Suprasegmental features in lexical processing – insights from ERP research

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EEG research on stress

1. Stress as a bundle of features

- pitch
- vowel reduction
- duration
- intensity
- spectral tilt

EEG research on stress

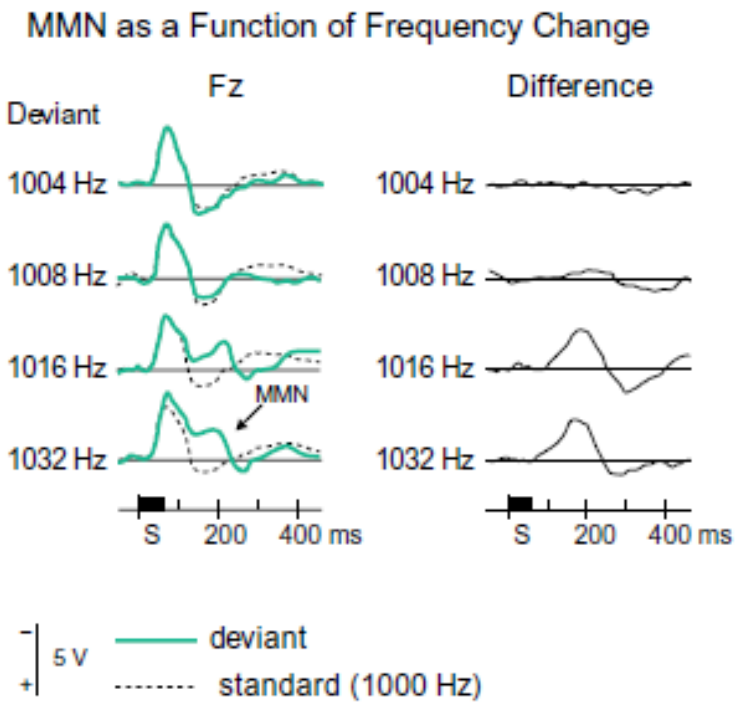
1. **Stress as a bundle of features**
   - pitch
   - vowel reduction
   - duration
   - intensity
   - spectral tilt

2. **Stress as an abstract category**

EEG research on stress

1. MMN

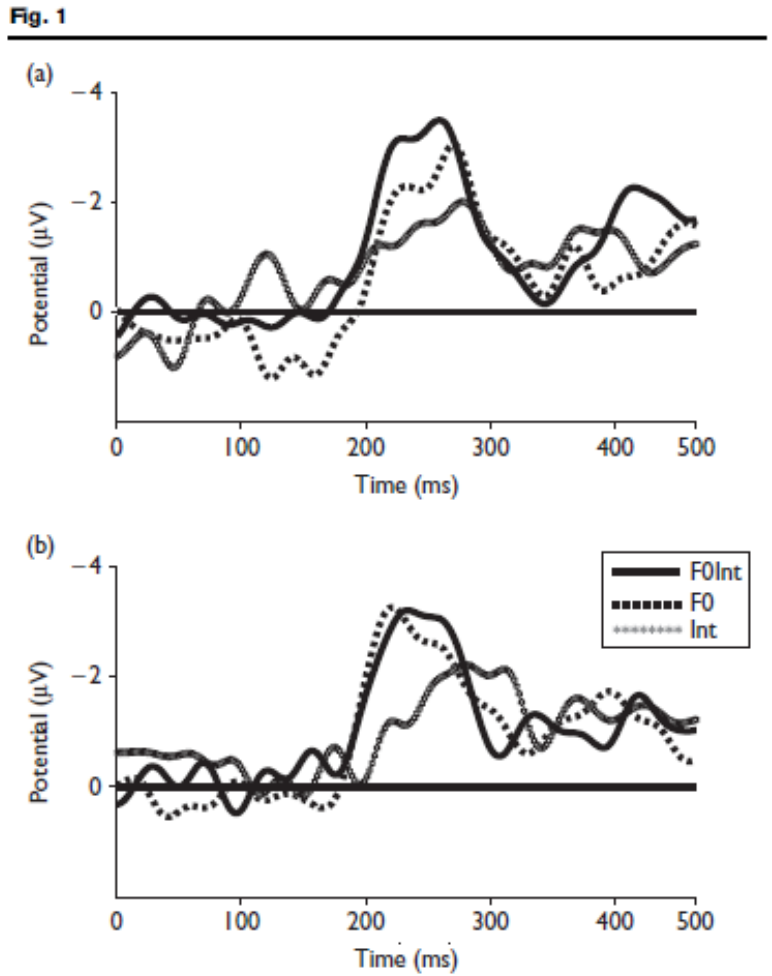
- Naatanen et al. 2007 (acoustic processing)



