

# An investigation of the neuronal signature of word order effects in Russian

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## BACKGROUND

Language comprehension proceeds by the activation of **specific words** (e.g. Kuperberg & Jaeger, 2016) and **graded prediction of upcoming word features** (Luke & Christianson, 2016; Stoops & Christianson, 2017; 2019)

EEG: Event-Related Potentials (ERP) - P600 mental representation update (Brouwer, et al., 2013)

**Posterior P600**

- grammatical violations (Frederici et al., 1996)
- semantic violations (sometimes preceded by N400; Kuperberg, 2013)
- unexpected garden-path sentences (Qian et al., 2018)

**Frontal P600**

- syntactically complex **grammatical** revisions **only** (Jackson et al., 2020; Kaan & Swab, 2003)

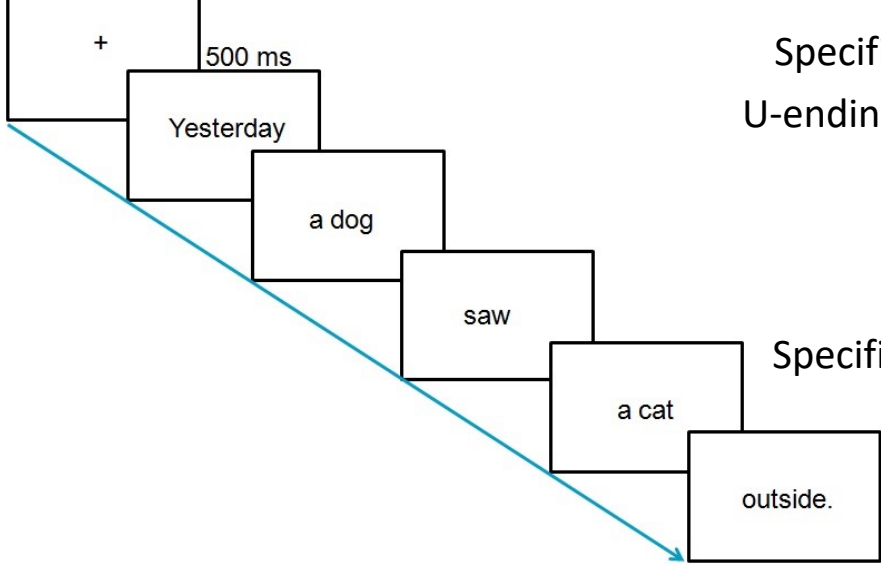
### LIMITATIONS

- Difficult to control for the target word/preceding context length in the studied languages
  - Ample evidence that such factors modulate language processing and comprehension (Meylan & Griffiths, 2021; Staub & Goddard, 2019; *i.a.*)
- Aggregate ERP signal pulls on different frequency bands
  - time-frequency (tf) measures could pinpoint what frequency oscillation at what topography contributes to the ERP components (Baastiaansen et al., 2008; Lewis & Bastiaansen, 2015; *i.a.*)

**GOAL:** To examine neuronal brain responses evoked by violations of word order **predictability** and **grammaticality** in Russian, controlling for the target word and preceding context length

## METHOD

### Experimental Paradigm



Specific word Cloze: 0.15%  
U-ending Noun Cloze: 94%  
Corpora: 60%  
Specific word Cloze: 0.12%  
Noun Cloze: 3%  
Corpora: 30%

### Stimuli: target word

**SVO:** Vchera sobaka uvidela koshku na ulitse.  
Yesterday dog-Nom saw cat-Acc outside.  
**\*SVS:** Vchera sobaka uvidela koshka na ulitse.  
Yesterday dog-Nom saw cat-Nom outside.  
**OVS:** Vchera sobaku uvidela koshka na ulitse.  
Yesterday dog-Acc saw cat-Nom outside.  
**\*OVO:** Vchera sobaku uvidela koshku na ulitse.  
Yesterday dog-Acc saw cat-Acc outside.  
Yesterday a cat saw a dog outside

