The impact of vowel length contrasts on locus equations and their implications for perceptual categorization

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Definition

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- LEs may constitute a source of relational invariance for the identification of stops' place of articulation;(Sussman et al., 1991)
- They also seem to be a good indicator of the degree of coarticulation in a CV sequence.(Krull, 1987)

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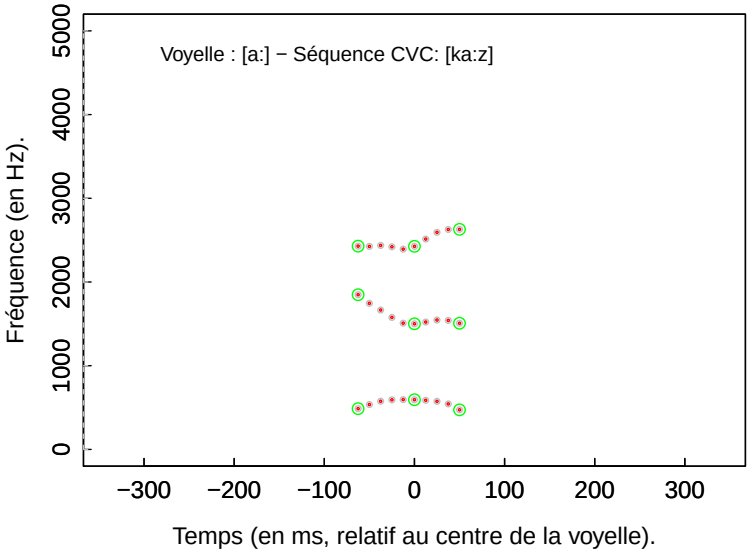

a)

Figure : Illustration of how locus equations are calculated.

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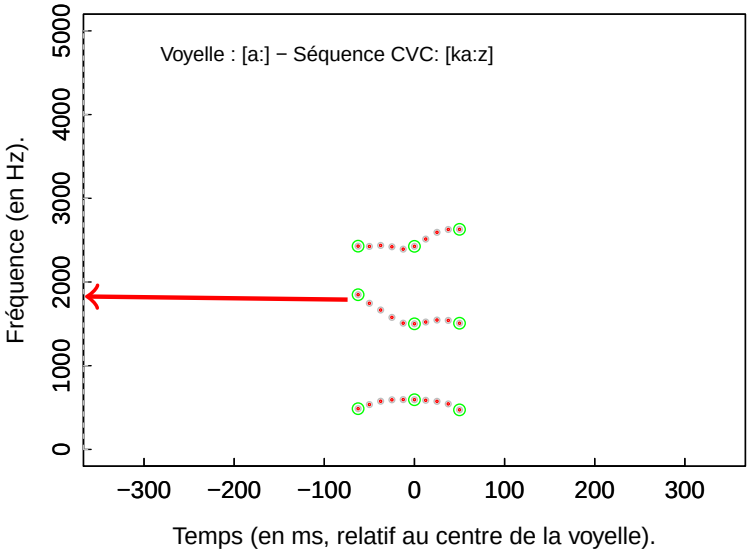

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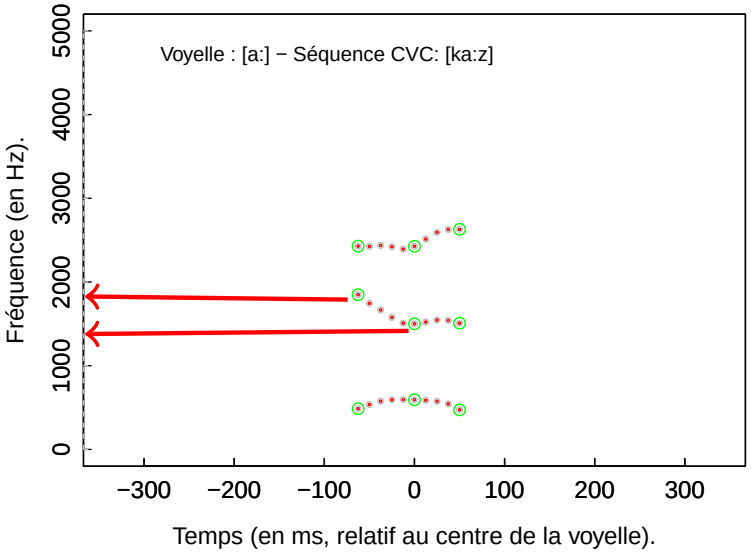

