Chapter 3

A phonetic and phonological analysis of the Rere vowel height system

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Previous research on Rere has documented an eight-vowel system /i e ɛ ɐ a u o ɔ/ with strict vowel harmony rules (Quint 2009). The present study provides an acoustic analysis of the Rere vowel system to capture the phonetic characteristics of vowel quality in phonological distributions and phonetic processes. Using elicited data with instrumental suffixation and valence-changing structures (including causatives and passives), we largely confirm the previous account of vowel height agreement in Rere. However, considerable variation in vowel height and vowel quality was also observed. To account for the exceptions, we propose that the mid front vowel /e/ is shifting to a higher vowel [ɪ], which better explains words with disharmonic combinations, mismatches between root and suffix vowels in the instrumental construction, and the lack of alternation in derived verbs in causatives.

1 Introduction

The way in which vowel height contrasts interact with ATR contrasts can be varied and imply different typologies deriving from harmony patterns (Pulleyblank 2011, Casali 2003, 2008). Kordofanian languages of the Niger-Congo family have been documented to have a generally pervasive vowel harmony system based on height features (Moro: Ritchart & Rose 2017), or ATR features (Laru: Abdalla Kuku 2012; Lumun: Smits 2017; Tocho: Alaki & Norton 2013; Acheron: Norton 2013; Dagik: Vanderelst 2016; Tima: Bashir 2013) based on their vowel inventories and trigger factors.

Yaqian Huang. 2024. A phonetic and phonological analysis of the Rere vowel height system. In James Essegbey, Brent Henderson, Fiona McLaughlin & Michael Diercks (eds.), *Pushing the boundaries: Selected papers from the 51–52 Annual Conference on African Linguistics*, 43–73. Berlin: Language Science Press. DOI: 10.5281/zenodo.14038735

Rere, or Koalib, belongs to the Heiban group of Kordofanian languages spoken in the Nuba Mountains of southern Sudan by an estimated population of 100,000 (Quint 2009). Rere has been documented as having an eight-vowel system containing no contrast between high front vowels, and previous work reports a pervasive vowel height system rather than ATR (Quint 2009). However, besides the phonological descriptions, an acoustic analysis of the Rere vowel system is lacking. Thus, the current study provides a phonetic analysis of the vowels in Rere to investigate its vowel distributions and vowel height agreement in morphophonological processes. Interestingly, the data reported here show a not-so-robust vowel harmony system with sizable variation and exceptions. In particular, this paper proposes that the mid front vowel [e] is shifting to a higher vowel [ɪ] with its shifting phonological properties, as will be shown in two grammatical processes, instrumental suffixation and causative constructions. This proposal provides a better account for the exceptions of disharmonic suffixed words and non-conformity of vowel harmony patterns. The fact that the present analysis does not completely agree with a previous phonological description by Quint (2009) is likely due to speakers' variation or language contact with Arabic (cf. Tabaq; Hellwig & Schneider-Blum 2014).

This paper presents a phonological as well as acoustic analysis of the elicited data from one male native speaker of Rere, Taitas Kanda, who was born and raised in the town of Kwandaŋ in the Abri area in Sudan. We elicited weekly sessions with Taitas from January to May 2019 and annotated the data using ELAN (all the examples can be accessed in the Kwaras Rere corpus at rere.ucsd.edu). For the acoustic analysis, I segmented words and phonemes in Praat (Boersma & Weenink 2019), and processed the acoustic measures in VoiceSauce (Shue et al. 2011). In Section §2, I demonstrate the vowel inventories as well as common phonetic processes such as vowel centralization and cross-word assimilation, in comparison to what has been discussed previously in Quint (2009). In Section §3, I investigate the within-word vowel harmony and raising alternations, which appear in a few grammatical processes including instrumental suffixation and valence-changing constructions. Sections §4 and §5 revisit the vowel inventory with regard to the alternation patterns observed in Rere, the typological patterns with neighboring languages, and conclude.

2 Rere vowel inventory

2.1 Vowels

Quint 2009 described the eight vowel phonemes /i e ɛ ɐ a u o ɔ/ in Rere, as shown in Table 1.

Table 1: Inventory of the vowel phonemes of the Rere dialect (adapted from Quint 2009: P31, Table 5)

	Front	Central	Back
High	i		u
Mid	e	ɐ	o
Low	ɛ	a	ɔ

In addition, Quint had noted that the phoneme /e/ had a higher point of articulation than the cardinal [e] and slightly lower than the high vowel /i/, which was also found in our data (the majority of [e] attested has an average F1 of 350 Hz).

We confirm Quint's (2009) findings that vowel length is contrastive and perceptible whereas nasalization is not. The long counterparts of the eight vowel phonemes were attested, as shown in Table 2. Note that in many of these examples, the long vowels are in the penultimate position of the word. Thus, there seems to be a tendency for penultimate vowels to be long, which could be an acoustic correlate of lexical prominence. We also found an additional degree of vowel length such that an extra-long vowel (i.e., notated by V::) is used to express an object at a fair distance, e.g., [kɔ́l̪âw ŋgwá::l̪à] 'that cat (over there)', as compared to [kɔ́l̪âw ŋgwàl̪à] 'that cat', whereas the word with a long vowel [kɔ́l̪âw ŋgwà:l̪à] was not attested. Based on the acoustic measurements, the regular vowels usually have a duration of 60-70 ms while contrastive long vowels typically exceed 100 ms and the super long vowel [a::] has a duration of 300 ms.

2.2 Vowel minimal pairs

Based on our research with Taitas, the eight phonemic vowels were attested in his speech. The following minimal pairs and near-minimal pairs illustrate the contrastive status of the eight vowel phonemes.

Table 2: Examples of long vowels. All the examples can be searched and accessed at http://rere.ucsd.edu.

iː	[îː]	‘drink’	TK01162019-6:07:22.4
eː	[ʈèːɾà]	‘girl’	TK02012019-6:02:00.9
ɛː	[l̀èːɖɛ̀r]	‘bowl’	TK02202019-5:12:31.3
ɐː	[éːmù]	‘rat’	TK02222019-1:12:42.7
aː	[jáːɾì]	‘ash’	TK01162019-3:11:50.7
aːː	[kʊ́l̀âw ŋgwáːːl̀à]	‘that cat (over there)’	TK02062019-4:04:17.7
uː	[kúːl̀ù]	‘smoke’	TK01162019-3:02:44.5
oː	[ôːɾì]	‘red’	TK01162019-4:11:08.0
ɔː	[ʈɔ́ːŋ̀ò]	‘gourd’	TK02202019-5:18:04.7

(1) a. a versus ɐ versus e

kâl̀ ‘stone’	TK01112019-7:01:47.9
kɐ̂l̀ ‘sheath’	TK04122019YHSC-2:08:01.6
kêl̀ ‘seed-hole’	TK04192019YHSC-2:04:27.2

b. o versus ɔ

ʈôr ‘child’	TK02012019-5:13:02.0
ʈ̂r ‘hammer’	TK05172019-2:02:46.9
ɗòŋ ‘group’	TK04122019YHSC-2:13:58.0
ɗ̂ŋ ‘back of skull’	TK04122019YHSC-2:12:57.9
kwórtò ‘rich person’	TK04122019YHSC-2:11:34.0
kwɔ́rtɔ̀ ‘blacksmith’	TK04122019YHSC-2:11:16.8

c. o versus u

l̀ùbòŋ ‘hole in tree’	TK04102019-7
l̀ùbùŋ ‘hole on ground’	TK04102019-79
ʈ̪òːròm ‘star’	TK01112019-5:07:56.0
ʈ̪úrùm ‘government’	TK04122019YHSC-2:10:33.69

d. e versus ɛ

l̀èːɾè ‘seed of gourd’	TK04192019YHSC-2:01:32.1
l̀éːɾɛ̀ ‘sky’	TK04122019YHSC-2:05:01.3

e. i versus e

l̀îː ‘they will drink’	TK04262019-YH2
l̀êː ‘they will wash’	TK04262019-YH2

The distribution of F1 and F2 of the eight vowel phonemes is plotted in Figure 1 based on the mean formant values over the entire duration of each of the eight

vowels in the representative words (see Appendix §6). Ten to twenty monosyllabic or disyllabic words which contain clear articulations were selected for each vowel.

