On-line formant shifting as a function of F0

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I. Introduction

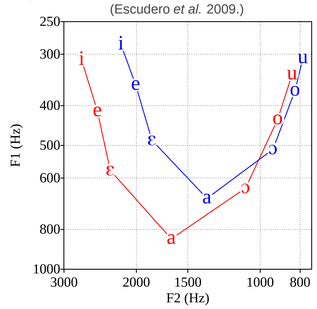
Vowel formants are higher in female than in male speakers.
BUT IN ADDITION
Vowel spaces are larger in female speakers (e.g. Fant 1974, see also Figure 1)**.**

Causes proposed in the literature:

Physiological cause	Socio-phonetic cause	Spectral undersampling
(e.g. Whiteside 2001)	(Lieberman 1986, Goldstein 1980)	(Goldstein 1980, Diehl *et al.* 1996)

The present study investigates whether
the height of a speaker's pitch has an effect on their vowel formants, and whether speakers produce more dispersed vowels when speaking at a higher-than-normal pitch.

Figure 1: Portuguese male and female vowels. (Escudero *et al.* 2009.)



II. Method

Data collection

- 18 native Czech speakers
- a list of 70 phrases:
  Ve slově CVC máme V.
  ('In the word CVC we have a V.')
  V = all 10 Czech vowels
  C = various (voiceless) consonants
- each speaker reads the list in **3 intended-pitch conditions**:
  Normal, High, Low

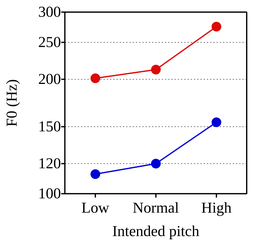
Data analysis

- 3780 vowel tokens
- F0, F1, F2 measured in Praat
- median log-value in each of the 3 pitch conditions
- repeated-measures ANOVA
- between-subject factor: gender
- within-subject factors: intended pitch, vowel category

III. Results: higher formants *and* enlarged vowel space

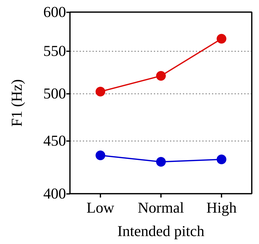
Figures 2a, 2b, 2c: F0, F1, and F2 as a function of intended pitch.
Mean male and female F0, F1, F2 values over the 10 vowel categories.

2a



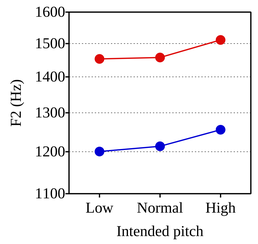
F0: main effect of intended pitch

2b



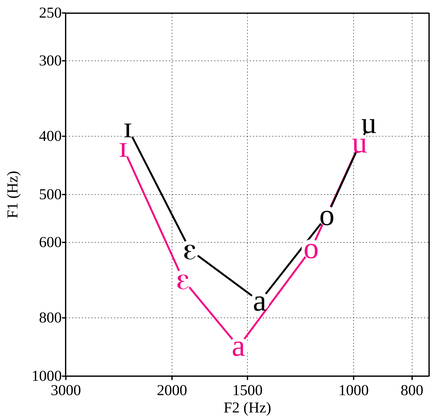
F1: main effect of intended pitch, interaction with gender

2c

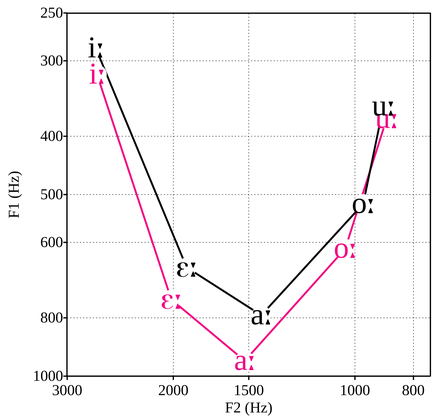


F2: main effect of intended pitch

3a: Czech females - short vowels



3b: Czech females - long vowels



Figures 3a and 3b: Vowels spoken at a High and **Low** intended pitch. Note that - even along logarithmic axes - the (F1) vowel space is larger in the high- than in the low-pitch condition.

Both shifting one's formants *and* increasing one's vowel space size compensate for the undersampling caused by a higher F0.

IV. Discussion

With a rising intended pitch, *female*, but not male, speakers raise their F1 ➠ Which of the proposed causes is supported by our results?

✘ **physiological:** articulatory implementation of high F0 = raising the larynx ⇒ shortens the vocal tract **BUT** this would predict that *both* sexes raise their F1

✘ **socio-phonetic:** women aim at speaking more clearly **BUT** why would women aim at speaking *even more* clearly at a higher-than-normal F0?

✔ **spectral undersampling:** the higher the F0, the fewer harmonics fit inside the vowel space ⇒ a loss of clarity ⇒ speakers compensate for this by increasing the size of the vowel space

SO WHY DO ONLY WOMEN ENLARGE THEIR VOWEL SPACE?

⇒ **spectral undersampling happens whenever F0 is very high:** a female high F0 of 300 Hz is perceptually worse (= will deteriorate vowel identifiability more) than a male high F0 of 180 Hz

V. Conclusion: compensation for undersampling

By raising their formants *and* by increasing the size of their F1 vowel space, female speakers recover much of the information that they lose by raising their F0.

The amount of information recovered is 64% (see paper for computation).

VI. References

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