The phonetics and phonology of word stress perception – neurophysiological evidence

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Research on stress

1. Stress as a bundle of features

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

2. Stress as an abstract category

- morphophonology
- syllable/matrical structure
- lexical properties

Cross-linguistic differences in stress perception

1. Behavioural studies

– Dupoux et al. (1997). A destressing 'deafness' in French?
– Peperkamp, S., and Dupoux, E. (2002). A typological study of stress 'deafness'
– Peperkamp et al. (2010). Perception of predictable stress: a crosslinguistic investigation.

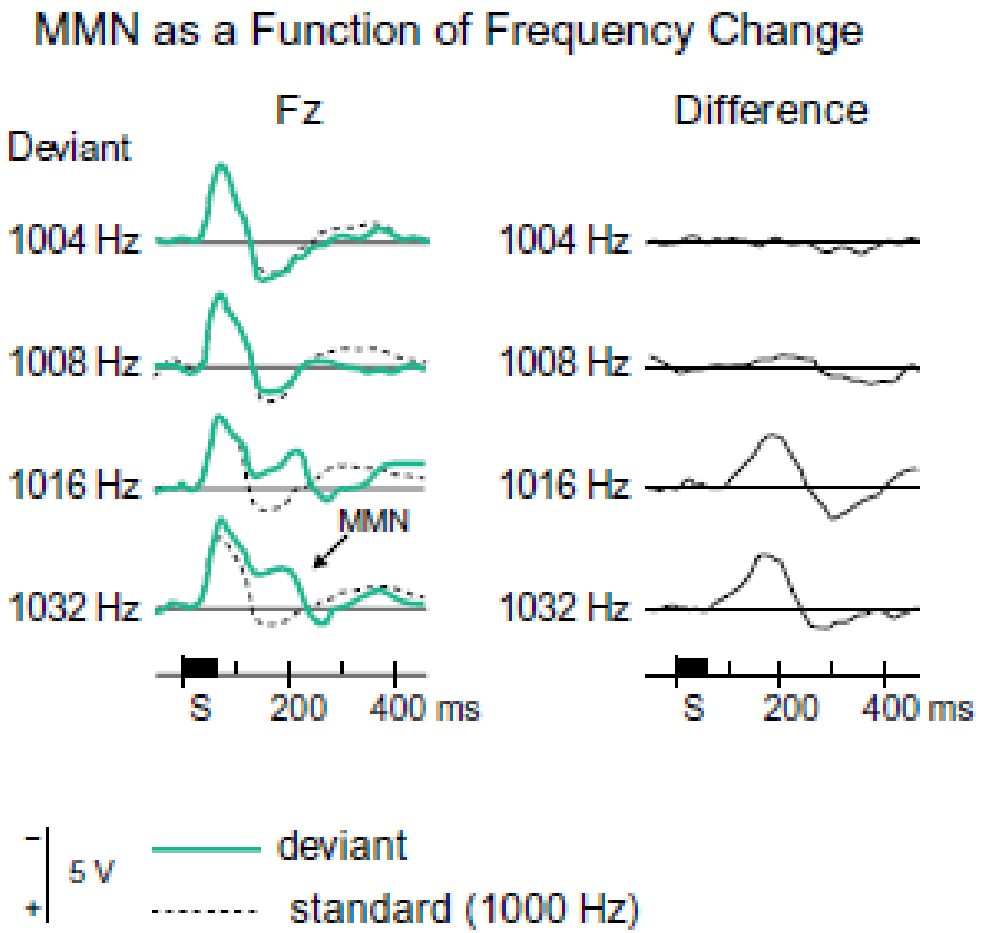
Cross-linguistic differences in stress perception

2. EEG studies

– Knaus et al. (2007). The processing of word stress: EEG studies on task-related components.
– Domahs et al. (2008). The processing of German word stress: Evidence for the prosodic hierarchy.
– Domahs et al. (2012a). Processing (un-)predictable word stress: ERP evidence from Turkish.
– Domahs et al. (2012b). Stress 'deafness' in a language with fixed word stress: an ERP study on Polish.
– Molczanow et al. (2013). The lexical representation of word stress in Russian: Evidence from event-related potentials.
– Domahs et al. (2013). Processing (un)predictable word stress: ERP evidence from Turkish.

EEG research on stress

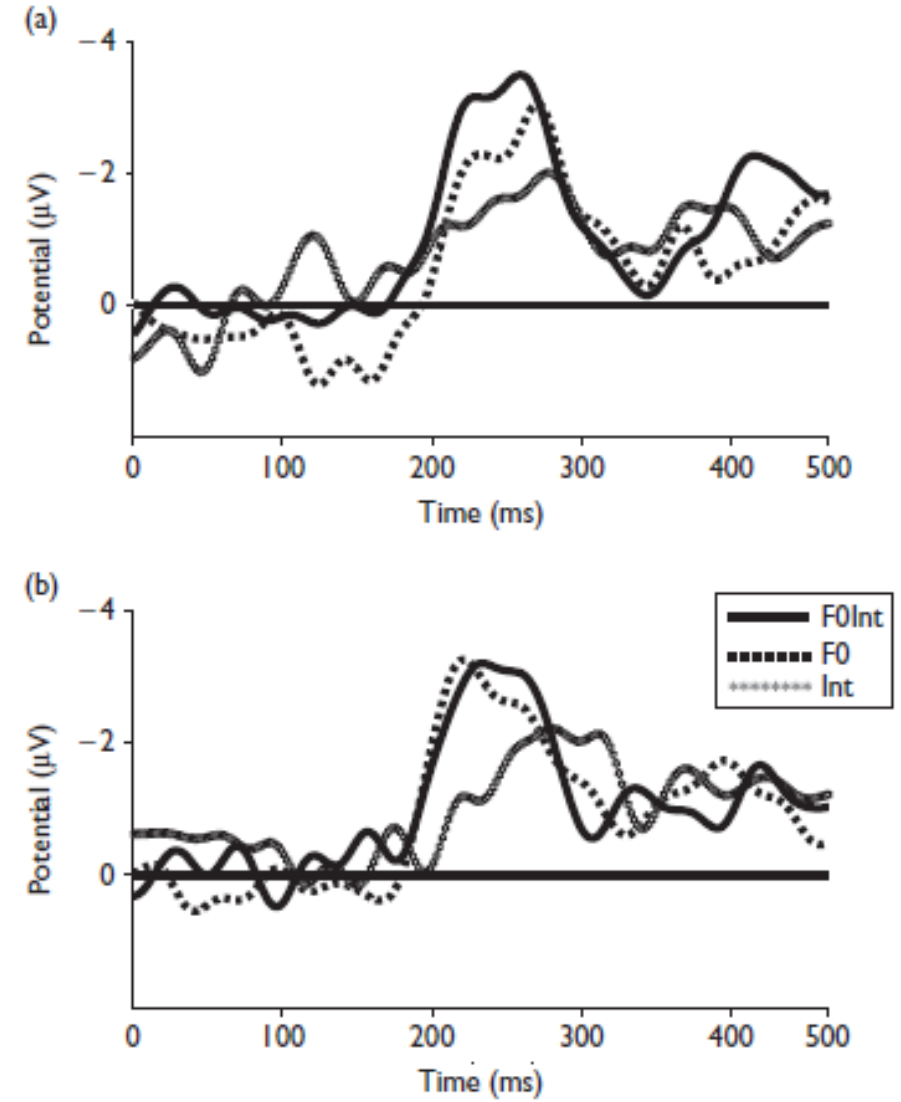
1. MMN
   - Naatanen et al. 2007 (acoustic processing)


MMN as a Function of Frequency Change
Fz
Difference
Deviant
1004 Hz
1008 Hz
1016 Hz
1032 Hz
MMN
S
200
400 ms
1004 Hz
1008 Hz
1016 Hz
1032 Hz
S
200
400 ms
5 V
deviant
standard (1000 Hz)

EEG research on stress

1. MMN
   - Naatanen et al. 2007 (acoustic processing)
   - Zora et al. 2016 (individual and cumulative stress cues)

Fig. 1


(a)
−4
−2
0
Potential (μV)
0
100
200
300
400
500
Time (ms)
(b)
−4
−2
0
Potential (μV)
F0Int
F0
Int
0
100
200
300
400
500
Time (ms)

EEG research on stress

1. MMN

- Naatanen et al. 2007 (acoustic processing)
- Zora et al. 2016 (individual and cumulative stress cues)
- Honbolygo & Csepe 2013 (evidence for long-term representation of word stress)