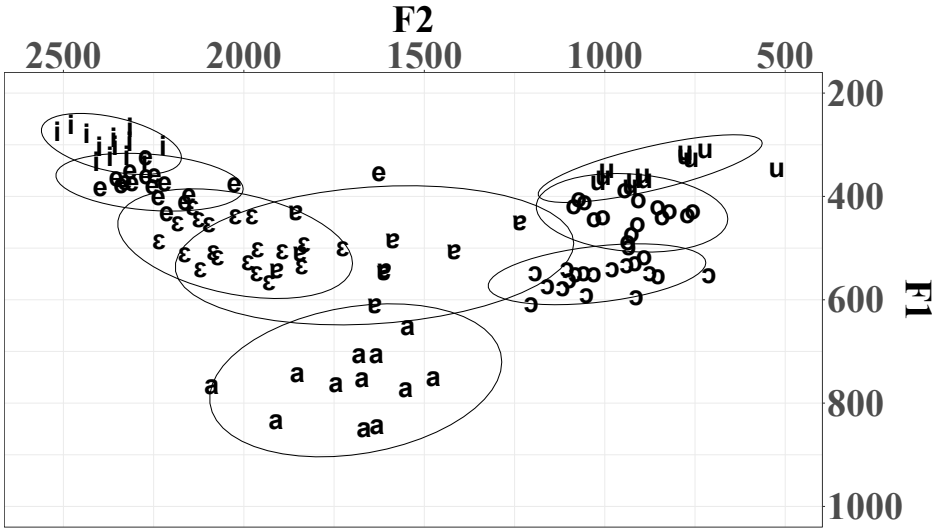

Figure 1: Mean F1 and F2 (Hz) of the eight Rere vowel phonemes

In particular, the cluster of mid central vowel [ɐ] shows much variation with some fronting, though not as front as the low front vowel [ɛ]. Also, several instances of [u] have relatively higher F2, which are closer to [ʊ]. The tokens of [e] are clustered closer in the vowel space to the high vowel [i].

Figure 2 shows the current vowel space based on the average F1 and F2 across the same vowel phonemes.

2.3 Vowel allophones and variations

Next, I show three allophones [ʊ e ə] as the variants of the phonemic vowels in different contexts with a discussion of changes in vowel including centralization and cross-word assimilation such as rounding, and raising. Overall, these allophones are more likely phonetic variants found in the realization of certain phonemes, or even in free variation, rather than caused by phonologically conditioning. For example, the schwa is typically a phonetic intrusive vowel occurring between consonants, or is an allophone of centralized vowels, and [e ʊ] are seen after certain consonants and/or at the word-final positions, to be detailed below.

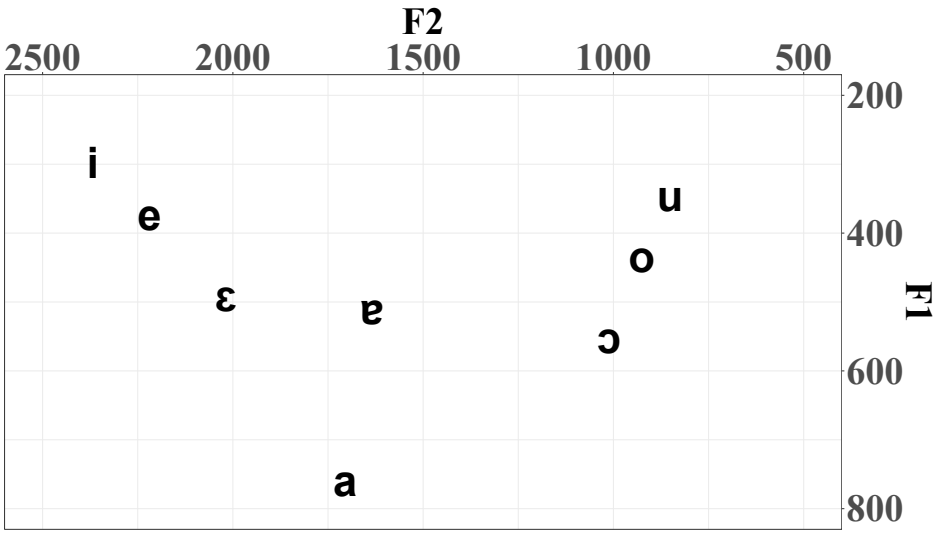

Figure 2: Representative Rere vowel space (in Hz)

The vowel [ʊ] is possibly an allophone of [o], which usually occurs after the palatal fricative [ç], for example, in [ç̟ʊ̟nd̪àŋ] < /çónd̪àŋ/ 'lion'. There is also free variation between [o] and [ʊ], as seen in [ɕʊ̟ːɾì] and [ɕóːɾè] 'be clean', from different elicitation sessions. However, in the current data, [ʊ] was not found to alternate with [o] in word-final positions.

In other circumstances, [ʊ] is a centralized version of [u], which has a similar F1 to the high vowel [u] but with a much higher F2. For example, it often appears in a closed syllable, as seen in [t̪ʊ̟l̩] < /t̪úl/ 'giraffe' and [t̪ʊ̂l̩] < /t̪ûl/ 'porridge', or it becomes short in [kʊ́l̩àw] 'cat' (26 ms; Quint 2009 had it as a centralized [u]), and [ɕʊ̀kúl̩è] 'edible gourd' (28 ms). These instances of [ʊ] have an F2 near 1200-1400 Hz, compared to a typical [u] in [kû:l̩ù] 'smoke', [l̩ùbùŋ] 'hole on ground', and [kwúrì] 'he will cut' with an F2 of 650-800 Hz.

(2) [ʊ] < /o, u/:

ç̟ʊ̟nd̪àŋ 'lion'	TK02062019-9:08:45.7
ɕʊ̟ːɾì 'be clean'	TK06072019YH
ɕóːɾì 'be clean'	TK03082019SCARYH-3
t̪ɨɕʊ̟ːɾì 'to clean'	TK03082019SCARYH-3
t̪ʊ̟l̩ 'giraffe'	TK02152019-8
t̪ʊ̂l̩ 'porridge'	TK02152019-8
kʊ́làw 'cat'	TK02062019-1
ɕʊ̀kúl̩ì 'edible gourd'	TK04122019YHSC-2:06:50.8

Though /e/ is a phonemic vowel, [e] also appears as surface realizations of other underlying vowels /ɛ, ɐ/, which results in neutralization. The allophonic [e] occurs when the underlying vowels are colored by palatal consonants. For example, in [l̀èj] < /l̀ɛ̀j/ 'eye', the underlying /ɛ/ is higher because of the influence of the following palatal fricative. Similarly, /ɐ/ becomes [e] in [éjjé] < /éjjɐ̀/ 'who' due to the adjacent palatal glide. In other cases, the vowel status is not particularly stable in that the word may be articulated with vowels of variable quality on one occasion versus another occasion, for example, [t̪ê] 'be cold' varies with [t̪ɛ̂] in casual versus careful speech.

