EXPLORING A RECENTLY DEVELOPED ROMANIAN SPEECH CORPUS IN TERMS OF COARTICULATION PHENOMENA ACROSS WORD BOUNDARIES[1]

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1. INTRODUCTION

In this article, we investigate coarticulation phenomena in word-final position pertaining to standard Romanian spontaneous speech. The data are gathered from an open-access speech corpus developed through our postdoctoral project financed by UEFISCDI titled "Acquiring and exploring an oral contemporary spoken Romanian corpus for linguistic purpose" (PN-III-P1-1.1-PD-2019-1029). The recorded speech corpus was annotated in Praat both orthographically (tier 1), and phonologically (tier 2). The transcriptions are aligned to the audio files via TextGrids in Praat. Due to space limitations, we will not be documenting all phonetic variation and reduction processes present in Romanian spontaneous speech. In turn, we will be looking at the most frequent coarticulation phenomena arising across word boundaries within the recently developed speech corpus. As a result, the analysis focuses on deletion processes, most notably the deletion of the definite article *-l*, hiatus reduction patterns at word-boundary, as well as word-final obstruent (de)voicing and fricativization of the voiced postalveolar affricate occurring in word-final position followed by a glide (in accordance with the recent description of Romanian phonology by Renwick 2021: 531–558). A secondary objective of this paper is to showcase the benefits of working on the speech corpus by correlating the transcripts with the audio recordings and extracting the relevant acoustic data pertaining to each of the aforementioned connected speech processes.

The paper is structured as follows. Section 2 describes data gathering and experimental design. Section 3 focuses on coarticulation phenomena present in the recorded speech corpus, while conclusions and future research interests are presented in section 4. The abbreviations used throughout the article are, in alphabetical order, the following: *C* – consonant; *CoG* – Center of Gravity; *F1* – first formant; *F2* – second formant; *G* – glide; *PoA* – place of articulation; S_x – speaker (odd numbers depict female speakers, while even numbers designate male

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speakers); T_c – time cursor (designates the specific time of the phonetic unit within the corpus); *V* – vowel; *V1* – first vowel in hiatus; *V2* – second vowel in hiatus.

2. DATA AND METHODOLOGY

The analysis is carried out on a Romanian speech corpus recently developed through the ROC-lingv postdoctoral research project (https://lingv.ro/pn-iii-p1-1-1-pd-2019-1029_roc-lingv/). The recordings were carried out in a sound-attenuated room, with a stand microphone connected to a laptop via an external audio interface. Twelve adult native speakers, six female and six male, between 30 to 45 years of age, without any speaking impairments, took part in the experiment (signing a GDPR form). All participants are representative of the southern dialect, on which the standard language is based on.

Both controlled and spontaneous speech are accounted for. Data segmentation and annotation took place in Praat. For each audio file (saved as .wav), a corresponding TextGrid was generated with the orthographic transcription present on the first tier paired with the phonological annotation on the second tier[2].

The corpus is designed to foster research at all levels within the linguistic system. Since one of the main advantages of this material resides in linking the audio input with the corresponding transcripts, we would evaluate the corpus as being better suited for analyses at the interface between phonetics and phonology. As such, our present research focuses on connected speech phenomena at word boundaries. The ways in which this topic is explored in the corpus are discussed in the following section.

3. COARTICULATION PHENOMENA IN CONNECTED SPEECH

Studies have shown that connected speech entails systematic interspeaker and intraspeaker variability with respect to various reduction processes (Ernestus and Warner 2011, Ernestus *et al*. 2015, Tucker and Ernestus 2016, among others). In this context, annotated speech corpora are proven to be beneficial particularly for phonetic research, and linguistics in general, by testing various hypothesis and examining sound change and variation (Adda-Decker 2006, Renwick *et al*. 2016).

Acoustic studies conducted on Romanian connected speech data are rather scarce, mainly due to lack of available aligned speech corpora suitable for analyses

[2] For an overview of the project, see Niculescu (2021: 28–36). For ways of working on the corpus, see Niculescu (2022: 148–149).

at the interface between phonetics and laboratory phonology[3]. Therefore, through our postdoctoral research project, implemented at the "Iorgu Iordan – Al. Rosetti" Institute of Linguistics of the Romanian Academy between September 1st, 2020, to August 30th, 2022, within the Department of Dialectology and Sociolinguistics, we aimed to fill in this gap by providing an open access speech corpus of standard Romanian, transcribed and aligned in Praat.

In this paper, so as to showcase the possible acoustic measurements that can be extracted from the speech corpus, we will be examining both duration patterns as well as frequency and spectral changes pertaining to various reduced pronunciation variants present in connected speech. A total of 140 examples are given, paired with 22 spectrograms derived from the corpus, distributed as following: §3.1 deletion of the definite article, also referred to as L-dropping (examples (1) to (24), spectrograms (1)–(2)), hiatus reduction processes at word-boundary (examples (25) to (44), spectrograms (3)–(4)); §3.2 obstruent devoicing ((45)–(73), spectrograms (5)–(14)); §3.3 obstruent voicing ((74)–(131), spectrograms (15)–(20)); §3.4 affricate fricativization ((132)–(140), spectrograms (21)–(22)).

For each example extracted from the corpus, a citing formula has been introduced ($S_{№}$, $T_c = t$). The first element identifies the speaker, while the second element in the formula marks the time given by the placement of the cursor within the TextGrid window. It is important to mention that the time frame is given from the beginning of the phonetic unit. In order to search for a specific example, users can access the "Select menu" and click on the "Move cursor" function. This will automatically lead to the selected area, as long as the example is present within the window frame. Otherwise, the window must be extended by Zoom-ing out (Ctrl-I for Windows users, Command-I or Mac users)[4]. This citing procedure is employed so as to allow for a straightforward identification of an acoustic phenomena within the recorded material.

3.1. Reduction in connected speech

The most common reduction process present in Romanian connected speech, as found in the corpus, is the deletion of the definite article *-l*. This phenomenon arises irrespective of the following context, that is before stops ((1)–(2)), fricatives ((3)–(4)), affricates ((5)–(6))[5], nasals ((7)–(8)), liquids ((9)–(10)), vowels (11) and glides (12), as well as succeeded by a silent pause (13). The deletion is interpreted

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[3] Research conducted especially by Dascălu Jinga (2002, 2006), Dascălu Jinga and Ștefănescu (2009), even though prominent, has mainly relied on written text data, without benefiting from the advantages of correlating the corpus transcriptions with audio signal.

