiment 3: da~~mu~~_fina_bumu_dena_simu_...

Teaching Phase

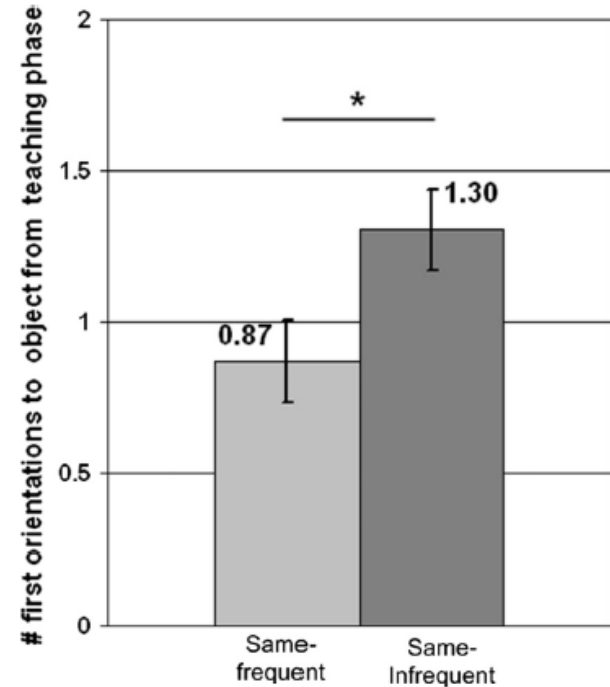
Verbal label + Visual object

Example: vomu + 

Visual object from Teaching Phase + one new object
Label derived from label presented during Teaching Phase



Exp. 1



Frequent-initial

Function words:

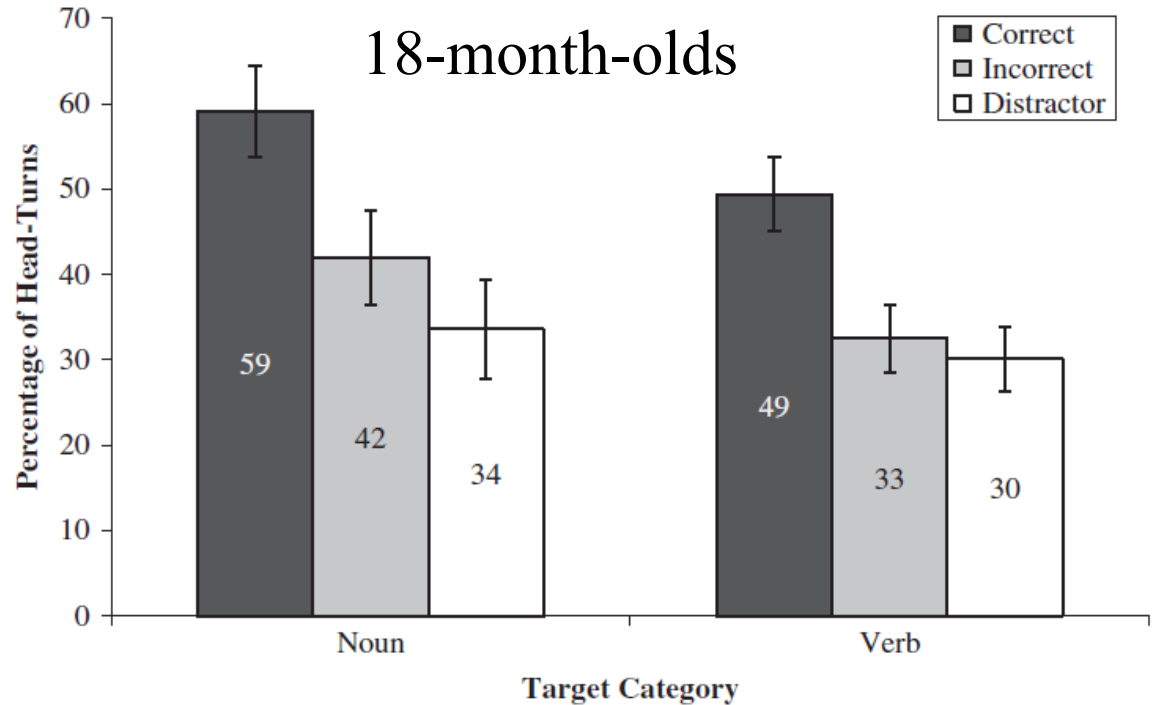
- Can be used to categorize content words:
 - ‘je jaurime’ -> ‘jaurime’ is a verb, refers probably to an action (*'it blicks'*)
 - ‘la jaurime’ -> ‘jaurime’ is a noun, refers probably to an object (*'the blick'*)
- * Höhle, Weissenborn, J. et al. (2004). *Infancy*: 16-month-old German infants: an article predicts a noun (although a pronoun does not yet predict a verb)
- * Shi & Melançon (2010) *Infancy*: 14-month-old French infants know the class of articles (not the one of pronouns).