(3) [e] < /ɛ, ɐ/:

lèj 'eye'	TK02082019-1:07:40.0
éjjé 'who'	TK03152019-4:01:04.8
t̪ê 'be cold'	TK04192019YHSC-2:26:26.5
t̪ɛ̂ 'be cold'	TK05102019-YH3

The reduced vowel [ə] never occurs in monosyllabic words. Consistent with the centralization process described in Quint (2009), the schwa is typically derived from any vowels that are too short to reach their target formant values, especially when they are adjacent to liquids or rhotics, or preceded by velars, as in [t̪ít̪árà] < /t̪ít̪érà/ 'cup', and [kàɽèl̪̀è] < /kèɽèl̪̀è/ 'nail' and [ŋ̀ərpò] < /ŋ̀òrpò/ 'tomorrow'. Sometimes, the schwa can also be an intrusive vowel without a tonal association occurring between two consonants, or according to Quint, the liquid becomes syllabic, for example, [kɛ́ɾəgɛ̀] 'hand'.

(4) [ə]:

t̪ít̪árà 'cup'	TK02202019-5:08:10.3
kɛ́ɾəgɛ̀ 'hand'	TK04192019YHSC-2:26:26.5
kàɽèl̪̀è 'nail'	TK02082019-4:05:28.8
ŋ̀ərpò 'tomorrow'	TK05012019-3:02:46.4

To add to the centralization process, word-final vowels and vowels in closed syllables are often centralized and reduced in duration. For example, [ɪ] as a centralized variant of /i/ in [t̪á:mìn] < /t̪á:mìn/ 'finger' has an F2 of around 1800 Hz, compared to the reference F2 value above 2000 Hz in Figure 2. Likewise, in [nánál̪̀ò] 'sit', the final vowel [o] reduced to 27 ms with an F2 of around 1200 Hz and in [t̪ɪ̀ɗàŋ̀àl̪̀ò] 'surface', [o] becomes centralized with a relaxed quality and an F2 of 1500 Hz. And in the sentence 'A dog is sleeping', the word-final vowel [o] becomes its centralized version [ɵ] in the two words, with an F2 of around 1600 Hz.

(5) ʈá:m**ɨ̀**n ‘finger’ TK03012019NK-4:00:41.0
nánáɭ**ò** ‘sit’ TK03152019-YH1:10:06.9
pìrʈ̪ìr ʈ̪ìɗàŋàɭ**ò** ‘Wipe the surface! (to PL)’ TK04242019-9
ʈíɲɛ́n kə́r**ó** ʈ̪ìnɖ̪ə́r**ò** ‘A dog is sleeping’ TK02202019-1:07:09.1

Further, vowel assimilation is seen in labial spreading across boundaries, particularly in connected speech. This phenomenon is referred to as velarization in Quint (2009). The following example in (6) provides a case of regressive assimilation: occasionally when the verb is followed by a word that contains a rounded vowel [o], the final vowel [ɛ] in the verb /ɛ́jɛ̀/ ‘see’ is labio-velarized to be [ɛ́jʷó]. However, this process seems to be subject to free variation and speech rate because the vowel [ɛ] in word [ɛ́jɛ̀] is retained in some other utterances of the same sentence.

(6) a. [ɲí-gw-ê:j**ʷó** kókò-ŋò]
/ɲí-gw-ê:j**ɛ́** kókò-ŋò/
1SG-CL$_{kw}$-see.IPFV koko-ACC
‘I will see Koko.’ (TK02152019-1)

b. [ɭ-ê:j**ʷó** kókò-ŋó ŋòrpò]
/ɭ-ê:j**ɛ́** kókò-ŋó ŋòrpò/
3PL-see.IPFV koko-ACC tomorrow
‘They will see Koko tomorrow.’ (TK02152019-3)

c. [ŋɛ́ŋɛ́ ɭê:j**ʷó** kókò-ŋó ŋòrpò]
/ŋɛ́ŋɛ́ ɭê:j**ɛ́** kókò-ŋó ŋòrpò/
2PL see.IPFV koko-ACC tomorrow
‘You all will see Koko tomorrow.’ (TK02152019-3)

Another similar case is that the vowel height of final centralized vowels can be conditioned by the height of the following vowel in the following word. For example, /mà:ní/ ‘cook’ is realized as [mà:nɨ́] (7a) when preceding a high vowel such as in [ʈ̪ʉ̀ɭì] ‘porridge (accusative)’, and as [má:nə̀] (7b) when preceding a non-high vowel as in [kàɣròŋé] ‘chicken (accusative)’.

(7) a. ɲí-gw-má:n**ɨ́** ʈ̪ʉ̀ɭ-ì nâ kàɣrò
1SG-CL$_{kw}$-cook.PFV porridge-ACC and chicken
‘I cooked porridge and chicken.’ (TK02222019-5:05:56.9)

b. ɲí-gw-má:n**ə́** kàɣrò-ŋé nâ ʈ̪ûɭ
1SG-CL$_{kw}$-cook.PFV chicken-ACC and porridge
‘I cooked chicken and porridge.’ (TK02222019-5:07:26.9)

The cross-word vowel height assimilation also targets the progressive marker, *ŋgó/ ŋgú*. The vowel in *ŋgó/ ŋgú* alternates between [o] and [u] depending on the vowel in the preceding word. When the subject is the first person singular, *ɲí* 'I', which contains a high vowel [i], *ŋgú* is produced (8a); when the subject is the second person singular, *ŋá* 'you', or a name such as Koko that includes [o] as a non-high vowel, *ŋgó* occurs (8b).

(8) a. ɲí **ŋgú** gw-àβrə̀-ŋà
1SG CL_{kw}.PROG CL_{kw}-run.away-2SG
'I am running away from you.' (TK03062019-8:04:15.6)

b. kókò **ŋgó** gw-àβrə̀-ŋà
koko CL_{kw}.PROG CL_{kw}-run.away-2SG
'Koko is running away from you.' (TK03062019-6:02:59.6)

3 Vowel height change/agreement in grammatical processes

Vowel harmony was described in Quint (2009) as being a pervasive phonological phenomenon such that within words vowels must belong to the same height class, which even applies to non-Koalib origin words. He further described the role of vowel harmony in morphophonology and derived verbs that change valence. Specifically, affixes alternate for vowel height according to the height class of the root, and vowels raise to indicate increased valency in derivational processes. Thus, in this section, I first show harmonic words that are consistent with the previously found pattern, and then present counterexamples of words containing vowels disagreeing in height. Moreover, I present data on multiple grammatical processes, including noun suffixation in instrumental constructions "with X", verbal conjugation in valency changing structures including causatives and passives, and possessives, to investigate the within-word vowel harmony patterns.

3.1 Root-internal harmonic and disharmonic vowel combinations

According to Quint, vowels can be divided into two sets: high vowels /i ɐ u/, and low vowels /e ɛ a ɔ o/, as shown in Table 3 (reproduced).

