Pitch, Formants, and Formant Differences are Decisive Factors in Vowel Processing – Electrophysiological Evidence from N1 Amplitude and Latency Analyses

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1 Introduction

- The perception of vowels such as [a] or [i] is based on their spectral properties, i.e. resonance frequencies (formants), and on fundamental frequency (f0) [1, 2]
- Yet, it is unclear whether early neural indices, i.e. the N1, of vowel processing are predominantly driven by f0 or by formant frequencies
- The N1 has found to reflect pitch differences in simple tones, but also general vowel differences [3]
- However, the co-variation of formant frequencies and f0 with either mean N1 amplitude or N1 latency has not yet been investigated in a principled manner

2 Research questions

1. How do pitch, formants, and formant distances influence the amplitude and latency of the N1?
2. Are the findings concerning intrinsic pitch best described through a place-code or temporal-code pitch representation?

3 Material and Methods

- Electroencephalography (EEG) using 32 active electrodes
- 20 healthy native speakers of German (mean age: 25.5), 50% female
- Stimuli: 6 vowels of the German vowel inventory ([aː iː œː yː ɔː uː]), 3 tones as a control condition white noise as a catch trial
- The vowel stimuli were manipulated in pitch to allow the investigation of intrinsic pitch differences
- Subjects were asked to press a button when hearing the catch trial (white noise) (experimental design adapted from [4])
- Stimuli were presented in a vowel and a tone block with varying interstimulus intervals, total duration: 30 min
- The analysis of the event-related potentials (ERPs) was done in MATLAB (FieldTrip and EEGlab) and the statistical analysis in R

4 Results

A Tones

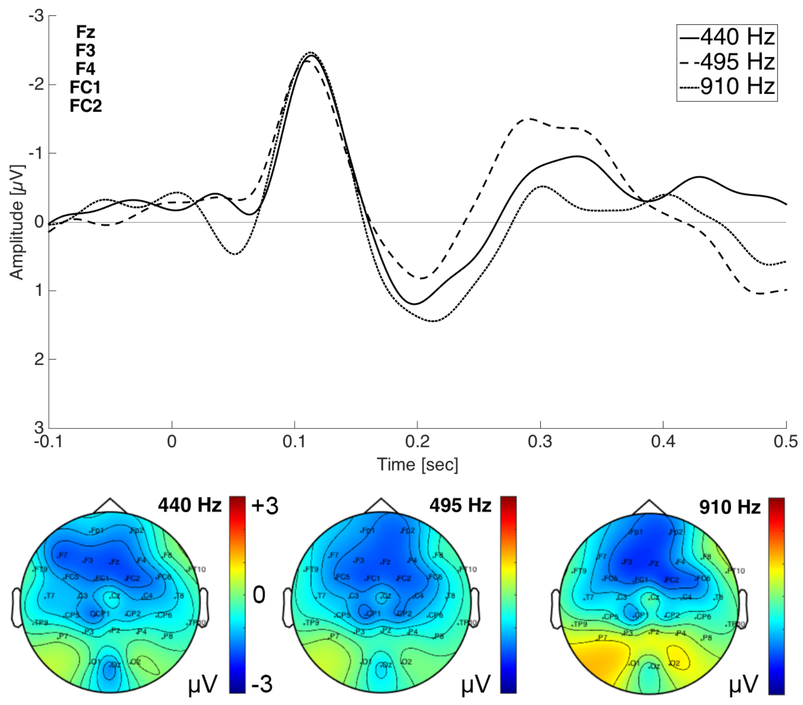


Figure A: Averaged ERPs and topographies for the tones 440 Hz, 495 Hz, and 910 Hz