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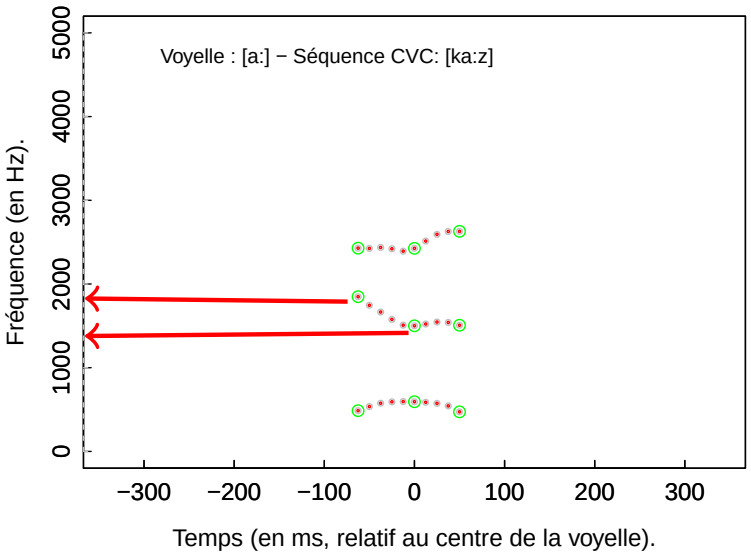

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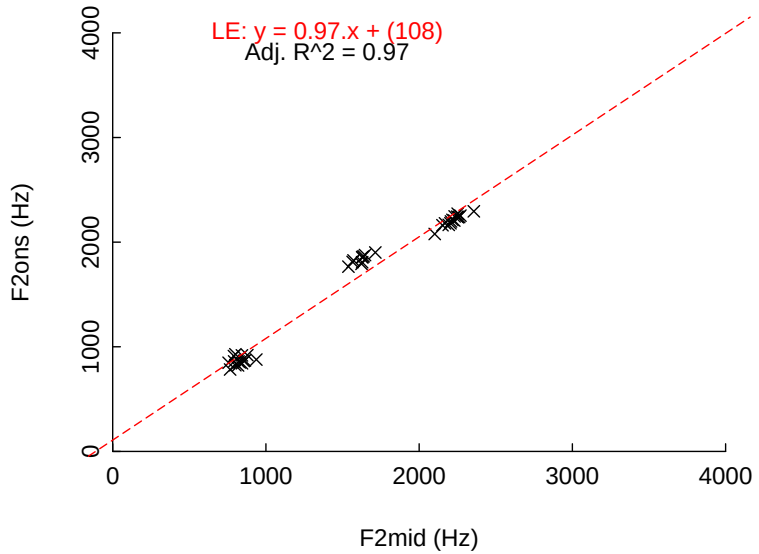

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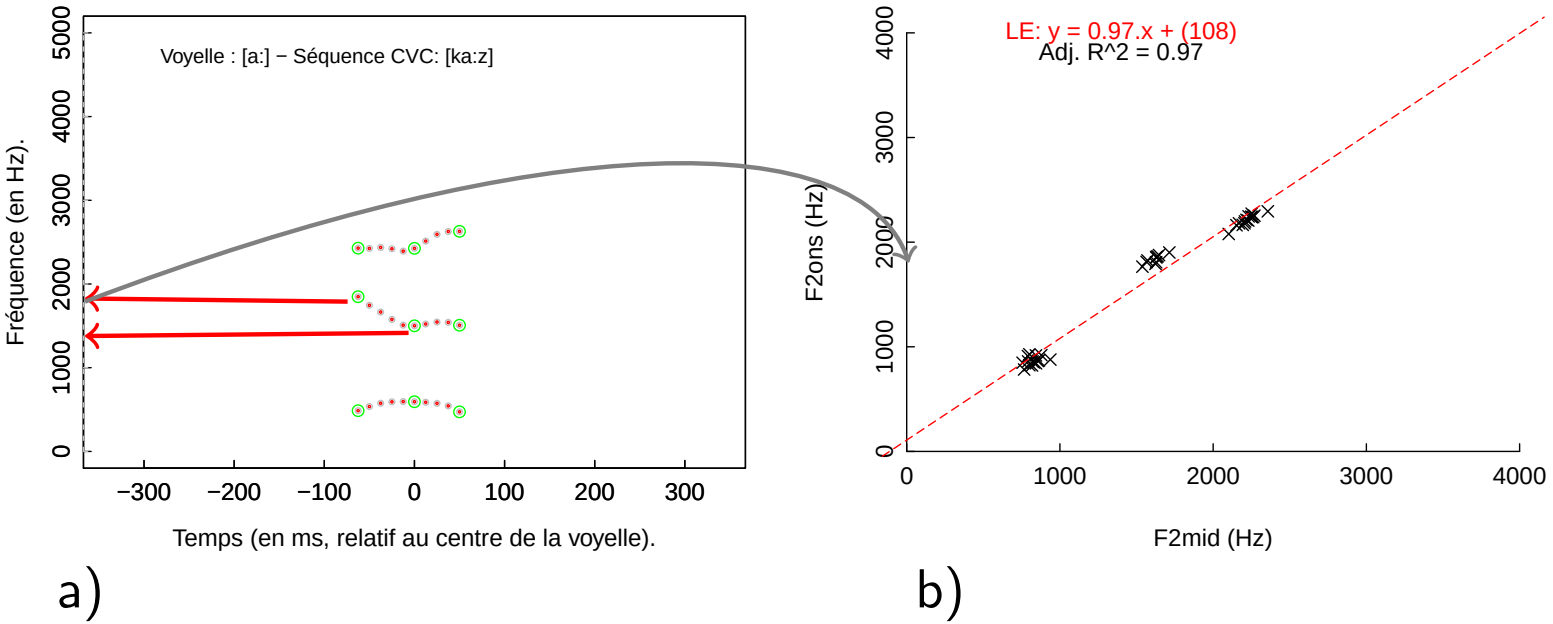