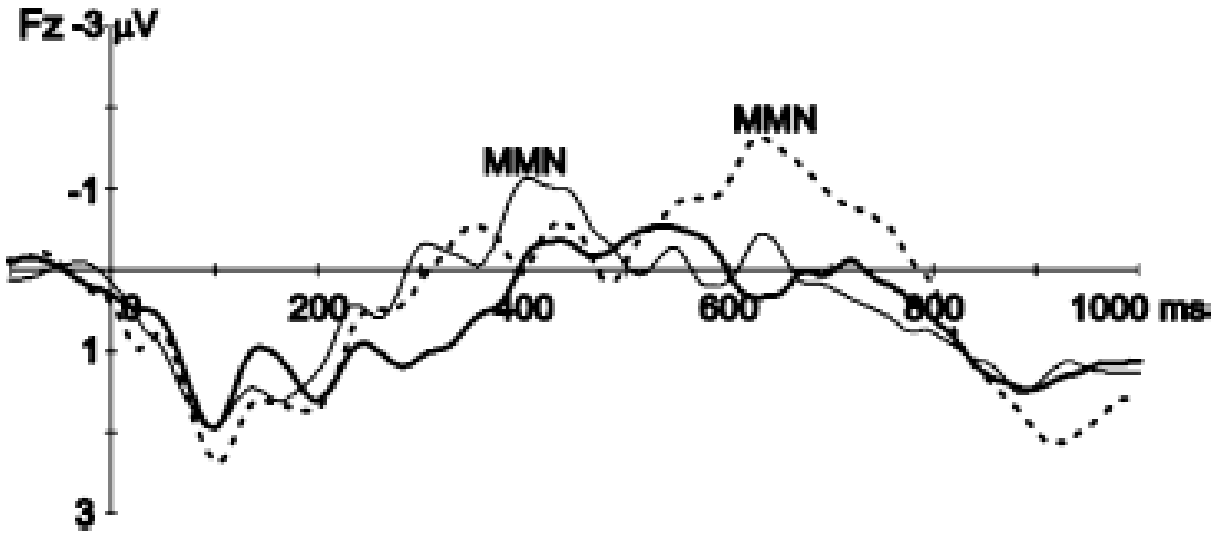
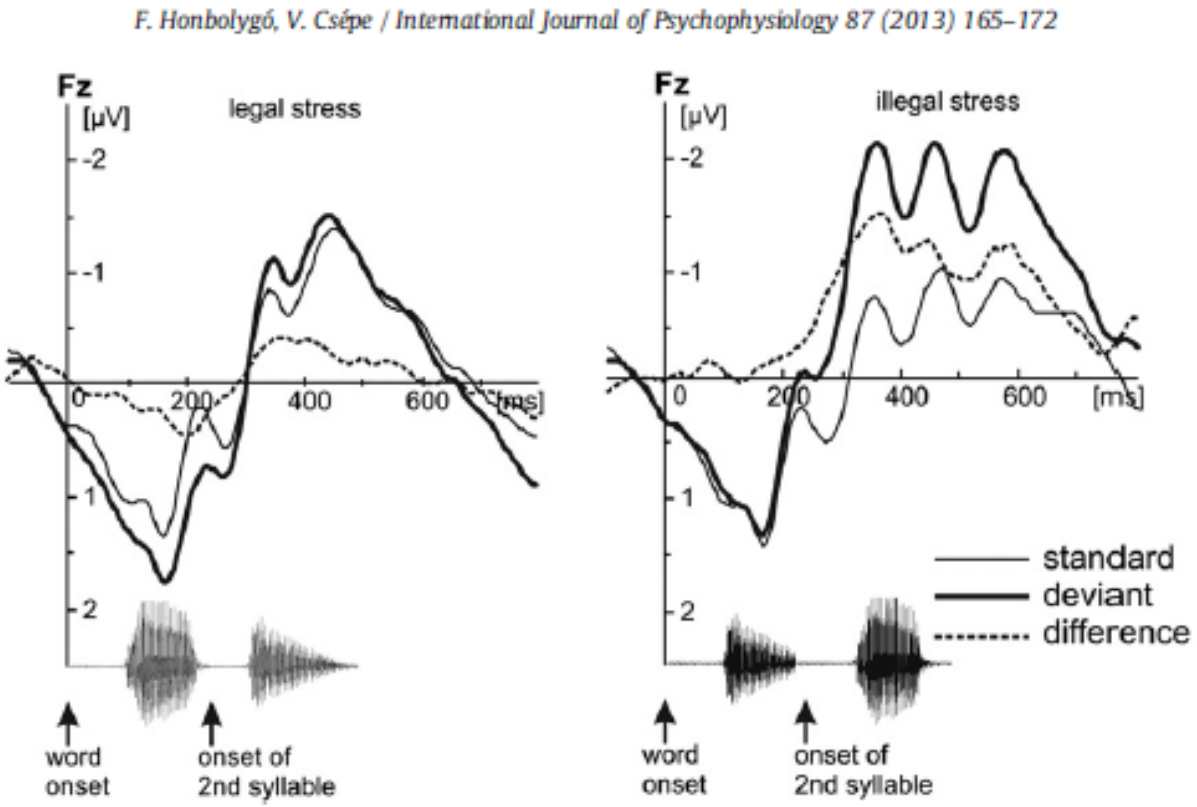


Fig. 2. Grand average ERPs to the standard (thick line), phoneme deviant (thin line) and stress deviant (dotted line) stimuli on Fz. Negativity is plotted upward and the curve is low-pass filtered with 20 Hz here and in the following figures.



lexical trace hypothesis: MMN depends on the familiarity of the deviant, the lexical status of the standard plays no role

My study on stress acoustics

"Melodic and temporal cues to stress perception in Spanish - a mismatch negativity study"

(in preparation)

MMN study on Spanish

Spanish stress - phonetic correlates

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

- 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

MMN study on Spanish

Spanish stress - phonetic correlates

- Ortega-Llebaria, M. & Prieto, P. (2007) – stress contrast in Spanish is maintained by differences in duration and spectral tilt in de-accented contexts

- Ortega-Llebaria, M. & Prieto, P. (2009) – duration and general intensity are cues to stress, not spectral tilt

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

MMN Experiment

Materials and procedure

video:
sand on glass

[fábula]

(standard)
probability: 74.5%
N=870

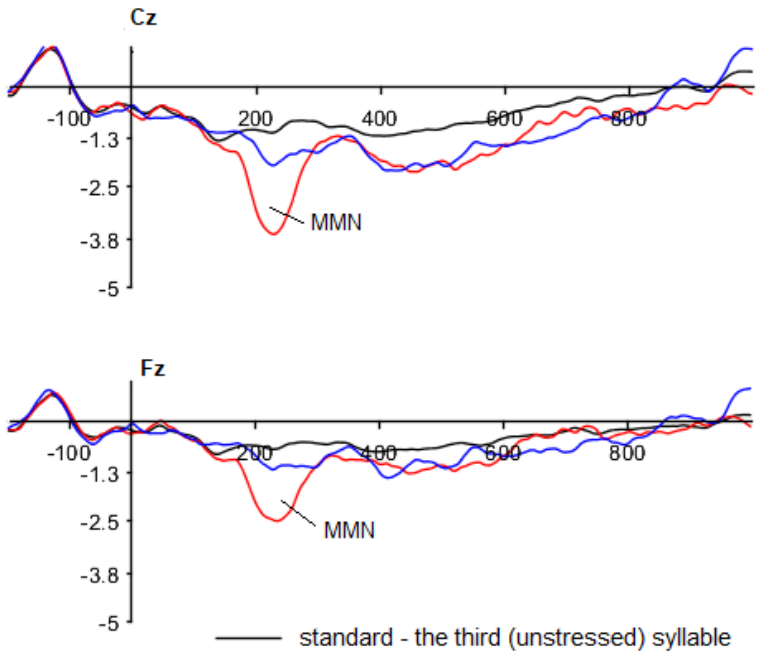
[fabulá] ST
[fabulá] F0
[fúbula] V

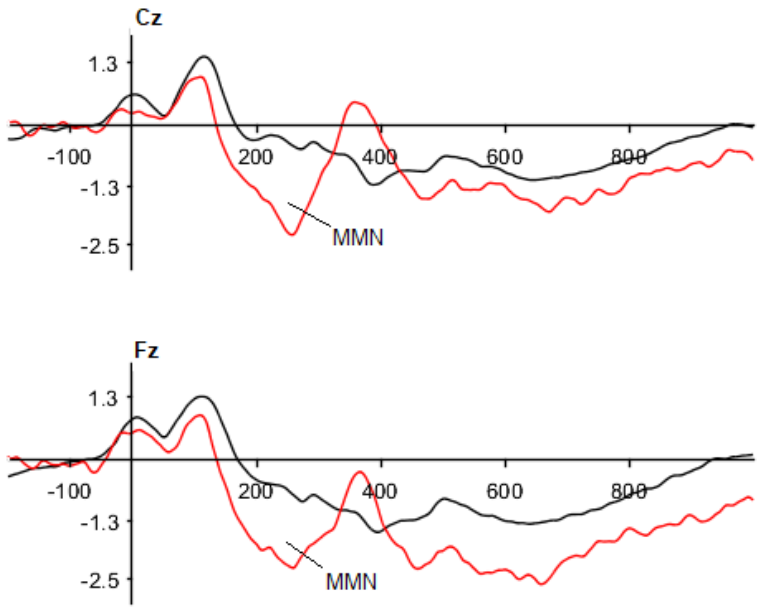
deviants
probability: 8.5%
N=100

ITI: 500-600 ms

MMN Experiment

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/

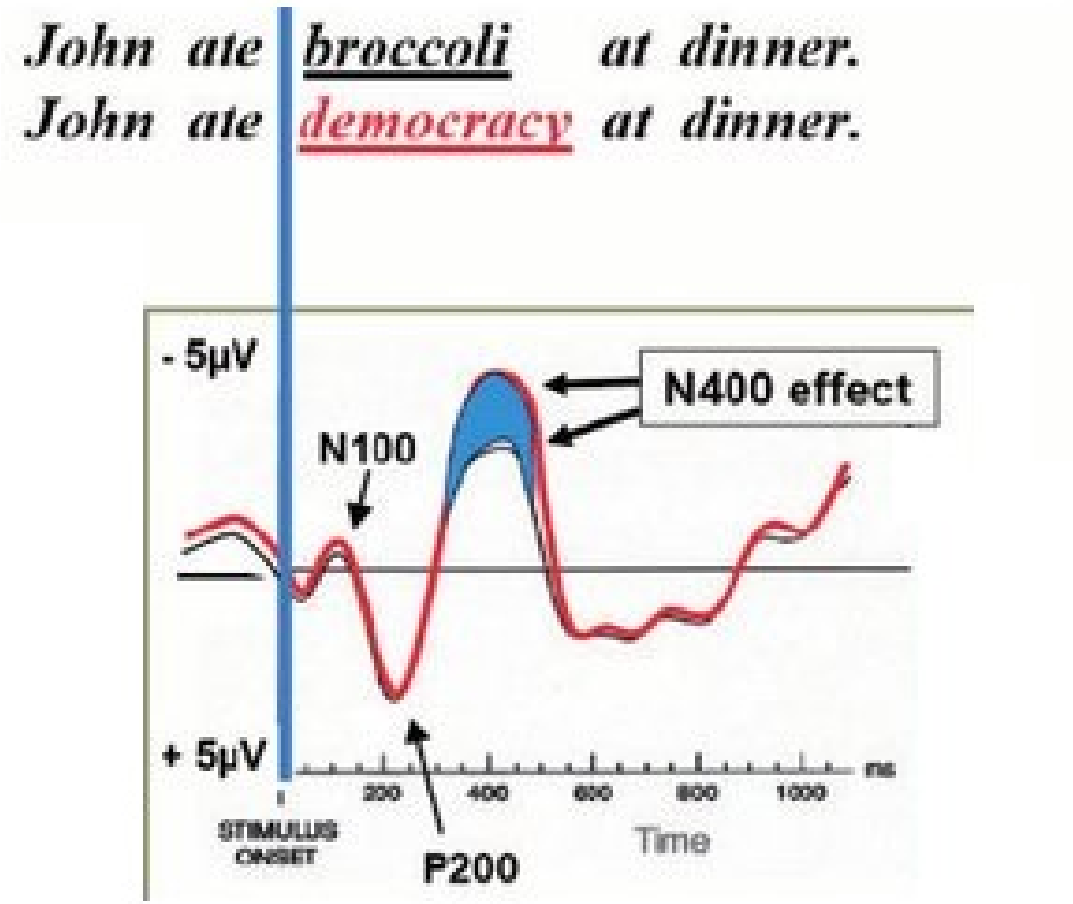
MMN Experiment

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 ($F = 4.87$, $p = 0.0584$)
- F0 confirmed as an important stress cue in Spanish
- Mixed results on intensity from previous studies may be because a mixture of several cues is necessary for stress information to be perceived correctly