Supposedly, words should contain vowels of harmonic combinations such that high vowels and non-high vowels do not appear within the root of a word. Table 4

Table 3: Distribution of Koalib vowels by vowel harmony set (reproduced from Quint 2009: P34, Table 6)

	Front	Central	Back
High	i	ɐ	u
Low	e	a	o
	ɛ		ɔ

Table 4: Example words containing vowels of the same height class

ɛ́ːmù	'rat'	kwɔ́rtɔ̀	'blacksmith'
íːgɛ̀	'fire'	kwàɾàl̪̊è	'cough'
ʈɔ́ːɲò	'gourd'	kìmɛ̀u	'doctor'
kúnɛ̀d̪̊ùrì	'number 9'	kwɛ̀l̪̊ùŋ	'liar'
úːmì	'sick'	kwɔ́àj	'slave'
ɲéːʈò	'goat'	t̪̊òɣwɔ̀r	'heart'

contains examples of harmonic words in which vowels belong to the same height class.

However, exceptions or counterexamples to the vowel height agreement rule are abundant in our elicitation with the speaker. Table 5 shows examples of root-internal disharmonic words.

Out of the 200 multisyllabic words including those containing identical vowels in our corpus, there are around 56 words that contain disharmonic vowel combinations (~28%). In the following section, I discuss variations in vowel harmony, using a case study of the instrumental suffix, showing that the harmony pattern is not shown as clearly as in previous work by Quint.

Table 5: Words containing vowels not agreeing in vowel height

jáːrì	'ash'	frìjàr	'flash of light'
kʈ͡ɕítçâ	'wine'	ʈíɲèn	'dog'
ôːɾì	'red'	ʈít̪̊ɤ́rà	'cup'
ɗùkka	'stick'	fóɾì	'light'
kòkòʈɛ̀ɲ	'few'	jɛ́ːnì	'ear'
l̪̊ùbòŋ	'tree-hole'	kímòw	'snake'

3.2 Suffix of the instrumental case: 'with X' construction

The morpheme that indicates the instrumental case in 'with X' constructions alternates between *-ki* and *-ke*, conditioned by the corresponding vowel height set of the root vowels. For example, in Quint's transcriptions, we can compare the suffix vowel agreeing with the low vowels in [kwá:rá[̱-gè] 'with the antelope' with that agreeing with the high vowels in [kwè[ùŋ-gì] 'with the liar' (here /k/ is realized as [g] after sonorants).

We elicited words containing vowels of different heights under suffixation, and Table 6 shows the alternating patterns in the instrumental case for the two sets of words with either high /i ɐ u/ or low vowels /o ɔ ɛ e a/ in the root. These are found to be largely consistent with previous findings in Quint (2009). The transcription was based on both perception and acoustic measures of their respective F1 and F2 values. Note that the consonant in the suffix /-ki, -ke/ is conditioned by noun class, thus we denote the instrumental case to be /-Ci, -Ce/.

Indeed, we see /u i ɐ/ form one group while /o ɔ ɛ e a/ form another group in conditioning distinct vowels in the instrumental suffix. However, counterexamples exist such that 1) words with low vowels can take the higher suffix /-Ci/; and 2) words take both suffixes in free variation, regardless of supposed vowel harmonic sets. Table 7 and Table 8 show the two scenarios respectively.

In Quint's classification, /e/ is grouped with other low vowels, as is supported by its use in alternation with /i/ in the instrumental suffix. However, we found that a few words containing /e/ select the higher suffix *-Ci*, instead of the suffix *-Ce*. This mismatch of vowel heights between root and suffix, along with cases with other low vowels /o a/, adds to the variation of the vowel harmony patterns in Rere. Interestingly, almost all disharmonic cases show a combination of a low root and a high suffix, rather than a high root and a low suffix, except when double forms exist, as in Table 8. Out of the 84 suffixed nouns, we found 19 words that are disharmonic (~23%), and 13 of them contain the vowel /e/. To some extent, the low vowels pattern with high vowels in terms of vowel harmony. In particular, it is possible that the vowel /e/ shifts to a higher vowel, which is consistent with its higher point of articulation (Quint 2009).

Moreover, the phonetic realizations of the suffixed forms are not stable in that the same suffix in the same word can be produced with different vowel qualities (see Table 8). Relatedly, even in words without a suffix, the status of [e] is not steady in that it freely varies with the higher vowel [i], for example, [t̪ê] 'arm' is sometimes produced as [t̪î].

Table 6: Two vowel sets with the instrumental case /-Ci, -Ce/

(a) High V

With + X		With + X		With + X	
wùɾúʈ̪-ʈ̪ì	'larger antelope'	kû:ɭú-ɣî	'smoke'	kú:ɾí-ɣî	'mouse'
ŋɛ̀ɭúŋ-ŋì	'lie'	ʈ̪úrùm-ðî	'government'	é:mù-wî	'rat'
kéɳɖɛ̀ŋ-ɣî	'knife'	gúɾùjí-ɣî	'money'	kí:ɾíɲ-ɣì	'warthog'
kímìji-kî	'kitchen knife'	jí:ðì-jì	'meat'	ɕùkúɭ̀-ɣî	'edible gourd'
ɲúr-ɲì	'fruit'	ʈ́ɲì-rî	'rabbit'	ɭùbùŋ-ɭ̀î	'ground-hole'
ɭùr-ɭ̀ì	'manure'	ì:gé-wì	'fire'	ʈ̪úɭ̀-ðì	'giraffe'
kî:ɾù-kì	'small antelope'				
TK04262019-YH1,2		TK05102019-YH			

(b) Low V

With + X		With + X		With + X	
ʈ̪óŋór-ðè	'elephant'	ʈ́ɔŋɔ̀r-rè	'boy'	lɛ̀blɛ́ʈ̪-ɭè	'cloud'
ʈ̪ò:ròm-ðê	'star'	kwɔ́rtɔ̀-gè	'blacksmith'	ɭɛ́:ɾɛ́-ɭè	'sky'
ɭóm-ɭè	'fish'	ʈ́ór-rê	'hammer'	ɭɛ̀:ɖɛ̀r-ɭê	'bowl'
kwór-ɣê	'man'	ɭɔ̀rɭɔ́ɭ́-ɭè	'beetle'	kéɭ̀-kè	'seed-hole'
ɗòŋ-ɭê	'group'	kâɭ̀-ɣè	'stone'	ɭè:ðè-ɭê	'pine tree'
ʈ́ór-rê	'child'				
'with elephant' in TK04262019-YH1,2; others in TK05102019-YH					

Table 7: Words containing low vowels with /-Ci/

ŋwéɛ̀ŋ-ŋî	'with soot'	TK04262019-YH1
ŋèà-ŋî	'with poison'	TK04262019-YH2
ɭè-ɭ̀ì	'eye'	TK05102019-YH
ŋé:ʈ̀è-ŋî	'goat'	TK05102019-YH
kwórtò-ɣì	'with rich person'	TK05102019-YH
kwá:rá̀ɭ̀-ɣì	'with antelope (biggest)'	TK05102019-YH

Table 8: Words with both forms of suffix

kwɔ́àj-ɣê	kwɔ́àj-ɣî	'with slave'	TK04262019-YH1
kwá:rá⌊-ɣè	kwá:rá⌊-ɣì	'with biggest antelope'	TK04262019-YH1
ʈ̪ù⌊-kè	ʈ̪ù⌊-kì	'with porridge'	TK05102019-YH
ʈ̪ú⌊ùŋ-rê	ʈ̪ú⌊ùŋ-rî	'with silo'	TK05102019-YH
ʈè:ɾà-ɽê	ʈè:ɾà-ɽî	'with girl'	TK05102019-YH
ʈ̪é-ðè	ʈ̪é-ði	'with arm'	TK05102019-YH
⌊è:⌊è-⌊ê	⌊è:⌊è-⌊î	'with termite'	TK04262019-YH1
ám⌊à-wê	ám⌊à-wî	'with trap'	TK05102019-YH

So far, we have seen counterexamples showing that not only words allow root-internal disharmonic vowel combinations, but also words with low vowels /e o a/ can be followed by the suffix containing the high vowel *-Ci*, and words can freely vary between the phonetic realizations of the suffix. This is at odds with Quint's description that all words only allow vowels of the same height group. To further probe the distinction between the vowel qualities in the two alternants of the instrumental case, I plotted the distribution of the mean F1 and F2 values for each [i e] in the suffix based on the transcriptions of the words from above (see Figure 3).

