Testing the sensory hypothesis of the early left anterior negativity with auditory stimuli.

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Evan D. Bradley Arild Hestvik

Department of Linguistics and Cognitive Science
University of Delaware

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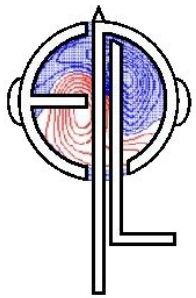


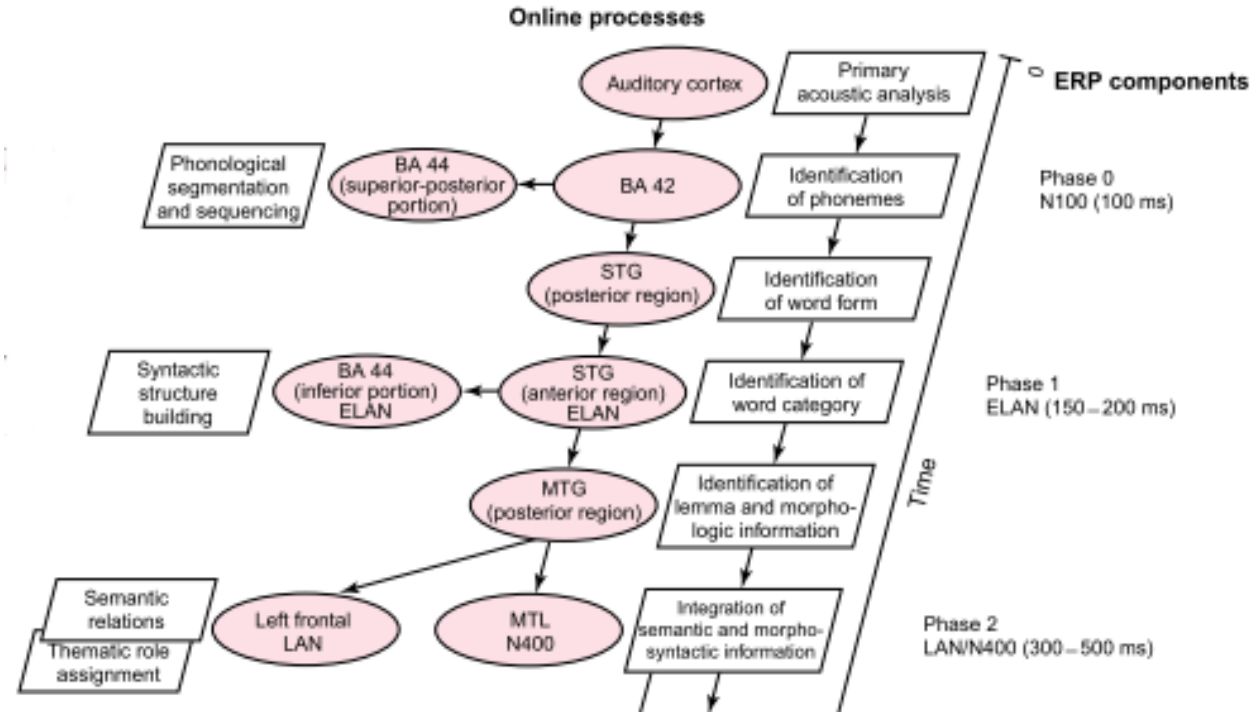
Outline

Early Left Anterior Negativity (ELAN)

- ERP associated with syntactic processing
- negative-going wave in left anterior electrodes
- as early as 120ms after unexpected of word category (Friederici et al., 1993), *inter alia*

ELAN

Serial processing model



(Friederici, 2002)

ELAN

- How can frontal, structure-building areas generate ELAN so quickly?
  - modulated by strength of expectancy (Lau et al., 2006)
  - indexes expectation violation rather than ungrammaticality *per se*

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Sensory hypothesis (Dikker et al., 2009b)