EEG research on stress

2. N400

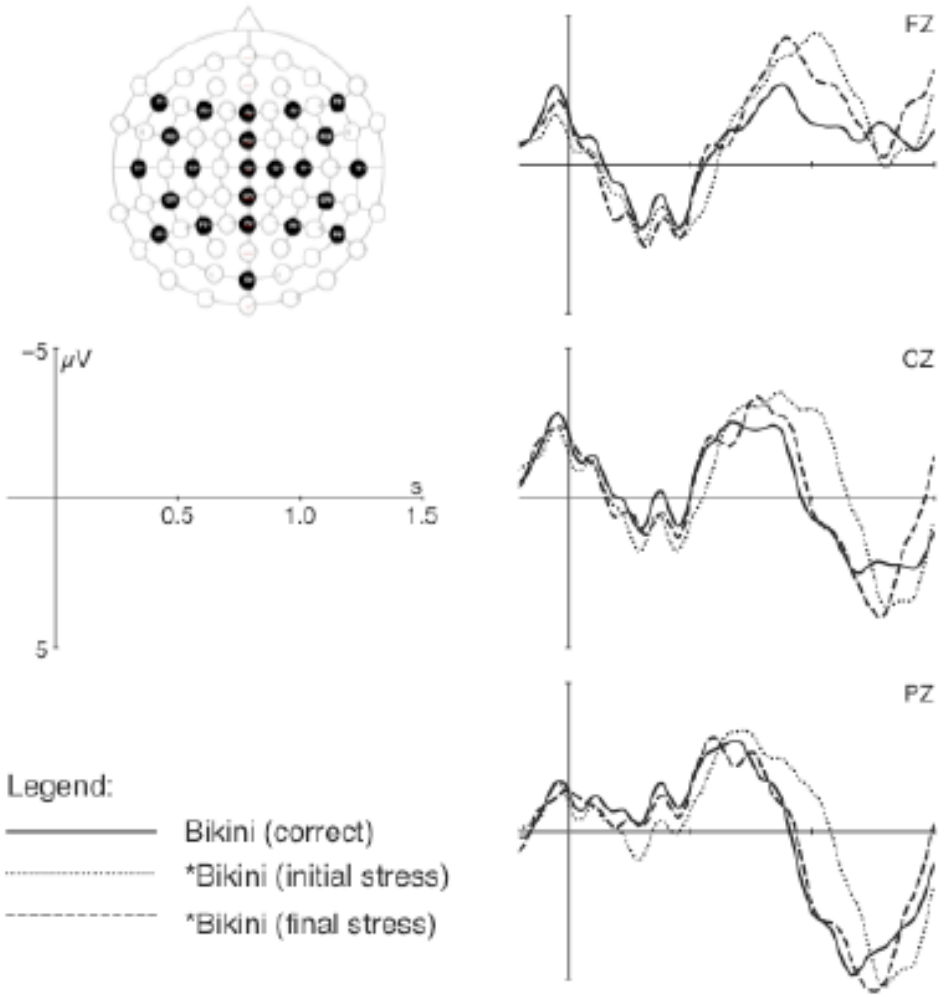


EEG research on stress

2. N400

- Knaus et al. - lexical stress in German

Figure 1: Grand average curves of correctly (solid line) stressed words, words with incorrect antepenultimate stress (dotted line) and with incorrect final stress (dashed line).



EEG research on stress

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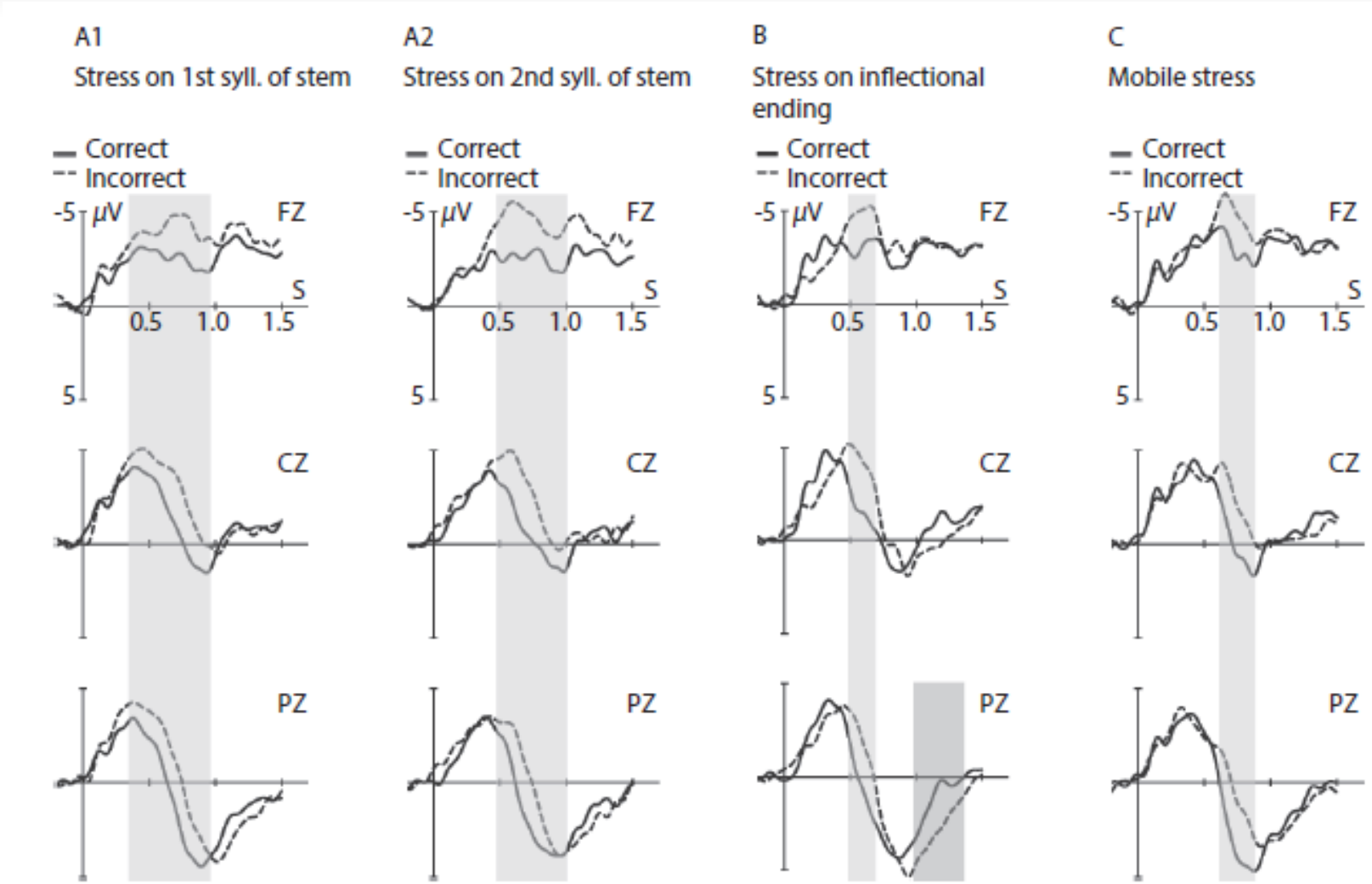
- Knaus et al. - lexical stress in German
- Molczanow et al. - lexical stress in Russian


A1
Stress on 1st syll. of stem
A2
Stress on 2nd syll. of stem
B
Stress on inflectional ending
C
Mobile stress
Correct
Incorrect
-5 μV
5
FZ
CZ
PZ
S
0.5
1.0
1.5

EEG research on stress

2. N400

- Knaus et al. - lexical stress in German
- Molczanow et al. - lexical stress in Russian
- Domahs et al. - lexical stress in Turkish

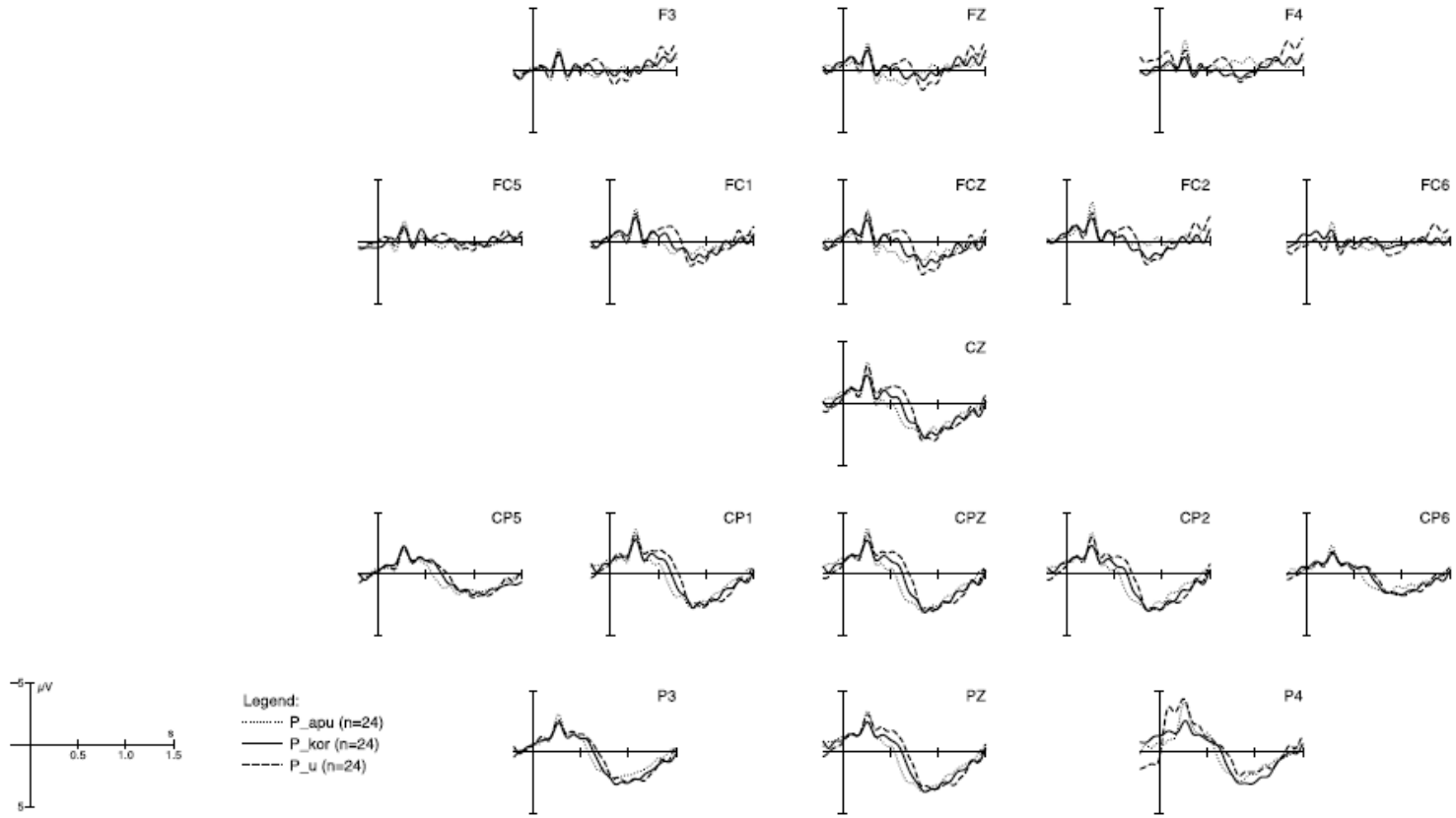
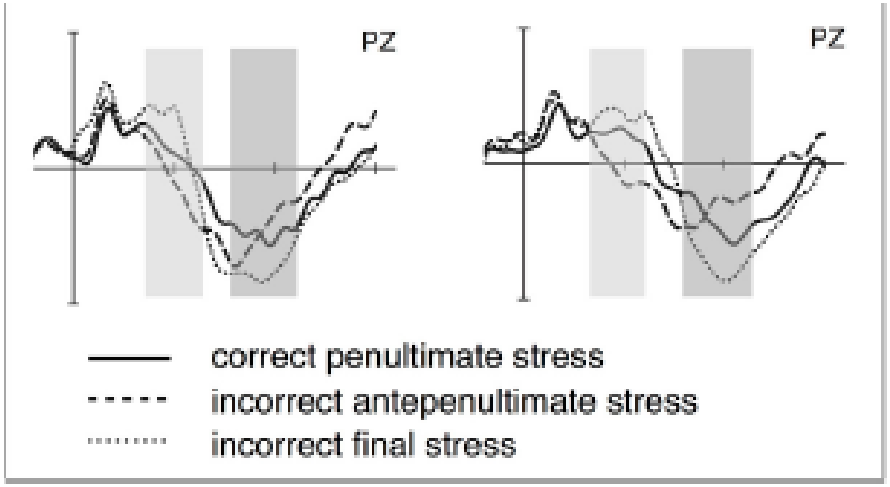