EEG research on stress

1. MMN

- Zora et al. 2016 (individual and cumulative stress cues)



EEG research on stress

1. MMN

- Honbolygo & Csepe 2013 (evidence for long-term representation of word stress)

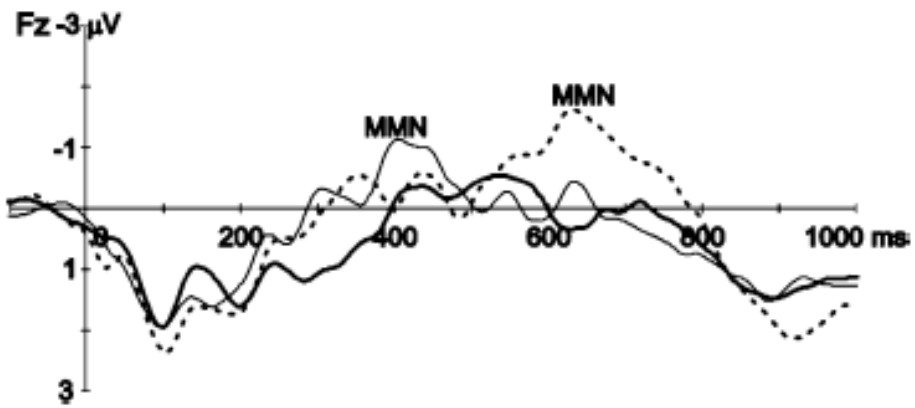


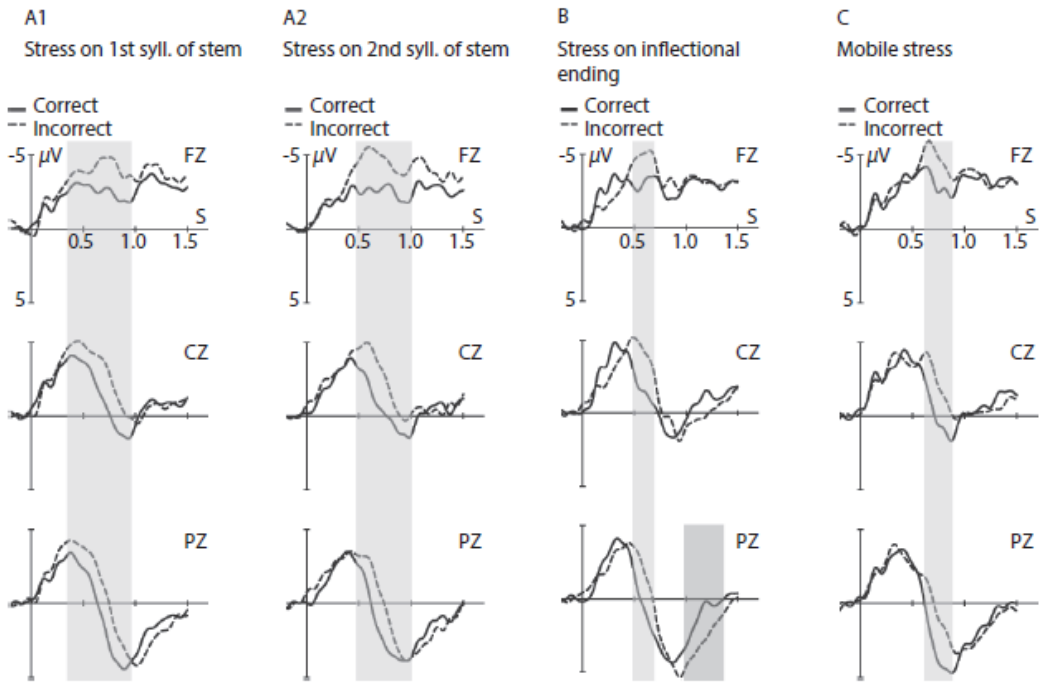
Fig. 2. Grand average ERPs to the standard (thick line), phoneme deviant (thin line) and stress deviant (dotted line) stimuli on Fz. Negativity is plotted upward and the curve is low-pass filtered with 20 Hz here and in the following figures.