Table 9: Mean vowel formants of [i e] in /Ci, Ce/ based on transcription

	mean F1 (Hz)	mean F2 (Hz)	mean F3 (Hz)	mean F2-F1 (Hz)
i	322.17	2276.07	2828.24	1953.90
ɪ	374.35	2136.40	2725.71	1762.05

The vowel labels based on human perception (by the author and colleagues in the fieldwork class) clearly show that /i/ is a higher and fronter vowel than /e/ in that its tokens are more concentrated in the top left corner of the vowel space with a lower F1 (with a difference > 50 Hz) and slightly higher F2. However, to preclude subjective biases from the transcription, I then used an alternative unsupervised machine classification approach (Stehr 2018) to separate two clusters of the two vowels [i e] by automatically specifying two centers in the K-means algorithm. The corresponding plot is shown in Figure 4.

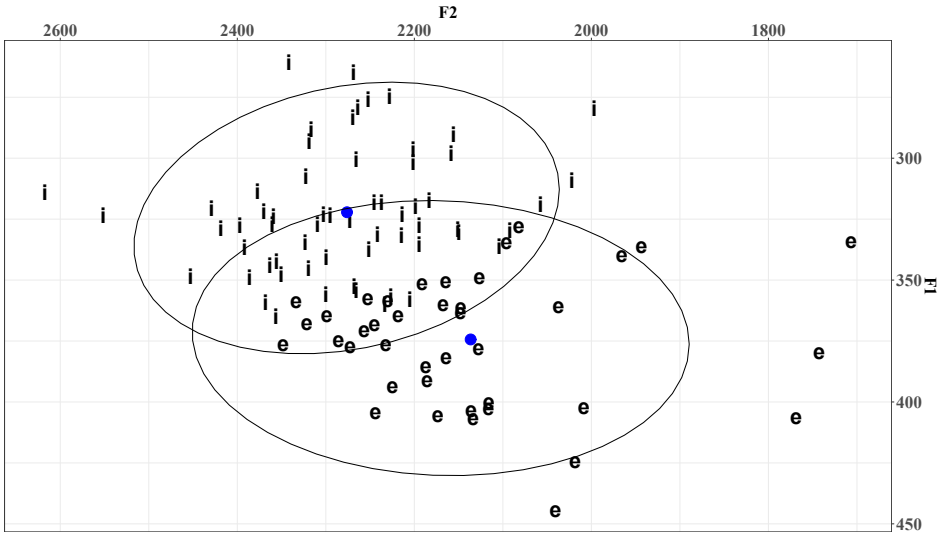

Figure 3: Mean F1 and F2 of [i e] in /Ci, Ce/ based on transcription. The blue dots show the center mean F1 and F2 of [i e] across all tokens. The values are shown in the following table.

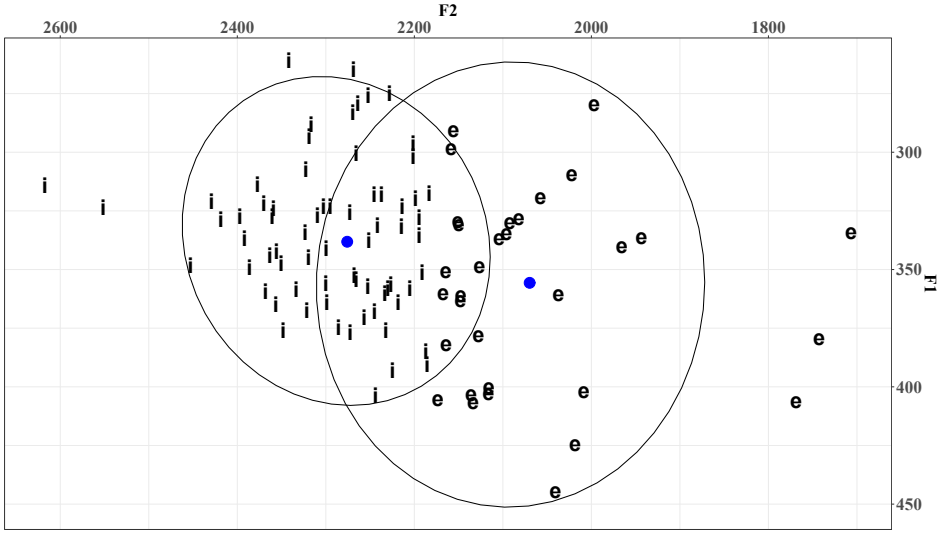

Figure 4: Mean F1 and F2 of [i e] in /ki, ke/ based on k-means clustering at two centers. The blue dots show the center mean F1 and F2 of [i e] across all tokens. The values are shown in the following table.

Table 10: Mean vowel formants of [i e] in /Ci, Ce/ based on k-means clustering

	mean F1 (Hz)	mean F2 (Hz)	mean F3 (Hz)	mean F2-F1 (Hz)
i	338.15	2275.85	2869.08	1937.70
ɪ	355.67	2069.75	2564.42	1714.08

The biggest difference between human perception and the computational analysis lies in the driving factor. We relied more on the difference of F1, or the height between the two vowels while the machine weighed more the linear difference of F2 (> 200 Hz) between the two vowels. Nonetheless, the regular [i] is more concentrated with a lower F1 and higher F2 whereas [e] is more variable with an overall higher F1 and lower F2.

Furthermore, inspired by (Hellwig & Schneider-Blum 2014), I adopted a third supplemental approach to sort out the vowel quality in the suffix *-Ci/ -Ce* by a priori labeling them into three groups: words that contain clearly high vowels /i u ʁ/, words that contain clearly low vowels /ɛ a ɔ o/, and words that contain the supposedly low vowel /e/. Figure 5 shows the distribution of the different suffixes by the three groups.