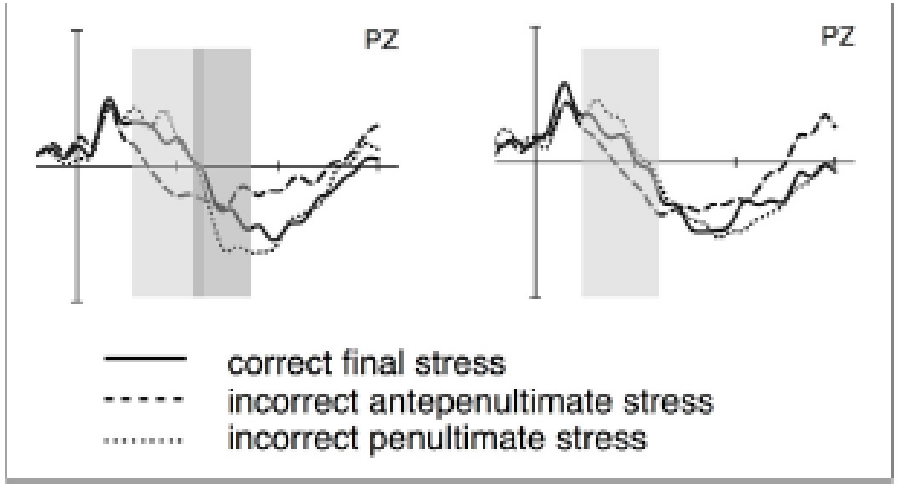
Figure 2. Grand averages of event-related potentials (ERPs) obtained for words with canonical penultimate stress (e.g., *ti'yatro*). The correct condition (*ti'yatro* = solid line) is plotted against the incorrect conditions with antepenultimate stress (**'tiyatro* = dotted line) and with final stress (**tiya'tro* = dashed line). Violations with antepenultimate stress yield a positivity effect between 400 and 700 ms post-word onset, whereas violations with final produce a negativity between 500 and 750 ms and no positivity effect.

EEG research on stress

3. P300

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


PZ
PZ
correct penultimate stress
incorrect antepenultimate stress
incorrect final stress


PZ
PZ
correct final stress
incorrect antepenultimate stress
incorrect penultimate stress

Spanish stress experiment

"Word stress processing integrates phonological abstraction with lexical access – an ERP study."

Broś, K., Meyer, M., Kliesch, M. and Volker Dellwo (2021). Journal of Neurolinguistics 57, 100959.

Approaches to lexical storage

1. Generativist models

- only unpredictable information that cannot be derived by rules is stored in the UR
- non-contrastive data and phonetic detail redundant for the processing of a given word are excluded
- by extension, predictable stress markers are excluded from the lexicon

Approaches to lexical storage

2. Usage-based models

- the theory of exemplars (Bybee, 2001, 2006): focus on the effects of frequency and other external factors on sound production and perception
- abandons fully abstract, phonemic representations of words or morphemes
- gradient, lexically diffuse differences in pronunciation are all stored in the mental lexicon as they are
- by extension, stress cannot be a derived or abstract category it is a bundle of acoustic and auditory features stored with each word represented in the exemplar cloud

Aim of the experiment

Put the two approaches to the test

Focus of the experiment

Spanish

- a language with variable stress
- prevalence of one stress pattern over the others: partial stress predictability
- 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
- so: default penult pattern derivable by rules, with lexical exceptions

Spanish: assumptions

- minimal pairs, sensitivity to stress cues in perception
- Spanish people not 'stress-deaf' (Peperkamp et al. 2010)

But: Is the default penultimate stress pattern processed differently than the exceptional antepenult?

Is the exceptional stress stored to facilitate word retrieval, as opposed to the default?

How to test this?

1. **Access to prelexical processing**

2. **Access to semantic activation**
(linking phonology with meaning)

3. **A paradigm evoking the N400 negativity effect**

Zurich experiment

- 32 native speakers of Spanish (19 females) aged 19-32
- 240 stimuli containing correctly and incorrectly stressed words
- 60 penults and 60 antepenults with a CV.CV.CV structure
- invariable carrier sentence
- words of matching frequencies
- controlled for phonological neighbourhood

Selection criteria

a) Proper names were excluded.

b) Words were chosen so as not to become real Spanish words (lexical competitors) after the stress shift (i.e. after changing the stressed syllable).

c) Words that have 10 or more phonological neighbours were excluded.

d) Words which have a phonological neighbour of a higher frequency were excluded.

e) Words which have a phonological neighbour with the other stress pattern under investigation were excluded.

Stimuli

4 conditions:

seMAna (PUs – standard)

PAjaro (APUs – standard)

SEmana (PUd – deviant)

paJAro (APUd – deviant)

Stimuli

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

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

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

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

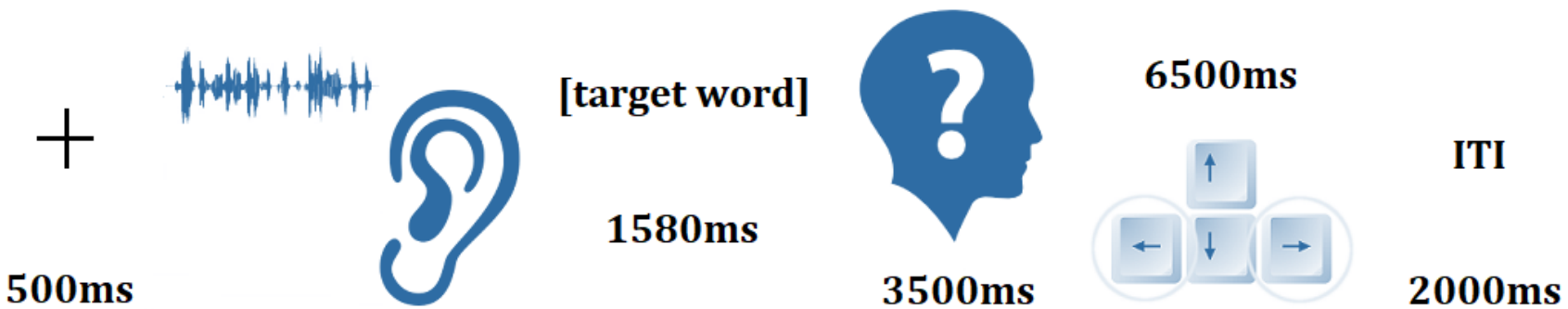
Marta pronunció la palabra [target word] *otra vez*

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

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

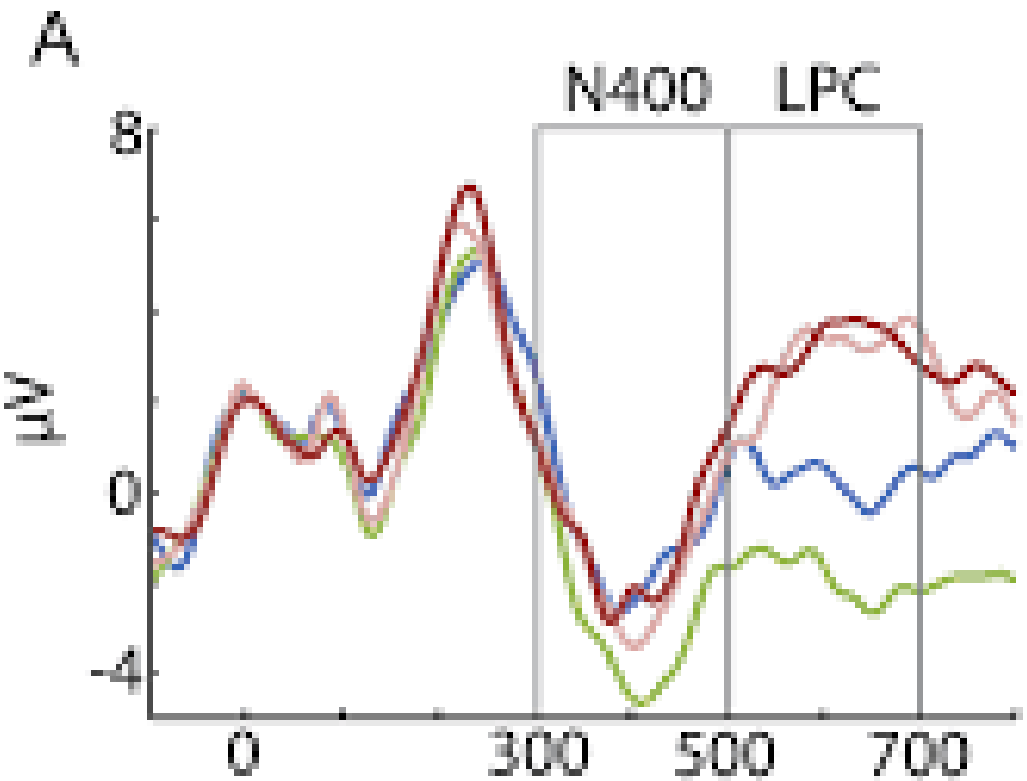
Zurich Experiment

Procedure



Hypotheses

- Incorrect stress will invoke a more robust negativity around 400 ms from the onset of the stimulus
- A significant difference between the two stress patterns
- Possibly, task-related positivity (LPC)