[4] For more information related to Praat usage, look up the freely available materials on the „Iorgu Iordan – Al. Rosetti" Institute of Linguistics website or see Niculescu (2022: 149–151) for further guidance on this issue.

[5] Even though (6), i. e. – dropping before a voiced postalveolar affricate, did not surface in the corpus, the context is linguistically possible in Romanian.

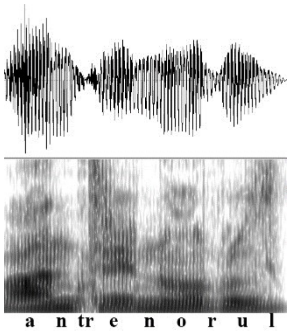
as a transfer of the grammatical function of the definite article to the desinence vowel *-u* as a consequence of reanalysis processes employed by native speakers (Avram 2009).

(1) /lukrul#ku/	[lu.kru.ku]	(S_6, T_c = 41.3)
(2) /perikolul#de/	[pe.ri.ko.lu.de]	(S_6, T_c = 168.6)
(3) /frigul#fərə/	[fri.gu.fə.rə]	(S_9, T_c = 467.3)
(4) /dreptul#vedete/	[drep.tu.ve.de.te]	(S_9, T_c = 604.6)
(5) /kapitolul#ʧe/	[ka.pi.to.lu.ʧe]	(S_9, T_c = 1154.6)
(6) /modul#ʤeneral/	[mo.du.ʤe.ne.ral]	
(7) /singurul#mod/	[sin.gu.ru.mod]	(S_9, T_c = 464.2)
(8) /modul#nostru/	[mo.du.nos.tru]	(S_6, T_c = 2344.4)
(9) /timpul#liber/	[tim.pu.li.ber]	(S_6, T_c = 177.9)
(10) /primul#rɨnd/	[pri.mu.rɨnd]	(S_1, T_c = 2.6)
(11) /priveg'ul#akasə/	[pri.ve.g'u.a.ka.sə]	(S_5, T_c = 505.8)
(12) /timpul#jera/	[tim.pu.je.ra]	(S_5, T_c = 834.9)
(13) /amuzamentul#/	[a.mu.za.men.tu]	(S_6, T_c = 107.6)

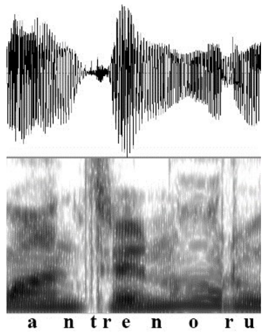
These observations are corroborated in a recent large scale oral corpora analysis conducted by Vasilescu *et al*. (2019) on several speaking styles including semi-prepared broadcast news (3.5h, 79 speakers), broadcast debates (3.5h, 48 speakers), spontaneous dialogues (3h, 29 speakers), read speech (0.5h, 29 speakers), and free monologues (0.5h, 1 speaker). The results show that deletion rates increase with the degree of spontaneity of the data (84% L-dropping in free monologues, compared to only 31% in prepared speech). Related to the following phonological context, data indicate that within broadcast news and debates, L-dropping is more frequent when followed by a consonant, while L-retention is favored before vowel-initial words. In casual speech, the deletion of the article is more frequent and the context is less important in terms of predicting the occurrence of reduced variants compared to other speaking styles (Vasilescu et al. 2019: 10–11).

In the monologue corpus, we observe interspeaker ((14)–(17)) as well as intraspeaker variation ((18)–(21)) regarding L-dropping vs. L-maintenance. However, the contexts in which the definite article is deleted highly outnumber the situations in which the article is maintained.

(14) /unul#dintre/	[u.nul.din.tre]	(S_5, T_c = 633.7)
(15) /unul#dintre/	[u.nu.din.tre]	(S_1, T_c = 2937.9)
(16) /totul#jeste/	[to.tul.jes.te]	(S_5, T_c = 2974.0)
(17) /totul#je/	[to.tu.je]	(S_2, T_c = 3313.8)
(18) /ɨnotul#deoparte/	[ɨ.no.tul.de̯o.par.te]	(S_6, T_c = 4739.5)
(19) /ɨnotul#te/	[ɨ.no.tu.te]	(S_6, T_c = 888.7)
(20) /timpul#ɨn/	[tim.pul.ɨn]	(S_1, T_c = 615.6)
(21) /timpul#ɨmj/	[tim.pum^{i}]	(S_1, T_c = 1013.8)



Spectrogram 1. L-maintenance
/antrenorul/ [antrenorul] (S_6, T_c = 2116.3)



Spectrogram 2. L-dropping
/antrenorul/ [antrenorul] (S_6, T_c = 4292.7)

In some cases, the deletion of the definite article gives rise to VV sequences. There are cases where hiatus is maintained (22), however, native speakers tend to avoid such sequences through various hiatus reduction processes ((23)–(24)).

(22) /kolektivul#adikə/ [ko.lek.ti.vu.a.di.kə] (S_8, T_c = 1545.8)
(23) /ʤenul#əla/ [ʤe.nu.ə.la] → [ʤe.nwə.la] (S_9, T_c = 521.8)
(24) /timpul#unej/ [tim.pu.u.nei̯] → [tim.pu.nei̯] (S_4, T_c = 1884.2)

Languages in general do not tolerate adjacent heterosyllabic vowels, either word-internal (VV sequence referred to as *internal hiatus*), or across word boundaries (vocalic sequence also known as *external hiatus*[6]). Consequently, the reduction of word-external vocalic pairs is another recurrent phonological process present in connected speech. One common strategy of hiatus avoidance is to elide one of the adjacent vowels. Elision of the first vowel is more common cross-linguistically and more productive than V2 elision (Casali 1997: 493). This observation holds true in our corpus as well, where we observe that speakers consistently elide the leftmost vowel (i.e. word-final V).

(25) /mə#apuk/ [ma.puk] (S_8, T_c = 3.3)
(26) /nu#o/ [no] (S_8, T_c = 1259.3)
(27) /ʃi#un/ [ʃun] (S_8, T_c = 195.2)
(28) /de#asta/ [das.ta] (S_8, T_c = 1107.1)

In standard Romanian, when V2 is deleted, the targeted vowel is /ɨ/ in the vast majority of cases[7].