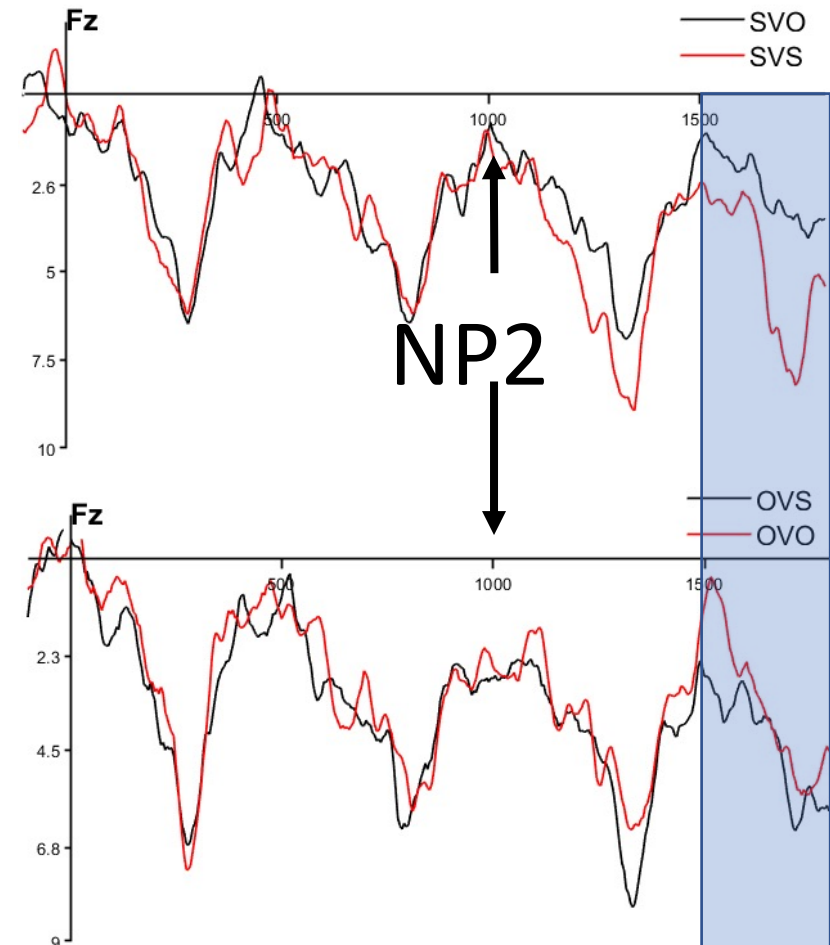
**Participants:** 12 native Russian speakers (6 female; age=25; range 21-40)  
**Data Collection:** Continuous EEG; 32 (10-20 EasyCap) scalp locations with standard reference and ground procedure; sample rate of 200 Hz  
**Artifacts Removal:** Eye blinks and other artifacts were removed automatically with peak-to-peak and step functions, verified through visual inspection in EEGLAB (<15%)  
**ERP:** epochs (-100:1800 with 100 ms prestim baseline, time locked to onset of first noun) in EEGLAB  
**Evoked Power (EP):** multitaper time-frequency filter (+ Hanning taper for smoothing) adaptive window (4 step increments) for each frequency applied to the averaged ERP for each subject in fieldtrip (Oostenveld et al., 2011)  
**Inter-Trial Coherence (ITC)** phase-locked to the target word onset - a mean of a scalar product of the normalized spectral density over trials  
**ERP and tf analyses:** separate LME for the N400 (300-500ms) and P600 (500-795ms) time windows of NP2. Fixed effects of canonicity, grammaticality, anteriority, and hemisphere with random intercepts for participants