A
N400
LPC
8
0
-4
μV
0
300
500
700

Hypotheses

- Explanation: N400 – response to a semantic violation
- If stress information is derived in online processing =>
  no problems with procesing incorrect stress
- If stress information is stored =>
  mismatch between the memorised and the perceived word
- Conclusion:
  no difference in processing changes to penults and antepenults
  supports exemplar models

  difficulty with antepenults but not penults supports
  the generative view

Zurich Experiment

Results – accuracy scores

- 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**

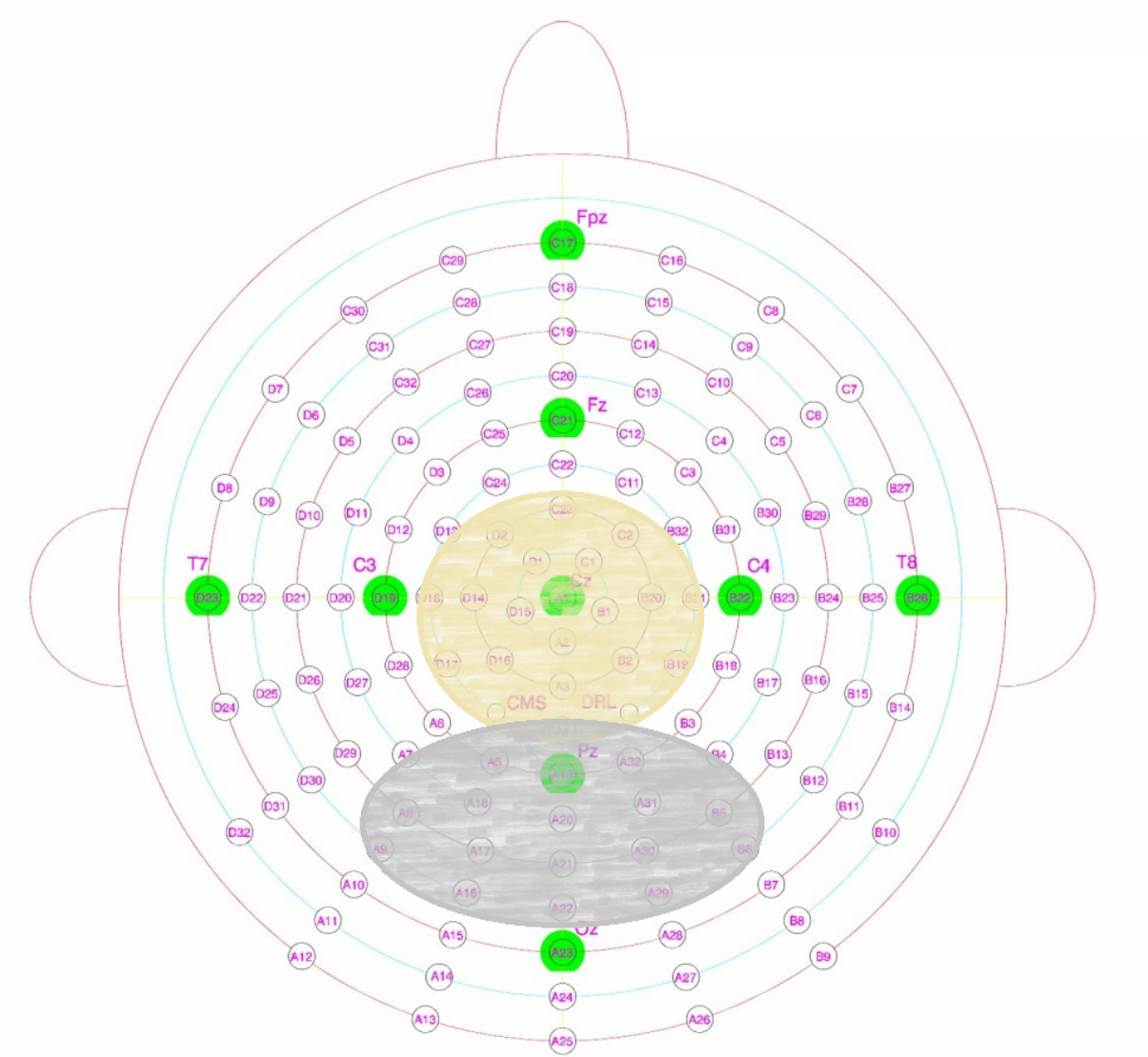
Zurich Experiment

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**
- **RT results match those of accuracy scores**

EEG results: Regions of interest (ROIs)



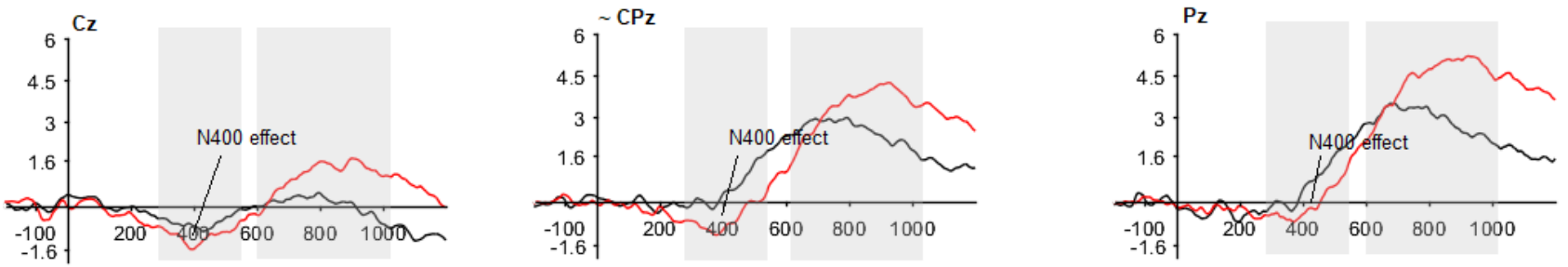
Zurich Experiment

Results – ERPs

APU condition

main effect of condition ($F(1,26) = 20.38$, $p < 0.001$)
main effect of region ($F(1,26) = 30.36$, $p < 0.001$)
no interaction ($F(1,26) = 0.68$, $p = 0.417$)

EEG results: Grand averages



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

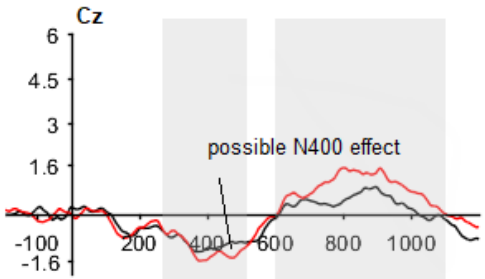
Zurich Experiment

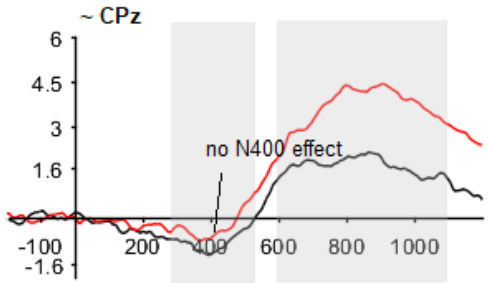
Results – ERPs

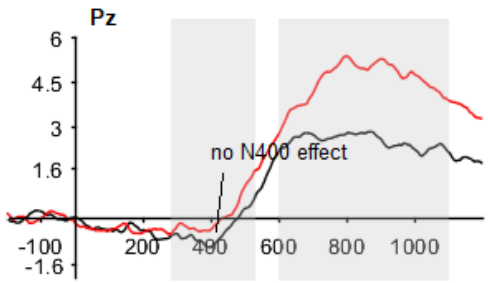
PU condition

no N400 effect ($F(1,26) = 1.562$, $p = 0.222$)
main effect of region ($F(1,26) = 23.63$, $p < 0.001$)
reverse interaction ($F(1,26) = 23.56$, $p < 0.001$)

EEG results: 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).

The 'two-syllable' time window

- the stressed syllable is not reliably longer or of higher pitch

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)**

Zurich Experiment

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.
- Human perceptual system cannot distinguish differences in pitch below 3 semitones (12Hz/220Hz, Nooteboom 1997)
- Confirmed by no latency difference in electrophysiological response

EEG results: Interpretation

PU words pronounced with the stress on the first syllable are **not in violation** of any expectation about the prominence of the second syllable

Hypothesis confirmed:

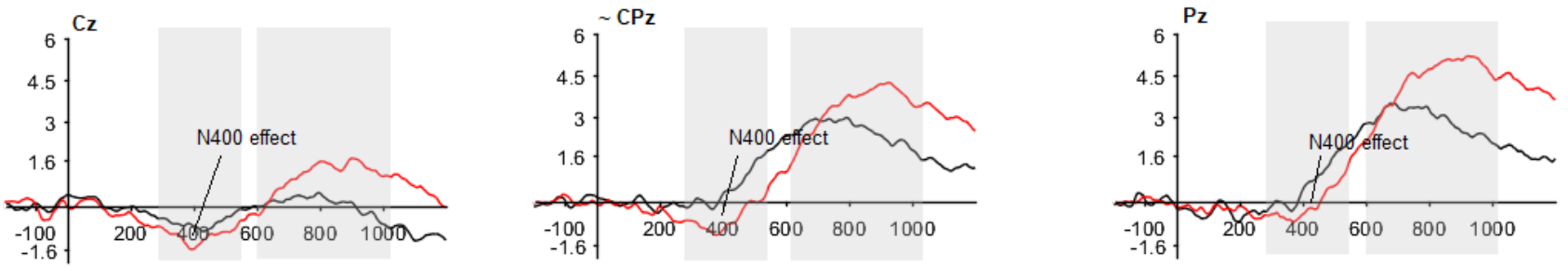
1. Significant difference between penults and antepenults