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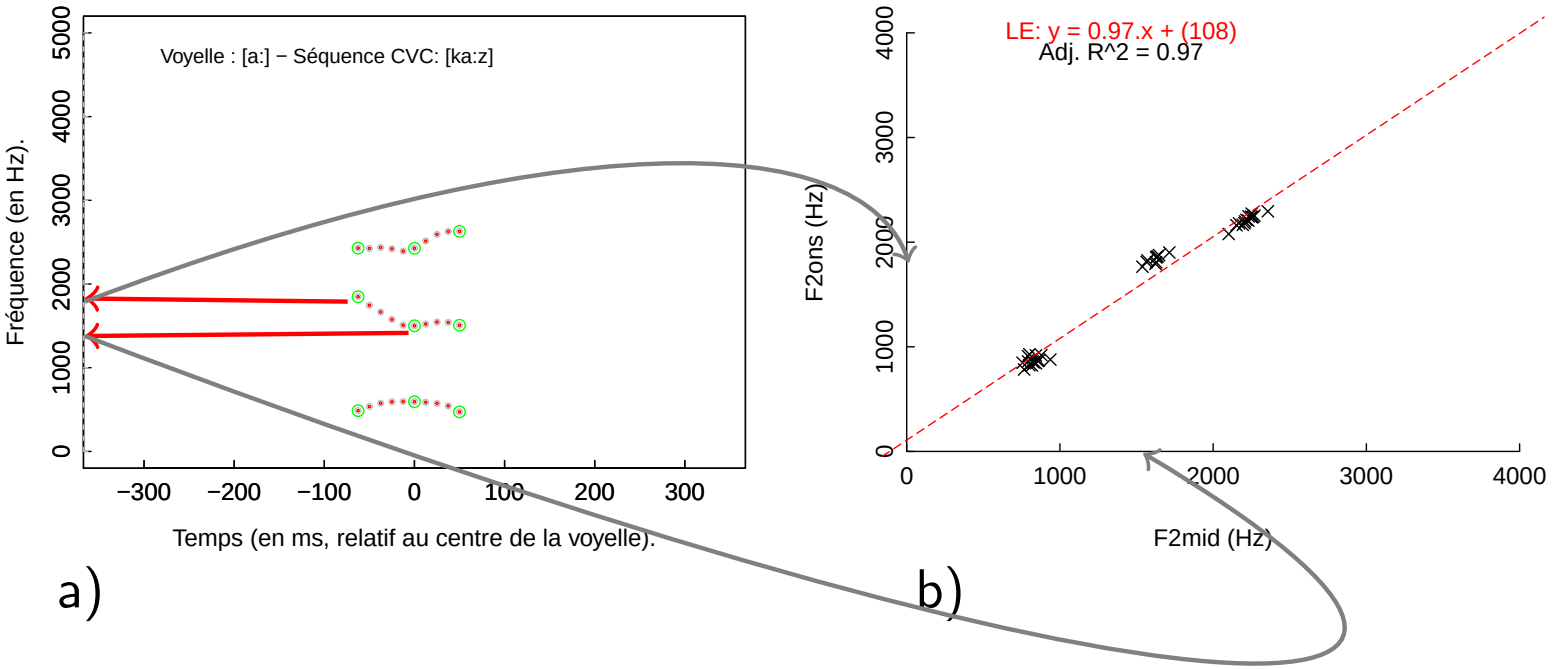