### PREDICTIONS:

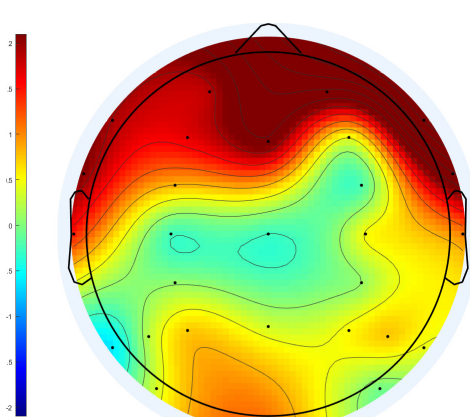
- Word level:** **posterior P600** (possibly with N400) for SVS/OVO
- Linguistic information at a level **higher than individual words:** **frontal P600** for SVS/OVO
- Word features + Preceding Context:** **frontal P600 ONLY** for **SVS**

## RESULTS

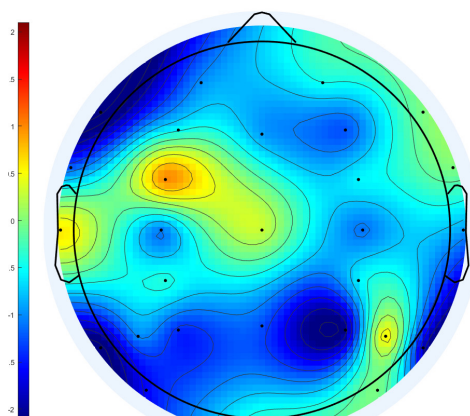
### Event-Related Potentials (ERP) – P600



SVS-SVO:

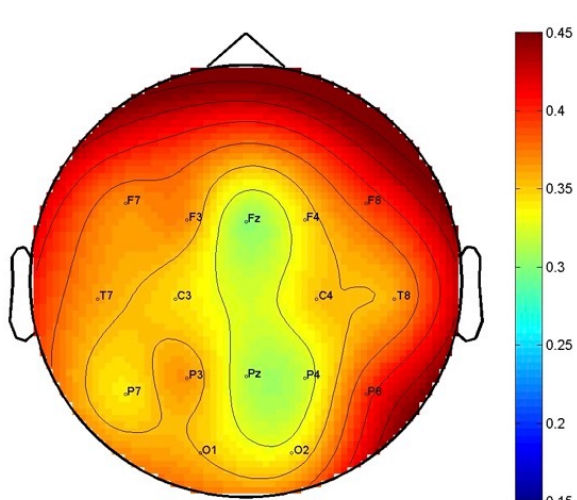
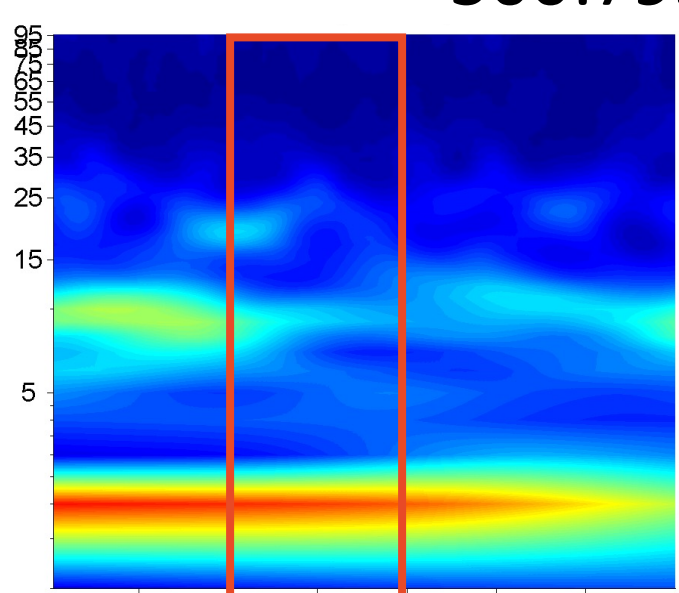


OVO-OVS:

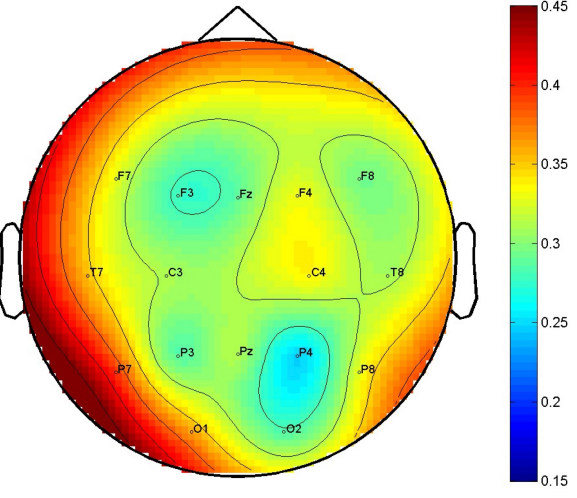
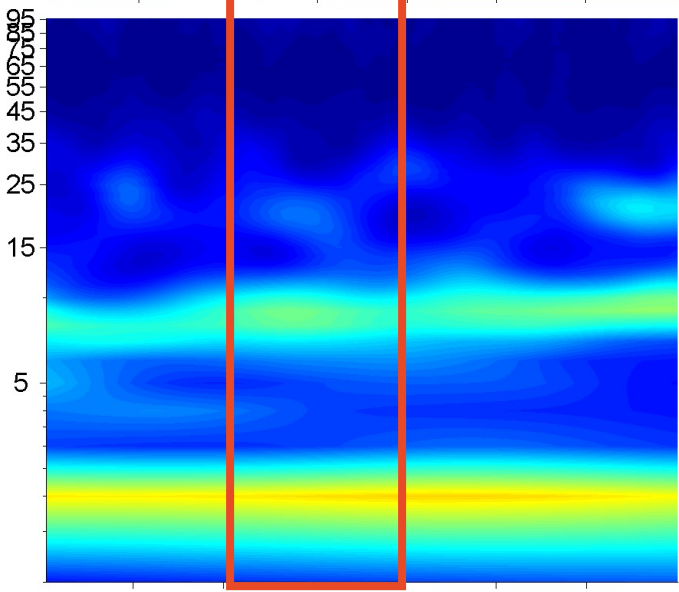


### Event-Related Spectral Perturbation (ERSP) -Delta (2-3Hz) 500:795 ms

SVS-SVO:

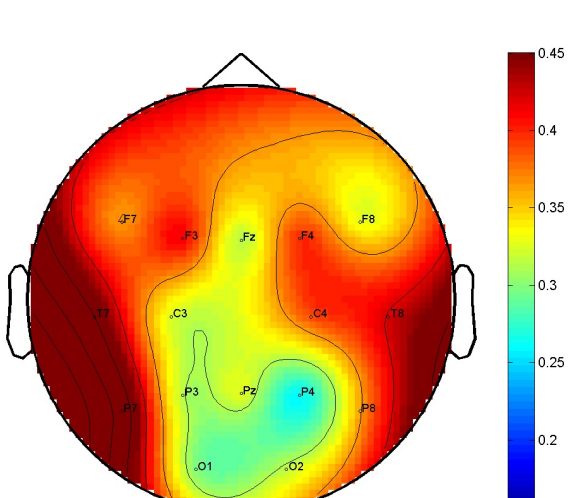
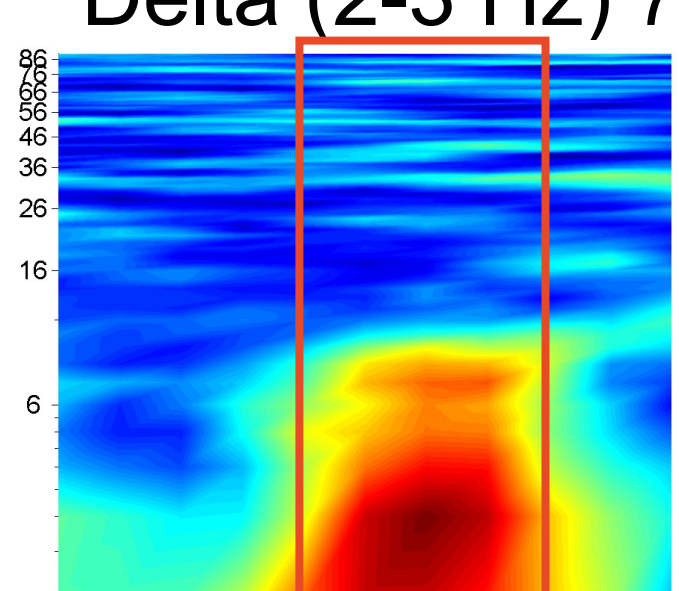


