Experimental methods to study early language acquisition.

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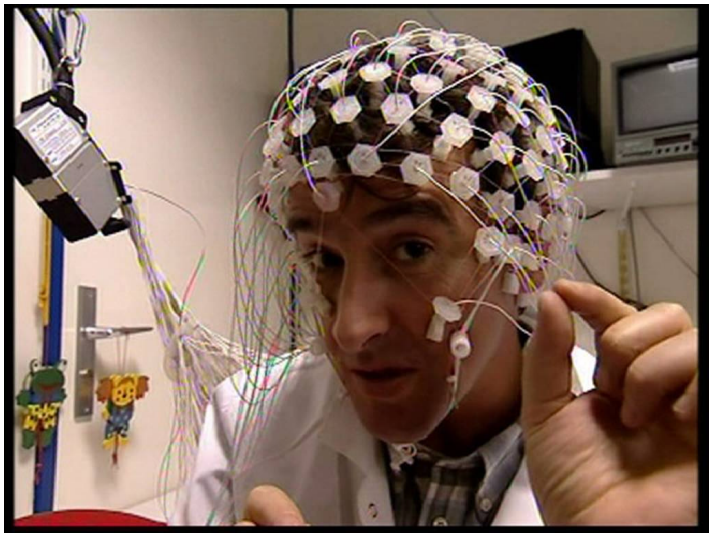
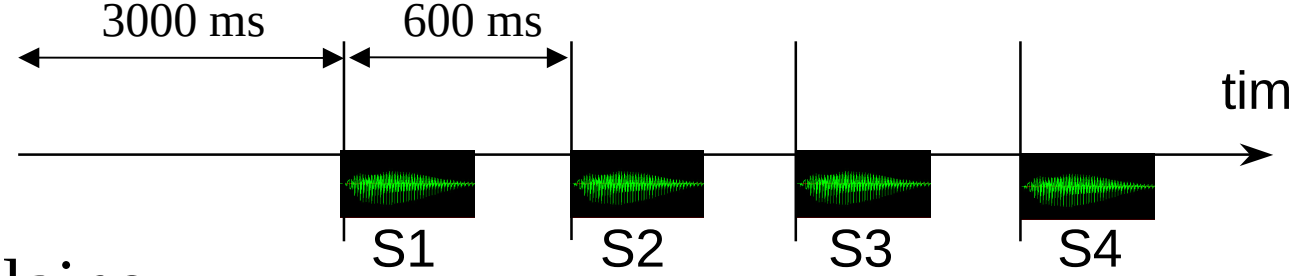
Outline:

- Series of ERP results on syllable perception in very young infants: work from Ghislaine Dehaene-Lambertz.
  => discussion of the advantages of the ERP technique for studying phonetic perception in very young infants

- Illustration of several behavioral techniques for studying early language acquisition (6-24 months infants)
  => discussion of the advantages and drawbacks of each of these techniques.



Testing phonetic perception in infants (and adults): Experimental Paradigm: habituation-deshabituation

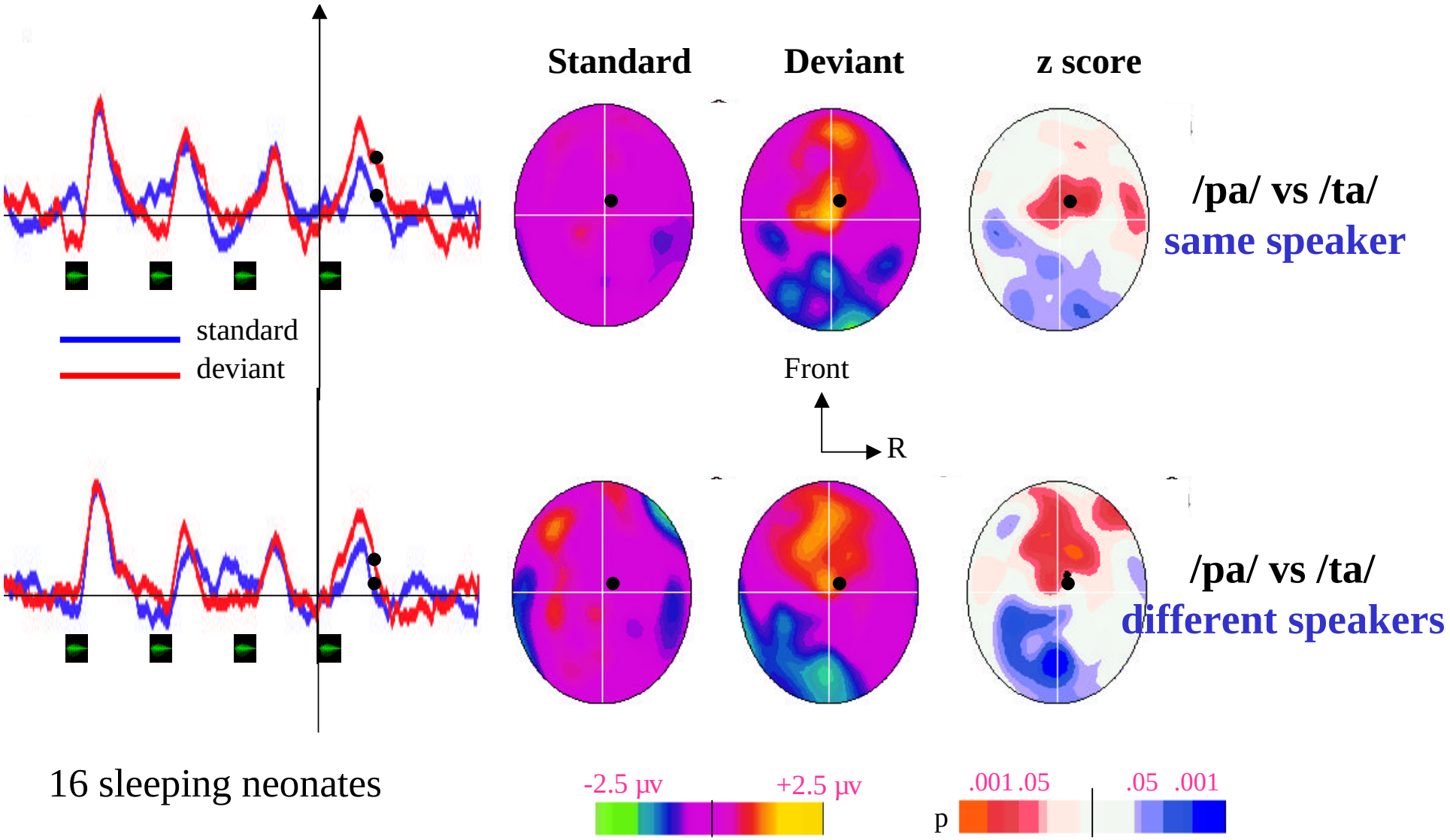


Ghislaine Dehaene-Lambertz

S1	S2	S3	S4
Ba	**Ba**	**Ba**	Ba
Da	**Da**	**Da**	**Ba**
Da	**Da**	**Da**	Da
Ba	**Ba**	**Ba**	Da

Response to a change

Normalization across different speakers



16 sleeping neonates

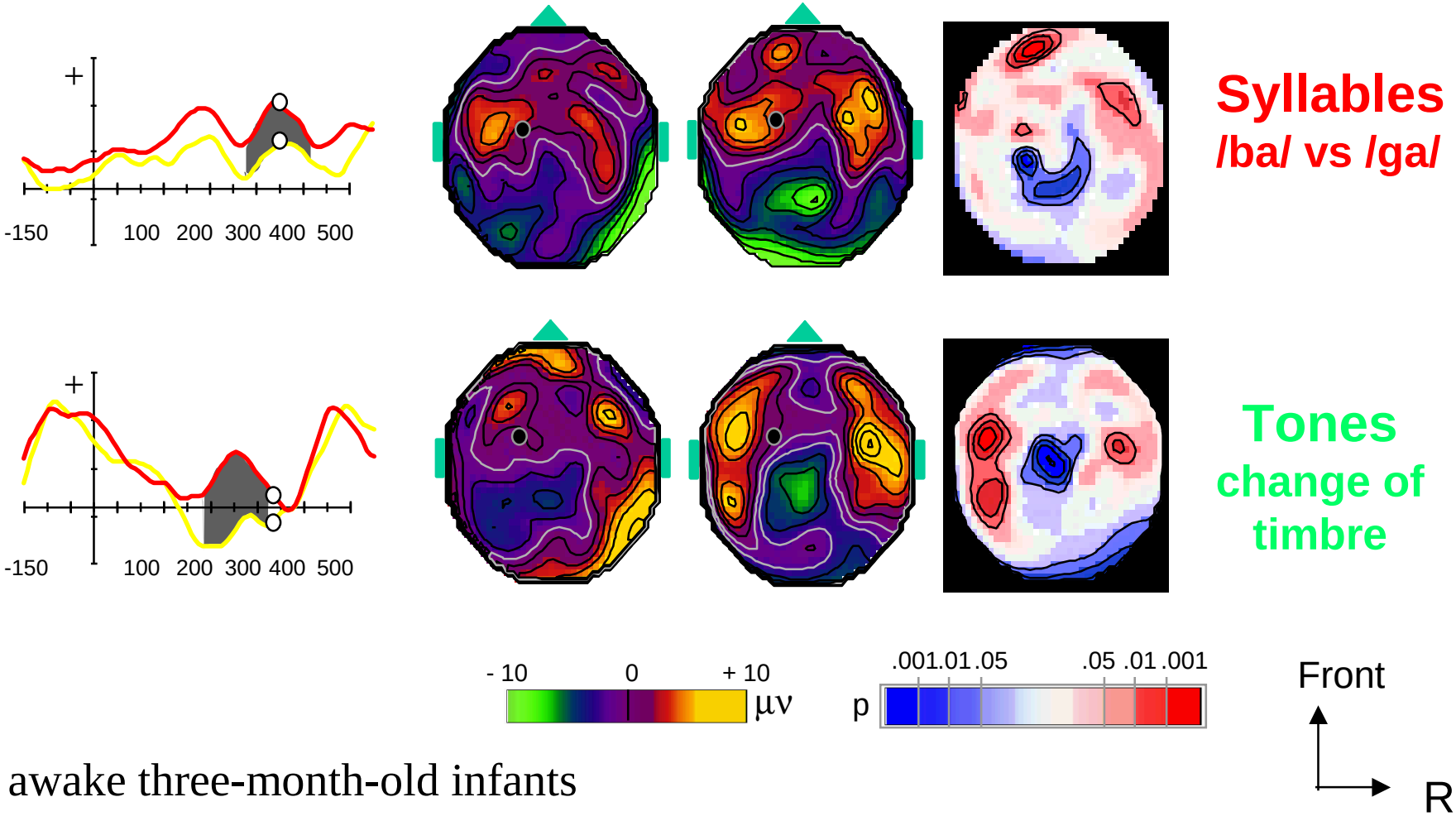
Dehaene-Lambertz, G., & Peña, M. (2001). Electrophysiological evidence for automatic phonetic processing in neonates. *NeuroReport*, *12*, 3155-3158

Methodological comparison: ERP/ Behavioral technique

- ERP result with the habituation-dishabituation paradigm: newborn infants can discriminate between pa and ta, even with varied speakers.
- The same result at the same age could have been obtained with non-nutritive sucking, same habituation-dishabituation paradigm

ERP advantages: 1. response latency, 400ms
2. less infants needed (16 vs 40 infants),
3. passive technique, sleeping infants OK.