Kids use function words to constrain lexical access:



Elodie Cauvet

Method: word detection;
conditioned head-turning



Trained on:	la balle, des balles	je mange, il mange
Correct context	J'adore les balles en mousse <i>I like foam balls</i>	Demain tu manges chez moi <i>Tomorrow you eat at my place</i>
Incorrect context	*Demain tu balles chez moi <i>*Tomorrow you ball at my place</i>	*J'adore les manges en mousse <i>*I like foam eats</i>
Distractor	J'adore les fraises au sucre <i>I like strawberries with sugar</i>	Demain tu chantes chez Paul <i>Tomorrow you sing at Paul's</i>

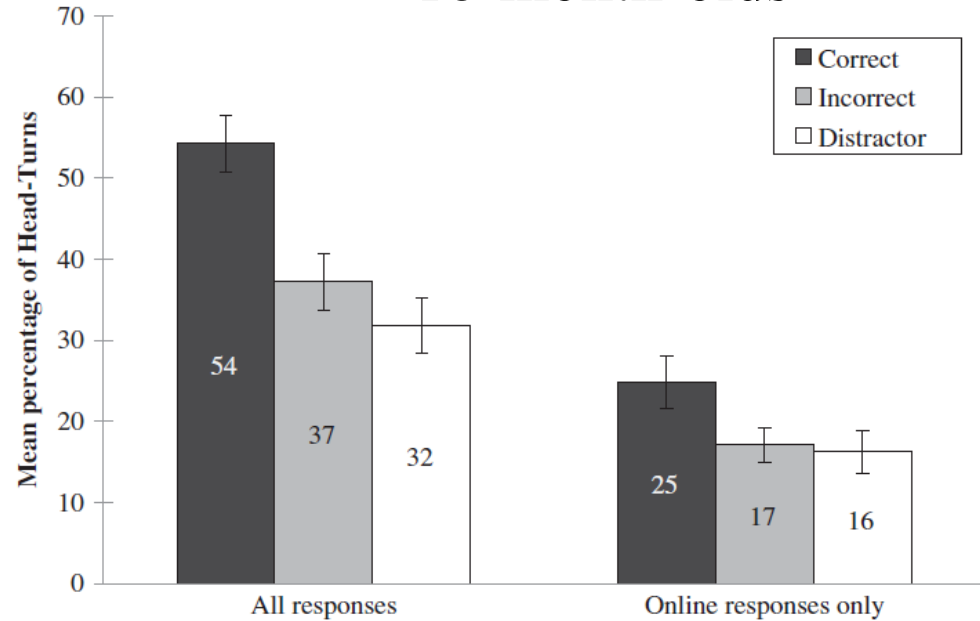
Kids use function words **on-line** to constrain lexical access:

18-month-olds



Elodie Cauvet

Method: word detection;
conditioned head-turning



Trained on:	la balle, des balles	je mange, il mange
Correct context	J'adore les balles en mousse <i>I like foam balls</i>	Demain tu manges chez moi <i>Tomorrow you eat at my place</i>
Incorrect context	*Demain tu balles chez moi <i>*Tomorrow you ball at my place</i>	*J'adore les manges en mousse <i>*I like foam eats</i>
Distractor	J'adore les fraises au sucre <i>I like strawberries with sugar</i>	Deman tu chantes chez Paul <i>Tomorrow you sing at Paul's</i>

Can 18-month-olds exploit the syntactic context in which novel words occur?

Swingley & Aslin (2007): difficult to learn the meaning of ‘tog’, neighbour of ‘dog’ – too ‘close’, confusable

How to place it further away?

Kids process words in context:

-> change syntactic category.

Noun-neighbor:

Un ganard (canard/*duck*)

= a tog (*dog*)

Verb-neighbor:

Un barti (parti/*gone*)