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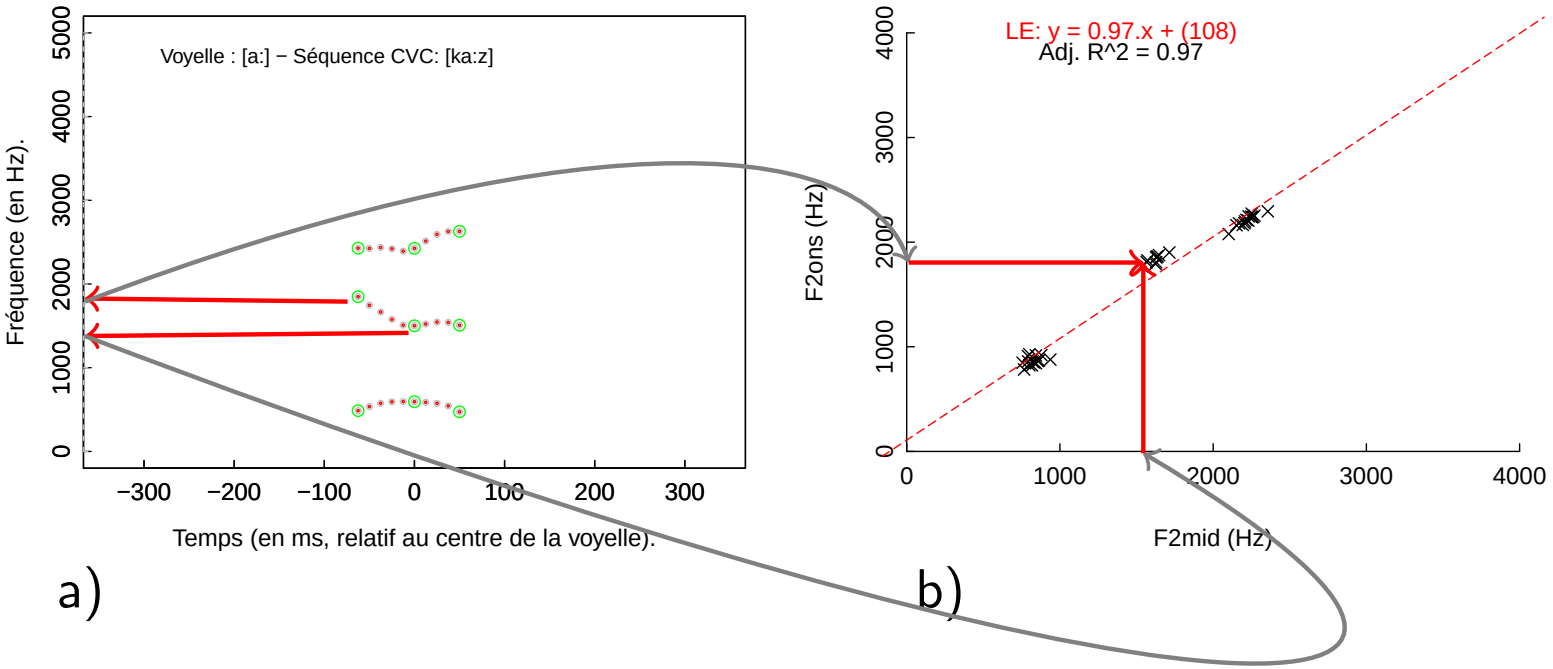

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- A slope value close to 1 indicates a high degree of coarticulation while a lower slope indicates a lower degree of coarticulation.
- LEs are used to describe CV interaction in many different speech production phenomena : speaking style (Krull, 1989), speaking rate (Berry and Weismer, 2013), emphatic stress (Agwuele et al., 2008), etc.

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- In addition, when performing discriminant analyses with either, slopes and y-intercepts, or $F2_{ons}$ and $F2_{mid}$ as the predictors, good to perfect discrimination of stop place was achieved.