[6] See Niculescu (2015) for classification and terminological proposal of VV sequences in standard Romanian; for a monographic account of internal and external hiatus in Romanian, see Niculescu (2018).

[7] When conduction an in-depth analysis on 68 Niger-Congo and 19 non-Ninger-congo languages, Casali (1997) observed an asymmetry in terms of elision patterns, V1 elision being the preferred outcome. However, this type of elision does not apply equally across all morpho-syntactic contexts. As a result, 4 types of juncture were delineated, with the following outcomes (Casali 1997: 496):

(29) /kə#ɨn/	[kən]	(S_8, T_c = 261.0)
(30) /te#ɨnvat͡sə/	[ten.va.t͡sə]	(S_8, T_c = 280.9)
(31) /ʃi#ɨn/	[ʃin]	(S_8, T_c = 455.3)

Another widespread hiatus repair mechanism present in connected speech is when two adjacent identical vowels merge, as shown in following examples:

(32) /ʃi#implit͡ʃit/	[ʃim.pli.t͡ʃit]	(S_4, T_c = 1283.9)
(33) /pentru#un/	[pen.trun]	(S_4, T_c = 99.4)[8]
(34) /niʃte#elemente/	[niʃ.te.le.men.te]	(S_4, T_c = 156.5)
(35) /kə#əsta/	[kəs.ta]	(S_1, T_c = 945.9)
(36) /jo#ofer/	[jo.fer]	(S_1, T_c = 847.7)
(37) /klipa#aja/	[kli.pa.ja]	(S_9, T_c = 1468.1)

Glide formation ((38) – (42)) and glide insertion ((43)–(44)) are two other possible strategies used for avoiding hiatus sequences across word boundaries.

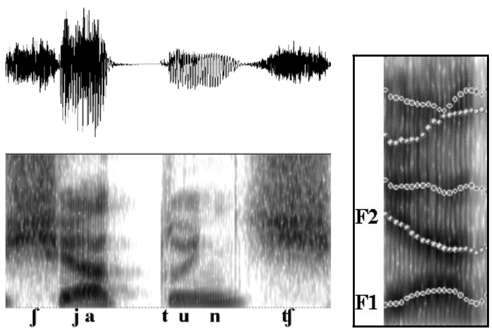
(38) /tare#adikə/	[ta.re̯a.di.kə]	(S_8, T_c = 134.9)
(39) /kare#o/	[ka.re̯o]	(S_1, T_c = 64.9)
(40) /ʃi#un/	[ʃjun]	(S_8, T_c = 148.9)
(41) /ku#əsta/	[kwəs.ta]	(S_8, T_c = 490.9)
(42) /ku#alt͡si/	[kwal.t͡si]	(S_8, T_c = 372.3)
(43) /lume#eksternə/	[lu.me.jeks.ter.nə]	(S_9, T_c = 232.9)
(44) /nu#am/	[nu.wam]	(S_1, T_c = 825.0)

When studying hiatus avoidance strategies in spontaneous speech, the two main acoustic ques are *duration* (in milliseconds) and *formant frequencies* (in Hertz), namely the first formant (F1 – related to vowel height; a high F1 value signals a low vowel, while a low F1 frequency characterizes a high vowel), and the second formant (F2 – related to the frontness/backness of a vowel; high F2 values are correlated with a front vowel, while low F2 values correspond to back vowels). Based on the aligned TextGrids, these acoustic measurements can be automatically extracted in Praat via scripts.

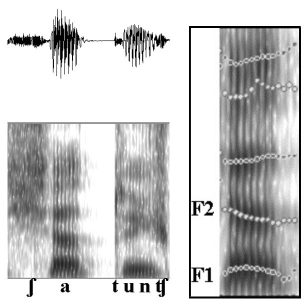
(I) at the boundary between two lexical words, elision always targets V1 (no language was found that regularly elides V2 at lexical word boundaries); (II) at the boundary between a lexical word and a following function word, V1 elision is more prevalent than V2 elision (at least 12 languages in the survey have been found that elide V2 in function words); (III) only V1 elision generally occurs at the boundary between a (minimally) CV prefix and a root (27 languages in the survey which have V1 elision in this context); (IV) at the boundary between a root and a suffix, either V1 or V2 elision is possible (21 language in the survey have been found that elide V1 in this context).

[8] Casali (1995) argues that identical VV sequences are excluded from glide formation on a near-universal basis. As things stand, in the recent version from 2021, DOOM[3] brings modifications with regard to pronunciation variants of borrowed adjectives ending in *-uu* (section 2.2.3.), recommending a VG utterance, while hiatus pronunciation is given as a second option. Further production and perceptual experiments need to be carried out in order to test this recommendation.

Let us consider the external hiatus /i.a/ avoided in the monologue of the eight speaker either through syneresis (spectrogram 3) or vowel elision (spectrogram 4). Firstly, we observe a reduction in the temporal domain from 102ms (GV sequence), to 56ms in the case of V1 elision. Secondly, in relation to the frequency domain, formant transitions from glide to vowel are visible, wereas a steady state characterises the monophthong. For an in-depth analysis, Praat can generate formant listings given a specific time frame (in this case, the underlying VV sequence). The results are displayed underneath the spectrograms.



Spectrogram 3. Hiatus avoidance through syneresis (duration = 102ms) /ʃi#atunʧ/ [ʃjatunʧ] (S_8, T_c = 1076.5)



Spectrogram 4. Hiatus avoidance through V1 elision (duration 56ms) /ʃi#atunʧ/ [ʃatunʧ] (S_8, T_c = 314.6)

Table 1.