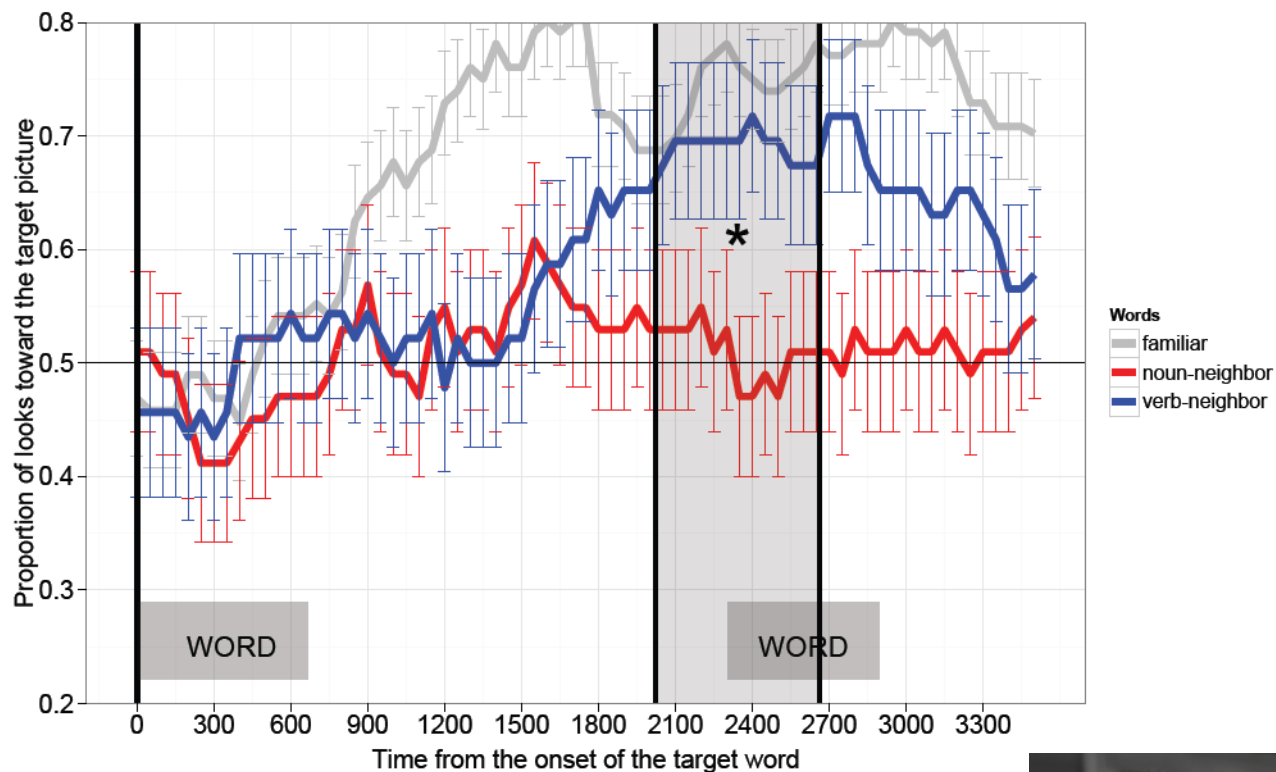
= a kive (*give*)



Isabelle Dautriche

Can 18-month-olds exploit the syntactic context in which novel words occur?

noun-neighbor: red
un ganard (canard/*duck*)
= a tog (*dog*)
verb-neighbor: blue
un barti (parti/*gone*)
= a kive (*give*)
(familiar words: grey)



Isabelle Dautriche

Dautriche, Swingley & Christophe (2014) *BUCLD*

Dautriche, Swingley & Christophe (submitted) *Cognition*

The syntactic category of an unknown word constrains its meaning

- 2-year-olds are able to infer the syntactic category of a novel word from the syntactic contexts in which it occurs (noun/verb) and therefore constrain its possible meaning (object/action)

Bernal et al. 2007, Waxman et al. 2009; Oshima-Takane et al. 2011

- Potential problems:

- 'je la mange' (*I eat it*), la+X but X is not a noun...

=> How accurate is syntactic processing at 2 years of age?

debate in literature... task problem

- production: don't produce many 'sentences' before age 2;5 - 3
(productive use // imitation?)
- comprehension: difficult to interpret looking times.

Evoked potential experiment with ambiguous function words in French



Correct

Verb

Alors elle **la mange**
(Then she eats it)

Noun

La poule prend **la fraise**
(The chicken takes the strawberry)

Incorrect

La fille prend **la mange
(The girl takes the eat)

Alors il **la fraise
(Then he strawberries it)

- passive listening, known words only
- To keep infants' attention focused, the speaker is playing with toy objects (e.g. strawberry) while she tells a short story; only her face is visible when she utters the test sentences.

Example of Script

Sur ma table, je vois une girafe (N) qui va à l'école. Elle regarde (V) la poule

1. Donc la poule **la** **regarde** aussi.

(Correct)

2. Pourtant, elle **la girafe** très vite!

(Incorrect)

On my table, I see a giraffe (N) who goes to school. She looks (V) at the hen.