Different mismatch responses depending on whether a phonetic or an acoustic characteristic of the stimulus changes



16 awake three-month-old infants

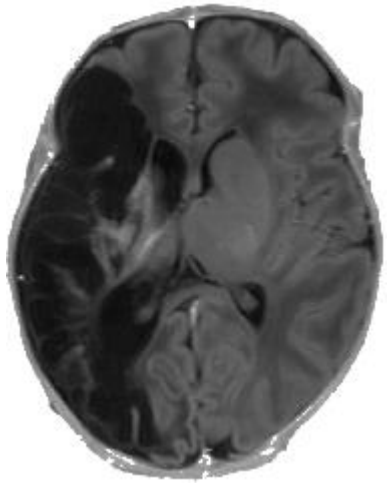
Methodological comparison: ERP/ Behavioral technique

- ERP result: 3-month-olds are able to discriminate both syllables and tones that differ in timber.
- We could test the same thing with sucking, same habituation-dishabituation paradigm, inter-subject experimental design

ERP advantage:

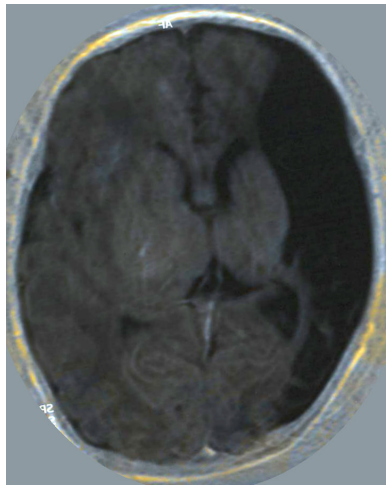
Discrimination responses are different for syllables (phonetic distinction) and tones (acoustic distinction): this tells us that different *processes* are involved.
(no way we could find that out with a behavioral method).

Studies of single subjects with neonatal cortical lesions

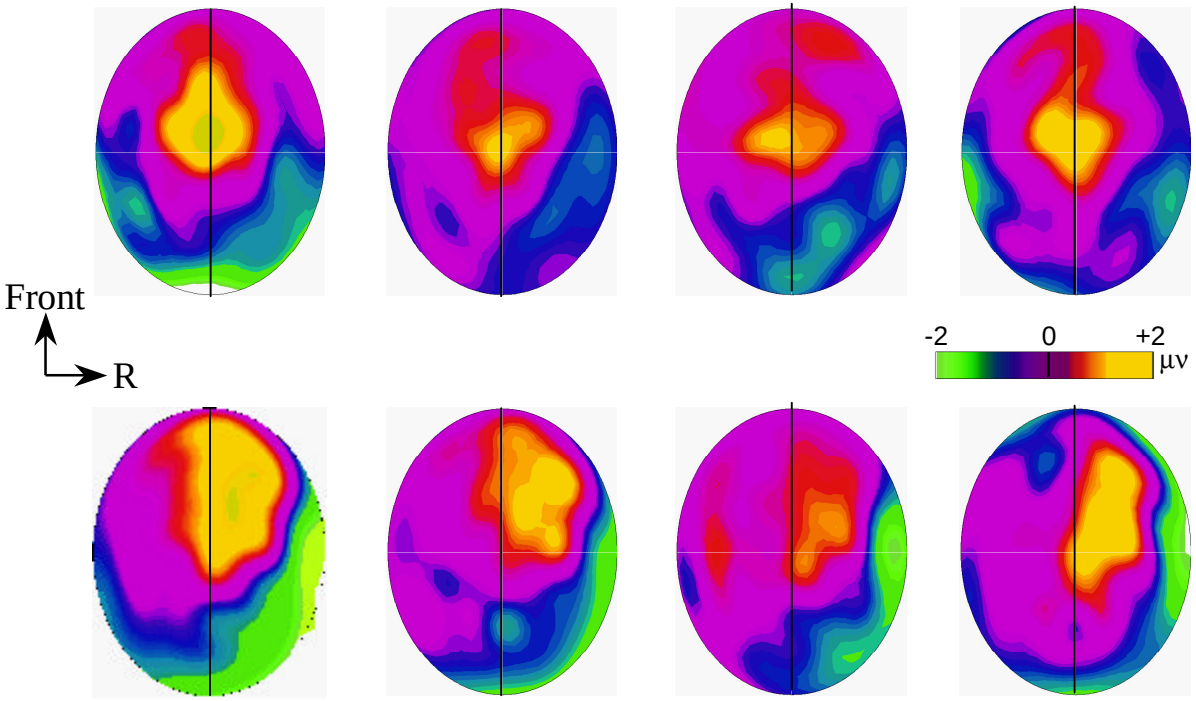
L  R

L. G., left infarct at birth
tested at 2 weeks of age

Dehaene-Lambertz, G., Pena, M., Christophe, A., Charolais, A., Landrieu, P. (2004). Phoneme discrimination in a neonate with a left sylvian infarct. *Brain & Language*, *88*, 26-38.