- indexes violation of *grammatically-generated* expectation about *physical* properties
- generated by sensory, rather than structure-building, brain structures

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Sensory hypothesis

Dikker et al. (2009b)

- previous ELAN findings used targets with closed-class functional morphology (1) (Friederici et al., 1993)

(1) * Das Baby wurde im gefüttert
the baby was in the fed

Sensory hypothesis

Dikker et al. (2009b)

- examined visual M100 MEG component
- M100 modulated by (2), but not (3)

(2) * The discovery was in the *reported*

(3) * The discovery was *report*

Sensory hypothesis

Dikker et al. (2009a)

- M100 modulated by phonologically typical nouns (4), but not less typical ones (5)
- no additional effect of morphology
  - suggests role of closed class morphology is to increase category typicality

(4) * The strongly *garlic* was used

(5) * The thickly *forest* was logged

Sensory hypothesis

corroborating evidence

- similar latency and topography to MMN (Pulvermüller and Shtyrov, 2003)
- 'syntactic MMN' elicited by morphosyntactic oddballs (auditory two-word phrases) (Herrmann et al., 2009)
  - generated in temporal cortex

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Intermediate Summary

Previous findings

- visual magnetic analogue of ELAN is:
  - sensitive to the presence of closed-class morphology
  - sensitive to the phonological form of targets
  - generated in visual cortex
- auditory MMN is sensitive to morphosyntactic information
- suggests auditory ELAN has a sensory basis

Intermediate Summary

Outstanding questions

1. how much does visual presentation tell us about the auditory ELAN?
2. do sMMN findings apply to real-time sentence processing?

Current goals

Examine sensory ELAN hypothesis:

1. during auditory processing of sentences
2. using ERP

Question

- does the presence of closed-class morphology modulate the ELAN response to syntactic category violations during real-time auditory sentence processing?

Predictions

if auditory cortex differentiates between categories based on form typicality enhanced by morphology, then:

1. ELAN will occur for category violations which are signaled by a functional morpheme (6) and not for those which lack it (7)
2. unexpected targets without such morphology cannot be diagnosed as quickly, and will be indexed by a later component
3. if ELAN indexes general failure of syntactic structure building, a similar response to each target is expected

(6) * The dog that the cat kissed *the turtle* on the nose ran far away

(7) * The dog that the cat kissed *turtles* on the nose ran far away

Experiment

Design

- two experiments:
  1. unexpected phrases introduced by closed-class morphology
  2. unexpected phrases without such morphology

Experiment 1

Stimuli

- filled-gap sentences based on Hestvik et al. (2007)
- (8) previously shown to elicit ELAN vs. control (9)
- frequency of each sentence type was 16.7% with fillers
- synthesized using *ModelTalker* text-to-speech system

(8) * The dog that the cat kissed *the turtle* on the nose ran far away

(9) The day that the cat kissed *the turtle* on the nose, they ran far away

Experiment 1

Subjects

- 18 adults (10 female)
- age 19–28

Experiment 1

Procedure

- auditory sentence presentation using E-Prime
- 2AFC comprehension questions (natural speech) with visual feedback
- 64 trials in test and control conditions (384 total trials per subject)
- 128-channel EEG acquired at 250Hz (EGI Geodesic Sensor Net)