1. So the hen **looks** at her too.

(Correct)

2. However, she **giraffes** it really fast!

(Incorrect)

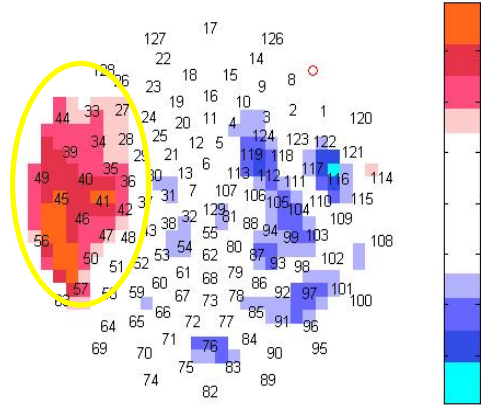


2-year-olds detect incorrect sentences

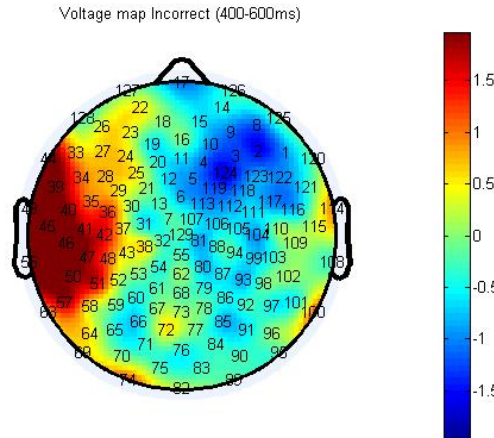


Savita Bernal

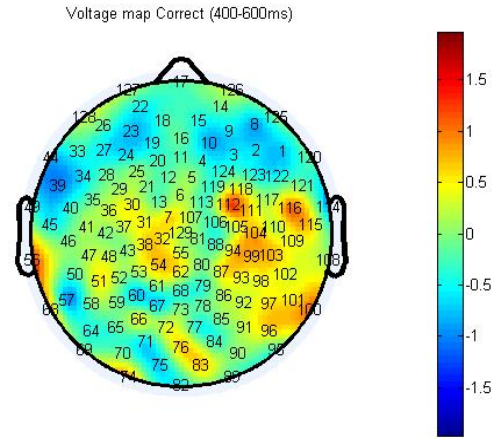
Incorrect-Correct



Incorrect

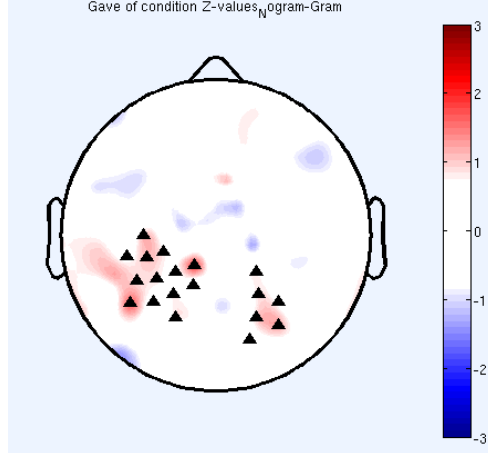


Correct

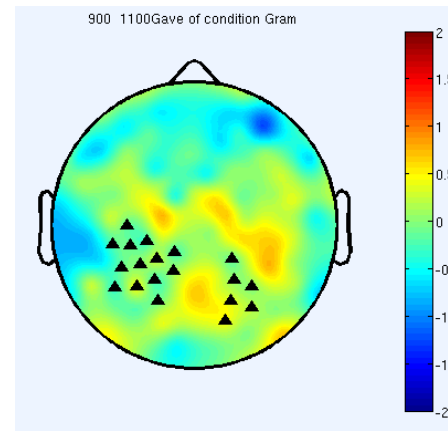
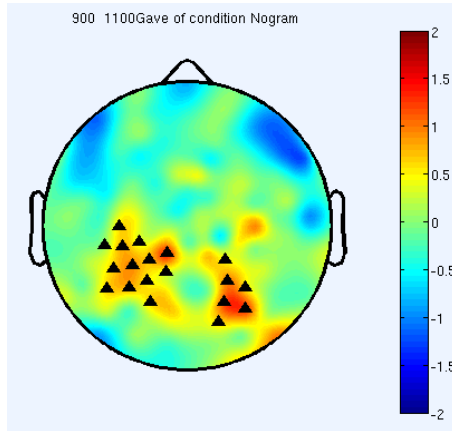


Bernal, Dehaene-Lambertz, Millotte & Christophe (2010). Two-year-olds compute syntactic structure on-line *Developmental Science*.

18-month-olds
also detect
incorrect
sentences



Perrine Brusini



900-1100 ms

Incorrect	Correct	
*La fille prend la mange <i>(The girl takes the eat)</i>	Alors elle la mange <i>(Then she eats it)</i>	verb
*Alors il la fraise <i>(Then he strawberry it)</i>	La poule prend la fraise <i>(The chicken takes the strawberry)</i>	noun

Perrine Brusini (PhD thesis)

Brusini, Dehaene-Lambertz, van Heugten, Fiévet & Christophe (submitted).

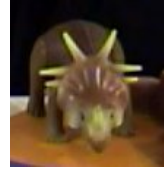
Toddlers compute syntactic expectations.