JA experiment

- In a previous study (Abuoudeh and Crouzet, 2014) where we tested the impact of vowel phonological length contrasts on LE parameters in Jordanian Arabic (JA) for 5 consonants /t, tˤ, k, q, ʔ/ coarticulated with long vs. short vowels /iː, aː, uː, i, a, u/,

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- Our analysis showed that LE slope of a consonant produced with long vowels is lower than the LE slope of the same consonant when it's produced with short vowels,

- and y-intercept values for a consonant produced with long vowels are higher thant y-intercept values of the same consonant produced with short vowels.

	Slope		y-Intercept		R^2	
C	Short V	Long V	Short V	Long V	Short V	Long V
t	0.78	0.67	375	549	0.94	0.95
tʕ	0.77	0.54	198	384	0.95	0.86
k	0.96	0.94	-33	3	0.95	0.94
q	0.84	0.78	43	158	0.93	0.92
ʔ	0.93	0.83	-62	119	0.98	0.94

Table : Mean values of slopes, y-intercepts and R^2 of LEs for each consonant coarticulated with long and short vowels.

- It was observed that slopes and intercepts of consonants associated with long vowels differ significantly from slopes and intercepts of consonants associated with short vowels (respectively $F_{(1,3)} = 41.46, p < .01$, $F_{(1,3)} = 41.33, p < .05$)

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- Therefore, the LE data of JA seem to be systematically influenced by alternations in vowel length and this may have strong implications on their relation to place of articulation categories.

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- It is not clear as to whether these differing slopes and intercepts may hinder place of articulation classification in terms of perceptual mechanisms.
- The aim of the present work is to investigate this issue more closely by using *Linear discriminant analysis*.

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- LDA has two approaches :

1. Estimate correct classification (group membership probability)
2. Predict correct classification (training-test prediction)

Hypotheses

A series of *LDA* with *Leave-One-Out Cross Validation* procedure has been conducted in order to investigate two hypotheses. As time in our experiment can be categorical (long/short) or continuous (duration in ms) variables :

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1. We hypothesize that adding time in it's continuous form as predictor with the 2 classical predictors ($F2_{onst} + F2_{mid}$) would increase classification accuracy. (First LDA approach was used)
2. Using the 2 time categories as 2 different training subsets (long/short) with alternative subsets (long/short)would produce contrasted results.(Second LDA approach was used)

First hypothesis

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- These analyses showed that /t, q, k/ slopes and intercepts are the most distinct of the 5 consonants.
- Reducing our analysis from 5 to 3 consonants categories was achieved in order to make our work more comparable with previous studies (ex.Sussman et al. (1991)) and also to avoid low classification accuracy which may be induced by a higher number of categories.

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V./predictors	$F2_{onst} + F2_{mid}$	$F2_{onst} + F2_{mid}$+duration
all	0.48	0.45
long	0.45	0.46
short	0.43	0.43

Table : Correct classification percentage for all consonants using $F2_{onst} + F2_{mid}$ and $F2_{onst} + F2_{mid}$+duration as predictors with all vowels, long vowels and short vowels.

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t	q	k
0.78	0.63	0.05

Table : Correct classification percentage for each consonant with all vowels

Front /i,a/ vs. Back Vowels /u/

F.V./predictors	$F2_{onst} + F2_{mid}$	$F2_{onst} + F2_{mid}$+duration
all	0.69	0.69
long	0.67	0.65
short	0.72	0.72

Table : Correct classification percentage for all consonants using $F2_{onst} + F2_{mid}$ and $F2_{onst} + F2_{mid}$+duration as predictors with all front vowels, long vowels and short vowels.

B.V./predictors	$F2_{onst} + F2_{mid}$	$F2_{onst} + F2_{mid}$+duration
all	0.65	0.65
long	0.67	0.68
short	0.63	0.65

Table : Correct classification percentage for all consonants using $F2_{onst} + F2_{mid}$ and $F2_{onst} + F2_{mid}$+duration as predictors with all back vowels, long vowels and short vowels.

Front /i,a/ vs. Back Vowels /u/

consonants with front vowels

consonants with back vowels

Front /i,a/ vs. Back Vowels /u/

consonants with front vowels

t	q	k
0.68	0.75	0.64

consonants with back vowels

Front /i,a/ vs. Back Vowels /u/

consonants with front vowels

t	q	k
0.68	0.75	0.64

consonants with back vowels

t	q	k
0.85	0.10	0.87

- We can notice that for all performed LDA tests, adding duration as predictor does not increase the classification accuracy.

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- None of these results supports our first hypothesis.

Second hypothesis

- In order to evaluate our second hypothesis, a series of 2-steps LDAs were performed with $F2_{mid}$ and $F2_{onset}$ as predictors with complementary training and test subsets (respectively long and / or short vowels).