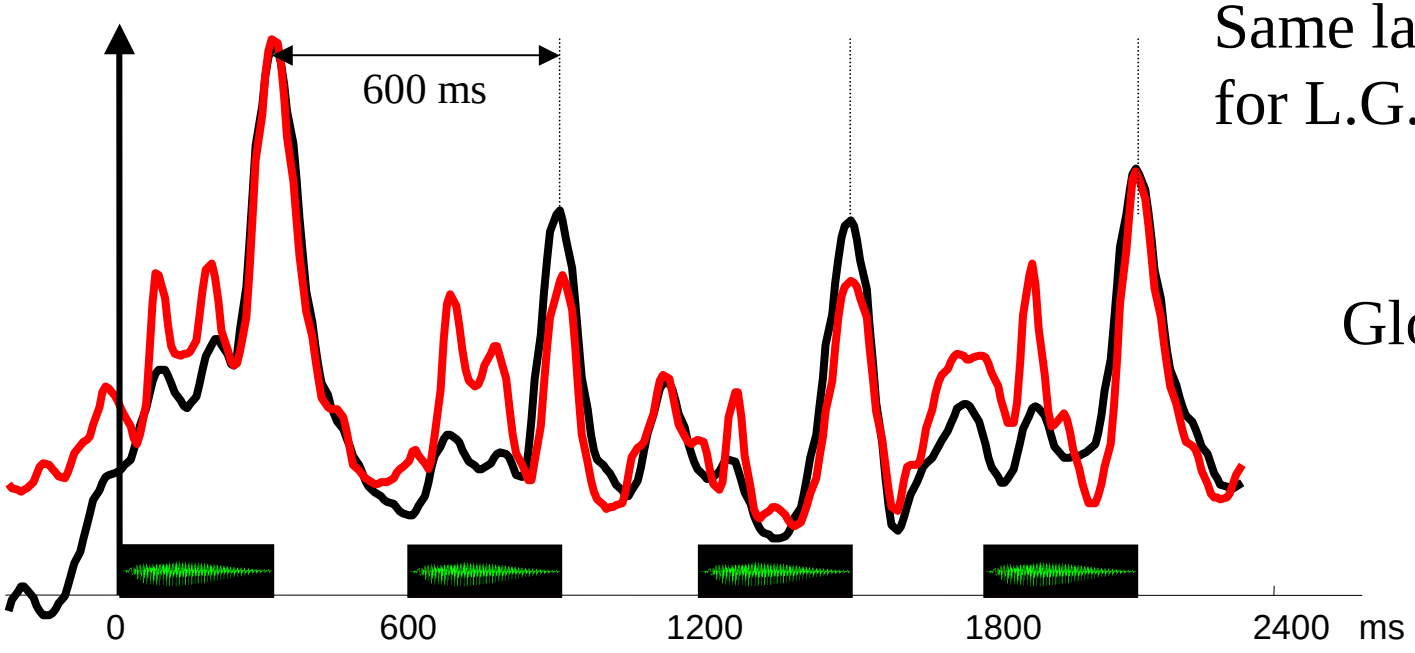
L  R

S.D., right infarct at birth
tested at 3 months of age



Normal neonates

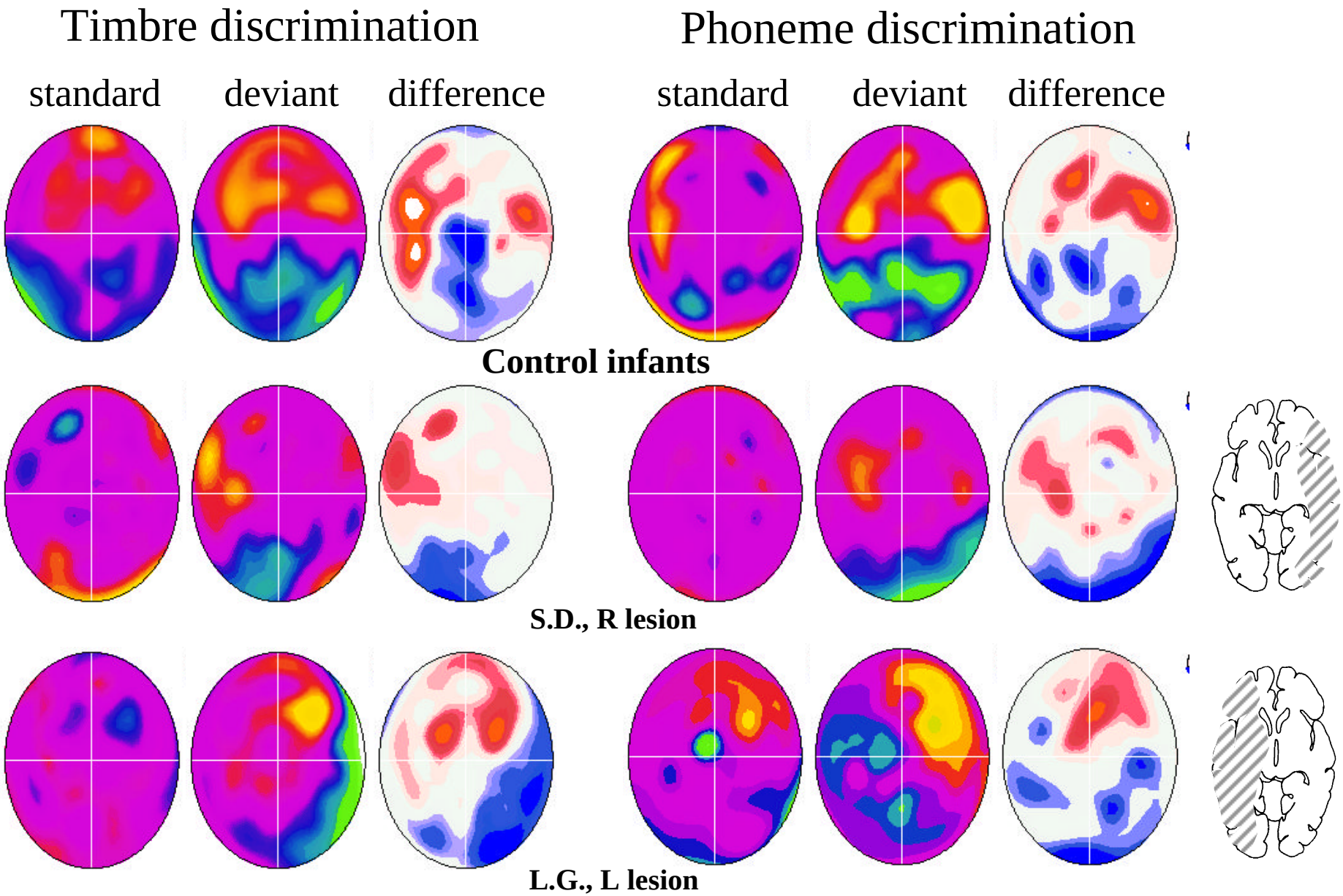
L.G.



Same latency for ERP for L.G. and controls.

Global field power

Discrimination Response in single subjects



Methodological conclusion: ERP and habituation-dishabituation.

- The habituation-dishabituation technique is not based on intrinsic properties of the electrical responses (e.g. N400 = semantic processing, P600 = response to syntactic violation). Rather, it is based on a functional description of the task.
- As a result, it allows us to compare subjects of different ages (where cortical organisation changes, thus modifying the shape and latency of electrical components).
- Moreover, one can use it to study brain-damaged individuals: again, the presence of a brain lesion can drastically change the shape and topography of the electrical responses, which is not a problem for this type of analysis.

ERP and single-subject testing:

- With ERPs and a passive task that demands no attention (works with sleeping newborns), one can test brain-damaged subjects, even though they would be completely unable to take part in a behavioral task.
- By repeatedly testing a single pathological individual, one can compute the same statistics than by testing a group of control, non-pathological subjects.

At present, I know of no behavioral study that yields individual results (even with test-retest, which has been attempted by some colleagues). In addition, they all require some amount of attention...

Word detection with infants: a variant of conditioned head-turning.

- Session 1: infants are trained to turn their head for ‘paper’ (background: *beacon*, target *paper*)

- Session 2: after warm-up trials, infants are tested on whole sentences:
  - containing *paper* (12):

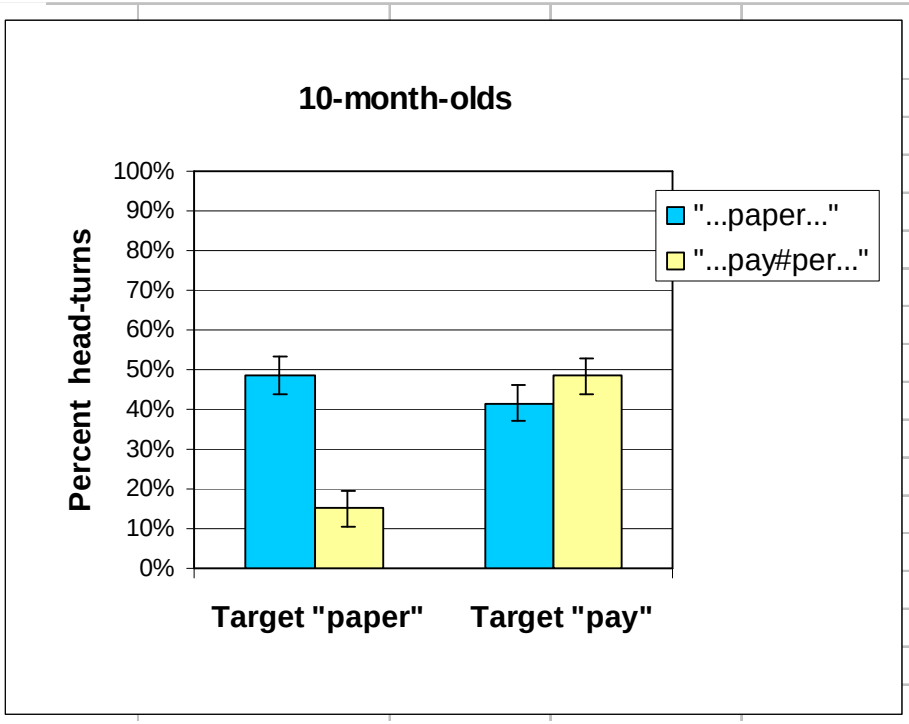
[The church] [with the most *paper* spires] [is heavenly].

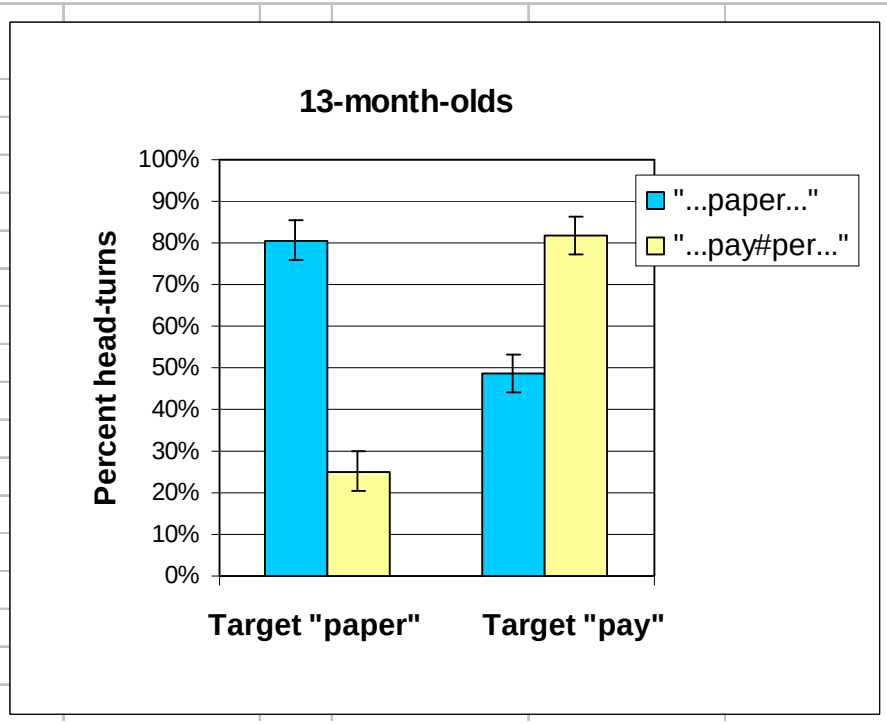
  - containing both syllables of *paper* (12):

[The man] [with the least *pay*] [*per*spires constantly].

  - distractor sentences (24).

Word detection: American infants





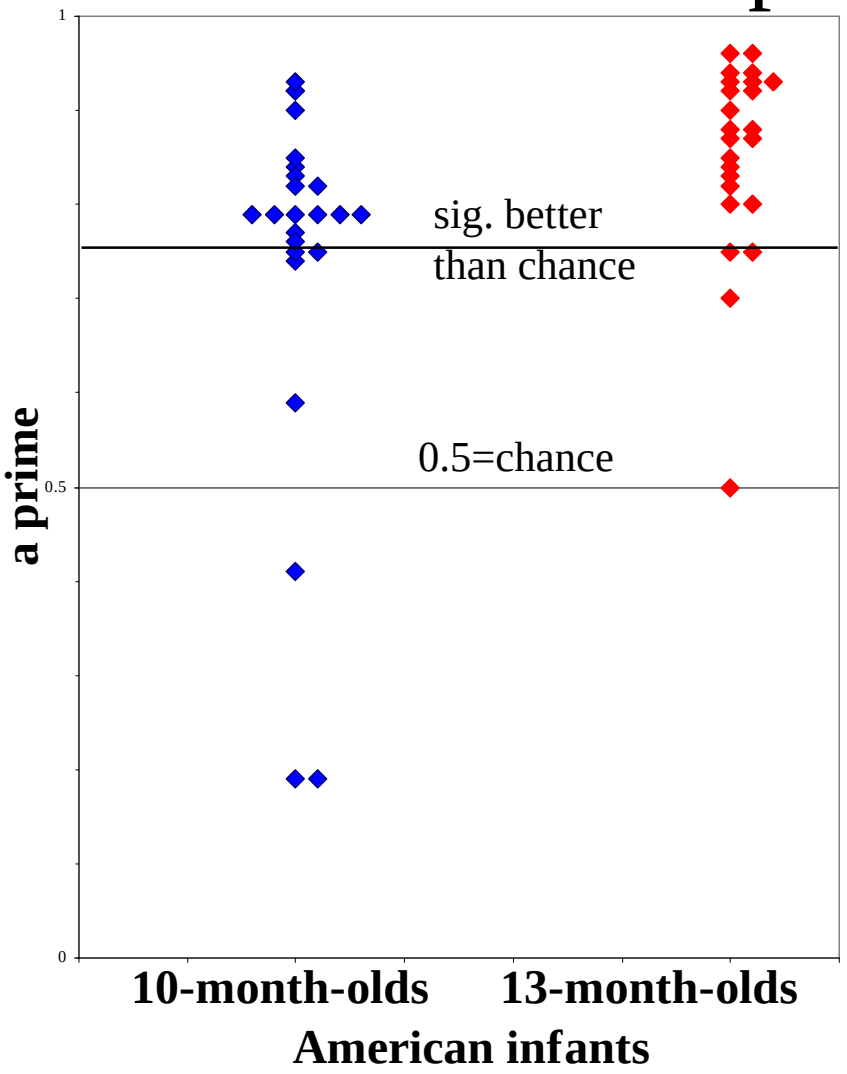
target = "paper": difference 34%, t(23)=7,1, $p<10^{-6}$
target = "pay": difference -7%, t(15)=-1.5, $p>0.1$
Interaction: $t(38)=5.8$, $p<10^{-6}$

target = "paper": difference 56%, t(23)=13.5, $p<10^{-11}$
target = "pay": difference -33%, t(15)=-5.5, $p<10^{-4}$
Interaction: $t(38)=12.5$, $p<10^{-14}$

[The church] [with the most *paper* spires] [is heavenly].
[The man] [with the least *pay*] [*per*spires constantly].