2. PMN

- Connolly & Phillips 1994 – fronto-central negativity peaking between 250 and 350 ms post-stimulus onset; reflects pre-lexical processing cost of expectation-violating phonemic information

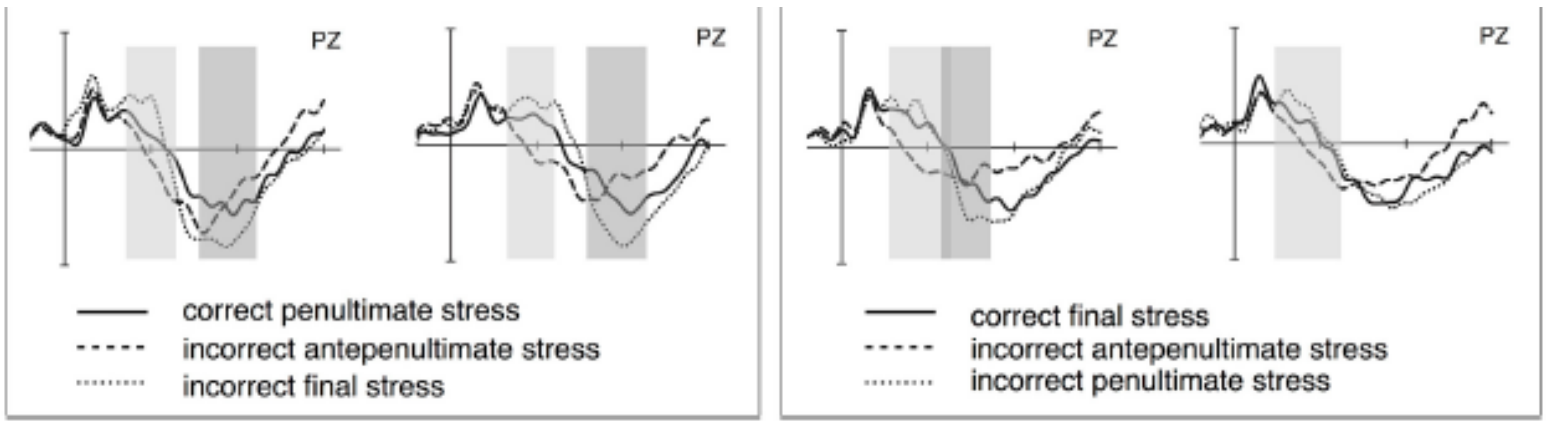
3. N400

- Molczanow et al. - lexical stress in Russian



4. P300

- e.g. Domahs et al. (2016) – biphasic response to incorrect stress in Arabic



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Spanish stress – phonology

- a language with variable stress
- prevalence of one stress pattern over the others: partial stress predictability
- Spanish speakers not stress-deaf

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– Harris, J. (1969). Spanish phonology.
– Roca, I. (2006). The Spanish stress window.
– Pineros, C-E. (2016). The phonological weight of Spanish syllables.
– Bakovic, E. (2016). Exceptionality in Spanish stress.
– Martinez Paricio, V. & Torres-Tamarit, F. (2018). Trisyllabic hypocoristics in Spanish and layered feet.