F1 and F2 values of the undelying /i.a/ vocalic sequence

Formant frequencies

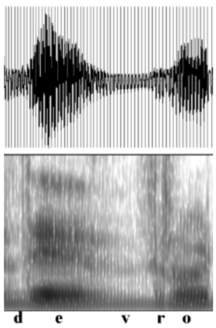
Time_s	F1_Hz	F2_Hz
1076.627366	382.731295	2064.590688
1076.633616	404.251317	1991.096705
1076.639866	408.171042	1928.018977
1076.646116	428.082887	1877.868869
1076.652366	499.430186	1824.547476
1076.658616	556.459363	1726.013134
1076.664866	587.410168	1648.787929
1076.671116	595.267118	1582.754487
1076.677366	625.970240	1553.154514
1076.683616	643.318795	1516.569609
1076.689866	652.842134	1479.926119
1076.696116	653.083700	1437.798639
1076.702366	648.083195	1407.889380
1076.708616	634.154387	1411.531341
1076.714866	578.826016	1410.711828
1076.721116	497.125012	1417.346317
1076.727366	445.456414	1389.541033

Time_s	F1_Hz	F2_Hz
314.785685	503.590294	1546.049786
314.791935	512.052836	1499.530602
314.798185	518.517440	1465.283280
314.804435	514.023846	1438.986889
314.810685	502.750196	1415.959438
314.816935	485.235813	1408.022464
314.823185	459.830246	1403.054754
314.829435	428.040834	1354.179670
314.835685	398.810791	1341.021383

Since the duration of the GV sequence is longer than the V output, the number of frames is greater (17 frames compared to 9 frames). In the first context, F1 values rise (from 383Hz to 648Hz), marking the transition from high /j/ to the low vowel /a/, whereas F2 frequencies drop from 2064Hz to 1389Hz, entailing the front-back transition. In the second context, there is a slower spectral tilt, F1 remaining at 500 and F2 at around 1400Hz, both values characteristic of the central low unrounded vowel /a/ (preceded by a postalveolar voiceless fricative) produced by a male adult speaker (Niculescu 2019).

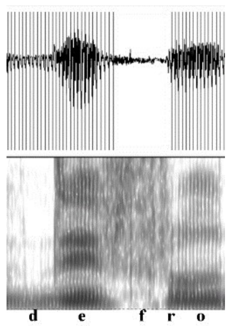
3.2. Obstruent devoicing

Devoicing refers to any phonological process whereby an underlying voiced segment loses its voicing. Following Gradoville (2011), the best way to conduct an acoustic study of obstruent devoicing is by making use of the *Voice analysis* in Praat. The glottal pulses appear the SoundEditor window as blue vertical lines spread through the waveform (they do not appear in the spectrogram). In order to activate this function in Praat, the user has to choose “Show pulses” from the Pulse menu. Within the Pulse menu, the Voice report function is available (the data are extracted based on the visible part of the selection). The report displays various voice measurements, such as “Pitch”, “Pulses”, “Voicing”, “Jitter”, “Shimmer” and “Harmonicity of the voiced parts only”. In order to determine the degree of voicing corresponding to selected item, we look at the Voicing information. So as to illustrate this technique, let us consider the following contexts, where the Voice report is carried out on the word-initial fricative.



Spectrogram 5. Alveolar voiced fricative in word-initial position
/de#vreo/ [devro] (S_6, $T_c = 2171.5$)

Time range of selection:
From 2171.722240 to 2171.802907 seconds (duration: 0.080667 seconds)
Pulses:
Number of pulses: 11
Number of periods: 10
Voicing:
Fraction of locally unvoiced frames: 0 (0 / 8)



Spectrogram 6. Alveolar fricative devoicing in word-initial position
/de#vreo/ [defro] (S_8, $T_c = 54.9$)

Time range of selection:
From 55.002393 to 55.091551seconds (duration: 0.089158 seconds)
Pulses:
Number of pulses: 0
Number of periods: 0
Voicing:
Fraction of locally unvoiced frames: 100.000% (8 / 8)

In the first context, all segments are voiced (stops /d/, vowels /e, o/, fricatives /v/, and liquids /r/), as a result, we hypothesize that voicing is spread throughout the entire sequence, leading to null percentage of unvoiced frames. This observation is backed-up by the Voice report, showing that the fraction of locally unvoiced frames is 0% out of a number of 11 pulses. In the second context, we observe a lack of voicing in the word-initial fricative, leading up to 100% locally unvoiced frames corresponding to the devoiced allophone.

Devoicing can occur both word-initial ((45)–(46)), word-medial ((47) – (50)), as well as word-final position (context further developed in this section).

(45) /#valabil/	[fa.la.bil]	(S_4, T_c = 970.5)
(46) /pus#bine/	[pus.pi.ne]	(S_6, T_c = 907.0)
(47) /miʒlocul/	[miʃ.lo.cu]	(S_4, T_c = 1506.5)
(48) /vəzut/	[və.sut]	(S_2, T_c = 1000.1)
(49) /observ/	[op.serv]	(S_9, T_c = 510.5)
(50) /obʦine/	[op.ʦi.ne]	(S_4, T_c = 1647.1)

In terms of word-final position, pre-pausal obstruent devoicing is recurrent across the speech corpus.

(51) /rezolv#/	[re.zolf]	(S_4, T_c = 56.5)
(52) /astəzj#/	[as.təs]	(S_6, T_c = 1881.3)
(53) /kuraʒ#/	[ku.raʃ]	(S_4, T_c = 709.1)
(54) /rɨd#/	[rɨt]	(S_9, T_c = 1972.1)
(55) /ɨnʦeleg#/	[ɨn.ʦe.lek]	(S_4, T_c = 657.0)

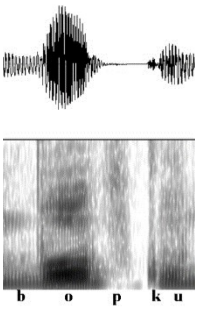
Another recurring context for obstruent devoicing in connected speech is before voiceless stops (/p/ (56)–(59), /t/ (60)–(61), /k/ (62)–(65)).

(56) /motiv#pentru/	[mo.tif.pen.tru]	(S_4, T_c = 1817.0)
(57) /pjerzj#parte̯a/	[pjers.par.te̯a]	(S_2, T_c = 2748.1)
(58) /vəd#pe/	[vət.pe]	(S_9, T_c = 1861.9)
(59) /ʃterg#puʦin/	[ʃterk.pu.ʦin]	(S_1, T_c = 965.9)
(60) /vezj#tu/	[ves.tu]	(S_1, T_c = 3893.5)
(61) /fiind#timpul/	[fi.int.tim.pu]	(S_4, T_c = 2082.1)
(62) /efektiv#ka/	[e.fek.tif.ka]	(S_1, T_c = 924.0)
(63) /vezj#kə/	[ves.kə]	(S_2, T_c = 2643.9)
(64) /bob#ku/	[bop.ku]	(S_6, T_c = 1529.2)
(65) /kred#kə/	[kret.kə]	(S_4, T_c = 614.9)

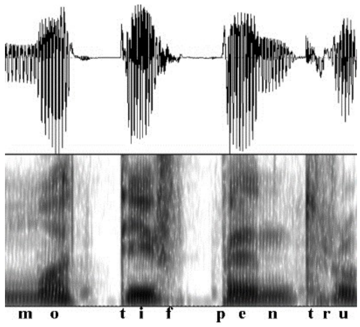
The loss of voicing in word-final obstruents also occurs when followed by voiceless fricatives (/f/ (66)–(68), /s/ (69)–(70), /ʃ/ (71)–(73)).