B f0 and F1

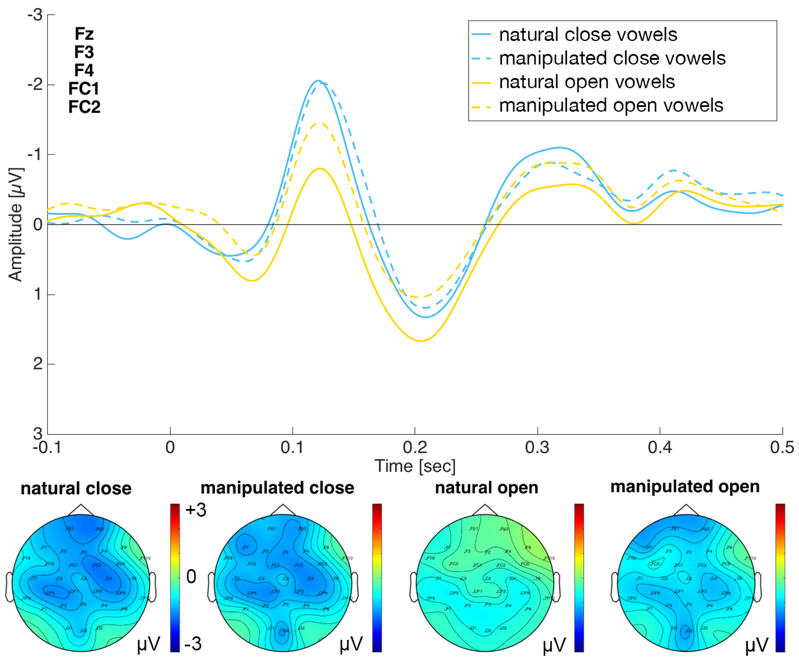


Figure B: Averaged ERPs and topographies for the categories close vowels with natural pitch, close vowels with manipulated pitch, open vowels with natural pitch, and open vowels with manipulated pitch

C f0 and F2

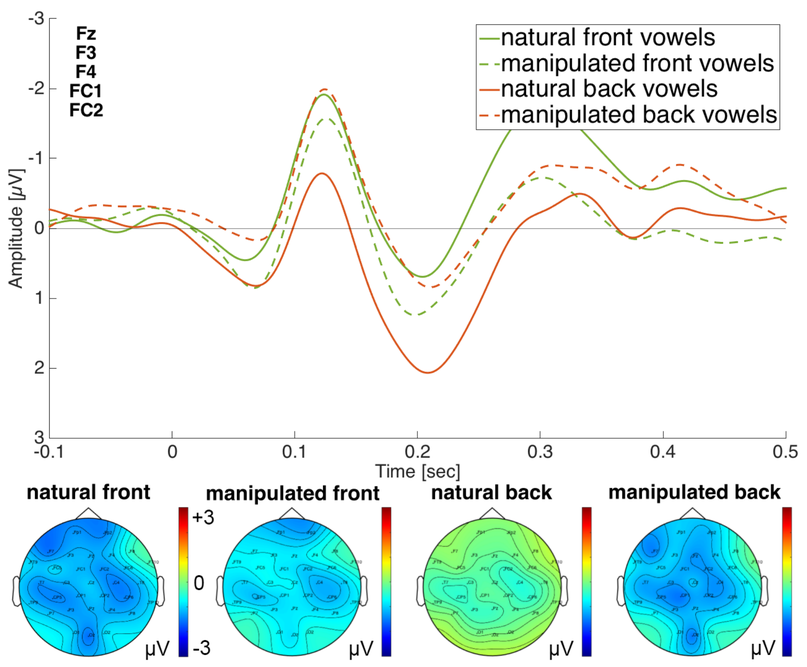
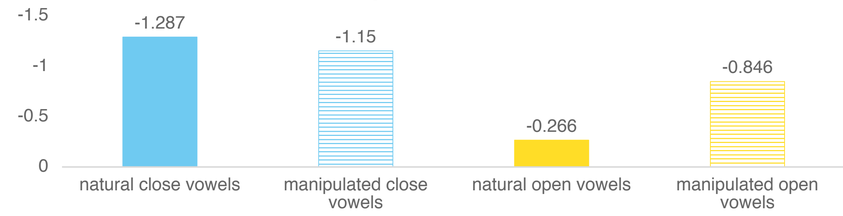


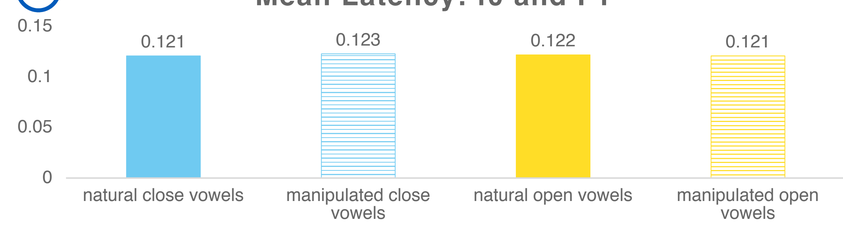
Figure C: Averaged ERPs and topographies for the vowel categories front vowels with natural pitch, front vowels with manipulated pitch, back vowels with natural pitch, and back vowels with manipulated pitch

