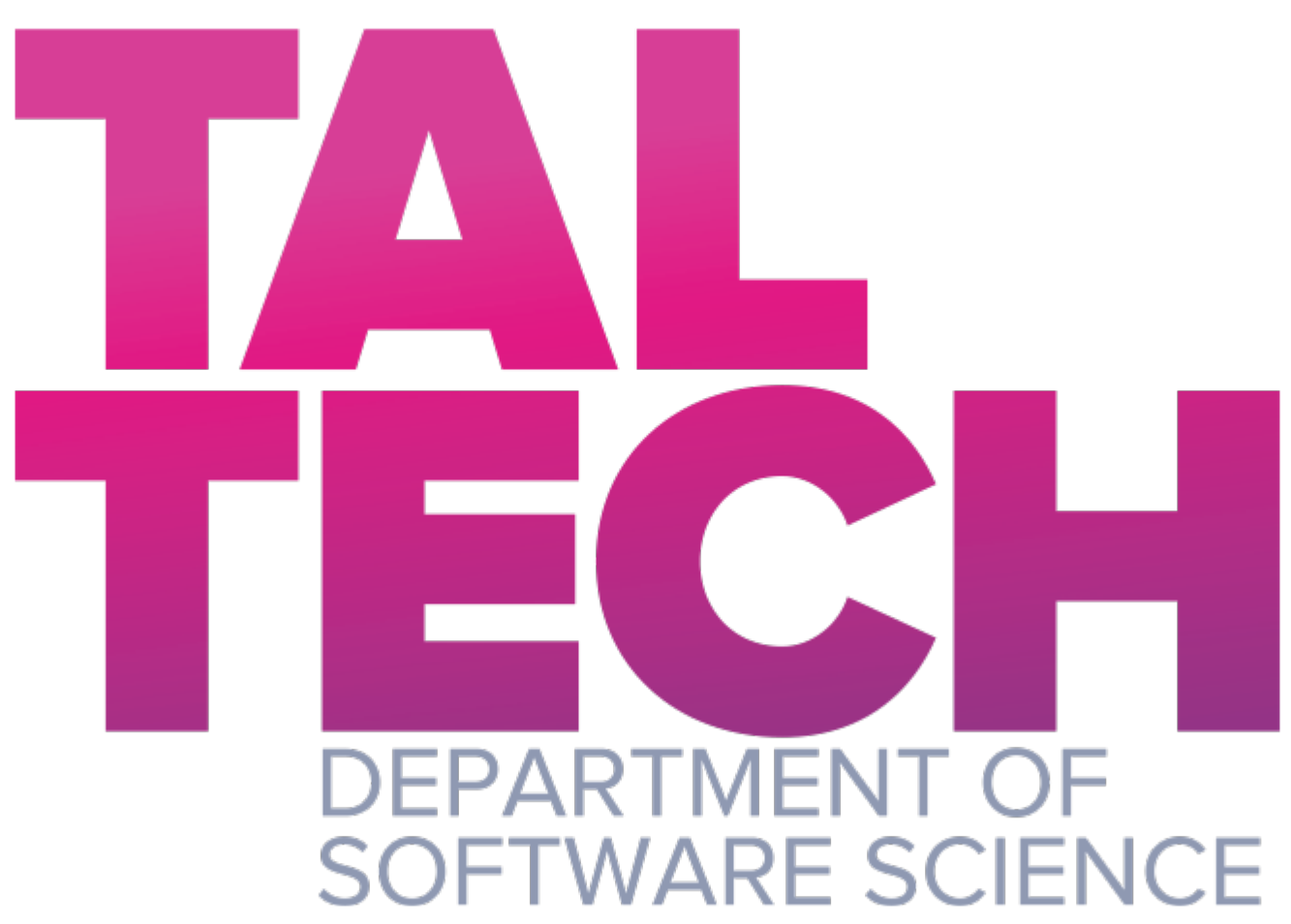


Developmental changes of fundamental frequency and temporal characteristics in Estonian adolescent speech

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Introduction

Age- and gender-related anatomic changes of the vocal apparatus during childhood and adolescence have a direct impact on speech acoustics, manifested in a sudden drop of fundamental frequency (F0) during puberty in boys and in a gradual decrease of the acoustic vowel space and formant frequencies in both genders. In parallel with anatomical changes, the development of speech-motor control as well as cognitive and linguistic processing takes place, which manifests itself in the increase of speech and articulation rates.