(66) /aksez#fo̯arte/	[ak.ses.fo̯ar.te]	(S_2, T_c = 28.5)
(67) /punɨnd#fo̯arte/	[pu.nɨnt.fo̯ar.te]	(S_8, T_c = 1912.9)
(68) /merg#fo̯arte/	[merk.fo̯ar.te]	(S_4, T_c = 802.7)

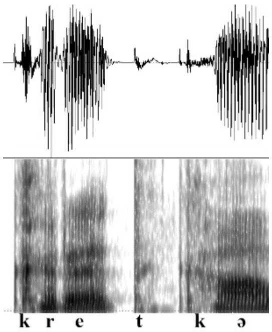
(69) /respektiv#sə/ [res.pek.tif.sə] (S_4, T_c = 398.6)
(70) /vəd#sə/ [vət.sə] (S_9, T_c = 230.6)
(71) /notez#ʃi/ [no.tes.ʃi] (S_1, T_c = 49.4)
(72) /ating#ʃi/ [a.tink.ʃi] (S_1, T_c = 787.9)
(73) /sud#ʃi/ [sut.ʃi] (S_8, T_c = 2424.5)



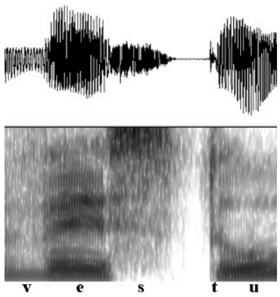
Spectrogram 7. Bilabial stop devoicing /bob#ku/ [bopku] (S_6, T_c = 1529.2)



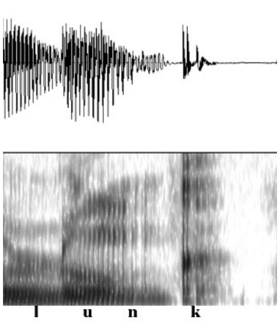
Spectrogram 10. Labiodental fricative devoicing /motiv#pentru/ [motifpentru] (S_4, T_c = 1817.0)



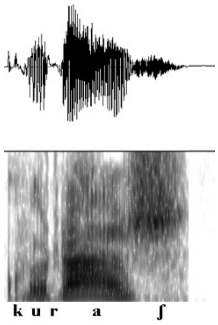
Spectrogram 8. Alveolar stop devoicing /kred#kə/ [kretkə] (S_4, T_c = 252.1)



Spectrogram 11. Alveolar fricative devoicing /vezj#tu/ [vestu] (S_1, T_c = 3893.5)



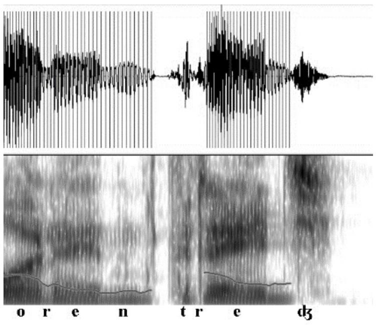
Spectrogram 9. Velar stop devoicing /lung#/ [lunk] (S_4, T_c = 26.6)



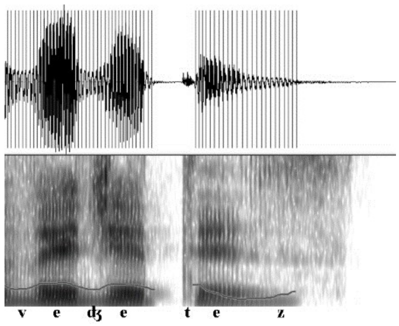
Spectrogram 12. Postalveolar fricative devoicing /kuraʒ#/ [kuraʃ] (S_4, T_c = 709.1)

The speech corpus developed through the ROC-lingv project allows for in-depth acoustic analyses. As a result, we can calculate the degree of devoicing, allowing for a distinction between fully voiced (voice ratio at 100%) and partially voiced segments (voice ratio under 100%). The 40/60 threshold, which was proposed by Gradoville (2011), can be used as an indicator to discriminate between voiced and devoiced consonants in syllable codas.

Partial devoicing was found to appear especially before a silent pause.



Spectrogram 13. Affricate partial devoicing
(S_6, $T_c = 3747.3$)
Pulses:
Number of pulses: 7
Number of periods: 6
Voicing:
Fraction of locally unvoiced frames: 64.286%
(9 / 14)



Spectrogram 14. Fricative partial devoicing
(S_6, $T_c = 524.6$)
Pulses:
Number of pulses: 11
Number of periods: 10
Voicing:
Fraction of locally unvoiced frames: 43.750%
(7 / 16)

In the case of the pre-pausal affricate, devoicing is found within the frication part of the consonant, while voicing is maintained only on the occlusion part, representing 36% of the total duration of the segment. As for the word-final dental fricative, the fraction of locally unvoiced frames total 44%.

3.3. Obstruent voicing

In this section of the paper, we will be looking at obstruent voicing in connected speech. Voicing refers to any phonological process whereby an underlying voiceless segment becomes voiced. This process can occur word-initial ((74)–(77)), word-medial ((78)–(83)), or in word-final position, the latter context being documented in this section.

(74) /sə#fi/	[sə.vi]	(S_6, $T_c = 430.4$)
(75) /pute̯a#sə/	[pu.te̯a.zə]	(S_6, $T_c = 58.5$)
(76) /se#po̯ate/	[se.bo̯a.te]	(S_8, $T_c = 924.5$)
(77) /minute#ku/	[mi.nu.te.gu]	(S_8, $T_c = 788.6$)
(78) /bufniʦə/	[buv.ni.ʦə]	(S_1, $T_c = 3729.7$)
(79) /atletism/	[a.tle.tizm]	(S_6, $T_c = 2616.8$)

(80) /obiʃnuit/	[o.biʒ.nu.it]	(S_9, $T_c = 2039.8$)
(81) /ɨntɨmplat/	[ɨn.tɨm.blat]	(S_8, $T_c = 659.5$)
(82) /fotbal/	[fodbal]	(S_8, $T_c = 903.2$)
(83) /adekvatə/	[a.deg.va.tə]	(S_6, $T_c = 2977.7$)

Obstruent voicing in word-final position is frequently targeted either by voiced stops ((84)–(91)), voiced affricates (92) or fricatives ((93)–(100)) present in the subsequent context.