Focus of the experiments

Spanish stress – statistics

- over 64% (78.9%) of all Spanish words are stressed on the penultimate syllable (Morales-Front 2014, Quilis 1981)
- antepenults constitute merely 8% (or 2.76%): exceptional
- the majority of words learned in infancy are trochees
- In conclusion: default penult pattern derivable by rules, with lexical exceptions

Focus of the experiments

Spanish stress - phonetic correlates

- **Llisterii et al. (2003)** – F0 contour alone is not enough to allow the identification of the stressed syllable
- In combination with duration, intensity or both, F0 is a relevant acoustic cue.
- Intensity and/or duration are not sufficient for the identification of a stressed syllable

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- **P. Prieto, M. Ortega-Llebaria (2006)** – syllable duration, vowel quality, and spectral tilt are reliable acoustic correlates of stress
- Accentual differences are acoustically marked by overall intensity cues

Focus of the experiment

Spanish stress - phonetic correlates

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- **Torreira, F., Simonet, M., & Hualde, J.I. (2014)** – durational and intensity cues to stress are produced by speakers and used by listeners above chance level
- Substantial amounts of phonetic overlap between stress categories in production, numerous errors in the identification
- In the absence of intonational cues, Spanish speakers must rely on context

Experiment 1

Experiment 1

Materials and procedure

video:
sand on glass

[fábula]