- 2-year-olds and 18-month-olds build on-line syntactic expectancies:
'je la' predicts a verb, whereas 'je prends la' predicts a noun;
Infants are not fooled by the article/object clitic homophony
- Toddlers do not simply react to transition probabilities between pairs of words: 'elle+la' OK, 'la+fraise' OK, '*elle la fraise'
- However, they could react to the probabilities of 3-word strings: they may have heard 'il la mange' before, whereas '*elle la fraise' has never been heard.

-> use newly-learnt words

Testing syntactic expectations with newly-learned words

- **Phase 1:** teach 4 new words:
2 nouns: touse, rane
2 verbs: dumer, pouner



Perrine Brusini

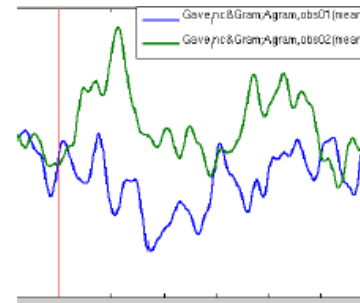
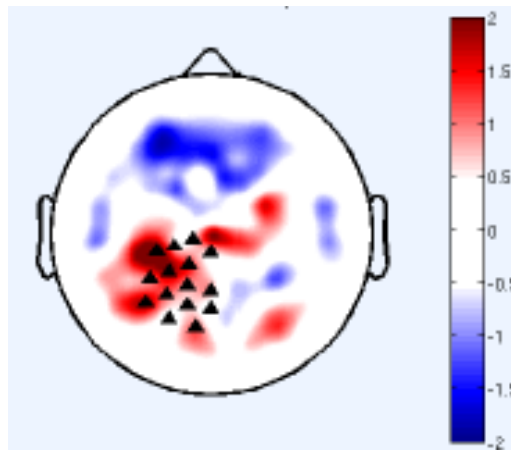
in an interactive play session (20mn), the new words are presented in many different syntactic structures, but not the test one: ‘le X’

(also well-known words: chien, chat, manger, donner)

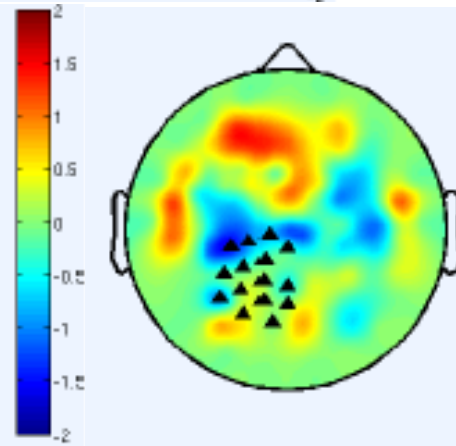
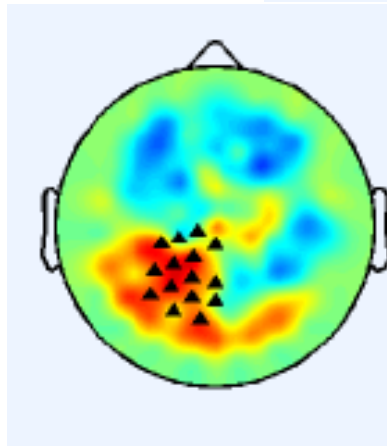
- **Phase 2** (a week later): toddlers watch videos containing test sentences, with the target structure ‘le X’, where X is the target noun or verb

Agrammatical	Grammatical	
*Marie prend le poune	Alors elle le poune	verb
*Alors il le touse	Martin voit le touse	noun

24-month-olds,
newly-learnt
words



700-1000 ms



Perrine Brusini

Agrammatical	Grammatical	
<p>*Maintenant le dume est plus calme <i>Now the dume is calmer</i></p>	<p>Alors Martin le dume maladroitement <i>then Martin dumes it clumsily</i></p>	<p>verb</p>
<p>*Martin le touse le poisson <i>Martin tooses the fish</i></p>	<p>L'indien pousse le touse vers la fleur <i>the indian pushes the toose towards the flower</i></p>	<p>noun</p>

Perrine Brusini (PhD thesis)

Brusini, Dehaene-Lambertz, Dutat & Christophe (in preparation).

2-year-olds compute syntactic structure on-line.

- Newly-learnt words trigger an agrammaticality effect, just like well-known words.
- 2-year-olds compute syntactic structure on-line:
'je le' predicts a verb, whereas 'je prends le' predicts a noun;
and this is true even though the newly-learnt nouns and verbs were never heard before in either context.
- Toddlers were thus able to assign the newly-learnt items to the noun or verb category (based on the contexts they heard them in during the teaching phase), and were able to generalize to novel correct contexts.

=> How do toddlers learn noun and verb contexts?