(84) /zis#bə/	[ziz.bə]	(S_6, $T_c = 2352.5$)
(85) /neapərat#bunə/	[ne̯a.pə.rad.bu.nə]	(S_9, $T_c = 533.1$)
(86) /ʒok#bask'et/	[ʒog.bas.k'et]	(S_8, $T_c = 41.9$)
(87) /jes#de/	[jez.de]	(S_8, $T_c = 609.9$)
(88) /oraʃ#de/	[o.raʒ.de]	(S_8, $T_c = 995.4$)
(89) /grup#de/	[grub.de]	(S_8, $T_c = 238.2$)
(90) /fəkut#de/	[fə.kud.de]	(S_8, $T_c = 336.2$)
(91) /trek#de/	[treg.de]	(S_8, $T_c = 824.9$)
(92) /fak#ʤen/	[fag.ʤen]	(S_2, $T_c = 2966.9$)
(93) /ales#vara/	[a.lez.va.ra]	(S_6, $T_c = 268.9$)
(94) /aʃ#vre̯a/	[aʒ.vre̯a]	(S_9, $T_c = 651.2$)
(95) /tot#vine/	[tod.vi.ne]	(S_1, $T_c = 1327.3$)
(96) /psiholoʤik#vorbind/	[psi.ho.lo.ʤig.vor.bind]	(S_9, $T_c = 1741.9$)
(97) /tot#zik/	[tod.zik]	(S_8, $T_c = 148.1$)
(98) /zik#zi/	[zig.zi]	(S_8, $T_c = 148.3$)
(99) /alt#ʒukətor/	[ald.ʒu.kə.tor]	(S_6, $T_c = 3445.2$)
(100) /ʒok#ʒok/	[ʒog.ʒok]	(S_8, $T_c = 54.3$)

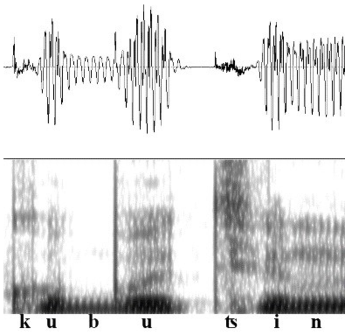
Final obstruent voicing before sonorants (nasals (101)–(106), liquids (109)–(116)) is highly widespread throughout the corpus.

(101) /oraʃ#mik/	[o.raʒ.mik]	(S_8, $T_c = 996.5$)
(102) /ʦip#maj/	[ʦib.mai̯]	(S_8, $T_c = 158.8$)
(103) /tot#maj/	[tod.mai̯]	(S_8, $T_c = 1366.3$)
(104) /pik#maj/	[pig.mai̯]	(S_8, $T_c = 219.9$)
(105) /ʧinematograf#nu/	[ʧi.ne.ma.to.grav.nu]	(S_2, $T_c = 2912.7$)
(106) /ɨnʦeles#nimik/	[ɨn.ʦe.lez.ni.mik]	(S_4, $T_c = 1405.0$)
(107) /absolut#nimik/	[ap.so.lud.ni.mik]	(S_1, $T_c = 89.8$)
(108) /pik#nu/	[pig.nu]	(S_8, $T_c = 521.8$)
(109) /tenis#la/	[te.niz.la]	(S_8, $T_c = 1002.0$)
(110) /oraʃ#la/	[o.raʒ.la]	(S_8, $T_c = 1000.5$)
(111) /timp#liber/	[timb.li.ber]	(S_1, $T_c = 826.2$)
(112) /ujt#la/	[ui̯d.la]	(S_8, $T_c = 510.8$)
(113) /petrek#la/	[pe.treg.la]	(S_1, $T_c = 2255.7$)
(114) /rup#rəul/	[rub.rə.ul]	(S_1, $T_c = 421.7$)

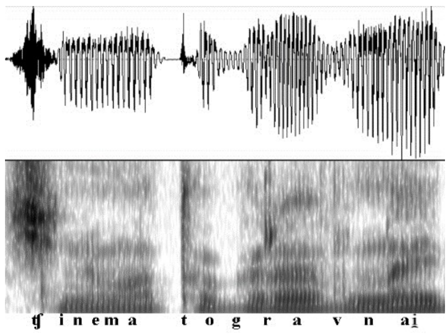
(115) /tot#riskul/ [tod.ris.ku] (S_8, $T_c = 2568.5$)
(116) /zik#rəspunsul/ [zig.rəs.pun.su] (S_6, $T_c = 746.8$)

Word-initial vowels trigger voicing of the preceding obstruent, as well as resyllabification so as to maximize the onset.

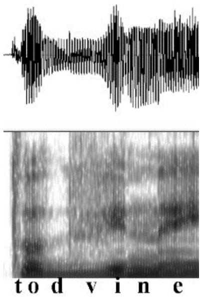
(117) /ʒos#atunʧa/ [ʒo.za.tun.ʧa] (S_1, $T_c = 2853.7$)
(118) /pot#aduʧe/ [po.da.du.ʧe] (S_4, $T_c = 670.9$)
(119) /fak#ɨn/ [fa.gɨn] (S_8, $T_c = 536.3$)



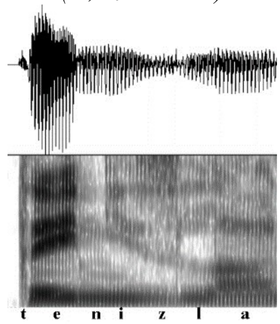
Spectrogram 15. Bilabial stop voicing /ku#puʦin/ [kubuʦin] (S_4, $T_c = 58.2$)



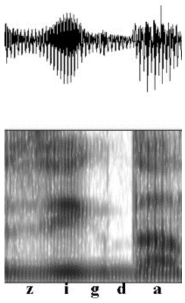
Spectrogram 18. Labiodental fricative voicing /ʧinematograf#nu#aj/ [ʧinematogravnai̯] (S_2, $T_c = 2912.7$)