Objectives

The study aims to document the acoustic characteristics of Estonian adolescent speech related to the speaker's age and gender. We explore:

1. the acoustic variations of the fundamental frequency F0
2. the measures of speaking rate

Materials and Methods

Speech material

The Estonian Adolescent Speech Corpus:

- Speech samples read by 309 native Estonian subjects (175 girls and 134 boys) in the age range of 9 to 18 years
- Cross-sectional speech data of different age groups recorded in ten schools around Estonia
- Contains linguistically diverse material – digits, phone numbers, time expressions, IT terms, sentences with name entities, phonetically rich sentences, and several samples of spontaneous speech
- In the current study, a subset of the corpus consisting of 20-25 read utterances (average duration of utterance 7.8 seconds) per subject, totalling 6964 utterances
- The utterances were segmented manually on the word and phone levels in Praat, syllable boundaries and types were added using a custom Praat script

Acoustic analysis

- For F0 a custom Praat script was compiled using the two-step procedure recommended by Hirst
- Two speaking rate measures for each utterance were calculated:
 - **Speech rate** = the number of syllables in an utterance / the duration of an utterance including pauses
 - **Articulation rate** = the number of syllables in an utterance / the duration of an utterance without pauses

Statistical analysis

R was used with the *mgcv* package for Generalized Additive Mixed Models (GAMM) and the *itsadug* package for model validation and visualization of the results.

Results

F0

GAMM fitted for F0 mean with the smooth term *age*, the explanatory factor *gender*, and *subject* as the random effect.

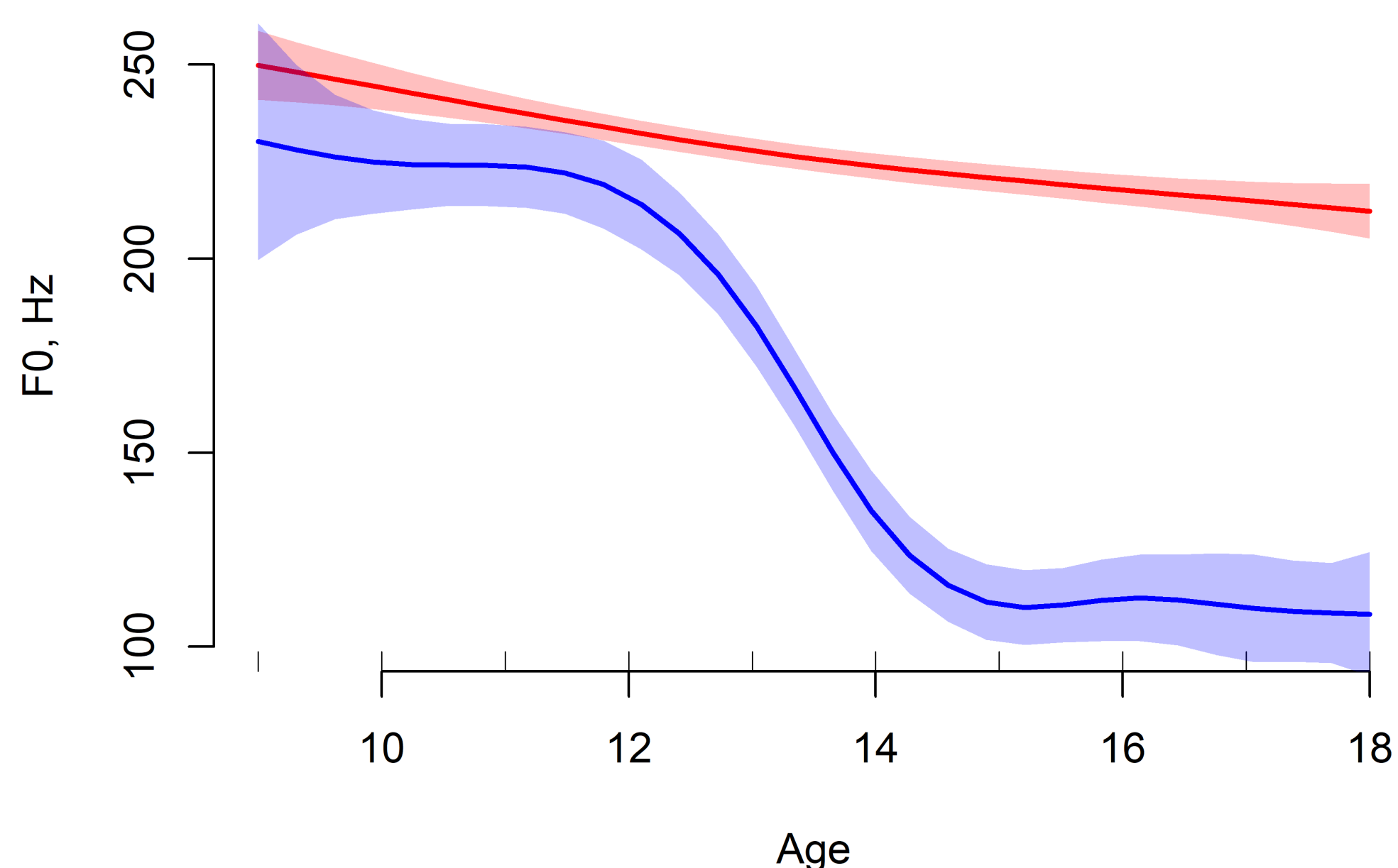


Figure 1: The age-dependent change of F0 mean with 95 percent confidence bands for girls (red) and boys (blue) as predicted by the GAMM.