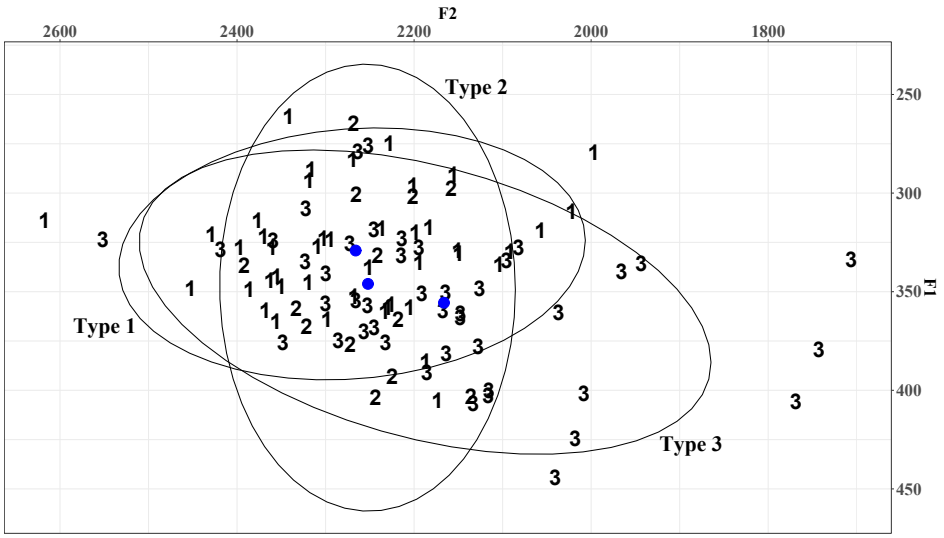

Figure 5: Mean F1 and F2 of [i e] in /Ci, Ce/ divided into three types based on the vowel classes in the root. Type 1: /i u ʁ/; Type 2: /e/; Type 3: /ɛ a ɔ o/. The blue dots show the respective center means of the three types.

Comparing to Figure 3, the circle of Type 1 suffixes resembles the vowel space of [i] with similar formant values with lower F1 and higher F2, which is consistent with our observations that words with higher vowels select *-Ci*. The suffixes in Type 3, the group of words with low vowels, show the opposite pattern of Type 1 by having higher F1 and considerably more variation in both formants, reflected in the few vowel-height mismatching cases discussed above. The suffixes in Type 2, the group of words with [e], however, are more variable along the F1 dimension and more constrained across F2 values, suggesting the unstable status of the height of this vowel, consistent with the above findings on disharmonic suffixation and free variation.

3.3 Valence-changing structures: causatives, passives

Verbal morphology is rich in Rere as it is involved in various derivational constructions. In contrast to the instrumental suffixation where the suffix is the target of harmony and the root is the trigger, in derived verbs in causative and passive constructions, the suffix triggers vowel harmony in the stem, sometimes even without the presence of the suffix. In particular, low vowels in the verb stem raise to become high vowels in the presence of a causative or passive suffix *-in* or *-ən* (a similar pattern occurs in the related language Moro with the causative suffix *-i*; (Strabone & Rose 2012). Here, I present data that show the vowel harmony process where the four low vowels /a ɔ ɔ ɛ/ raise to [ɐ u ʊ i (ɪ)].

The examples (9) and (10) show raising of the central low vowel /a/ to the central high vowel [ɐ] in verbs /áŋgʈí/ 'draw water' and /màːní/ 'cook' under causative constructions, triggered by the causative suffix *-in*.

(9) a raises to ɐ:

a. ɲí-gw-t̪-ɛ́mɟ-í ɲìːɾà t̪ə̀-ɾ-**àŋgʈì**
1SG-CL$_{kw}$-HAB-make-TAM CL$_{ɲ}$.girl HAB-3PL-draw.water
(TK03012019-3:05:38.2)
'I make the girls draw water.'

b. ɲí-gw-t̪-**ɛ́ŋgʈ**-*ín*-í ɲìːɾà
1SG-CL$_{kw}$-HAB-draw.water-CAUS-TAM CL$_{ɲ}$.girl
(TK03012019-3:07:22.2)
'I make the girls draw water.'

(10) a. ɲí-gw-t̪-ɛ́mɟ-í ɲì:rà t̪ə̀-r-**mà:nì**
1SG-CL$_{kw}$-HAB-make-TAM CL$_{ɲ}$.girl HAB-3PL-cook
(TK03012019-3:00:36.2)
'I make the girls cook.'

b. ɲí-gw-t̪í-**mɛ́:n**-*ín*-í ɲì:rà
1SG-CL$_{kw}$-HAB-cook-CAUS-TAM CL$_{ɲ}$.girl
(TK03012019-3:09:45.6)
'I make the girls cook.'

The two sets of sentences in (11) and (12) show that /o/ in the adjectives 'be clean' and 'be dry' changes to [u] in the verbs 'be cleaned' and 'be dried' under passive constructions, triggered by the passive suffix *-ən*.

(11) o raises to u:

a. jìɽáðí jí-**jòɾ-ò**
CL$_{j}$.clothes CL$_{j}$-be.clean-TAM
'Clothes are clean.' (TK06072019-YH)

b. jìɽáð jì-t̪ì-**jùɾ**-*ən*-ì
CL$_{j}$.clothes CL$_{j}$-HAB-clean-PASS-TAM
'Clothes are cleaned.' (TK06072019-YH)

(12) a. jíɽɛ̀t gíjó j-**ònd̪-ò**
CL$_{j}$.clothes CL$_{j}$.DEM CL$_{j}$-be.dry-TAM
'These clothes are dry.' (TK03082019SCARYH-3)

b. jìɽɛ́ð jì-t̪-**ùnd̪**-*ən*-ì
CL$_{j}$.clothes CL$_{j}$-HAB-dry-PASS-TAM
'Clothes are dried.' (TK06072019-YH)

Also note that the instances of [u] in *jì-t̪ì-jùɾ-ən-ì* (11b) and *jì-t̪-ùnd̪-ən-ì* (12b) have a centralized quality as the F2 reaches 1200-1300 Hz.

The examples in (13) and (14) show the low vowel /ɔ/ raises to [ʊ] or [u] in the two verbs /ɔ́:l̥ɔ̀/ 'insult' and /ɔ́rɔ́/ 'become' in causative sentences with the presence of the causative suffix *-in*.

(13) ɔ raises to u/ʊ:

a. kw-ɔ̂:l̥-ɔ̀
CL$_{kw}$-insult.IPFV-TAM
'He will insult.' (TK05102019-YH)

b. ɲú-gw-**û**:ɭ**ɔ̀**-ð[1]-*ən*-í ʈɔ̀:ŋɔ́r-ɔ́ gwɔ̀:r-ɔ̀
1SG-CL$_{kw}$-insult.IPFV-SUF-CAUS-TAM CL$_{ʈ}$.boy-ACC CL$_{kw}$.man-ACC
'I will make the boy insult the man.' (TK05312019-YH)

(14) a. ɲí-gw-ɔ́mɟ-ɛ́ ʈɔ̀:ŋɔ́r-ɔ́ àð-**ɔ́rɔ́** gw-ɔ́mnɛ̀
1SG-CL$_{kw}$-make.PFV-TAM CL$_{ʈ}$.boy-ACC INF-become CL$_{kw}$-something
'I made the boy become something.' (TK05292019-6)

b. ɲú-gw-**ùrù**-ð-*in*-á ʈɔ̀:ŋɔ́r-á kɨ́mòw
1SG-CL$_{kw}$-become.PFV-SUF-CAUS-TAM CL$_{ʈ}$.boy-ACC CL$_{k}$.snake
'I made the boy become a snake.' (TK05312019-YH)

In particular, in (13b), the second [u] in the verb *ɲú-gw-ù:ɭɔ̀ð-ən-í* has a lax quality with an F2 around 1450 Hz. Thus, the low vowel [ɔ] raises to both the high vowel [u] and a phonetic [ʊ], especially in a closed syllable.