B Mean Amplitude: f0 and F1



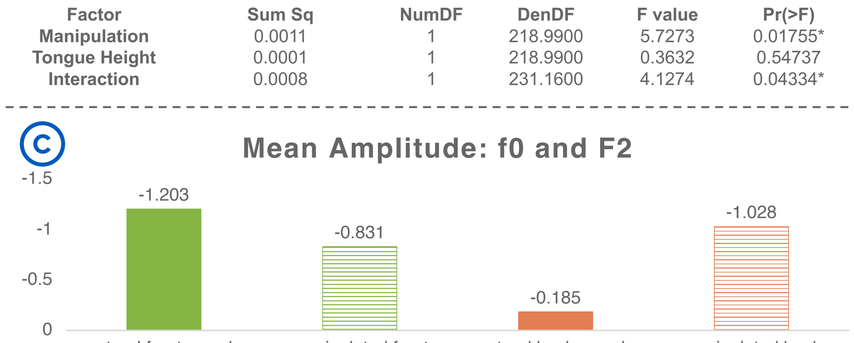
Factor	Sum Sq	NumDF	DenDF	F value	Pr(>F)
Manipulation	0.4828	1	218.03	0.2135	0.6445
Closure	18.0613	1	218.03	7.9874	0.0051**
Interaction	5.4762	1	225.34	2.4218	0.1210

B Mean Latency: f0 and F1



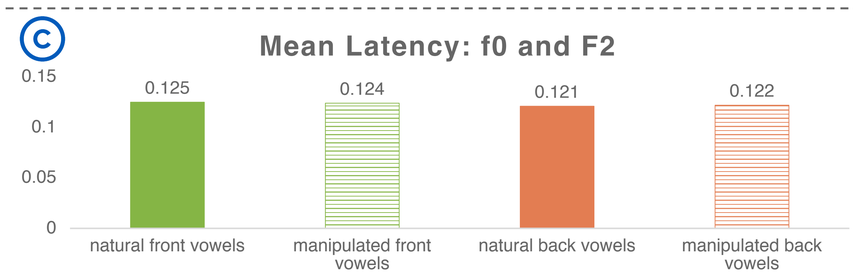
Factor	Sum Sq	NumDF	DenDF	F value	Pr(>F)
Manipulation	0.0011	1	218.9900	5.7273	0.01755*
Tongue Height	0.0001	1	218.9900	0.3632	0.54737
Interaction	0.0008	1	231.1600	4.1274	0.04334*

C Mean Amplitude: f0 and F2



Factor	Sum Sq	NumDF	DenDF	F value	Pr(>F)
Manipulation	0.2503	1	141.7000	0.0994	0.75302
Tongue Position	6.9835	1	141.7000	2.7733	0.09806
Interaction	3.1507	1	155.7600	1.2512	0.26505

C Mean Latency: f0 and F2



Factor	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Manipulation	0.0017	0.0017	1	141.6800	10.0718	0.0018**
Tongue Position	0.0004	0.0003	1	141.6800	1.8567	0.1752
Interaction	0.0003	0.0003	1	156.0000	1.5905	0.2091

Highlights:

- Spectral and periodicity properties of vowels are investigated using EEG.
- The component of interest (N1) is sensitive to both properties in complex sounds.
- Early vowel processing is dominated by spectral information.

5 References

[1] Ladefoged, P. (2001). Vowels and Consonants: An Introduction to the Sounds of Languages. Malden, MA: Blackwell.

[2] Stevens, K. N. (1998). Acoustic phonetics (Vol. 30). Cambridge, MA; London, England: The MIT Press.

[3] Näätänen, R., & Picton, T. (1987). The N1 wave of the human electric and magnetic response to sound: A review and an analysis of the component structure. Psychophysiology, 24, 375-425.

[4] Scharinger, M., Poe, S., & Idsardi, W. J. (2011). A three-dimensional cortical map of vowel space: Evidence from Turkish. Journal of Cognitive Neuroscience, 23, 3972-3982.