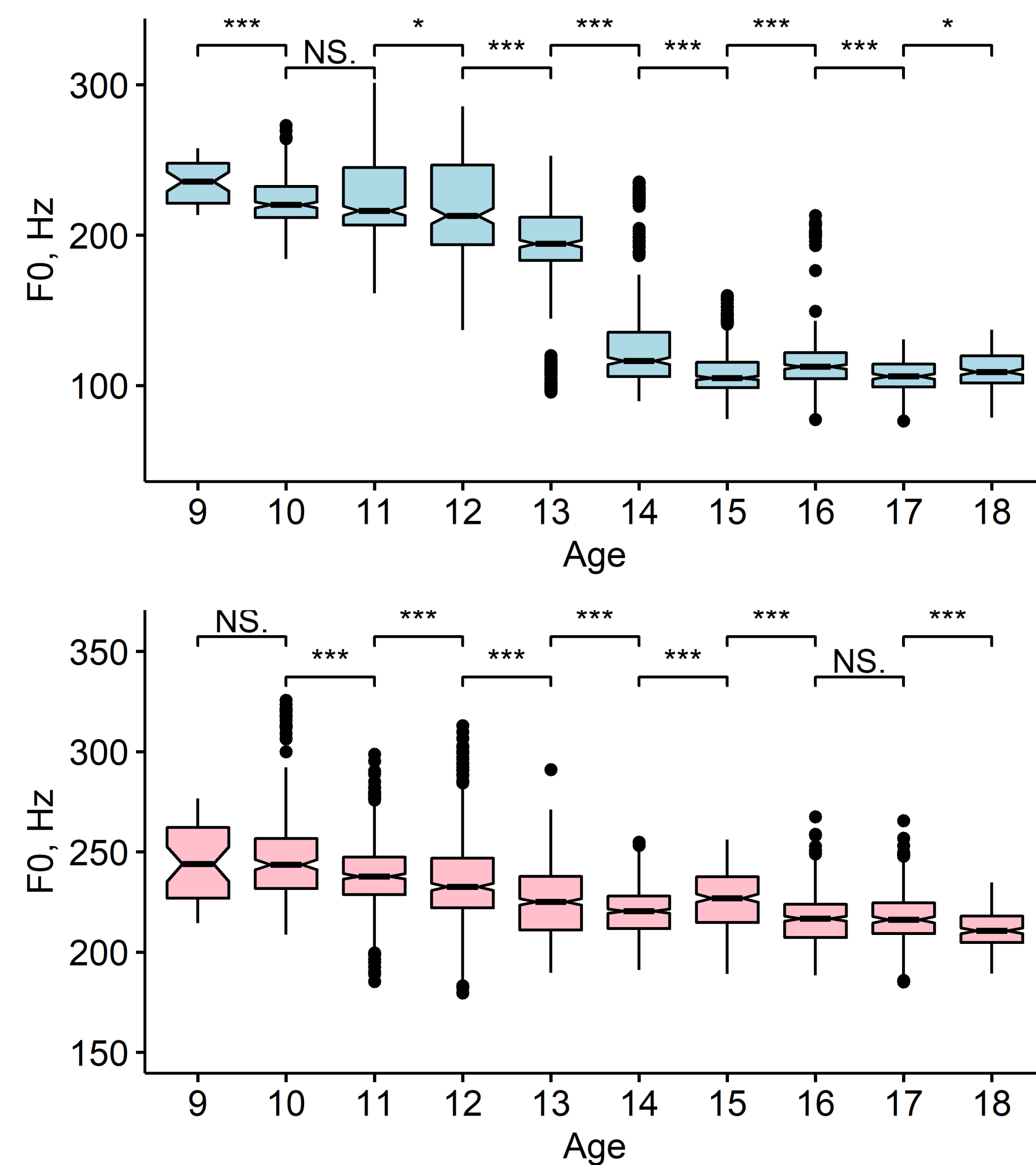


Figure 2: Male (top) and female (bottom) speakers' boxplots of F0 means by age.

Speaking rates

GAMMs fitted for the **speech** and **articulation rates** with the smooth terms *age* and *text length*, and the explanatory factor *gender*; *subject* was added as an independent random variable.