(standard)
probability: 74.5%
N=870

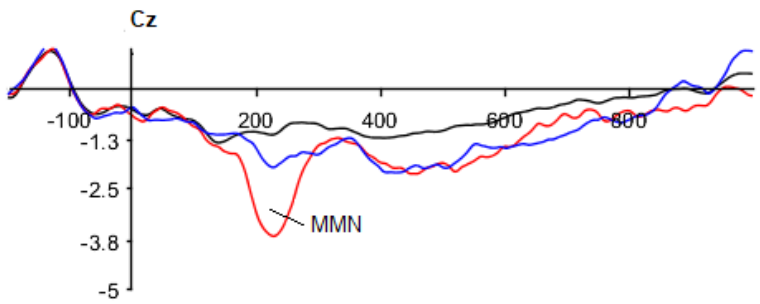
[fabulá] ST
[fabulá] F0
[fúbula] V

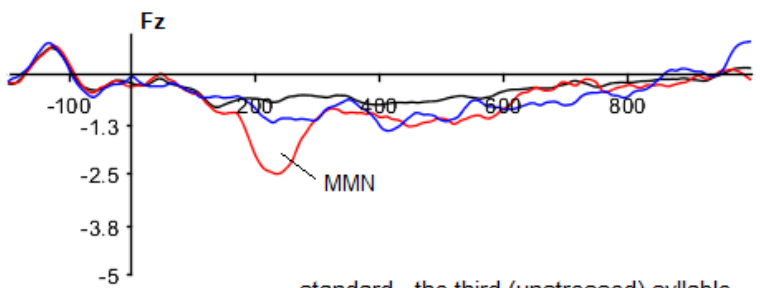
deviants
probability: 8.5%
N=100

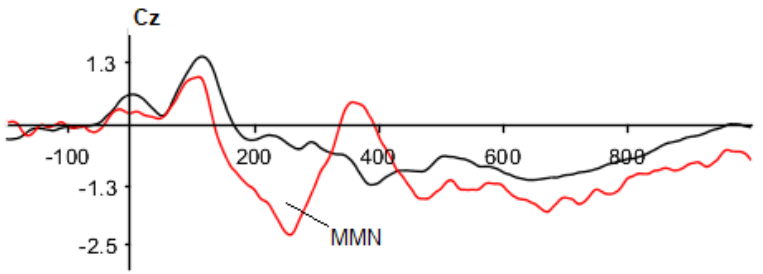
ITI: 500-600 ms

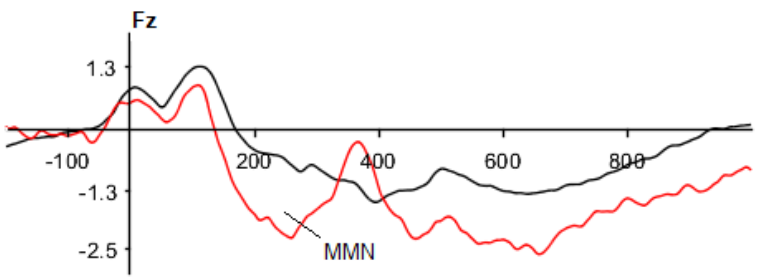
Experiment 1

Results









standard - the third (unstressed) syllable

deviant - the third syllable stressed by changing the F0

deviant - the third syllable stressed by changing spectral tilt

standard - the first (stressed) vowel /a/

deviant - the first (stressed) vowel with /a/ changed to /u/

Experiment 1

Results

- F0: strong MMN effect around 200 ms from syllable onset ($F = 38.2$, $p < 0.001$)
- vowel swap: strong MMN effect around 200 ms from vowel onset ($F = 22.04$, $p < 0.01$)
- spectral tilt: no MMN effect ($F = 4.87$, $p = 0.0584$)

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- F0 confirmed as an important stress cue in Spanish
- Mixed results on intensity from previous studies may be due to mixture of several cues is necessary for stress information to be perceived correctly – see Experiment 2

Experiment 2

Experiment 2

Materials and procedure

- 32 Spanish natives aged 20-35
- N400 paradigm: N = 240
- correctly and incorrectly stressed trisyllabic words
- 60 CV.CV.CV penults and 60 antepenults of matching frequencies x 2
- invariable carrier sentence
- controlled for phonological neighbours
- Task: correctness judgement

Stimuli

seMAna (PUs – standard)

PAjaro (APUs – standard)

SEmana (PUd – deviant)

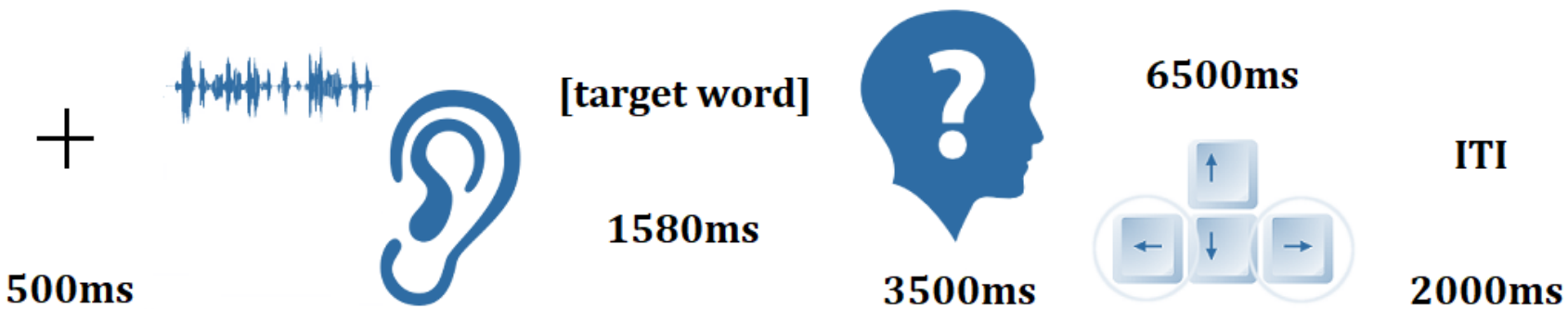
paJAro (APUd – deviant)

carrier sentence:

[name] pronunció la palabra [target word] *otra vez*

Experiment 2

Procedure



Experiment 2

Results – accuracy

- threshold was 75% (ensure comprehension, SNR)
- average of 9 misses in the experiment
- significant effect of condition ($p = 0.0235$) but not stress pattern
- Bonferroni-corrected: significant difference between APUd and both APUs and PUs ($p = 0.002055$, $p = 0.000894$)
- **APUd condition is especially difficult and caused most errors in stress correctness detection**

Experiment 2

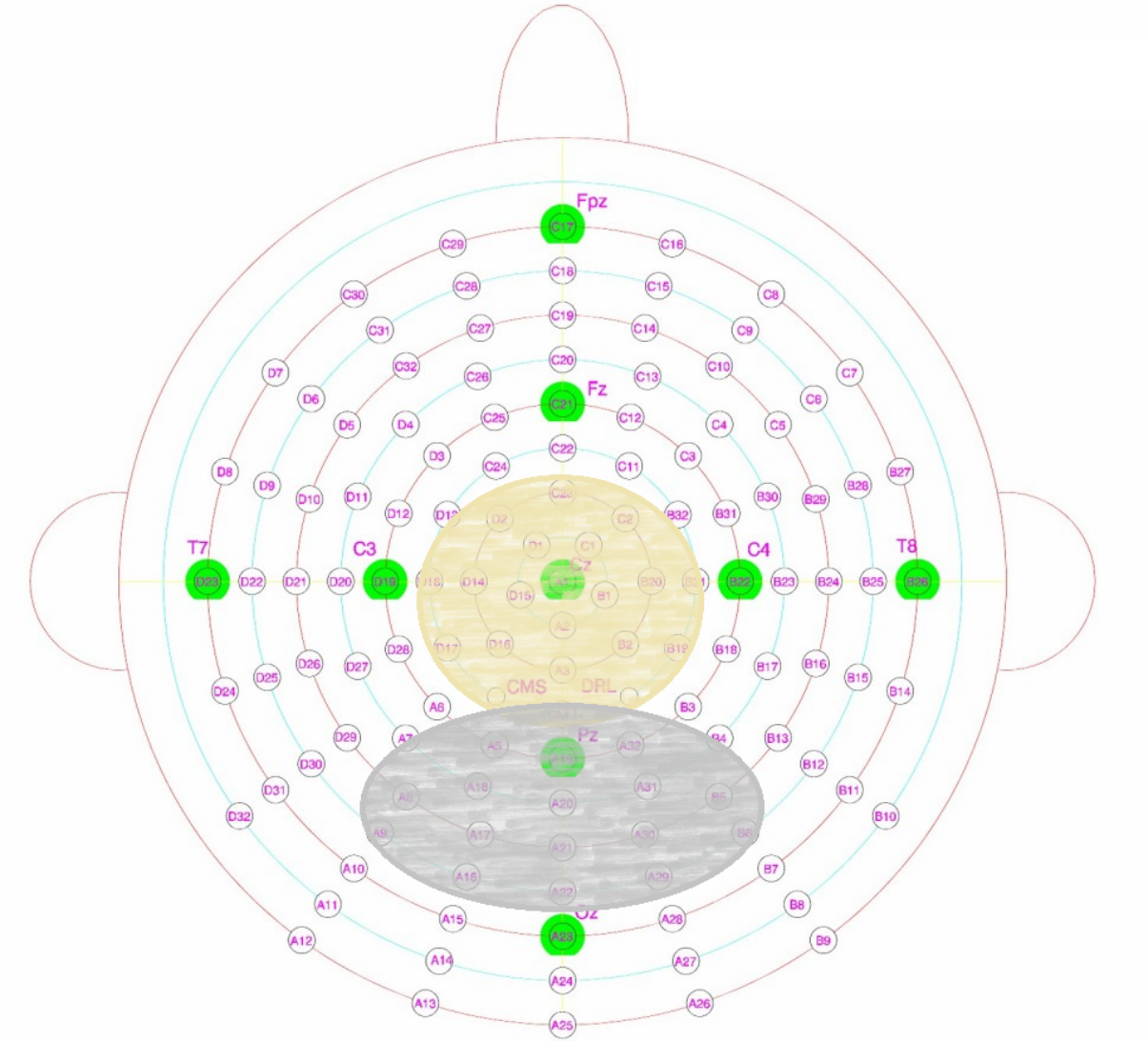
Results – RTs

- Mean RTs: 504 ms for APUs, 636 ms for APUd, 514 ms for PUs and 559 ms for PUd
- difference in RTs (between standard and deviant) much greater in the case of the exceptional APU (132 ms) than in the case of the default PU (45 ms)
- significant effect of condition ($F(3,78) = 4.415$, $p = 0.0064$)