Gout, Christophe & Morgan (2004) *Journal of Memory and Language*

Individual results from word-detection experiments:



-10-month-olds: 21/ 24 infants in expected direction;

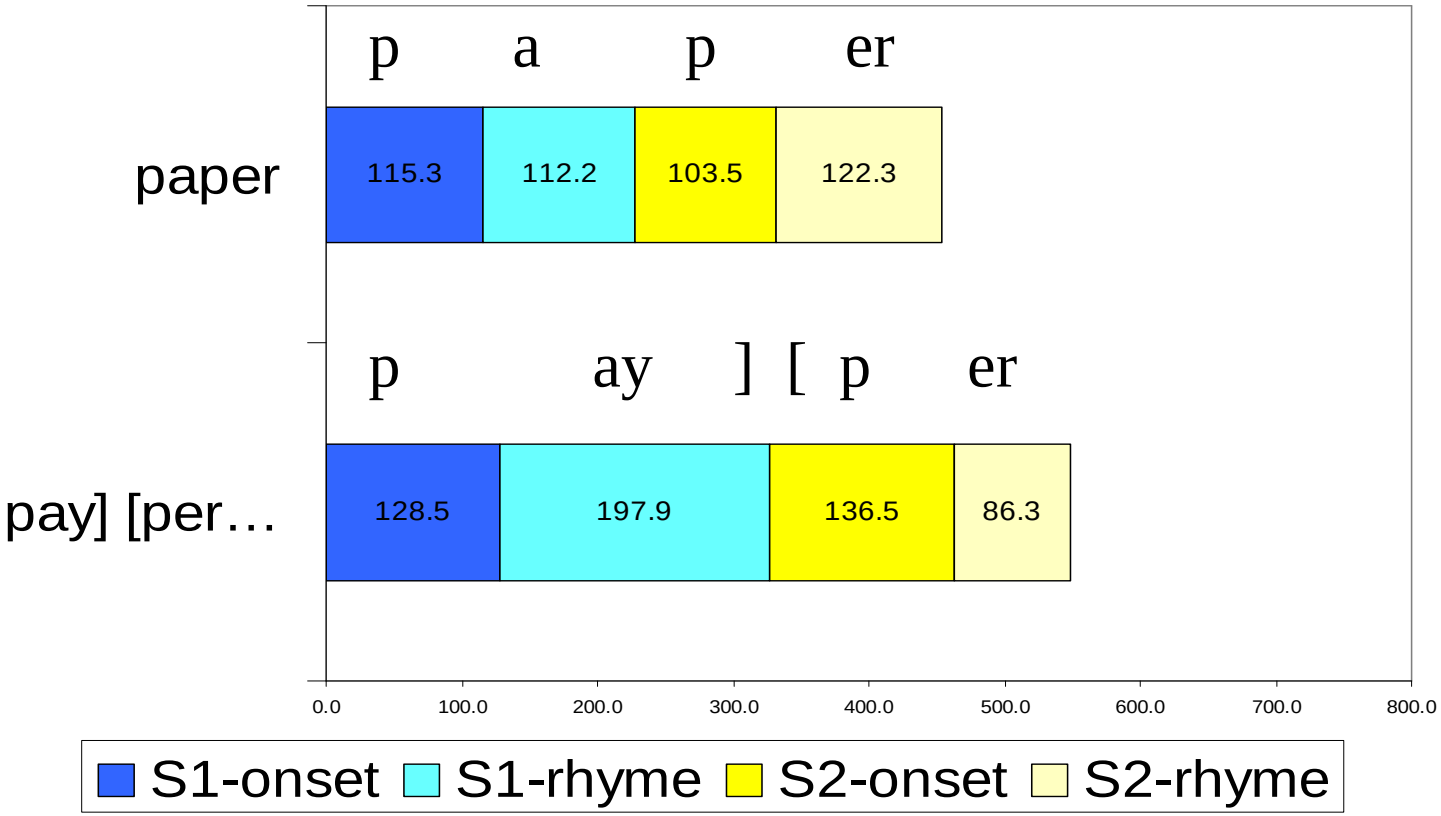
17/24 perform significantly above chance.

- 13-month-olds: 23/ 24 infants in expected direction

20/24 perform significantly above chance;

Gout, Christophe & Morgan (2004) *Journal of Memory and Language*

Prosodic influence of phi boundary



Word+phrase -final lengthening: 86 ms or 76%, $t(23)=8.6$, $p<0.001$

Word+phrase -initial lengthening: 33 ms or 32%, $t(23)=7.5$, $p<0.001$

Vowel onset to vowel onset: 132 ms or 61%, $t(23)=8.7$, $p<0.001$

Methodological comparison: ERP/ Behavioral technique

- Could we run the same experiment with ERP? Problem: high sensitivity to the acoustic properties of the stimuli: paper ≠ pay] [per therefore potentials are bound to be delayed in one condition relative to the other. How to interpret it?

- The word detection task allows us to obtain an explicit response from infants, for each sentence presented:
  - possible to run an item analysis
  - possible to analyse results from a single subject.

It is almost impossible to imagine an experimental design where the acoustic properties of stimuli are controlled across conditions.

Sanders, L. D., & Neville, H. J. (2000). Lexical, syntactic, and stress-pattern cues for speech segmentation. *Journal of Speech, Language, and Hearing Research*, *43*, 1301-1321.

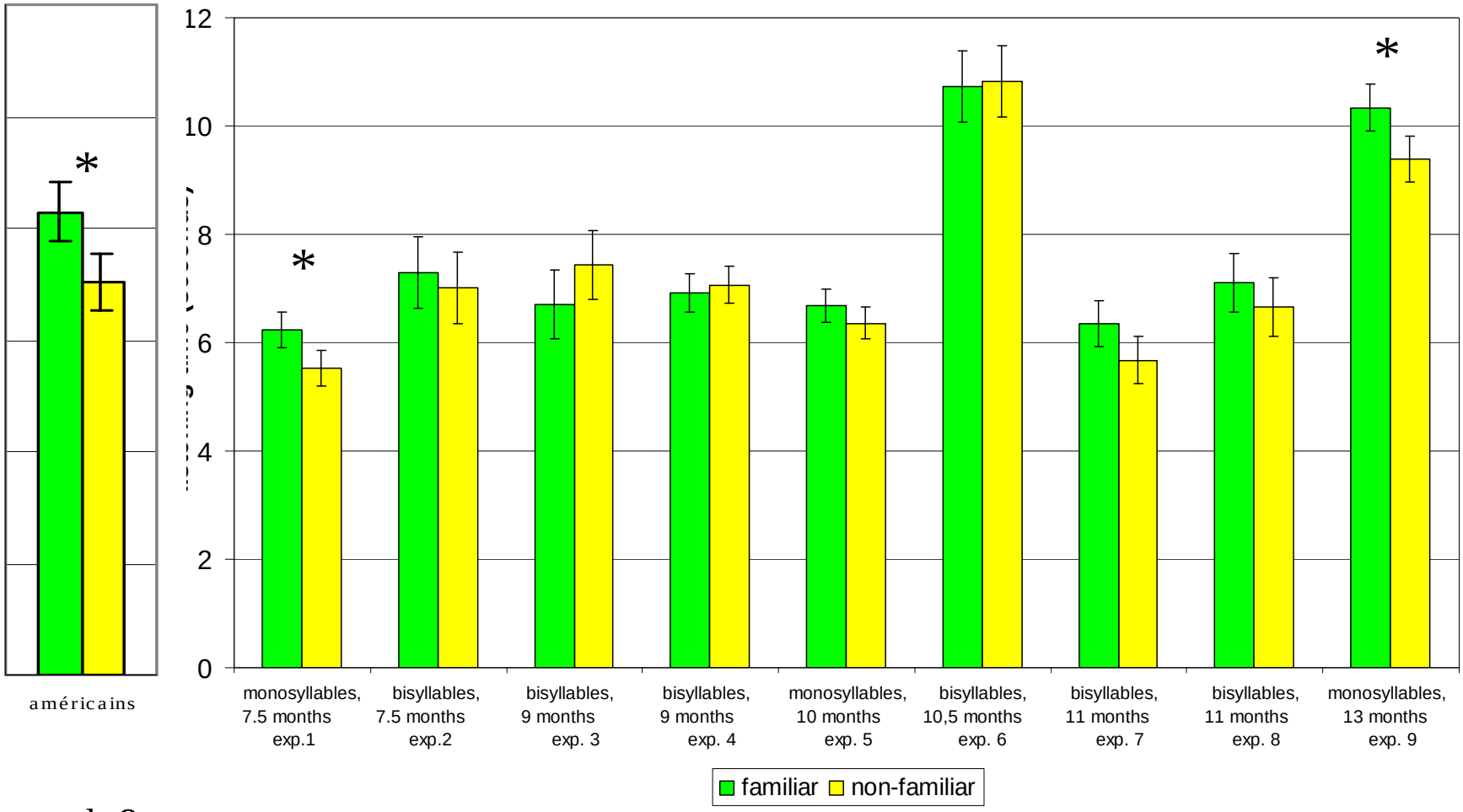
Another technique to test word segmentation: the Head-Turn Preference Procedure

Jusczyk & Aslin, 1995.

- Familiarization phase: infants listen to two words e.g. ‘bike’ and ‘cup’
- Test phase: infants listen to 4 types of passages, 2 containing the ‘ familiar ’ words (‘ bike ’ and ‘ cup ’) and 2 containing new words (‘ feet ’ and ‘ dog ’)

- Results: infants typically listen longer to passages containing familiar words.