Learning noun and verb contexts

- Hypothesis: contexts are learnt on the basis of a few known nouns and verbs = *semantic seed*
- Toddlers managed to learn the meaning of a few highly frequent nouns and verbs representing concrete objects and actions;
- They group words representing objects together, and words representing actions together (Carey, 2009)
- To test it: we trained a model on a corpus of child-directed speech where a few nouns and verbs are categorized (e.g. 6 Nouns and 2 Verbs, 6N-2V; 12 Nouns and 4 Verbs, 12N-4V, etc). The others words remain uncategorized.

A model of Noun/Verb categorization

- The model collects trigram frequencies (strings of 3 words – e.g. ‘je la VERB’)
- At test, the model categorizes every not-too-frequent word from a test corpus that has not been seen before, by using their immediate contexts: e.g. ‘je la X’
the model selects the most frequent thing that occurred in this context, either a category (here, VERB) or in some cases a specific item.
- Two measures are computed for noun and verb responses :

-precision : $hits / (hits + FA)$

“when the model gives a noun response, is it correct or not?”

(high precision= lots of hits,
low precision = lots of FA)

- recall : $hits / (hits + misses)$

“how many times did the model fail to respond noun when it encountered a noun ?”

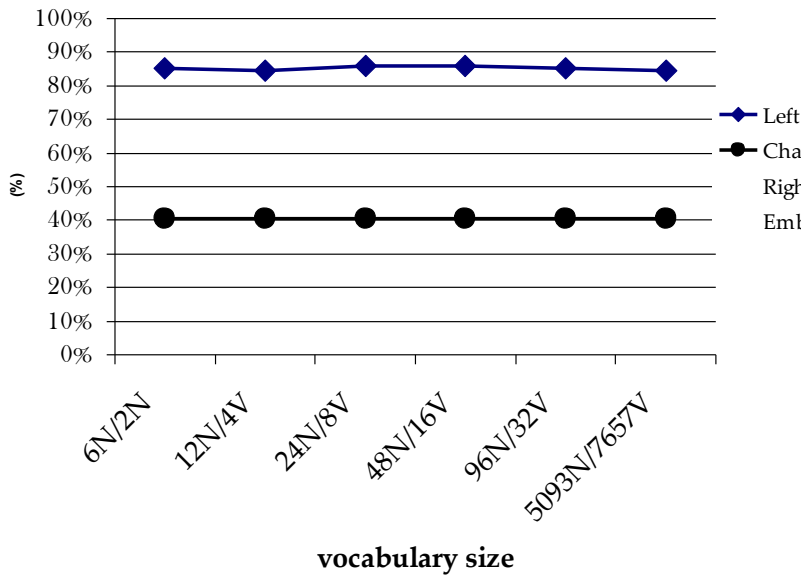
(high recall=lots of hits,
low recall = lots of misses)

Perrine Brusini (PhD thesis)

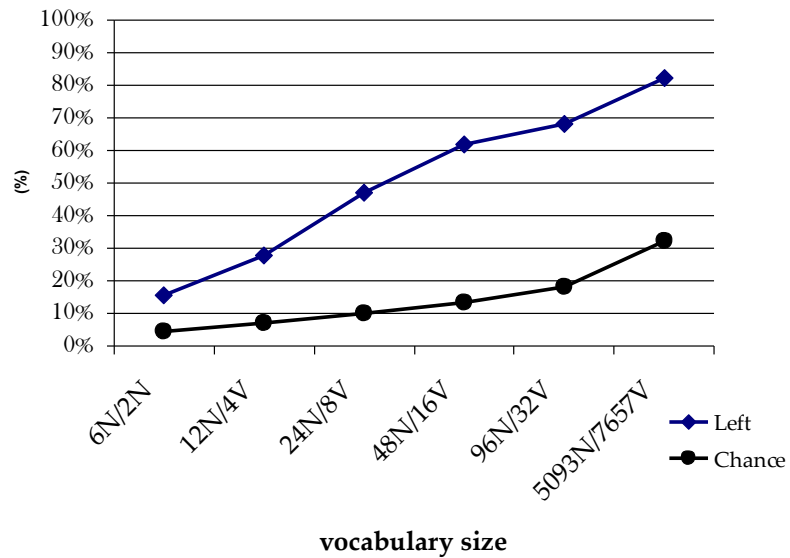
Brusini, Amsili, Chemla, van Heugten & Christophe (in preparation).

