

Production of Long and Short Vowels in Malayalam

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1. Introduction

Malayalam—a South Dravidian language—retains all Proto-Dravidian vowels (/a, i, u, e, o/) with phonemic length contrast [1]. Although prior studies (e.g., [2], [3]) have addressed Malayalam vowel acoustics, none have analysed their dynamic temporal patterns. In this study, we employed a three-point model that captures formant values at 20%, 50%, and 80% of vowel duration, a method shown to enhance vowel identification and classification accuracy [4]. Accordingly, the objectives of this study are: (1) to examine durational and acoustic differences across gender (Male/Female) and speaking conditions (IS/CW); and (2) to evaluate vowel classification performance using three-point formant measurements with (F+D) and without duration (F+NoD).

2. Methodology

Twelve native Malayalam speakers (6 male, 6 female), aged 20–30, were recorded in a soundproof studio at 44.1 kHz and 16-bit resolution. Each speaker produced 10 vowels in isolation (IS) and in a /V1.C1V2/ word context (CW), with five repetitions per condition. Of the 1,200 tokens, 10 were excluded due to mispronunciations or noise. Vowel duration and F1–F3 values were extracted using a Praat script using To Formant (Burg) method, with maximum formant frequencies of 5 kHz (male) and 5.5 kHz (female), 5 formants, a 0.025s window length, and a 0.01s time step. A linear mixed-effects model (LMM) with a random intercept for speaker was fitted using the lme4 package to test the effects of gender (M/F) and condition (IS/CW) on vowel duration and formants (F1–F3) at intervals (20%, 50%, and 80%). Statistical significance was assessed using likelihood ratio tests (ANOVA). Linear Discriminant Analysis (LDA) was used to evaluate vowel classification, with accuracy for each vowel assessed against a 10% chance level.

3. Results

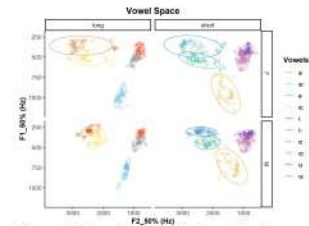


Figure 1: Raw F1 and F2 values for long and short Malayalam vowels measured at 50% of vowel duration, from 6 male and 6 female speakers.



Figure 2: Formant trajectories of the long vowels across different male (above) and female (below) speakers. The x-axis represents the vowel interval (20%, 50% and 80% of the vowel duration), and the y-axis represents the frequency values (Hz).

Fixed Effects	F1	F2	F3
Gender	$\chi^2(1) = 25.40, p < 0.001$	$\chi^2(1) = 4.02, p = 0.045$	$\chi^2(1) = 13.26, p < 0.001$
Gender: Interval	$\chi^2(1) = 0.53, p = 0.46$	$\chi^2(1) = 0.18, p = 0.67$	$\chi^2(1) = 14.41, p < 0.001$
Condition	$\chi^2(1) = 31.25, p < 0.001$	$\chi^2(1) = 1.12, p = 0.29$	$\chi^2(1) = 434.12, p < 0.001$
Condition: Interval	$\chi^2(2) = 21.39, p < 0.001$	$\chi^2(2) = 4.88, p = 0.087$	$\chi^2(2) = 57.44, p < 0.001$

Table 1: Summary of statistical results from mixed model comparisons examining the effects of gender, condition, and their interaction with interval (formant dynamics).

Vowels	F+No D	F+D
a:	86.21	95.69
i:	61.34	88.24
e:	64.71	85.71
o:	65.55	84.03
u:	74.17	91.67
ɐ	54.17	97.5
ɪ	50	86.67
ɛ	72.03	92.37
ɔ	60.83	86.67
ʊ	55.46	88.24

Average 64.447 89.68

Table 3: LDA classification accuracy (% correct attribution) for long and short vowels based on formants, with (F+D) and without duration (F+NoD). The chance level is 10%.

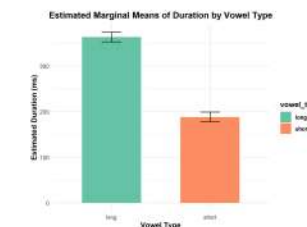


Figure 3: Shows the mean duration (in ms) by vowel types (long/short), with error bars representing the standard error of the group.

Fixed Effects Results

Fixed Effects	Results
Gender	$\chi^2(1) = 1.93, p = 0.16$
Condition	$\chi^2(1) = 1030.7, p < 0.001$
Vowel Type	$\chi^2(1) = 1541.9, p < 0.001$

Table 2: Summary of mixed model comparison statistics for gender and condition effects on vowel duration.

4. Discussions

In general, female speakers exhibit consistently higher F1 and F2 values across both long and short vowels compared to male speakers. Notably, the short vowel /a/ demonstrates greater variability among speakers of both genders (Figure 1).

Main Effects: Gender and condition significantly affect F1 and F3. F2 is unaffected by gender and condition. Intervals (formant dynamics) show marginal effects on F1 and F2, but a strong effect on F3.

Durational Analysis: Gender did not significantly affect vowel duration, whereas condition had a significant effect. Long vowels had a significantly greater mean duration ($M = 364$ ms) compared to short vowels, with an estimated difference of 176 ms, indicating an approximate 2:1 ratio [3].

LDA Scores: Including duration along with formants improves classification accuracy for all vowels. Short vowels show greater gains, with /a/ increasing from 54.17% to 97.50%. The highest accuracy without duration is for /a:/ (86.21%), and the lowest is for /i/ (50.00%). With duration, /a/ achieves the highest score (97.50%), while /o:/ has the lowest (84.03%). The overall classification accuracy of short and long vowels increases from 64.45% (without duration) to 89.68% (with duration). These results confirm that vowel duration is a key feature for distinguishing short and long vowels in Malayalam.

5. References

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