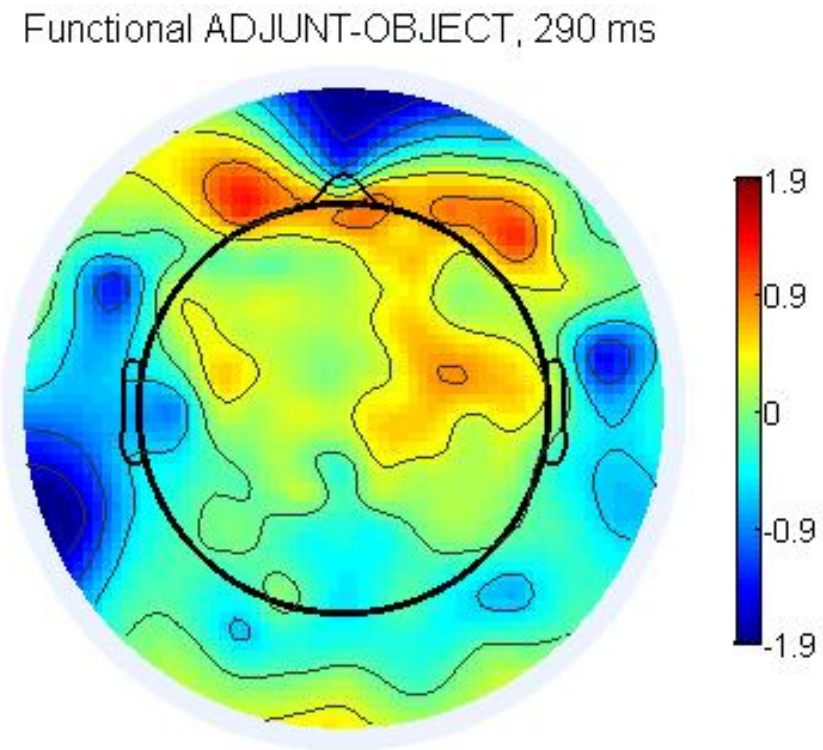
Experiment 1

Analysis

- 1000ms epochs with a 200ms baseline period
- synchronized to the onset of the first word following the relative clause verb
- bad channels replaced using spherical spline interpolation, baselines corrected
- trials containing eye blinks or artifacts discarded
  - two subjects eliminated due to excessive artifacts ($>$ 50% of trials)