Noun

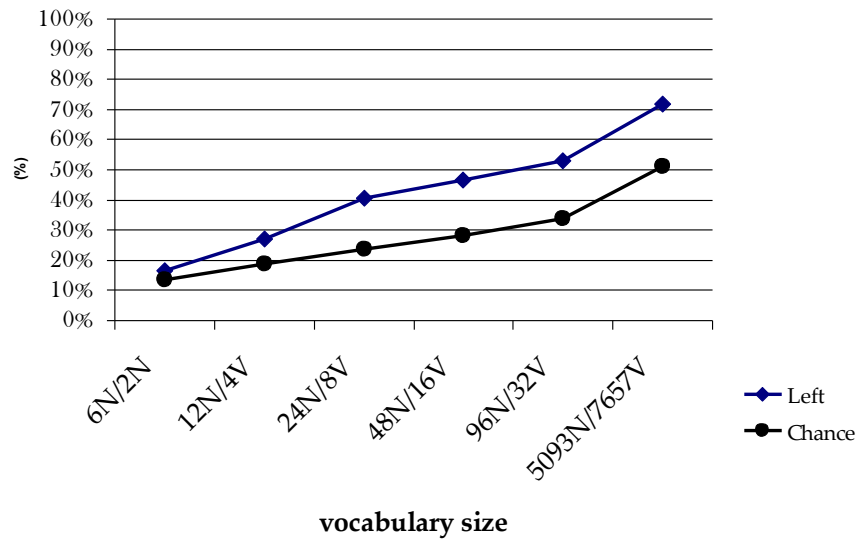
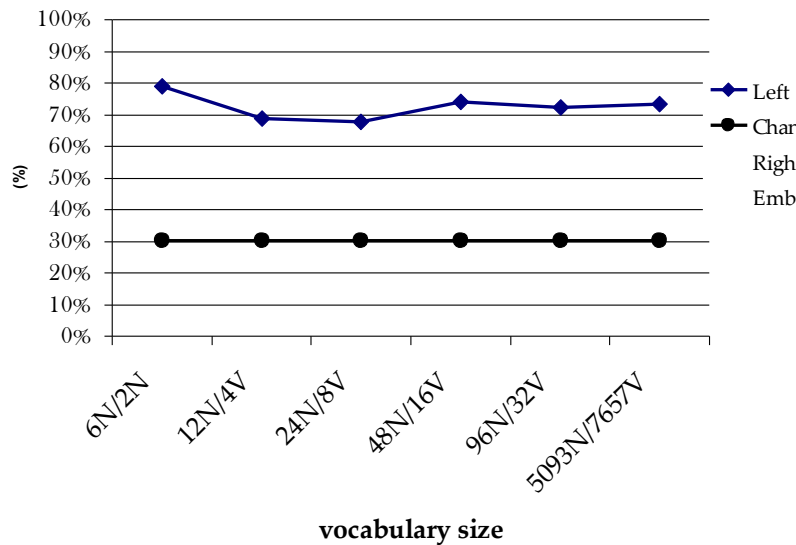
Precision



Recall



Verb



Most frequent Noun and Verb contexts

Noun contexts:

Verb contexts

context	nb noun	nb verb	Model's answer	translation	context	nb Noun	nb Verb	Model's answer	translation
# UN	78	1	Noun	# A	# TU	1	603	Verb	# YOU
EST UN	62	0	Noun	IS A	# ON	0	225	Verb	# WE
VERB LE	60	31	Noun	VERB THE/IT	# JE	0	187	Verb	# I
NOUN DE	56	15	Noun	NOUN OF/TO	# VERB	3	110	Verb	# VERB
VERB UN	55	0	Noun	VERB A	# IL	0	101	Verb	# HE
VERB DES	52	0	Noun	VERB SOME	# CA	0	95	Verb	# IT
# LE	46	1	Noun	# THE	QUE TU	1	81	Verb	THAT YOU
# UNE	45	0	Noun	# A	TU VERB	5	58	Verb	YOU VERB
DE LA	41	4	Noun	OF THE	ON VERB	2	52	Verb	WE VERB
VERB LA	39	19	Noun	VERB THE/IT	TU AS	6	46	Verb	YOU HAVE
VERB LES	34	12	Noun	VERB THE/IT	VERB PAS	1	45	Verb	VERB NOT
# LA	33	0	Noun	# THE	QU' IL	0	45	Verb	THAT HE
VERB DU	33	0	Noun	VERB OF	QU' ON	0	44	Verb	THAT WE
à LA	32	1	Noun	TO THE	VERB VERB	6	42	Verb	VERB VERB
VERB UNE	32	0	Noun	VERB A	VERB LE	60	31	Noun	VERB THE/IT

Function words do the categorization work – even though they don't have a special status to begin with... Sheer frequency (see also Mintz, 2003)

A model of Noun/Verb categorization

- ♣ Categorizes words in context;
- ♣ *Semantic seed* highly efficient;
- ♣ The model gets tricked by ambiguous function words – contrary to the 2-year-olds from the ERP experiment!
 - ♣ Listeners have more refined representations than the model (e.g., not just ‘VERB’, but what kind of verb it is).
 - in ‘je prends la mange’, (*I take the eat*) the sentence is wrong only because ‘prendre’ cannot take a verbal complement;
 - in contrast, ‘je veux le manger’ (*I want to eat it*) is perfectly all right.
 - ♣ 2-year-olds already have these refined representations
- ♣ Is it possible to integrate phrasal prosody and function words to build a model of the syntactic skeleton?