The low front vowel /ɛ/ also provides substantial evidence for the vowel harmony process, as seen in the verbs 'go', 'wipe', 'dance', 'hit lightly', and 'finish' with causative suffixation. Note that, besides the regular causative suffix conjugation, causatives can also be formed solely by vowel raising without a segmental suffix, such is the case of /ɛ/ in *kẃ-ʈ̱-ɛ́ɭ-ɛ̀* 'He goes' raising to [i] in *gw-ʈ̱-íɭ-ì* (15b). In the following examples, the vowel /ɛ/ raises to [i] or [ɪ] depending on whether the syllable is open or closed, as examples (16) - (19) show that [ɪ] occurs in closed syllables while [i] occurs in an open syllable in (15).

(15) ɛ raises to i/ɪ:

a. kẃ-ʈ̱-**ɛ́**ɭ-**ɛ̀**
CL$_{kw}$-HAB-go-TAM
'He goes.' (TK02152019SCYHAR-2)

b. ɲú-gw-ʈ̱-**íɭ-ì**
1SG-CL$_{kw}$-HAB-go.CAUS-TAM
'I make him (somebody) go.' (TK05102019-YH)

(16) a. kwɔ̀-m-**pɛ̀rʈ̱-á** ʈ̱ìɗà-ŋ-àɭò
CL$_{kw}$-REC-wipe-TAM CL$_{ʈ̱}$.surface-ACC-O
'He has just wiped the surface.' (TK04242019-9)

[1]We observed that certain verbs have an optional [-ð] or [-Vð] suffix in conjugation. For example, 'insult', 'become', and 'milk (verb)' have it in causatives. The role of the additional suffix is yet to be determined.

b. kẁ-t̪ɪ-**βírt̪**-*ín*-í ʈɔ̀ːŋɔ́r-ɔ́ t̪ìɗà-ŋ-à⌊ò
CL_{kw}-HAB-wipe-CAUS-TAM $CL_{ʈ}$.boy-ACC $CL_{t̪}$.surface-ACC-on
'He makes the boy wipe the surface.' (TK05312019-3)

(17) a. kw-**ɛ̀rt̪-è**
CL_{kw}-dance.IPFV-TAM
'He will dance.' (TK05102019-YH)

b. ɲí-gw-t̪-**írt̪**-*ín*-í ɲɔ̀ŋɔ́r-à
1SG-CL_{kw}-HAB-dance-CAUS-TAM $CL_{ʈ}$.boy-ACC
'I make boys dance.' (TK05312019-YH)

(18) a. kw-**ɛ̀rt̪-ɛ̀**
CL_{kw}-hit.lightly.IPFV-TAM
'He will hit lightly.' (TK05102019-YH)

b. kẁ-t̪-**írt̪**-*ín*-í ʈɔ̀ːŋɔ́r-á gwɔ̀ːr-ò
CL_{kw}-HAB-hit.lightly-CAUS-TAM $CL_{ʈ}$.boy-ACC CL_{kw}.man-ACC
'He makes the boy hit the man lightly.' (TK06072019-YH)

(19) a. kw-**ɛ́rn-ɛ́** t̪ù⌊-ì ŋɔ̀rpò
CL_{kw}-finish.IPFV-TAM $CL_{t̪}$.porridge-ACC tomorrow
'He will finish the porridge tomorrow.' (TK05242019-6:14:37.5)

b. kwù-t̪-**írn**-*ín*-í ʈɔ̀ːŋɔ́r-á t̪ù⌊-ì
CL_{kw}-HAB-finish-CAUS-TAM $CL_{ʈ}$.boy-ACC $CL_{t̪}$.porridge-ACC
'He makes the boy finish the porridge.' (TK05312019-3)

Next, I show examples that indicate no change in vowel quality for [e] and [ɐ] under causative constructions.

(20) e does not raise to a higher vowel like [i]:

a. ɲí-gw-t̪-ɛ́mɟ-í ʈòr-ó t̪-ùŋ-**èndèrè**
1SG-CL_{kw}-HAB-make-TAM $CL_{ʈ}$.child-ACC HAB-SUBJ-sleep
(TK03082019SCARYH-3)
'I make the child sleep.'

b. ɲí-gw-t̪-**éndér-é** ʈòr-ò
1SG-CL_{kw}-HAB-sleep.CAUS-TAM $CL_{ʈ}$.child-ACC
(TK03082019-6)
'I make the child sleep.'

Contrary to what Quint (2009: p. 37) has documented, that the vowel /e/ in verb [èntèré] 'sleep' changes to [i] in [ìndìrí] 'to put to sleep' in causatives, we did not observe a vowel change comparing the sentences in (20). That is, [e] does not raise to a higher vowel. This again implies that [e] can pattern as a high vowel instead of being a pure non-high vowel, as we already saw in the instrumental suffixation, so that it does not change in causatives. While a possible explanation could resort to the absence of the causative suffix -in to trigger raising of [e], we have seen cases in (15) where the low vowel /ɛ/ raises to /i/ without the causative suffix.

Likewise, [ɐ] does not exhibit height changes because it already patterns as a high vowel in the corresponding vowel harmony set.

(21) ɐ does not raise to higher vowels such as the phonetic vowel [ə]:

a. kẃ-**wɐ́** ŋìʤà ŋərpò
   CL_{kw}-milk cow tomorrow
   'He will milk the cow tomorrow.' (TK06052019-YC:10:39.3)

b. ŋí-gw-**wɐ̀ð***in*-í ʈɔ:ŋór-à ŋìʤà
   1SG-CL_{kw}-milk.IPFV-CAUS-TAM boy-ACC cow
   'I will make the boy milk the cow.' (TK05312019-YH)

In sum, we confirm the vowel harmony patterns in Quint (2009) with the exception of /e/ raising to [i]. Table 11 in my analysis summarizes the attested raising patterns compared to Quint's analysis (Table 8; 2009, p.37).

Table 11: Attested vowel harmony in valence-changing verbs

Simple verb	èndèrè 'sleep'	ɛ́ʅɛ̀ 'go'	má:ní 'cook'	ɔ́rɔ̀ 'become'	ònn̪dò 'be dry'
Derived verb	èndèrè 'make sleep'	íʅì 'make go'	mɐ̀:nì 'make cook'	úrù 'make become'	ùnn̪dù 'be dried'

3.4 Possessives

Another potential case for vowel harmony processes is the possessive construction. Several kinship terms with possessive suffixes show variation in vowels depending on the person marker where the vowels in the roots are conditioned by the vowels in the suffix marker.

Table 12: Vowel harmony shown in kinship terms with possessive suffixes

t̪ɛ́ɾɪŋ-ɛ́ɾí	'my father'	TK02012019-6:07:20.9
t̪áɾəŋ-âl̥ò	'your.SG father'	TK03152019NDYC-1:05:38.4
mɛ́ðiɣ-ɛ́ɾí	'my close friend'	TK05172019-3:14:32.0
máðɪɣ-ál̥ò	'your.SG close friend'	TK05172019-4
ɛ́ŋg-ɛ́ɾí	'my sibling'	TK05242019-YH
áŋg-ál̥ò	'your.SG sibling'	TK05242019-YH

Most of the alternations happen among [ɐ] and [a], which corroborates the raising correspondence in example (21) from the above section §3.3 on vowel height raising triggered by the causative marker. For example, in [t̪ɛ́ɾɪŋ-ɛ́ɾí] 'my father', [ɐ] and [i] belong to the same height group and in [t̪áɾəŋ-âl̥ò] 'your.SG father', [a] and [o] are of the same height.