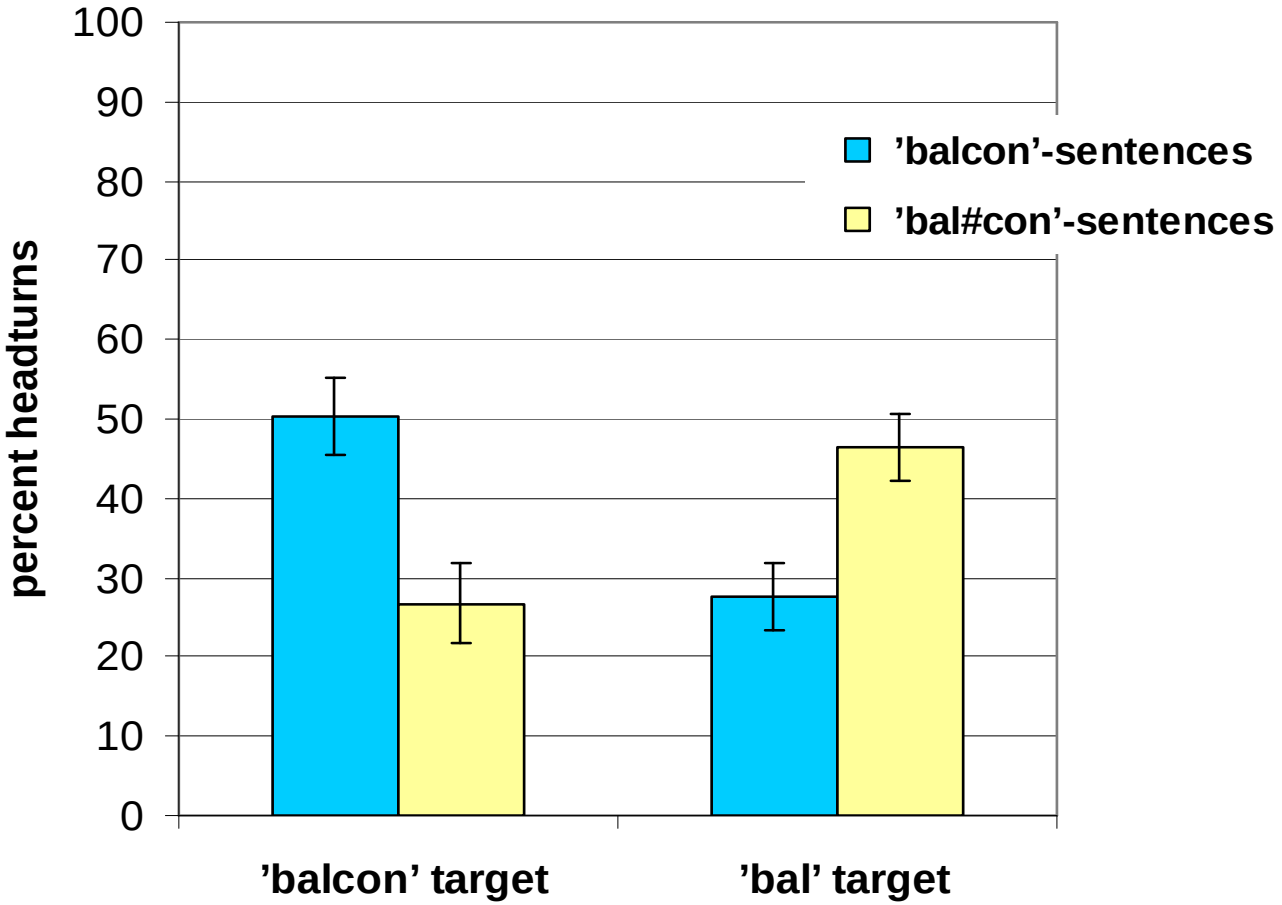
Word segmentation experiments with French infants using the Head-Turn Preference Procedure:



Jusczyk & Aslin, 1995

Gout, A. (2001) PhD thesis.

Word detection: French 16-month-olds

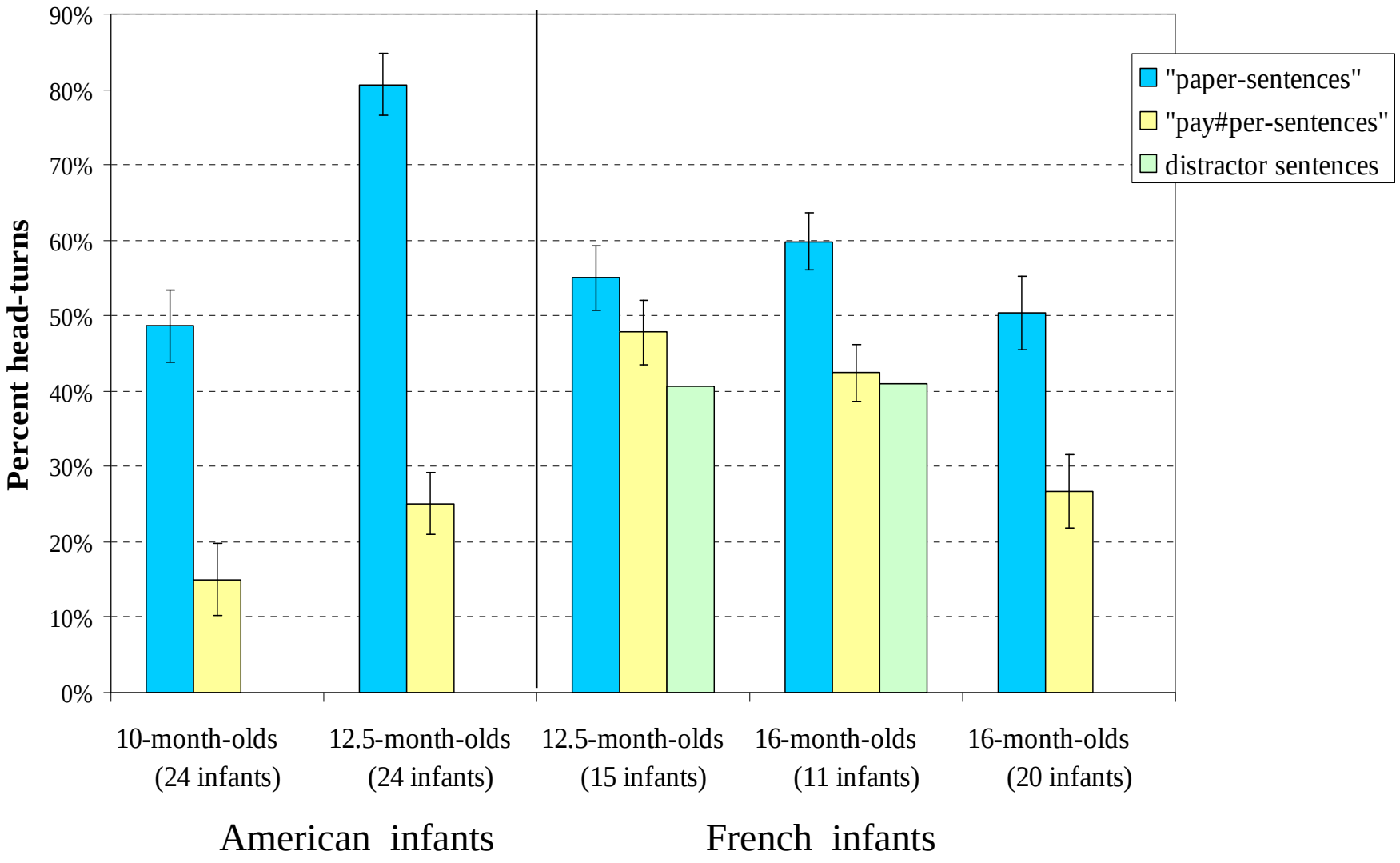


[La rangée de *balcons*] [fait face au cloître] [du monastère]

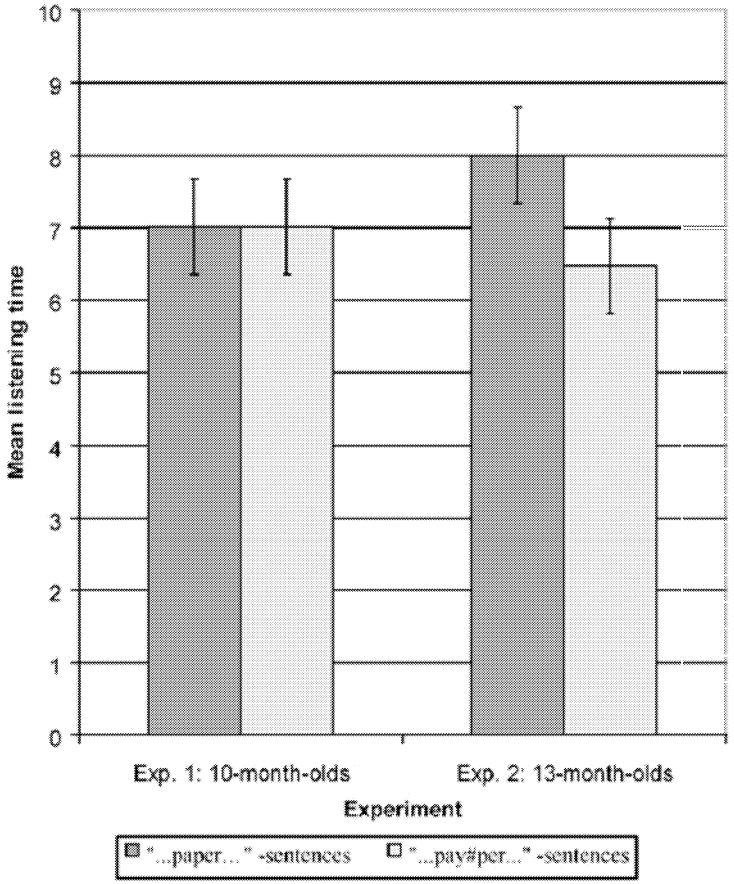
[La grande salle de *bal*] [*con*fère un air solennel] [au château].