- Bonferroni-corrected: significant effect in APUd compared to APUs ($p = 0.0066$) and PUs ($p = 0.0155$)

- **Significant difference in responses to deviants depending on the stress pattern**

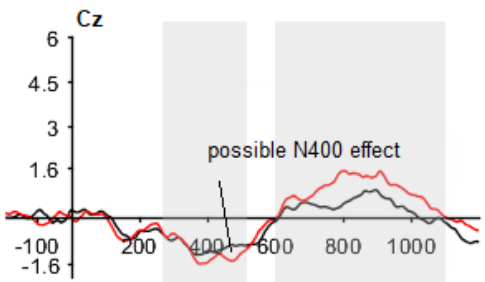
Experiment 2

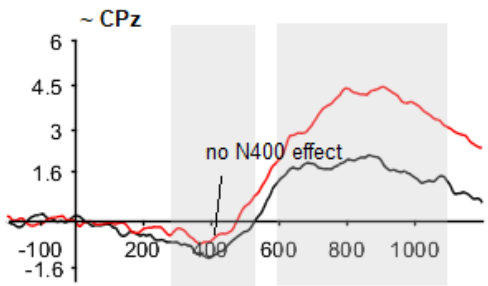
ERPs – Regions of interest (ROIs)

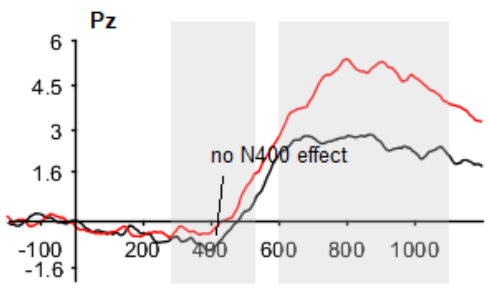


Experiment 2

ERPs – Grand averages







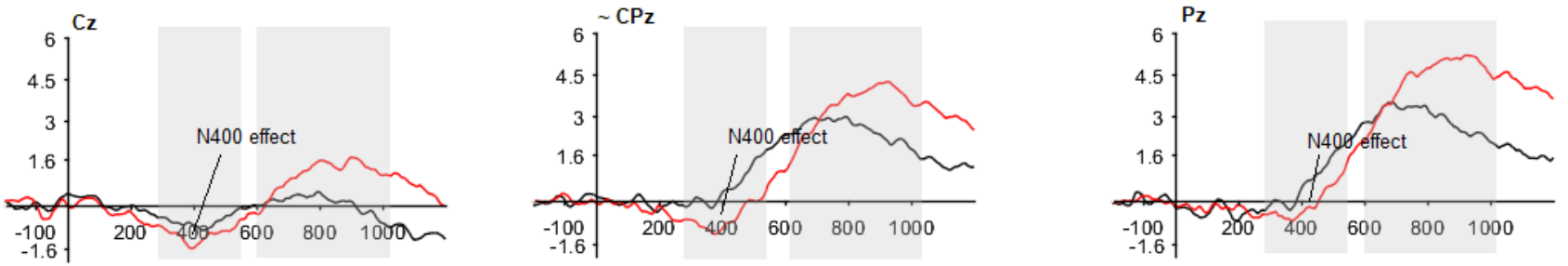
correctly stressed penults followed by correct response

incorrectly stressed penults followed by correct response

ANOVA results: no N400 effect was confirmed for the penults ($F(1,26) = 1.562$, $p = 0.222$). The hypothetical effect in the Cz electrode region was not confirmed statistically. In other regions, an opposite effect is seen instead: incorrect stress causes a less negative inflection in the 350-600 ms windows than correct stress (cf. antepenults).