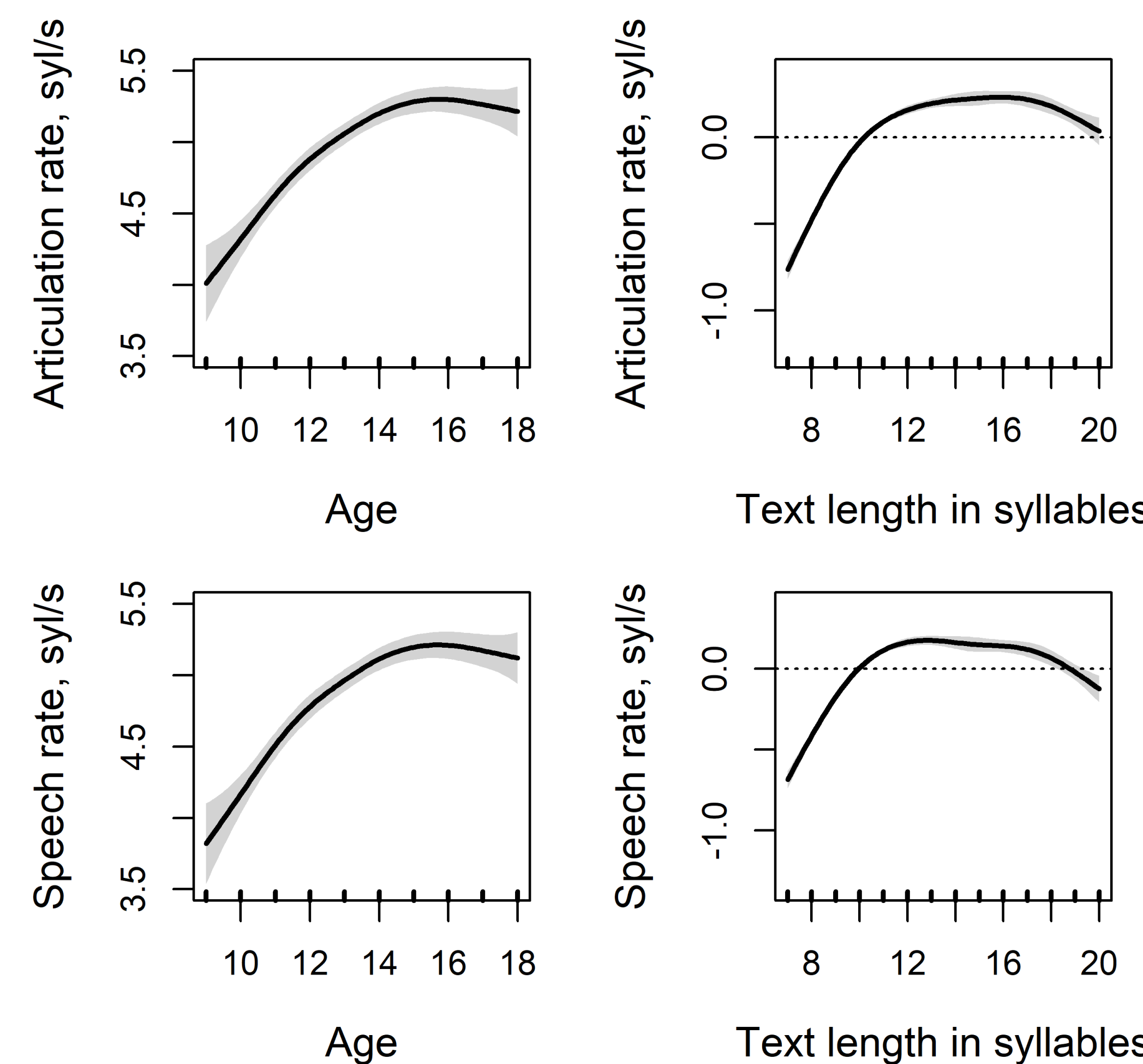


Figure 3: The age-dependent change of F0 mean with 95 percent confidence bands for girls (top) and boys (bottom) as predicted by the GAMM.

Conclusions

The results show the expected age-dependent patterns:

- a decline in F0 with a sharp drop of about 100 Hz in boys aged 12–15 years
- a gradual F0 decline in girls
- an increase in speech and articulation rates up to 15 years of age
- gender differences in temporal characteristics are not significant, although boys tend to speak slightly faster than girls
- Estonian adolescents achieved speech-motor control skills similar to adults between the ages of 14 and 15 years

The results are in line with the findings reported for several other languages and can be considered reference data for Estonian-speaking subjects aged 9–18 with typical language development.