Millotte, S. (2005) PhD thesis

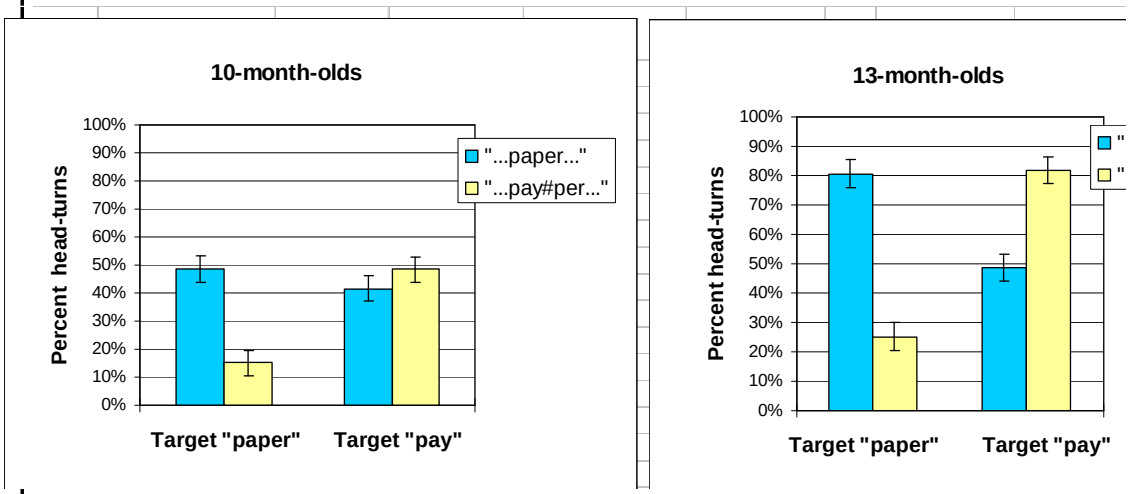
Comparison between French and American infants in the word-detection task:



Comparison between word detection and HPP, on *paper*-sentences:



Gout, Christophe & Morgan (2004) *Journal of Memory and Language*



Familiarized with 'paper' and 'beacon'

Test: 'paper' and 'beacon'-sentences (familiar)

vs 'pay#per' and 'bee#con'-sentences (new)

Methodological advantages of the word detection task:

- An active task, in which the infant *has to* pay attention (whereas you can pass HPP even if half-asleep).
- quantitative results:
  => adequate for comparison between infant groups: different ages, different maternal languages (better than "all-or-none" as in HPP)
- statistically robust results;
- possibility to measure *latencies*;
- possibility to do *item analyses*;
- potentially individual results:
  American 10-month-olds: 17/24 perform significantly above chance.
  American 13-month-olds: 20/24 perform significantly above chance;
- Drawbacks: difficult to use, high rejection rate: definitely not good for pathological subjects.

Aside: why do French infants segment words later than American infants?

Potential differences:

- Language processing itself: it may be harder to segment French sentences. For instance SW rhythm in American may help them focus on units smaller than whole phonological phrases, and pay attention to words earlier.
- Cultural differences: for instance, Americans use very exaggerated ‘motherese’ with slow speech rate and lots of pitch excursions. (Quebec/France? States/Britain?).
- Methodological (not too likely, given replication with different techniques, and different labs, also results from Thierry Nazzi, in Paris).

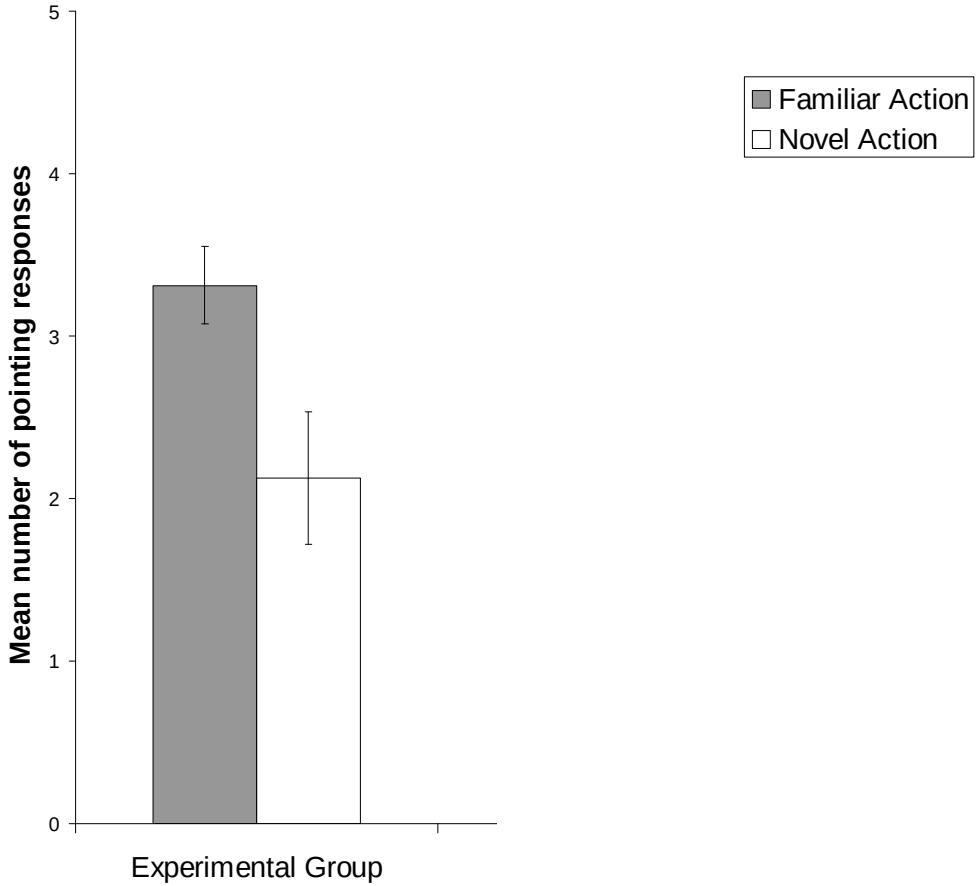
The pointing task:

(Can infants exploit the syntactic category of a new word to constrain its meaning?)

	Video	Audio
Familiarization	Apple turning	Regarde, elle dase ! (*look, it's dazzing*)
Test	Two apples, one turns, one does something else	Montre-moi celle qui dase ! (*show me the one that dazzes !*)

Response: pointing (infants are trained to point beforehand on known words, both objects and actions)

Results: 23-month-old French infants



Show me the one that dazzes!

Savita Bernal (2006). PhD thesis; in collaboration with Jeff Lidz.

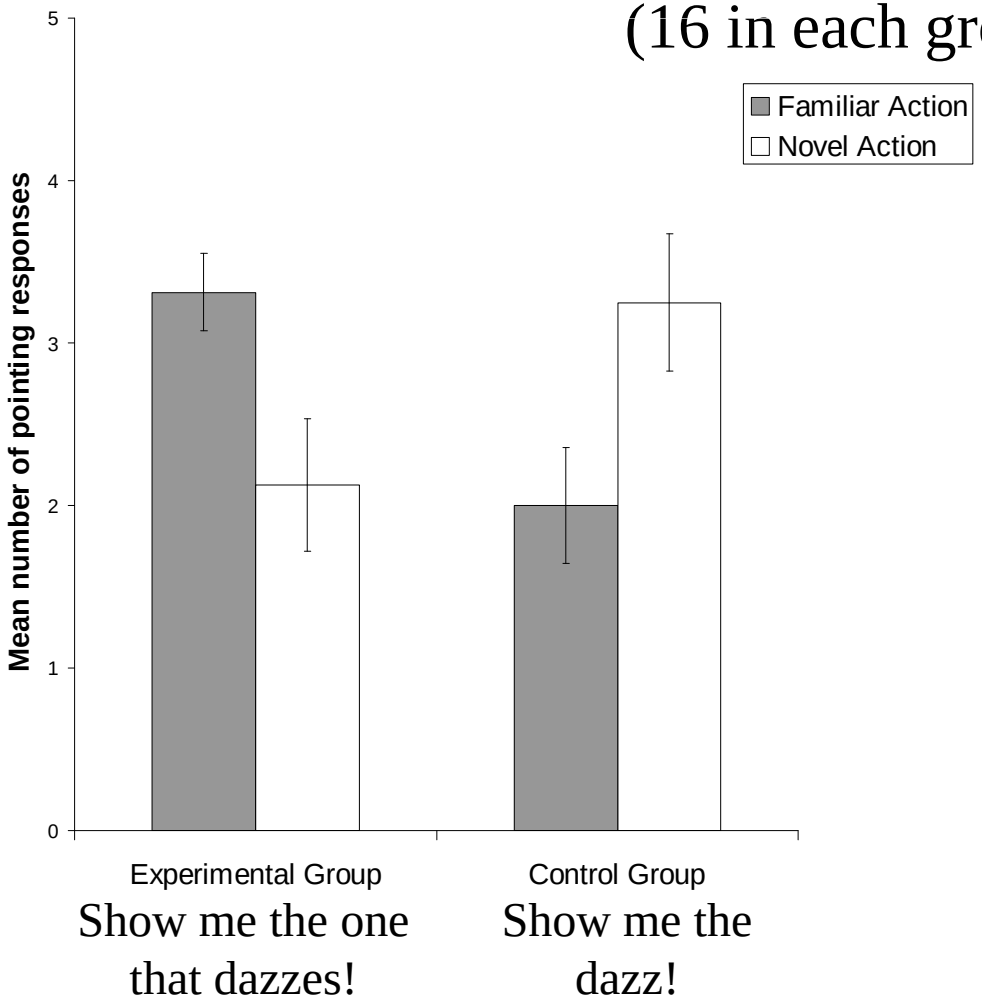
Bernal, Lidz, Millotte & Christophe (2007) Syntax constrains the acquisition of verb meaning. *Language Learning and Development*