Training	Test	Prediction
Short	Short	
Long	Short	
Short	Long	
Long	Long	

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Table : Prediction percentages for each Training-Test subsets Short and/or Long vowels.

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Short	Short	0.49
Long	Short	0.41
Short	Long	0.48
Long	Long	0.48

Table : Prediction percentages for each Training-Test subsets Short and/or Long vowels.

Training	Test	Prediction
Short	Short	0.49
Long	Short	0.41
Short	Long	0.48
Long	Long	0.48

Table : Prediction percentages for each Training-Test subsets Short and/or Long vowels.

- Test-predictions on the short vowels subset reached 49% accuracy when preceded by training on short vowels (in-domain) but only 41% accuracy when preceded by training on long vowels (out-domain).

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- Though this observation seems to be in accordance with our second hypothesis,
- Test-predictions for the long vowels subset does not seem to be impacted by the training subset (classification accuracies reach 48% for both out-domain and in-domain training).

Discussion

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- However, the predicted behaviors may partly be hidden by the relatively low classification accuracies observed when compared with traditional studies.
- This issue may be related to $F2_{onset}$ position choice, as computing LE of $F2_{@burst}$ instead of $F2_{onset}$ indicates more accurate classification for voiceless consonants (Modarresi et al., 2005).

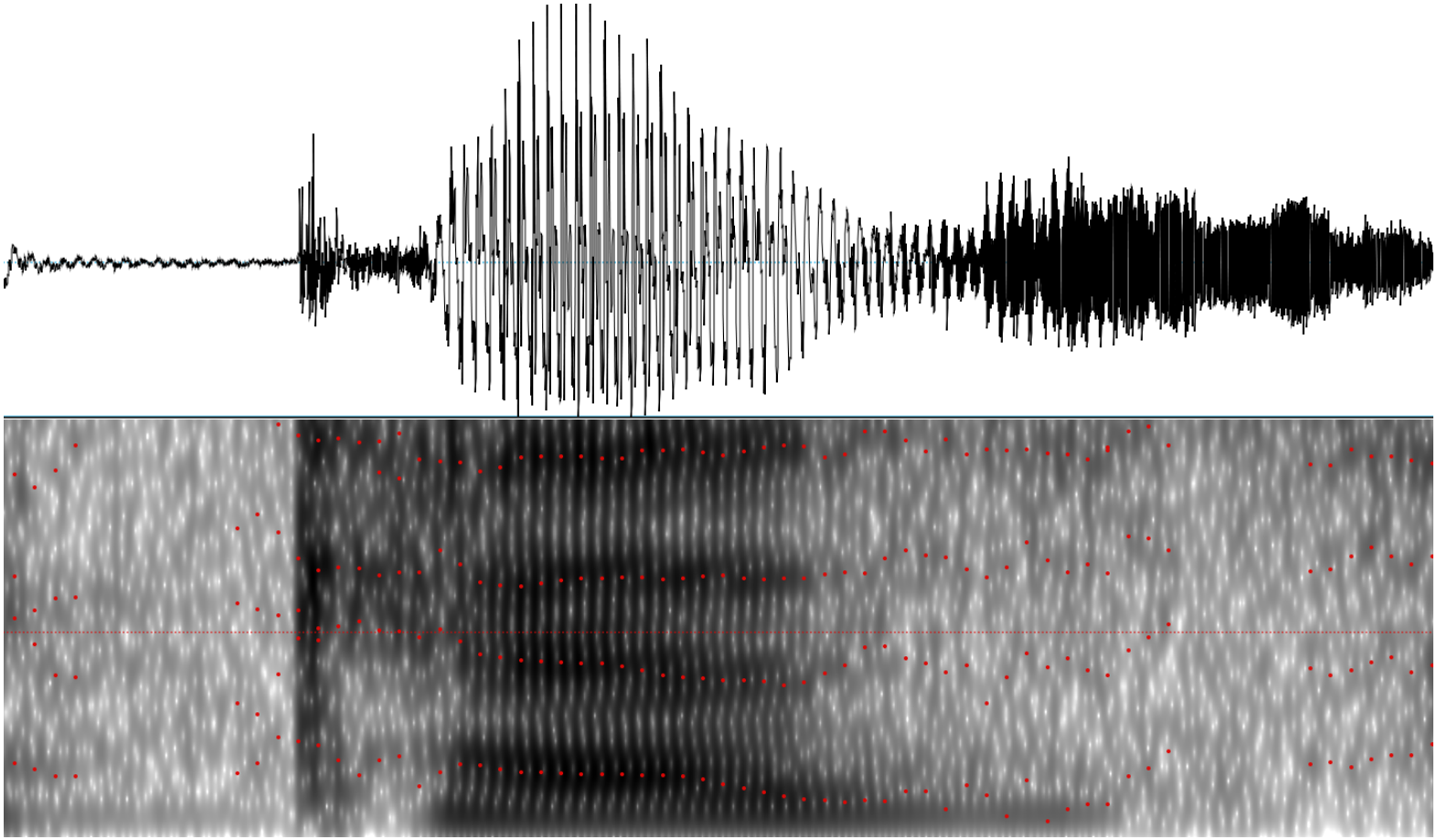
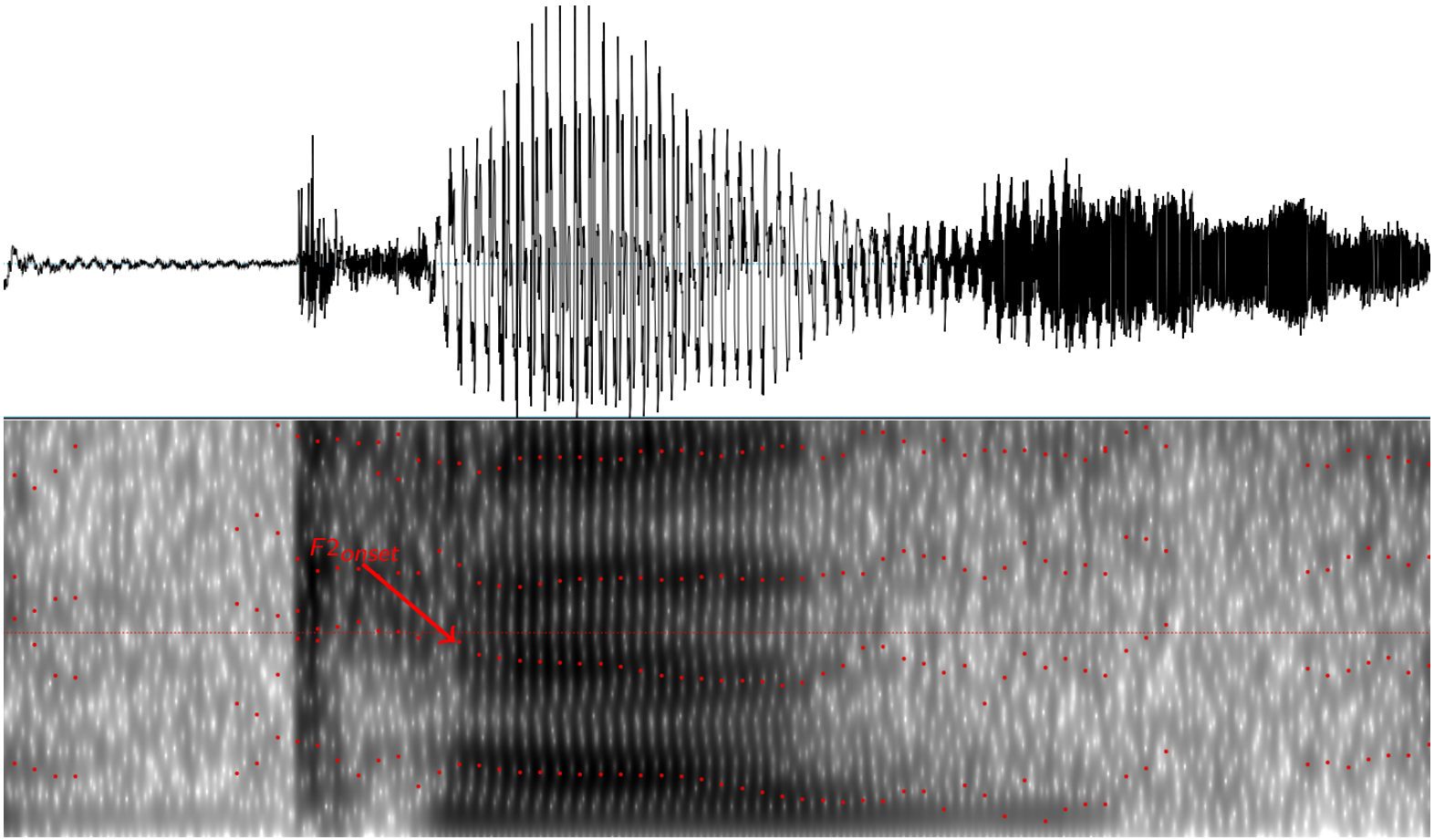