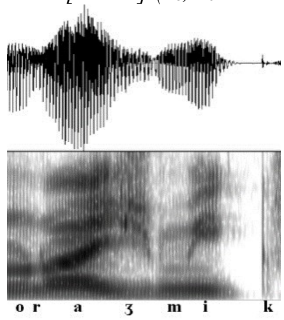
Spectrogram 16. Alveolar stop voicing /tot#vine/ [todvine] (S_1, $T_c = 1327.3$)



Spectrogram 19. Alveolar fricative voicing /tenis#la/ [tenizla] (S_8, $T_c = 1002.0$)



Spectrogram 17. Velar stop voicing /zik#dar/ [zigda] (S_8, $T_c = 713.9$)



Spectrogram 20. Postalveolar fricative voicing /oraʃ#mik/ [oraʒmik] (S_8, $T_c = 996.5$)

Since reduction processes are marked throughout the corpus, we can also investigate obstruent voicing preceded by word-final deletion. This represents a lesser studied context of obstruent voicing in Romanian connected speech. Let us first consider fricative voicing following the deletion of a word-final stop.

(120) /vorbesk#deʒa/	[vor.bes.de.ʒa]	→	[vor.bez.de.ʒa]	(S_6, $T_c = 2221.1$)
(121) /aʧest#moment/	[a.ʧes.mo.ment]	→	[a.ʧez.mo.ment]	(S_2, $T_c = 1814.3$)
(122) /gɨndesk#la/	[gɨn.des.la]	→	[gɨn.dez.la]	(S_8, $T_c = 883.1$)
(123) /primeʃtj#de/	[pri.meʃ.de]	→	[pri.meʒ.de]	(S_2, $T_c = 708.0$)
(124) /jeʃtj#nebun/	[jeʃ.ne.bun]	→	[jeʒ.ne.bun]	(S_8, $T_c = 418.1$)
(125) /jeʃtj#la/	[jeʃ.la]	→	[jeʒ.la]	(S_8, $T_c = 1131.0$)

Secondly, a prevalent process in connected speech, which ultimately leads to plosive voicing, is that of final stop deletion in clusters. Since the vast majority of stop-final clusters end in an alveolar stop[9], we will be looking at /kt/ and /pt/ pairs, where the deletion of the alveolar voiceless stop creates a favorable context for regressive assimilation processes, as illustrated by the following examples:

(126) /projekt#de/	[pro.jek.de]	→	[pro.jeg.de]	(S_4, $T_c = 346.7$)
(127) /impakt#maj/	[im.pak.mai̯]	→	[im.pag.mai̯]	(S_4, $T_c = 368.2$)
(128) /subjekt#la/	[su.bjek.la]	→	[su.bjeg.la]	(S_4, $T_c = 1424.8$)
(129) /fapt#de/	[fap.de]	→	[fab.de]	(S_6, $T_c = 896.5$)
(130) /fapt#nu/	[fap.nu]	→	[fab.nu]	(S_6, $T_c = 1048.1$)
(131) /fapt#la/	[fap.la]	→	[fab.la]	(S_6, $T_c = 4467.1$)

3.4. Fricativization

Fricativization is related to any phonological process whereby a plosive turns to a fricative[10]. For the purpose of this article, we will be documenting the fricativization of the postalveolar affricate /ʤ/.

In Romanian connected speech, the word-final affricate undergoes fricativization to /ʃ/ when followed by voiceless obstruents.

(132) /merʤj#trej/	[merʃ.trei̯]	(S_6, $T_c = 2248.9$)
(133) /koleʤj#kare/	[ko.leʃ.ka.re]	(S_6, $T_c = 2951.4$)
(134) /kɨʃtiʤj#punktul/	[kɨʃ.tiʃ.punk.tu]	(S_6, $T_c = 4617.8$)
(135) /ɨnʦeleʤj#ʧeva/	[ɨn.ʦe.leʃ.ʧe.va]	(S_8, $T_c = 278.2$)

Regressive assimilation processes from /ʤ/ to [ʒ] are spread throughout the corpus. The affricate turns to a voiced postalveolar fricative before voiced obstruents ((136)–(137)) and sonorants ((138)–(140)). It is important to mention

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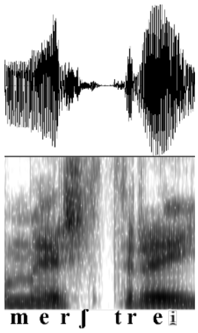
[9] For a phonotactic account on standard Romanian written data, see Roceric-Alexandrescu (1968).

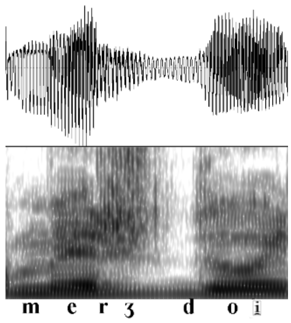
[10] We are not documenting cases of spirantization, such as the development of Latin intervocalic voiced plosives into Romance fricatives. For a recent account on this subject matter, see *Manual of Romance Phonetics and Phonology*, edited by Meisenburg *et al.* (2021: 349–350; 418–421).

that fricativization occurs after the deletion of the word-final glide (Renwick 2021: 531–558).

(136) /kɨʃtidʒj#banj/	[kɨʃ.tiʒ.ban^{j}]	(S_8, T_c = 2096.9)
(137) /fudʒj#de/	[fuʒ.de]	(S_9, T_c = 1480.3)
(138) /aʒundʒj#la/	[a.ʒunʒ.la]	(S_6, T_c = 3739.5)
(139) /merdʒj#maj/	[merʒ.mai̯]	(S_6, T_c = 3814.3)
(140) /parkurdʒj#niʃte/	[par.kurʒ.niʃ.te]	(S_6, T_c = 478.6)



Spectrogram 21. Voiced affricate fricativization to voiceless fricative /merdʒj#trej/ [merʃtrei̯] (S_6, T_c = 2248.9)



Spectrogram 22. Voiced affricate fricativization to voiced fricative /merdʒj#doj/ [merʒdoi̯] (S_6, T_c = 2251.2)

The aligned speech corpus can provide the necessary data for an exploratory acoustic analysis on this phonological process. In terms of extracting data related to PoA, we adapted a script written by DiCanio (https://www.acsu.buffalo.edu/~cdicanio/) for *center of gravity* (CoG[11]) (data were derived from the frication part of the affricate), while for voicing we relied upon the *pulse-based voice report* in Praat (measurement discussed previously in §3.2). The analysis conducted on the monologue of the sixth speaker entails the following results (Table 2).