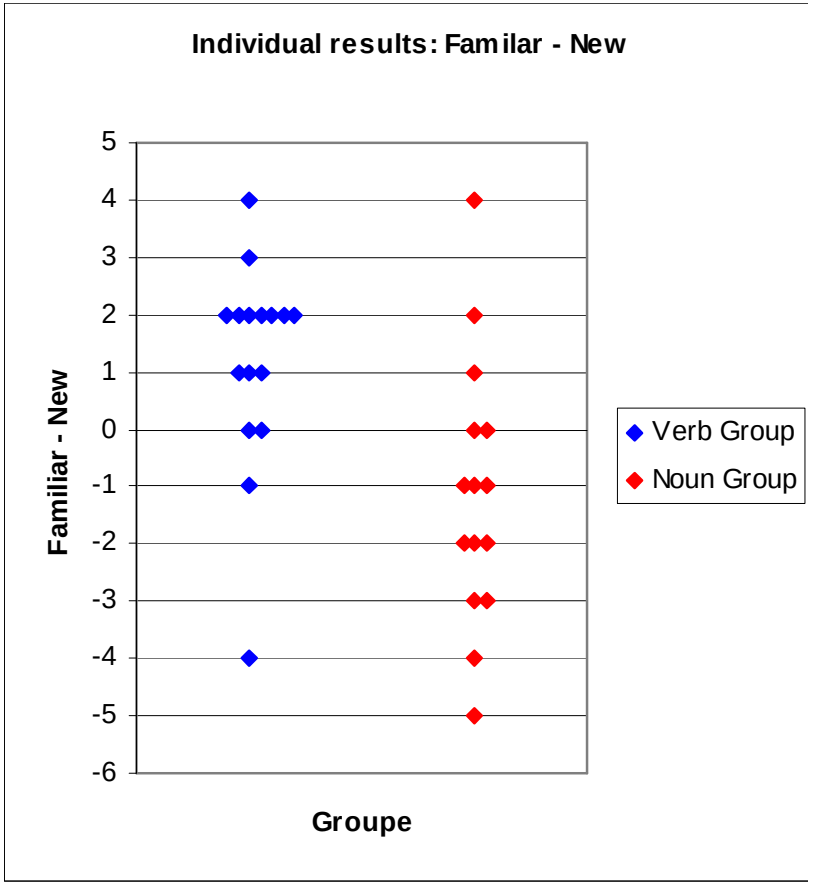
Control group:

	Video	Verb group	Noun group (control)
Familiarization	Apple turning	Regarde, elle dase ! *(look, it's dazzing !)*	Regarde la dase ! *(look at the dazz !)*
Test	Two apples, one turns, one does something else	Montre-moi celle qui dase ! *(show me the one that dazzes !)*	Montre-moi la dase ! *(show me the dazz !)* (stupid question)

Results: 23-month-old French infants

(16 in each group)

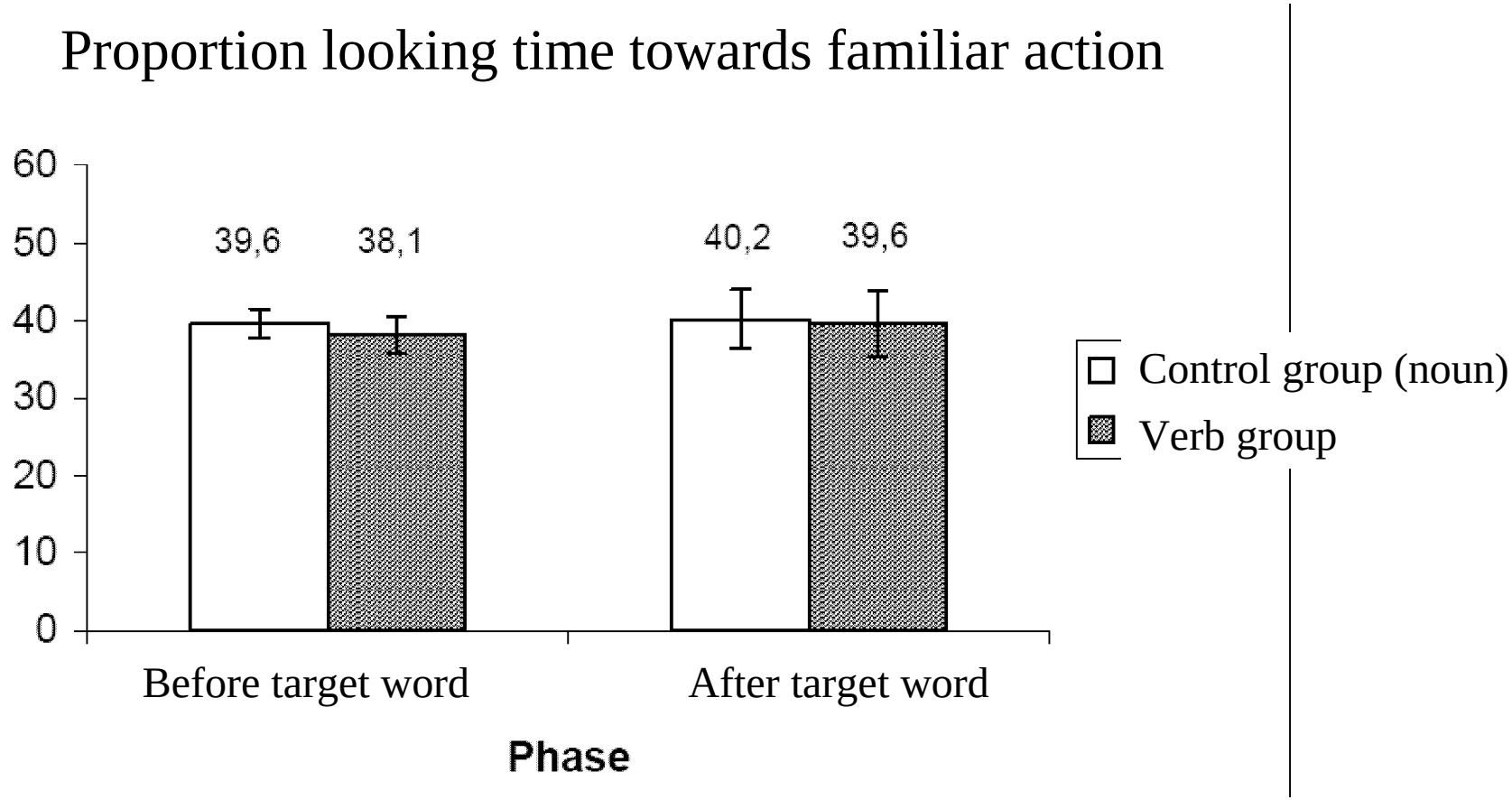




Interaction: $F(1,30)=11$, $p<0.005$

Bernal, Lidz, Millotte & Christophe (2007) Syntax constrains the acquisition of verb meaning. *Language Learning and Development.*

Same experiment in preferential looking:



Savita Bernal (2006) PhD thesis

Methodological advantages of the pointing task:

- An active task, in which the question asked 'show me the one that dazzes', allows the experimenter to test the meaning assigned by the child to the new word.
  Because the task is explicit, the response is non-ambiguous (as opposed to preferential looking)
- quantitative results:
  => adequate for comparison between infant groups (better than “all-or-none” as in preferential looking)
- statistically robust results (much better than preferential looking);
- possibility to measure latencies;
- Drawbacks: high rejection rate (some infants never point); does not work with younger infants. Definitely not good for pathological subjects.

Can 2-year-olds compute syntactic structure beyond simple transition probabilities?

	Syntactic category	
	Verb	Noun
Correct	Alors elle **la mange** *(Then she eats it)*	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 strawberry it)*

- No particular task: passive listening
- Use of known words only (from CDI questionnaire)
- To keep infants' attention focussed, 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.

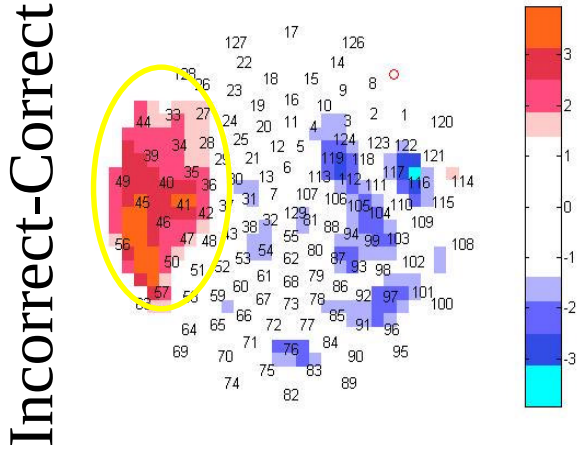
1. So the hen looks at her too.

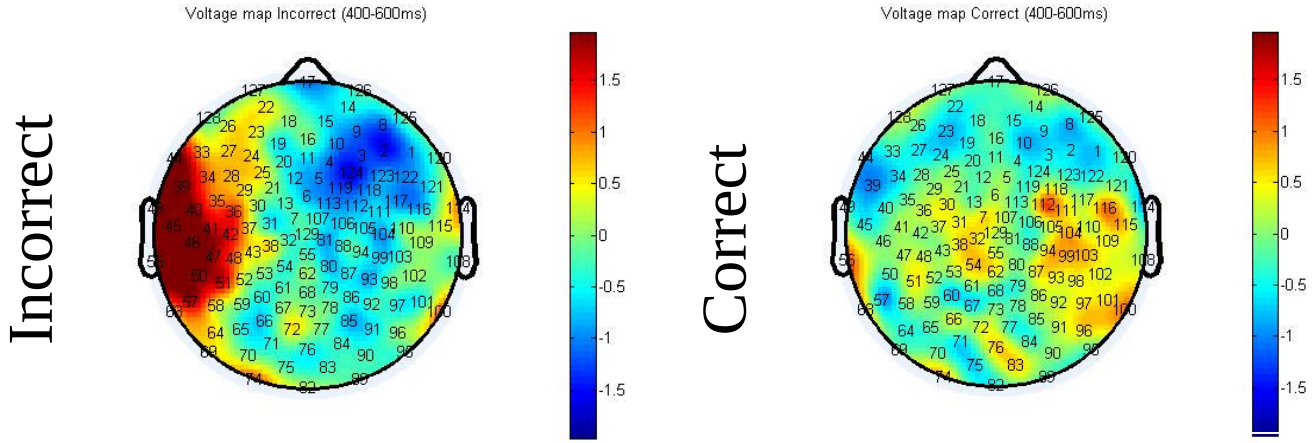
(Correct)

2. However, she giraffes it really fast!

(Incorrect)