2. N400 effect only in the case of changes to the exceptional pattern

LPC results

– significant effect of condition ($F(1,26) = 23.05$, $p < 0.001$)
– no effect of stress ($F(1,26) = 0.125$, $p = 0.726$)
– interaction between the two ($F(1,26) = 4.721$, $p = 0.039$)

EEG results: Grand averages



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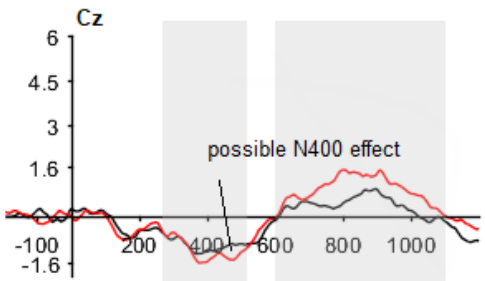

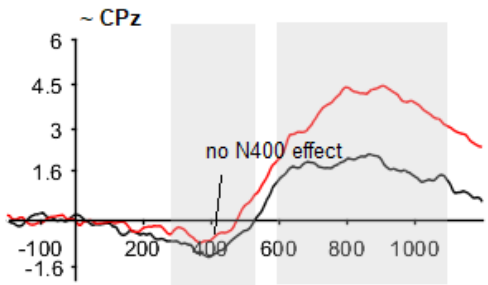

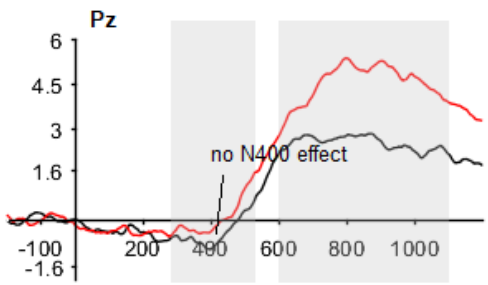

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– interaction between the two ($F(1,26) = 4.721$, $p = 0.039$)

- **correctness judgment occurs at this stage**
- **prevalence of stress effects in the first TW points to the processing of prosody (stress pattern)**
- **later on the hearer has to decide whether what (s)he heard was correct or incorrect: phonological-semantic integration must have taken place**

Conclusions from the experiment

– **Penults** behave as true defaults whose underlying abstract representations are not indexed with stress information
– the stress is inferred (or computed) from grammatical rules concerning default stress assignment
– **Antepenults** must be stored together with the information concerning the syllable that is stressed
– deviation from this lexical stress is costly for the hearer

The data **support the generative phonology framework** which assumes that only unpredictable information is stored in the mental lexicon

Discussion

Grammatical operations, which translate acoustic detail and auditory cues into abstract features and constituents, cannot be limited to mere statistical inference

Stress should be conceived of as an abstract category and disentangled from both segmental phonetic information and semantics

– Hearers respond to stress separately from the meaning of the word
– Bottom-up speech perception approach (Norris et al. 2000)
– Top-down wrap-up, integration of prosody and semantics
– compatible with Poeppel et al.'s (2008) speech perception theory

L2 stress perception and acquisition

Paper by Sandra Schwab, Nathalie Giroud, Martin Meyer and Volker Dellwo (2020). Journal of Neurolinguistics.

"Working memory and not acoustic sensitivity is related to stress processing ability in a foreign language: An ERP study"

L2 stress perception and acquisition

- effect of discriminating non-native phonetic features on brain activity
- language without lexical stress contrasts (French): disadvantaged listeners, stress-'deaf'
- is stress learned and stored in the lexical representation of a word in L2 acquisition?

Background

- listeners' sensitivity to a particular stress pattern in L2 depends on native language
- French listeners have more difficulties in identifying Spanish lexical stress in final syllables
- more challenging to identify the default as functionally marked in a foreign language
- but: French speakers are able to perform tasks such as identification (detection of acoustic cues)
- the French are not 'acoustically deaf', they are 'phonologically stress-deaf'

Study design

- native speakers of Swiss French, no knowledge of Spanish or other Romance languages, some knowledge of German and English
- behavioral experiments: identification + odd-one-out, pre- and post-training performance
- active oddball paradigm one year after training
- N2b: when a deviant stimulus in a continuous stimulus stream is attended to
- P3b: neural marker of cognitive updating as a function of changes in auditory stimuli, associated with working memory
- assumption: P3b only in detected/categorised changes, N2b only sensory response
- expected: listeners who better keep stress differences in working memory (i.e., higher P3b) perform better in behavioral tasks

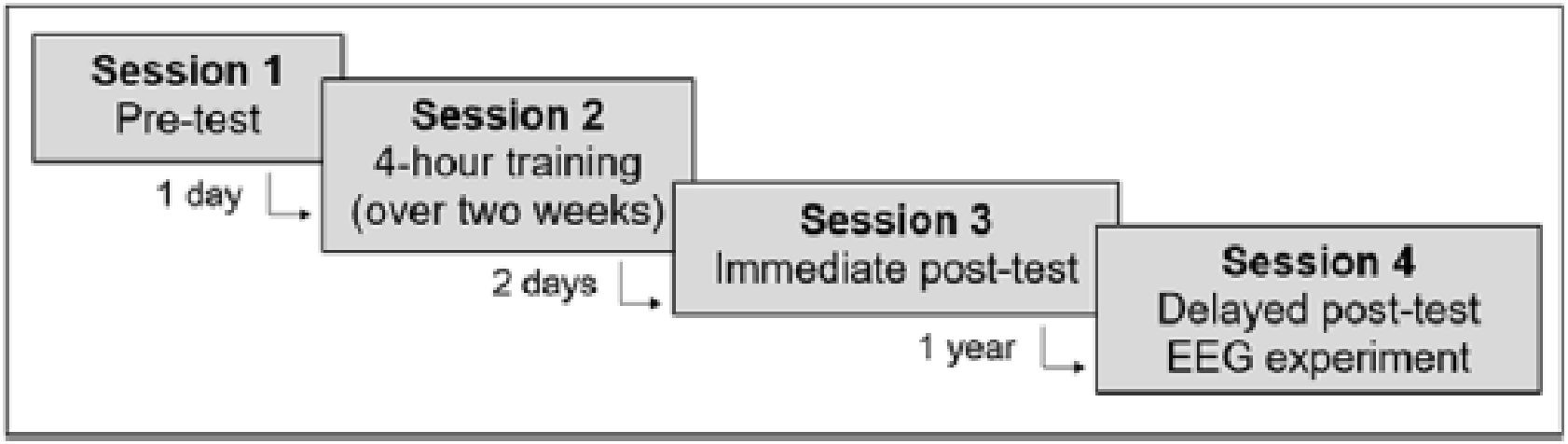
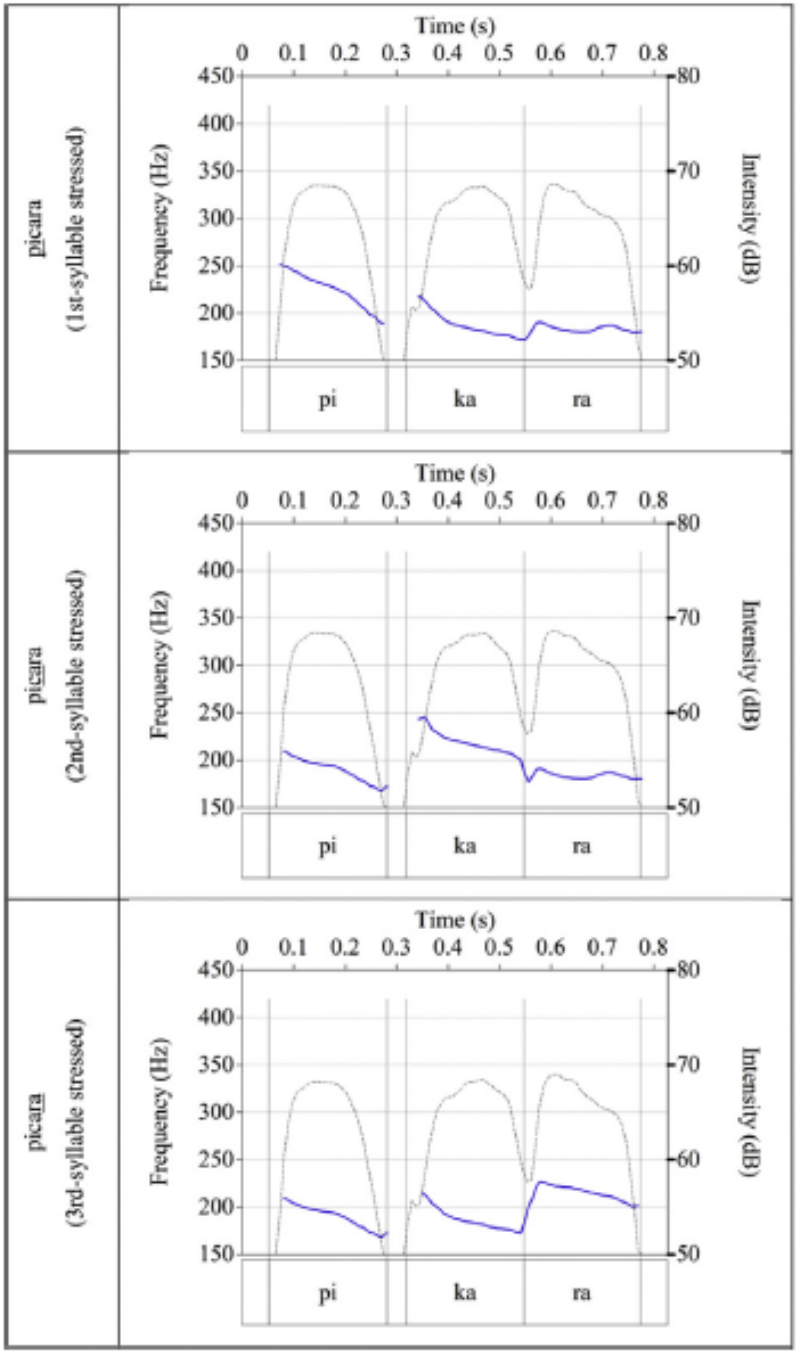
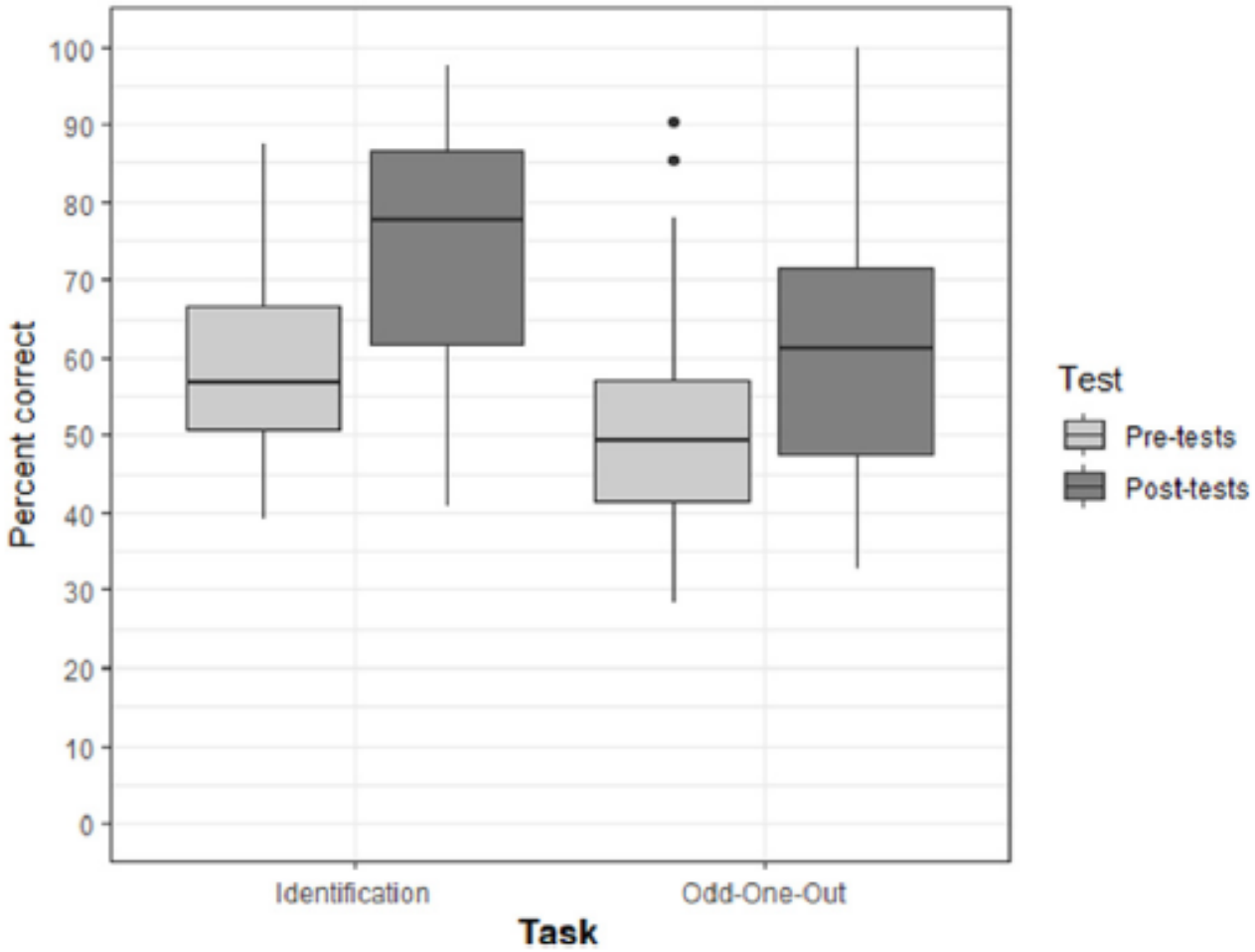