Figure : Demonstration of $F2_{@burst}$ and $F2_{onset}$ positions



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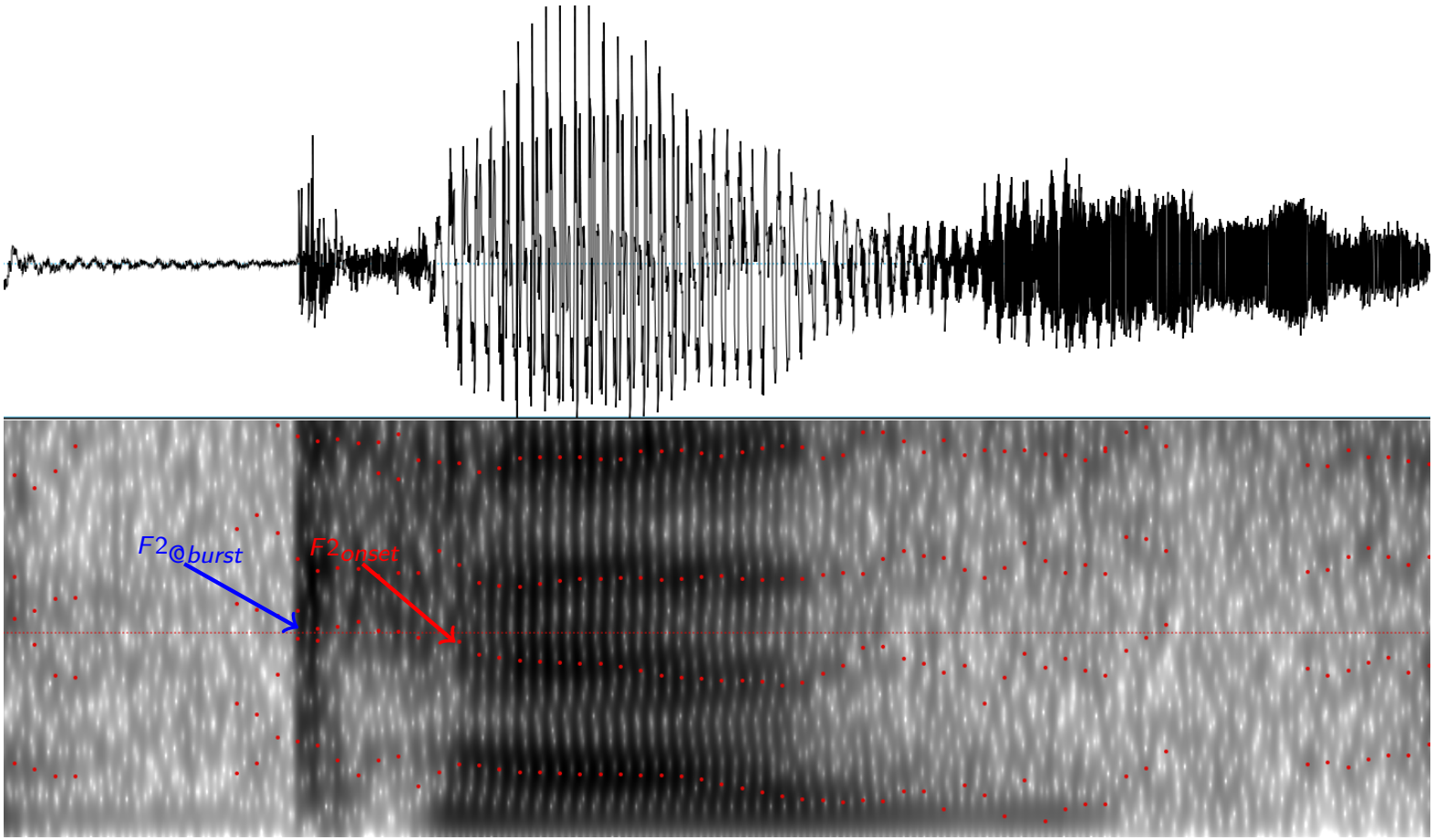

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- That could explain the relatively high slope values of our data and the low classification rate comparing to previous studies.

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- Further study is planed to compute LE at burst release ($F2_{@burst}$) instead of $F2_{onset}$, that would provide a better consonant classification.

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