2-year-olds detect the incorrect sentences





Incorrect

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

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

Correct

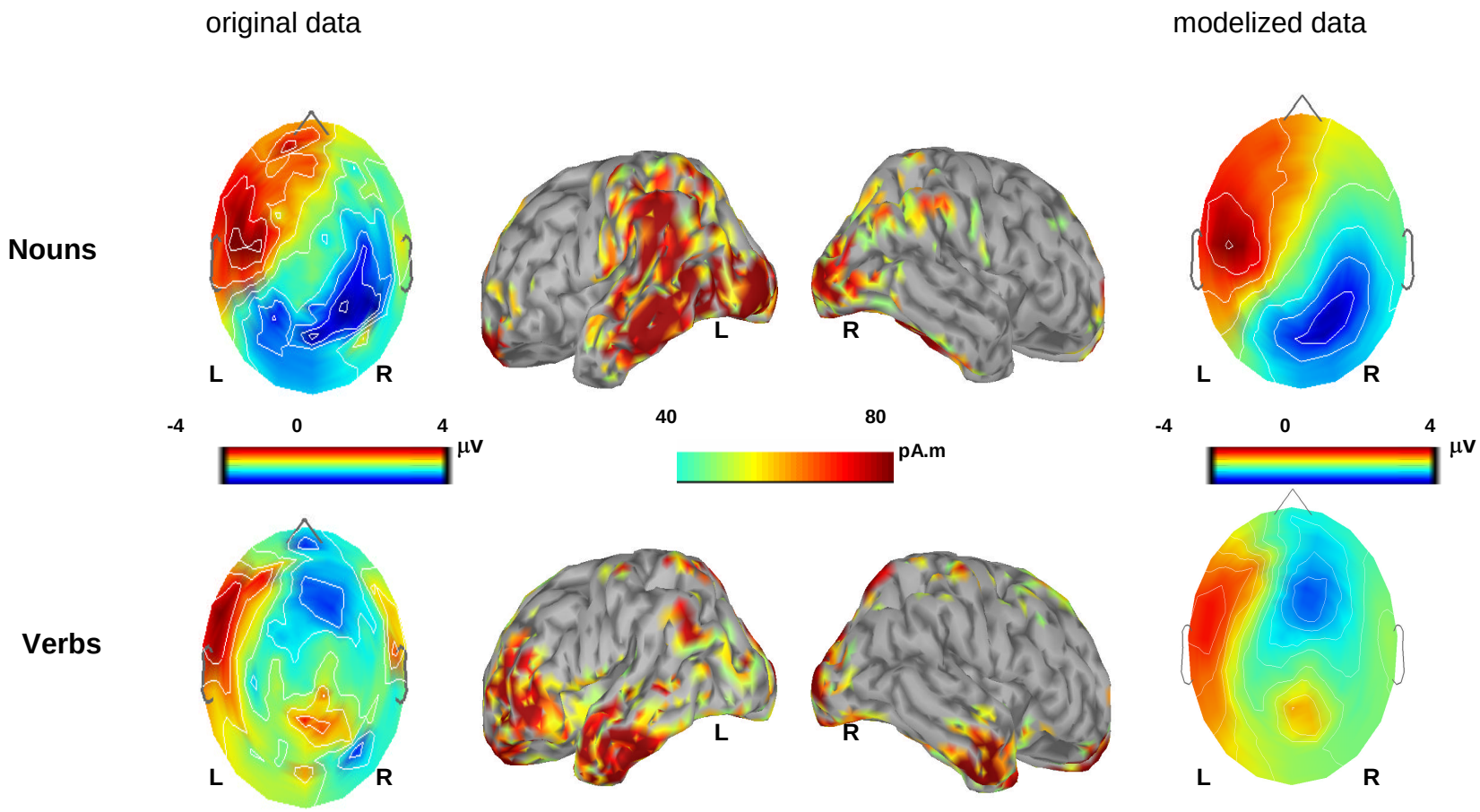
Alors elle **la mange**
(Then she eats it)

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

Savita Bernal (2006). PhD thesis.

Bernal, S., Dehaene-Lambertz, G., & Christophe, A. (submitted). Two-year-olds compute syntactic structure on-line. *PNAS*.

Distinct neural networks for nouns and verbs



Bernal, Dehaene-Lambertz & Christophe (submitted). Two-year-olds compute syntactic structure on-line *PNAS*.

Methodological comparison: ERP/ Behavioral technique

- ERPs show that infants react to the agrammaticality, even though the acoustic signal is similar between condition (e.g. 'la mange'), and the transition probabilities between pairs of words are all high.
- Could we test the same thing with a behavioral technique? Not easily done… Problem found in all studies of syntactic processing: it is difficult to get young children to perform a grammaticality judgement task (after age 3 years: 'truth-value-judgment task')

Additional result in ERPs: different neural networks involved for nouns and verbs.

Ccl: Methodological comparison: ERP/ Behavioral technique

ERPs:

Passive method =>
also works on sleeping or non-cooperative infants, also if one cannot find a way to ask the experimental question.

On-line method
(information on processing time)

Behavioral method:

Active task =>
explicit response asked from subject, facilitates the interpretation (the most explicit the response, the easier the interpretation).

Most methods give little information as to processing time.

Methodological comparison: ERP/ Behavioral technique

ERPs:

Possible to observe differences in response topography or latency, that can be interpreted.

High sensitivity to surface properties of the stimuli => necessary to control perfectly stimuli across conditions (not always feasible).

Behavioral technique:

'All-or-none response' (most often); e.g. discrimination Yes/No. (Note that some techniques give quantitative data).

Different experimental conditions can be easily compared; generalization to new conditions can be tested.

Take-home messages:

- Never assume that results obtained in another language should replicate 'by default'. Failure to replicate may either be due to a methodological difficulty, or to a genuine difference between languages.

- Select the methodology depending on the question asked, not the reverse. Be prepared to design your own methodology if none of the available ones are satisfactory.

Use of phonological phrases in on-line syntactic processing

- Locally ambiguous sentences
  - Verb sentence:

    [le petit chien] [mord la laisse] [qui le retient]…

    (*the little dog bites the leash that restrains it*)

  - Adjective sentence :

    [le petit chien mort] [sera enterré demain]…

    (*the little dead dog will be buried tomorrow…*)

→ Up to the ambiguous words: same phonemic content

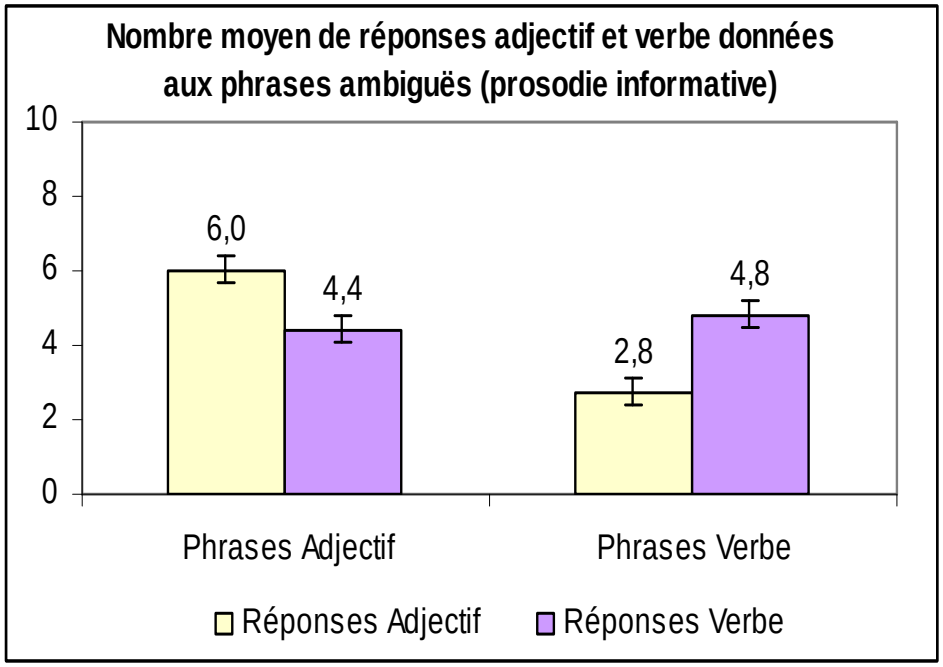
→ only difference: syntactic structure, and therefore prosodic structure

Are prosodic cues exploited on-line? Yes

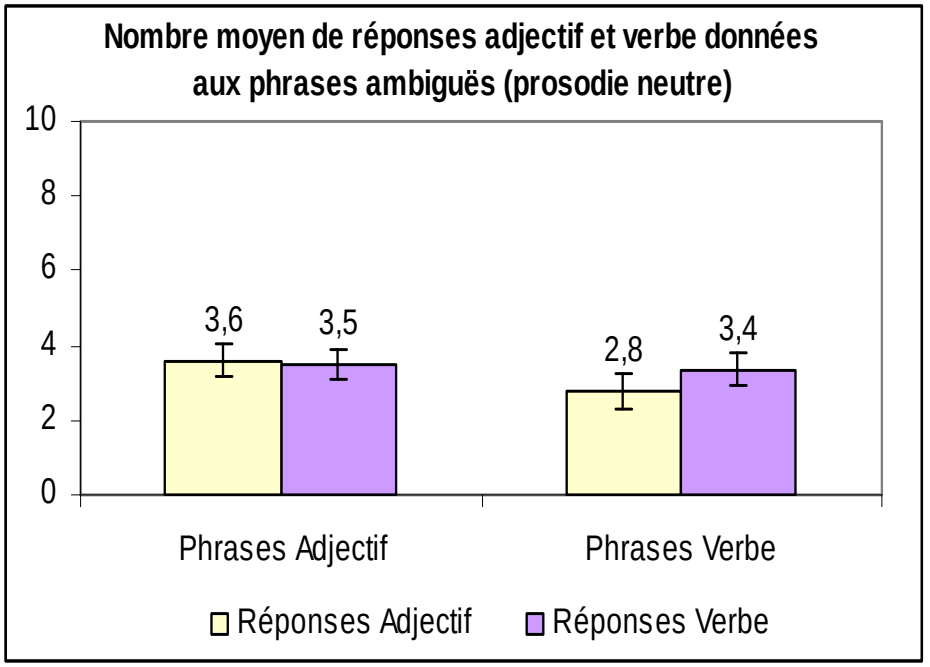
Task: abstract word detection; e.g. ’mordre’ (to bite)
respond to verb sentences, refrain from responding to adjective sentences

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

Informative prosody



Neutral prosody



Millotte, René, Wales & Christophe (in revision) *JEP: LMC*

Comparaison ERP/comportement:

- Pourrait-on faire la même expérience en ERP? Pas facile.. Pb d'acoustique, mord ≠ mort (à cause de position dans la structure prosodique)
  Mais aussi: quelle différence de potentiel attendrait-on pour un adjectif vs un verbe???
- La tâche de détection de mot permet de savoir en temps réel s'ils ont accédé au nom ou au verbe.

Même si on imaginait un moyen de contrôler les propriétés acoustiques des stimuli, il reste le problème du dessin expérimental. Réfléchi à : phrases 'chimérique' (début de l'une et fin de l'autre), on attend une erreur…