Results

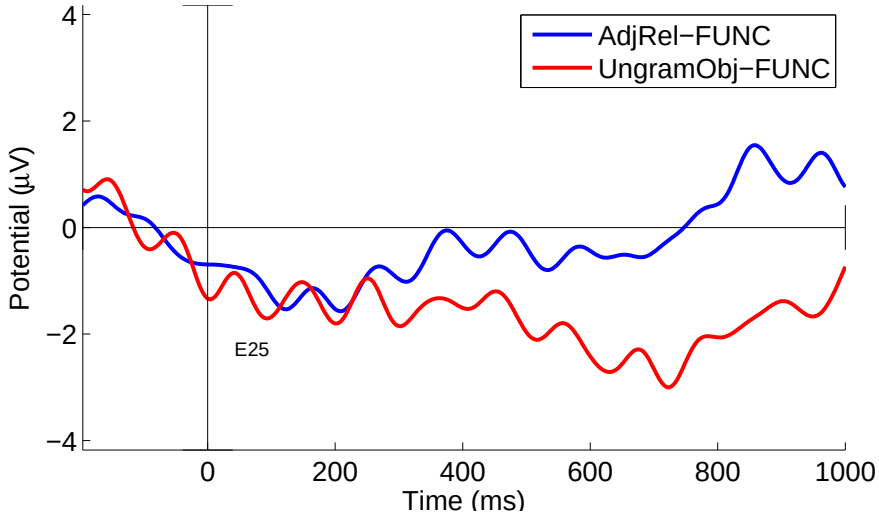
Anterior Negativity

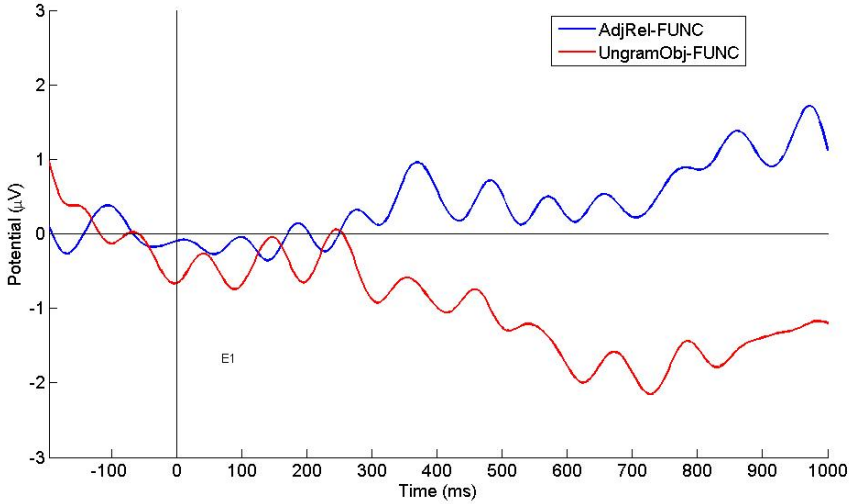


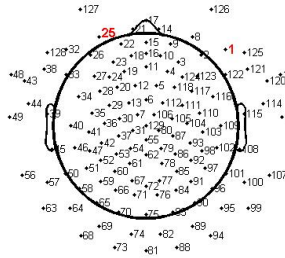
- CONDx20ms time bin ANOVA sig. over peak electrode, 240–440ms, $p < .05$