OVO-OVS:

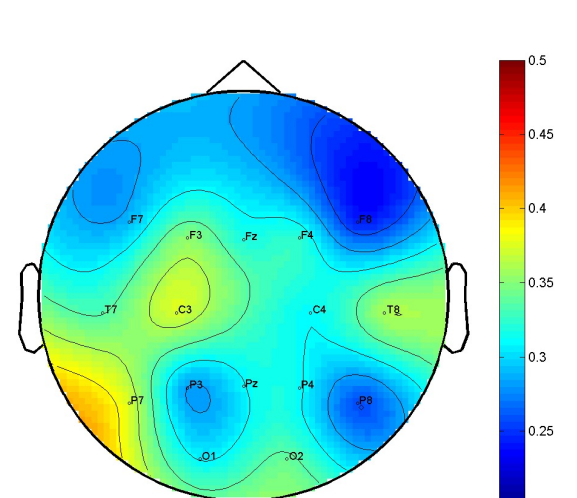
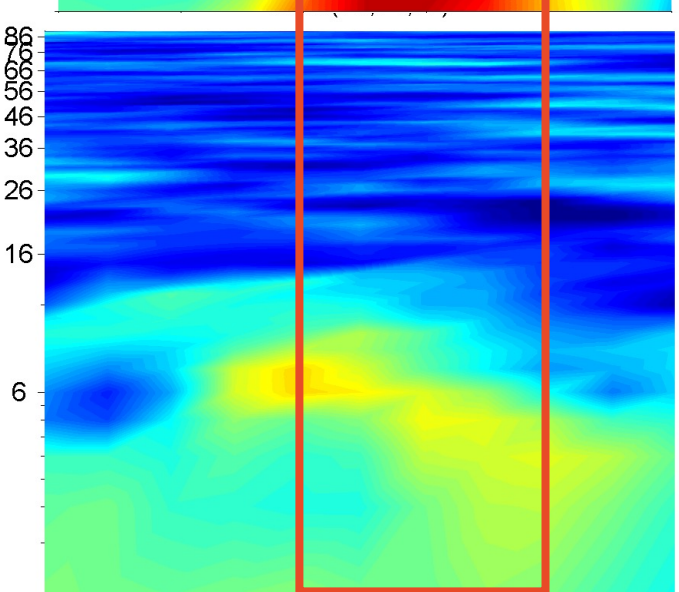


### Inter-Trial Coherence(ITC) phase-locked to the NP2 onset Delta (2-3 Hz) 700:900 ms

SVS-SVO:



OVO-OVS:



## Key Findings

- Processing second subject instead of an **expected** object was more disruptive than a second object instead of an unexpected subject (frontal P600 only for SVS not for OVO)
- Our study enriches the literature on P600 and delta oscillations by demonstrating that evoked (ERSP) delta power is sensitive to the processing of linguistic information at a level higher than individual lexical item – i.e. grammatical case that indicates thematic role assignments in Russian

## Conclusion

- Skilled readers engage in prediction of linguistic information at a level higher than individual lexical items
- Preceding context can induce expectations regarding word order and case inflections as reflected in the electrophysiology of neuronal oscillations

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