Fig. 1. Experimental design of the behavioral and EEG experiments.

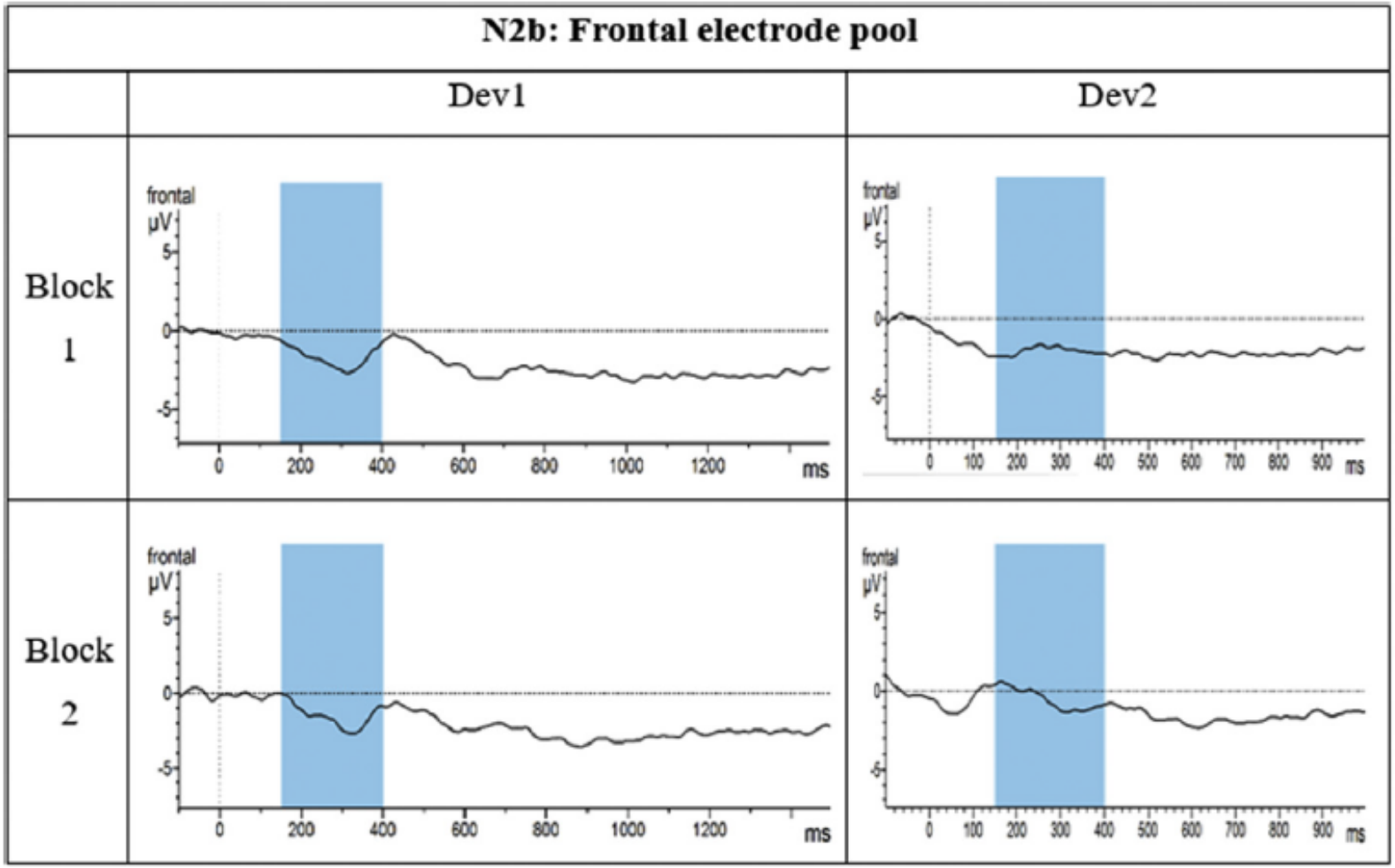
Study design

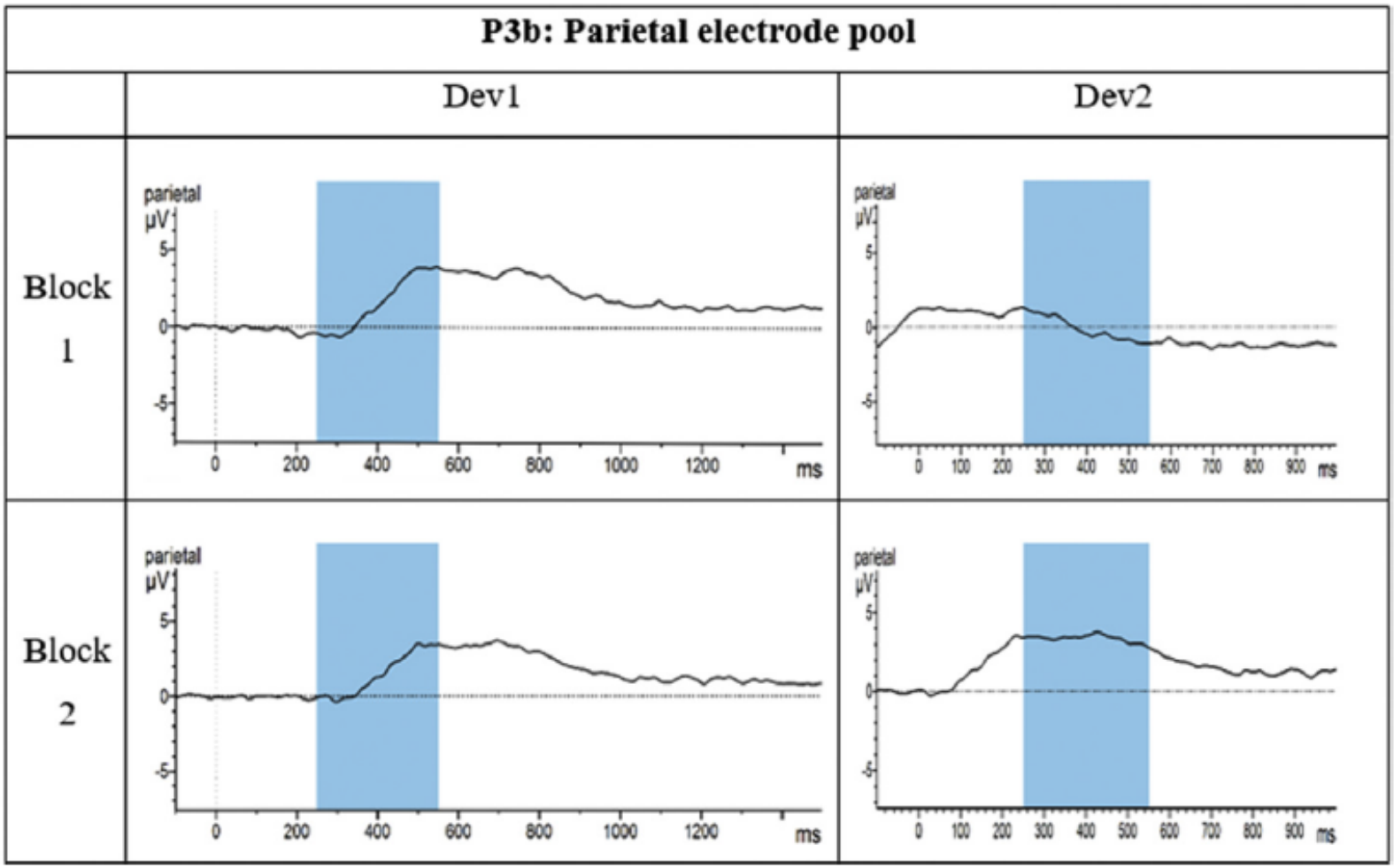
- identification task: 120 trisyllabic Spanish words, 2 native speakers, falling/rising intonation
- Odd-One-Out task: 216 trials of three segmentally identical Spanish words (e.g., *numero*)
- EEG study: trisyllabic Spanish word *picara* (change of grammatical category from noun/adjective to verb)
- stimuli only differed in F0 (increase of 17% or 32 Hz)
- antepenult standard, deviant probability: 20% (n= 120)
- natural stimulus changed to neutral F0, then F0 changed upwards in the syllable that was supposed to be stressed (see figure)