Experiment 2

ERPs – Grand averages



ANOVA results: main effect of condition (correct/incorrect) for the antepenults in the range of 350-600 ms from word onset ($F(1,26) = 20.38$, $p < 0.001$)

Experiment 2

Results – ERPs

- N400 effect evoked by shifting stress in antepenults only ($F = 20.38$, $p < 0.001$)

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- N400 effect evoked by shifting stress in antepenults only ($F = 20.38$, $p < 0.001$)
- LPC in response to deviants vs. standards ($F = 8.201$, $p = 0.008$), no effect of stress – increased processing cost and error monitoring

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- N400 effect evoked by shifting stress in antepenults only ($F = 20.38$, $p < 0.001$)
- LPC in response to deviants vs. standards ($F = 8.201$, $p = 0.008$), no effect of stress – increased processing cost and error monitoring
- processing of prosody in the earlier TW followed by correctness judgment

The ‘two-syllable’ time window

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APU words:
– pitch is quite high at the beginning and steadily rising
– duration is greater in the stressed syllable and falls in the unstressed one

The 'two-syllable' time window

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APU words:
– **pitch is quite high at the beginning and steadily rising**
– duration is greater in the stressed syllable and falls in the unstressed one

PU words:
– the second syllable is equally long or shorter than the first
– pitch rises to 200 Hz, never as high as in APUs
– **the rise is much greater in APU words (40 Hz)**

Experiment 2

Phonetic parameters of the stimuli

		stressed antepenult (sd)		stressed penult (sd)	
standard	*F0*	222.9 Hz	(21.9)	200.9 Hz	(13.7)
	Int.	71.8 dB	(3.4)	69.9 dB	(2.0)
	Dur.	187 ms	(59)	182 ms	(29)
deviant	*F0*	224.0 Hz	(23.6)	203.1 Hz	(6.9)
	Int.	73.0 dB	(2.6)	69.5 dB	(3.0)
	Dur.	196 ms	(46)	193 ms	(23)
comparison	*F0*	F(1,78)=0.05, p=0.81		F(1,78)=0.82, p=0.37	
	Int.	F(1,78)=3.1, p=0.08		F(1,78)=0.44, p=0.5	
	Dur.	F(1,78)=0.67, p=0.41		F(1,78)=3.7, p=0.06	
		unstressed antepenult (sd)		**unstressed penult (sd)**	
standard	*F0*	180.9 Hz	(15.7)	267.5 Hz	(11.44)
	Int.	72.8 dB	(2.4)	69.8 dB	(2.5)
	Dur.	190 ms	(34)	153 ms	(23)
deviant	*F0*	181.9 Hz	(13.4)	264.2 Hz	(11.7)
	Int.	72.0 dB	(1.9)	70.8 dB	(2.3)
	Dur.	200 ms	(35)	151 ms	(23)
comparison	*F0*	F(1,78)=1.62, p=0.2		F(1,78)=0.09, p=0.76	
	Int.	F(1,78)= 3.41, p=0.07		F(1,78)=2.44, p=0.12	
	Dur.	F(1,78)=0.2, p=0.65		F(1,78)=2.07, p=0.15	

The 'two-syllable' time window

- Neither of the parameters alone can explain stress differences between syllables and guide hearers as to which syllable is stressed

- A comparison of several cues across two syllables is necessary to identify stress, which confirms the relational (or combinatorial) nature of stres.

Conclusions

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– EEG provides objective data on the processing of phonetic and phonological categories

Thank You!

Slides available at: *www.karolinabros.eu*