Results

Anterior Negativity

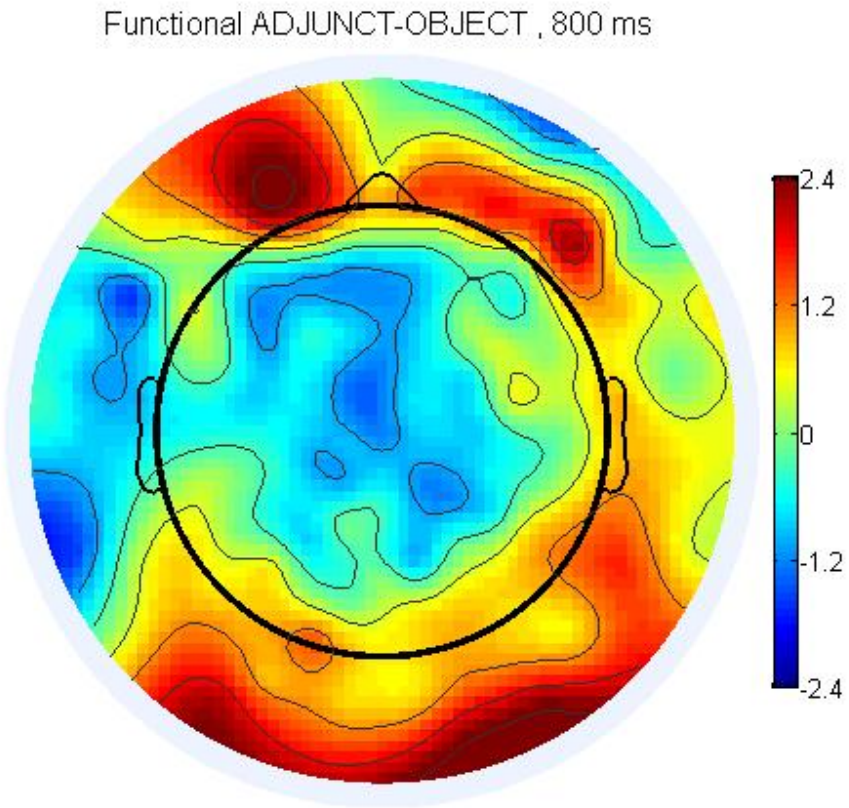






Results

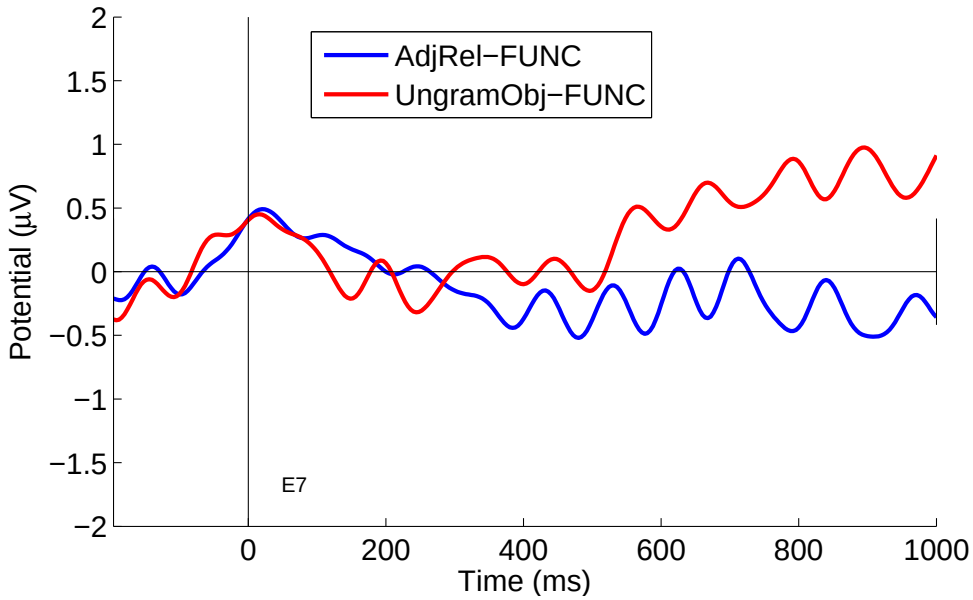
Central Positivity

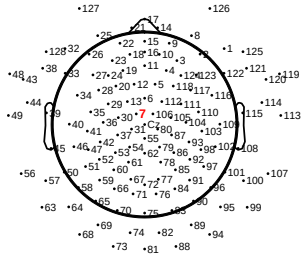


- CONDx20ms time bin ANOVA sig. over peak electrodes, 500–700ms, $p < .01$

Results

Central Positivity





Discussion

Anterior Negativity

- latency is longer than typical ELAN
- more consistent with LAN
- associated with syntactic dependency resolution (Kluender and Kutas, 1993)

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Central Positivity

- consistent with P600
- associated with syntactic reanalysis/repair

Experiment 2

- Procedure and analysis identical to Experiment 1

Experiment 2

Stimuli

- Experiment 1 sentences with plural NP instead of *the* phrase:

(10) * The dog that the cat kissed *turtles* on the nose ran far away

(11) The day that the cat kissed *turtles* on the nose, they ran far away

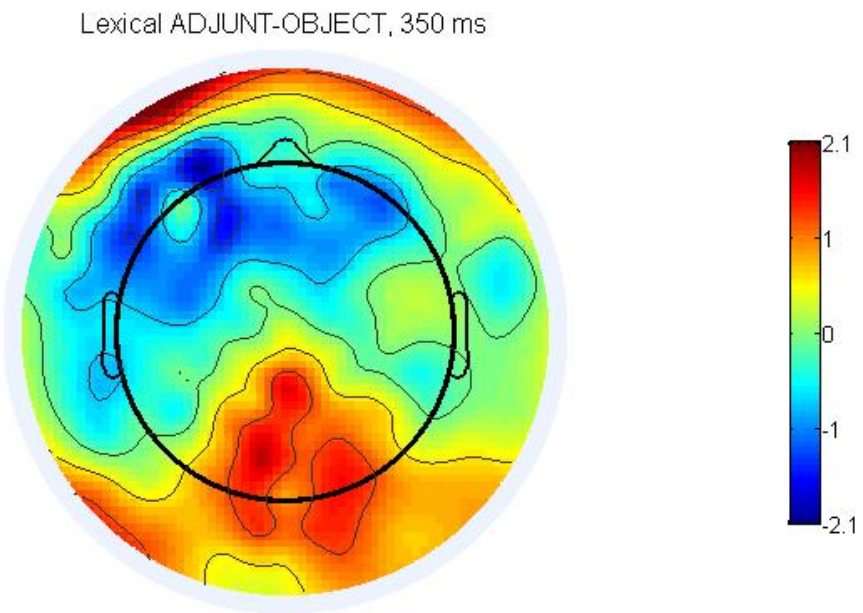
Experiment 2

Subjects

- 17 adults (10 female)
- age 19–38
- three eliminated due to artifacts

Experiment 2

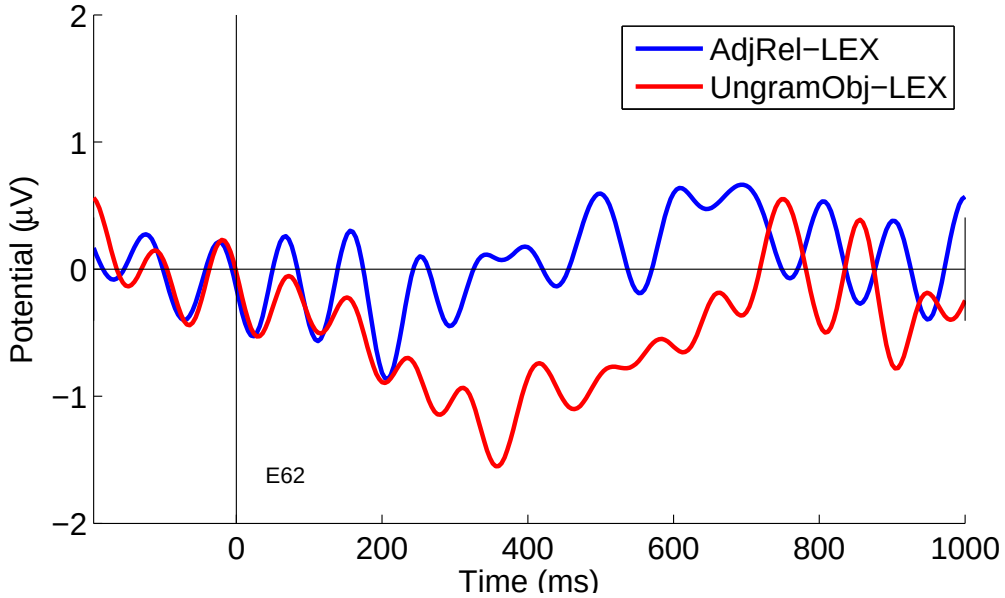
Results

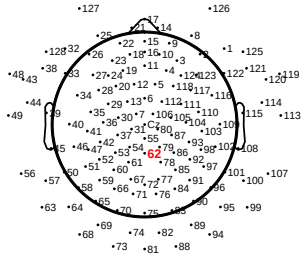


- CONDx20ms time bin ANOVA sig. over peak electrode, 300–500ms, $p < .01$

Experiment 2

Results





Experiment 2

Discussion

- consistent with N400
- associated with semantic integration
- suggests processing of content, as well as category

General Discussion

whither ELAN?

- synthetic speech?
- attention?
- ELAN to these sentences sensitive to frequency (Hestvik et al., 2009)

General Discussion

whence N400?

- targets are not violations of *strictly local* phrase structure
- key is strength of expectation and availability of cues

General Discussion

the Sensory Hypothesis

- N400 suggests slower recognition of bare NP targets
- suggests difficulty incorporating the 'extra' NP into argument structure
- our speculation:
  - *the* NP targets allow form-based recognition of syntactic errors
  - parsing is abandoned as soon as offending morphology is encountered
  - category of bare NPs cannot be determined until whole word is heard
  - argument structure integration proceds anyway

Summary

- filled-gap NPs introduced by overt closed-class functional morphology elicit syntactic components
- filled-gap NPs without such morphology elicit a later semantic component
- results support components of the sensory ELAN hypothesis in the auditory domain to the extent that
  1. an earlier response is elicited when the target is introduced by an acoustically salient functional category
  2. qualitatively different components are elicited by structural violations dependent on the form of targets

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Selected references

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