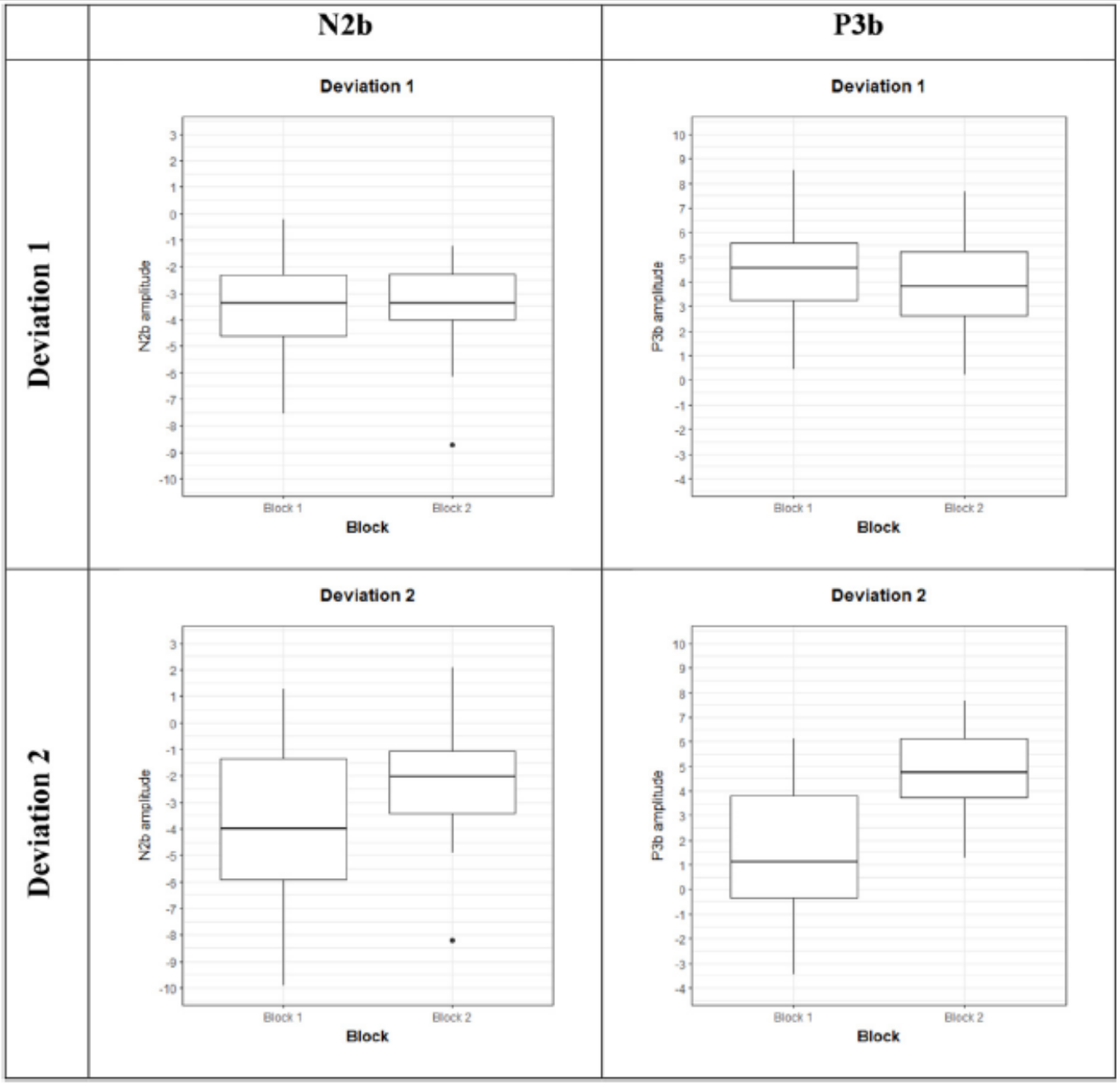

pícara
(1st-syllable stressed)
Time (s)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Frequency (Hz)
450 400 350 300 250 200 150
Intensity (dB)
80 70 60 50
pi ka ra
pícara
(2nd-syllable stressed)
Time (s)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Frequency (Hz)
450 400 350 300 250 200 150
Intensity (dB)
80 70 60 50
pi ka ra
picára
(3rd-syllable stressed)
Time (s)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Frequency (Hz)
450 400 350 300 250 200 150
Intensity (dB)
80 70 60 50
pi ka ra



listeners fared better with the identification task (as expected), there was improvement after training in both cases, with individual differences - some speakers did not improve, especially in the odd-one-out task


N2b: Frontal electrode pool
Dev1
Dev2
Block 1
Block 2
frontal
μV
5
0
-5
0
200
400
600
800
1000
1200
ms
frontal
μV
5
0
-5
0
100
200
300
400
500
600
700
800
900
ms
frontal
μV
5
0
-5
0
200
400
600
800
1000
1200
ms
frontal
μV
5
0
-5
0
100
200
300
400
500
600
700
800
900
ms


P3b: Parietal electrode pool
Dev1
Dev2
Block 1
Block 2
parietal
μV
5
0
-5
0
200
400
600
800
1000
1200
ms
parietal
μV
5
0
-5
0
100
200
300
400
500
600
700
800
900
ms


N2b
P3b
Deviation 1
Deviation 2
N2b amplitude
P3b amplitude
Block 1
Block 2
Block

EEG results: comments

- Deviation 1 corresponds to the lack of stress on the first syllable in the deviant with respect to the antepenult standard
- Deviation 2 corresponds to the stress added on the final syllable (Block 1) or on the penult (Block 2)
- N2b: for pre-tests, no relationship between its amplitude and the listeners' performance in neither of the two behavioral tasks
- P3b: results showed a positive correlation between its amplitude and the listeners' performance in behavioral tasks
- There is no difference between the blocks in either N2b or P3b in Deviation 1 (taking out the stress from the first syllable)
- There is a difference in the N2b amplitude in Deviation 2 – more negativity in Block 1 (final stress), as expected
- There is a difference in the P3b amplitude in Deviation 2 – more positivity in Block 2 (penult stress), which is unexpected; more working memory was to be engaged in processing final stress

Results: additional comments

"Since final-syllable stress is the default pattern in French [...] we predicted larger N2b and P3b peak amplitudes (i.e., indicating higher auditory sensitivity and larger ability to maintain the information in working memory, respectively) for final-syllable stressed deviants relative to second-syllable stressed deviants"

cf. background info:

French listeners have more difficulties in identifying Spanish lexical stress in final syllables – more challenging to identify the default as functionally marked in a foreign language

Karolina: Given the background info, I do not understand the hypothesis; I would expect exactly what we see if P3b is related to phonological processing: default stress is 'ignored' because it is not learned/retained in long-term memory

Results: additional comments

Some final remarks:

The authors do not explain the reason why they used real speech and not psudowords with speakers whose knowledg of Spanish is null or why they did not test people with the knowledge of Spanish

I remain a bit sceptical as to whether such a study design can lead to knowledge on phonological vs. phonetic processing

As for the speakers themselves, since they are multilingual by definition (Swiss), knowledge of languages with variable stress may predispose them to be quite good at stress identification (compare studies on French speakers from France)

Results: conclusions

- stress presented on the last syllable increased neural responses (i.e., larger N2b peak amplitude) in comparison with stress on the second syllable
- listeners auditorily more sensitive in L2 to the default pattern of their native language
- contrary to predictions, listeners' ability to categorize events and update them in working memory was smaller for third-syllable deviants than for second-syllable stressed deviants
- discrimination of L2 stress contrasts is more strongly related to working memory than to auditory sensitivity
- this supports the behavioral results that showed that French listeners were not able to encode phonological stress information in their lexicon, but were able to process acoustic differences related to stress

Another interesting study on L2 stress

Word stress representations are language-specific: Evidence from event-related brain potentials

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Abstract

Understanding speech at the basic levels entails the simultaneous and independent processing of phonemic and prosodic features. While it is well-established that phoneme perception relies on language-specific long-term traces, it is unclear if the processing of prosodic features similarly involves language-specific representations. In the present study, we investigated the processing of a specific prosodic feature, word stress, using the method of event-related brain potentials (ERPs) employing a cross-linguistic approach. Hungarian participants heard disyllabic pseudowords stressed either on the first (legal stress) or on the second (illegal stress) syllable, pronounced either by a Hungarian or a German speaker. Results obtained using a data-driven ERP analysis methodology showed that all pseudowords in the deviant position elicited an Early Differentiating Negativity and a Mismatch Negativity component, except for the Hungarian pseudowords stressed on the first syllable. This suggests that Hungarian listeners did not process the native legal stress pattern as deviant, but the same stress pattern with a nonnative accent was processed as deviant. This implies that the processing of word stress was based on language-specific long-term memory traces.

General conclusions

– EEG provides **objective data** on the processing of phonetic and phonological categories (but: certain overlap and uncertainty)
– Data from many experiments confirm the **combinatorial** / **cumulative** nature of stress
– Different **(bundles of) stress cues** are responsible for marking stress depending on the language
– **Default** stress does not seem to be stored in the lexicon as opposed to exceptions (both in free- and fixed-stress languages)
– **Training** improves performance in L2 stress perception (but possibly only enhances sensory sensitivity and not phonological categorisation)
– **There is still room for exploration of the different ERP components as markers of phonetic as opposed to phonological, and statistical as opposed to abstractionist processing of stress in L1 and L2**

Thank You!

Slides available at: *www.karolinabros.eu*

Contact me: *k.bros@uw.edu.pl*

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