Using function words and prosody together: Modelling the syntactic skeleton

Is it possible to learn to categorize prosodic phrases into Noun Phrases, Verb Phrases, and Others?

Hypothesis: as in the previous model, toddlers know the meaning of a few nouns and verbs, grouped into objects and actions: the *semantic seed*;

Model trained on the same corpus of child-directed speech, marked with prosodic boundaries.

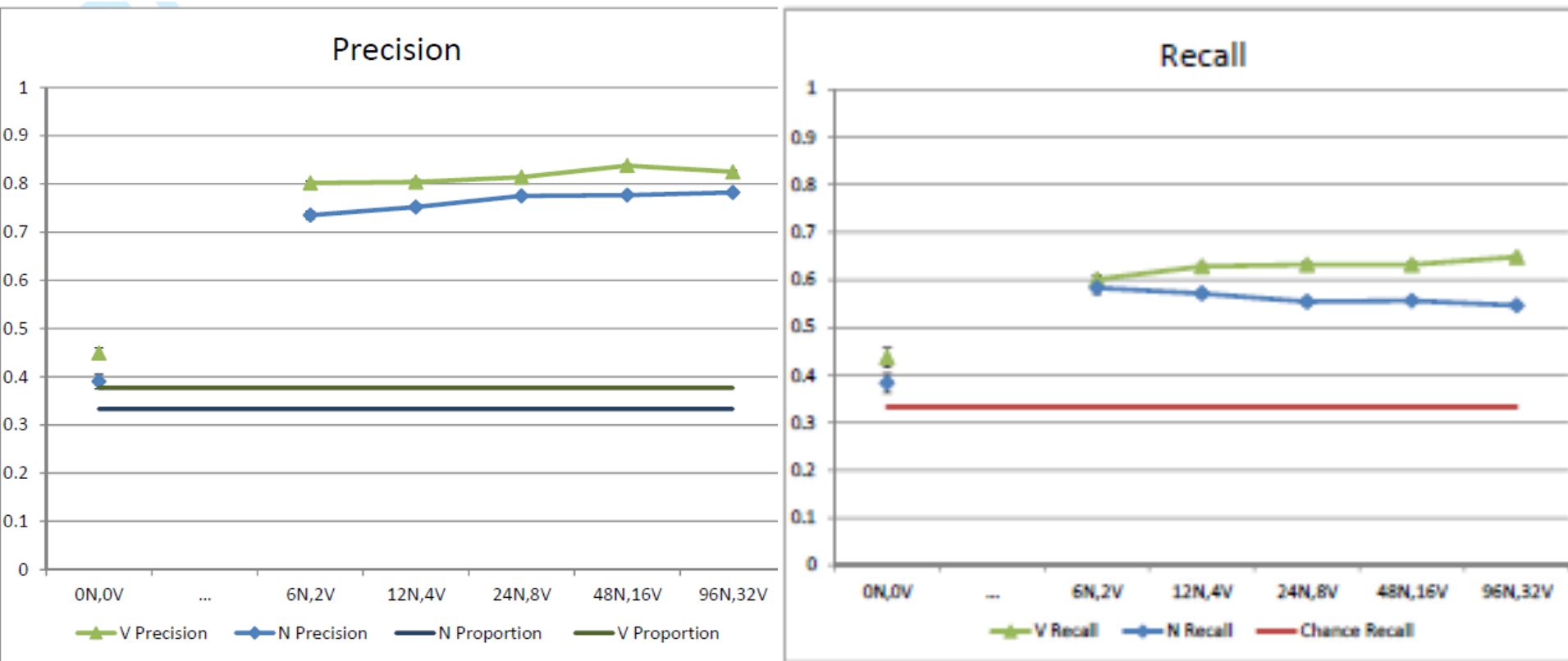
Known words used to categorize a few prosodic phrases:

e.g. [the yellow teddybear_N] NP

Variables: rightmost word, two leftmost words (ex: [and the boy]), leftmost word from the preceding prosodic unit.

Bayesian modeling.

Modelling the syntactic skeleton



Precision and recall are good, don't depend on the size of the initial vocabulary
Most informative cues = leftmost word, then second word (usually function words)

Syntactic skeleton

- Before the age of 18 months, infants adequately perceive phrasal prosody, and exploit it to constrain lexical access and syntactic processing on-line;
- They know the contexts in which nouns and verbs occur, and build on-line syntactic expectations.
- They may learn noun and verb contexts by computing common contexts for a few concrete nouns and verbs.

• *Syntactic skeleton:*

[the xxx]_{NP} [is xing]_{VP} [an x]_{NP}

maybe around 14-18 months...

=> potentially enough information to constrain the acquisition of word meanings (nouns vs verbs, different classes of verbs...).