Ten variables were used, three nominal (*right context*, *input* and *output*), and seven numerical variables related to *intensity*, *CoG*, *standard deviation*, *skewness* and *kurtosis*, number of *locally unvoiced frames* and *degree of voicing*. Based on these measurements, we observe that the affricate undergoes fricativization in 61% of the cases, paving the way to an ongoing phonologization process. When the consonant is followed by a silent pause (43% and 64%), a vowel (33%) or by a voiceless stop (42%), it undergoes partial devoicing.

[11] By analyzing the spectral moments found within the consonant release, CoG can function as an acoustic indicator for place of articulation. In this framework, as the backness of a consonant increases, the CoG values decrease.

Table 2

Acoustic measurements pertaining to pronunciation patterns
of the postalveolar voiced affricate in monologue speech

NR	CONTEXT	R_CTXT	INPUT	OUTPUT	INTENS	COG	SDEV	SKEW	KURT	FRAMES	UNVOICED
1	koledʒj_ku	voiceless stop	dʒ	ʒ	61.619	773.97	960.53	4.075	35.234	(0 / 5)	0%
2	merdʒj_ɨn	vowel	dʒ	dʒ	45.993	3395.5	1029.4	4.8918	44.79	(4 / 12)	33%
3	parkurdʒj_niʃte	nasal	dʒ	ʒ	61.281	487.07	680.61	9.1112	163.2	(0 / 4)	0%
4	merdʒj_de	liquid	dʒ	ʒ	55.861	666.21	781.41	5.4124	63.934	(0 / 6)	0%
5	culedʒj_via	voiced fricative	dʒ	ʒ	56.437	1723.5	1677.4	1.0597	2.8267	(0 / 9)	0%
6	culedʒj_via	voiced fricative	dʒ	dʒ	45.957	3283.6	1942.1	3.0507	16.834	(0 / 11)	0%
7	merdʒj_trej	voiceless stop	dʒ	ʃ	59.331	3816.9	1307.3	3.9328	23.017	(9 / 9)	100%
8	merdʒj_doj	voiced stop	dʒ	ʒ	58.879	1487.8	1674.9	1.9725	6.7669	(0 / 8)	0%
9	mindʒj_#	pause	dʒ	dʒ	57.978	3263.5	967.48	3.6562	28.427	(3 / 7)	43%
10	mindʒj_adikə	vowel	dʒ	dʒ	48.985	3131.6	1681.2	0.8505	6.3353	(0 / 4)	0%
11	koledʒj_kare	voiceless stop	dʒ	ʃ	52.803	4117.9	1438.8	3.4846	20.561	(5 / 5)	100%
12	tradʒj_de	voiced stop	dʒ	ʒ	53.226	1432.7	1792.2	2.5204	12.017	(0 / 4)	0%
13	aʒundʒj_la	liquid	dʒ	ʒ	51.345	1053.4	1463.2	3.945	25.922	(0 / 6)	0%
14	ɨntredʒj_#	pause	dʒ	dʒ	56.074	4170.1	887.61	4.9797	63.598	(9 / 14)	64%
15	aledʒj kontinuj	voiceless stop	dʒ	dʒ	62.824	3673.3	937.32	4.1486	34.909	(11 / 26)	42%
16	merdʒj_maj	nasal	dʒ	ʒ	56.503	2367.7	1645.4	1.2692	5.9895	(0 / 6)	0%
17	kɨʃtidʒj_punktul	voiceless stop	dʒ	ʃ	58.436	3743.3	1932.1	3.5111	15.086	(5 / 5)	100%
18	mindʒj_jera	vowel	dʒ	dʒ	46.004	3422.8	2092.9	1.2074	4.8906	(0 / 5)	0%

This topic in particular is of great interest to us, as we intend to broaden the analysis so as to include all standard Romanian affricate consonants, both word-initial and word-final, thus marking the starting point of new studies on the subject.

4. CONCLUSIONS AND FUTURE RESEARCH

For each coarticulation phenomena under investigation, relevant examples from the corpus were given, alongside the corresponding acoustic measurements suited for each phonological process. In this regard, duration patterns of VV pairs were corelated with formant trajectories in order to compare underling hiatus vowel sequences with diphthongized or vowel elided outputs. These acoustic measurements can distinguish and account for various hiatus avoidance mechanisms employed by native speakers in connected speech. In order to differentiate between fully and partially voiced obstruents, the Voice report in Praat was used. Examples were given for stop and fricative devoicing, with a focus on word-final position. Pre-pausal obstruent devoicing was also accounted for. Relying on the data gathered by the Voice report, we could determine the degree of devoicing. If the Voice report offers data related to unvoiced frames, the reverse can be done when studying obstruent voicing patterns. The last connected speech phenomena under investigation was fricativization, more precisely the reduction of the word-final postalveolar voiced affricate depending on the following phonological context. To account for PoA, measurements related to center of gravity were taken. The data were automatically extract via a script in Praat and correlated to the Voice report so as to also account for assimilation in voice to the following context.

Each topic can be furthered examined alongside other connected speech phenomena. The data acquired can contribute to the ongoing phonological investigation of fortition and lenition processes present in Romance languages (Hutin et al. 2020, 2021). Studying the way in which reduction processes occur in connected speech can benefit linguistics and automatic speech recognition models alike. Integrating the results obtained from linguistic data can ultimately improve speech production models.

In conclusion, the purpose of the article was to showcase the advantages of working on an open-access speech corpus suited for analyses at the interface between phonetics and laboratory phonology.

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EXPLORING A RECENTLY DEVELOPED ROMANIAN SPEECH CORPUS IN TERMS OF COARTICULATION PHENOMENA ACROSS WORD BOUNDARIES

Abstract

The purpose of this article is twofold. On the one hand, we aim to investigate coarticulation phenomena in word-final position pertaining to standard Romanian spontaneous speech. The analysis focuses on deletion processes, most notably the deletion of the definite article-l, external hiatus repair mechanisms, word-final obstruent devoicing and voicing phenomena, as well as fricativization of the voiced postalveolar affricate. On the other hand, we aim to showcase the benefits of working on a recently developed Romanian speech corpus by correlating the transcripts with the audio recordings and automatically extracting the relevant acoustic data pertaining to each of the aforementioned connected speech processes.

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