4 Current Rere vowel system and vowel harmony

Based on the present analysis of the Rere vowel behaviors in grammatical processes that involve vowel agreement and alternations, we observe that, despite the largely consistent vowel harmony patterns, considerable variation is found. In particular, the mid front vowel /e/, might be shifting its phonological properties towards a higher vowel [ɪ] in that it can pattern as a high vowel, as seen in the disharmonic words, instrumental suffixation, and causative constructions. The shifting process should be under way, such that the mid front vowel still retains the low vowel characteristics: it would co-occur with low vowels root-internally or during instrumental suffixation. Here, I propose two variants of /e/, such that the higher variant gradually moves towards the mid-high vowel /ɪ/, forming a contrast with the high vowel /i/ only in rare minimal pairs (e.g., [kwîː] 'he will drink' vs. [kwîː] 'he will wash' with a difference of 80 Hz in F1), and the lower variant patterns with other low vowels with a clearly higher F1 (400 Hz). The two harmony sets are hypothesized as high vowels /i ɪ ɐ u/, and low vowels /e ɛ a ɔ o/, as shown in Table 13.

A possible explanation of the apparent lack of harmony is that /e/ is shifting to a high vowel. In instrumental suffixation, under the current analysis, it is expected that *-Ci* will appear after words that contain [ɪ] (the higher variant of /e/) and that [ɪ] can co-occur with other high vowels /i ɐ u/ within a word. In

Table 13: Proposed vowel height classification in Rere

	Front	Central	Back
High	i	(ə)	u
	[ɪ]	ɐ	(ʊ)
	↑		
	/e/		
Non-high	/e/ → [e]		o
	ɛ	a	ɔ

causatives, if /e/ has shifted to [ɪ], it does not need to raise to a higher vowel. These could explain some of the counterexamples in Sections §3.1 - §3.3. However, in the previous analysis by Quint (2009), /e/ is a low vowel and so it would only occur after low vowels.

Table 6 shows selected examples where /e/ behaves like a high vowel [ɪ] and where it behaves like a low vowel [e]. Among the words that contain /e/ in the stem, suffix, or derived forms, the relative frequency of the higher form is about the same as the lower form with the constant variation being the most prominent observation. This may be extended to the entire vowel system, or limited to idiosyncratic characteristics of a sole speaker, but it is clear that vowel harmony is not as robust as it appears to be in previous work.

	/e/ → [ɪ]	/e/ → [e]
(Dis)harmonic word	ké:nì ‘ear’	ŋé:ɽə̀ ‘goat’
	ûɽèjì ‘earth’	éjè ‘see’
	ʈíɲèn ‘dog’	pɛ́ɾʈ̪è ‘wipe’
	íjè ‘eat’	éɽl̥âl̥â ‘stand’
		rèl̥ò ‘wait’
Instrumental suffix	ŋé:ɽè-ŋî ‘with goat’	kél̥-kè ‘with seed-hole’
	l̥è-l̥ì ‘with eye’	l̥è:ðè-l̥ê ‘with pine tree’
	ʈ̪é-ðì ‘with arm’	ʈ̪é-ðè ‘with arm’
	l̥è:l̥è-l̥î ‘with termite’	l̥è:l̥è-l̥ê ‘with termite’
Causatives	èndèrè ‘make sleep’	

Figure 6: Examples illustrating variants of /e/ in different constructions

Figure 7 further illustrates the current vowel system with raising patterns found in the valence-changing structures discussed in the above section on vowel harmony.

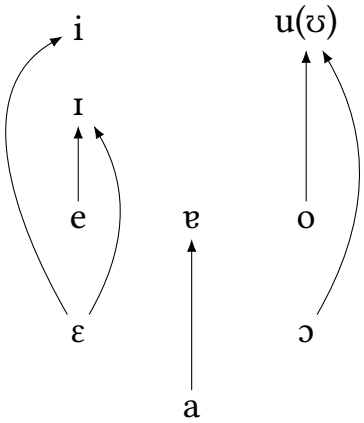

Figure 7: Vowel raising patterns in Rere

We see height raising patterns happening in four low vowels /ɛ a o ɔ/. In particular, the raising schemes shown in (22) suggest that, in accordance with Quint (2009), Rere displays more of a height harmony rather than ATR harmony (also see Moro, a related Kordofanian language, for a height harmony system; Ritchart & Rose 2017). For example, in related languages [ɛ ɔ ɪ ʊ] are [-ATR] vowels, if there is ATR harmony involved in Rere, one would expect alternations between [-ATR] and [+ATR] vowels (e.g., /ɔ/ → [o]) whereas height should not be the conditioning factor. However, in Rere, those supposedly [-ATR] vowels do not always raise to [+ATR] but are allowed to raise to higher [-ATR] vowels (e.g., /ɔ/ → [ʊ]). Moreover, in the causative constructions at least, in closed syllables, /ɛ/ and /ɔ/ become /ɪ/ and /ʊ/ whereas in open syllables, they become /i/ and /u/, respectively, and /o/ goes to /u/ regardless of syllable type.

(22) a. o → u / __ i ə
b. ɛ → i(ɪ) / __ i ə
c. ɔ → u(ʊ) / __ i ə
d. a → ɐ / __ i

Specifically, the vowel raising patterns are derived from the conjugated verbal constructions under valence-changing structures. The trigger of the harmony could be the high vowels or schwa in the causative/passive suffix *-in/ən*; however, we have examined the cases where vowels are raised without the presence of this suffix. Because the trigger of the height harmony can be optional, the

vowel raising may be a morphophonological alternation process, rather than an agreement one.

So far, we have seen the vowel height agreement or alternation processes targeted instrumental suffixation, were triggered by causatives, passives, and possessives, as well as some cross-word harmony patterns. Though vowel harmony languages usually restrict vowels of the same harmony set to appear within the same root or word (with few exceptions), Rere does not conform strongly to the vowel height agreement rule. In general, there does not seem to be a pervasive vowel agreement pattern in terms of height or ATR throughout Rere, in that it exhibits substantial root-internal and word-internal disharmonic vowel combinations and free variation of realization of suffix vowels, unlike some other Kordofanian languages studied so far (e.g., Tima, Moro, Laru, Dagik, Acheron, Tocho, Lumun, with more details below).

To summarize, the present paper proposes that, the mid front vowel /e/ is shifting to a higher vowel /ɪ/, resulting in an asymmetric vowel system between front and back vowels, drawing evidence from the patterns of vowel alternations seen in the vowel agreement and raising processes. Still, the nature of the raising patterns needs to be further investigated with more speakers and data. For example, /o/ → [u] would be height harmony, but /a/ → [ɐ] could be height or ATR or both. /ɛ ɔ/ → [i u] agrees on both height and ATR, but /ɛ ɔ/ → [ɪ ʊ] seems to agree on height only, except that the exact realization of /ɛ ɔ/ after raising is conditioned by syllable structure.

5 Typological implications

In this section, the vowel system of Rere is compared to other systems in neighboring languages. First, the eight-vowel system in Rere resembles but does not completely accord with the 1IU vowel system discussed in Casali (2017). 1IU systems, often seen in West African languages, have seven vowels /i u e o ɛ ɔ a/, which typically refers to vowel systems that do not have contrast among high front vowels. Even with the proposed Rere vowel height system where high vowels are forming contrasts, it is unclear if there is evidence for ATR vowel harmony in Rere, as the main factor accounting for harmony is still height.

Second, neighboring languages such as Laru (Abdalla Kuku 2012), another Heiban language, and Talodi languages including Dagik (Vanderelst 2016), Acheron (Norton 2013), Tocho (Alaki & Norton 2013), and Lumun (Smits 2017) also have an eight-vowel inventory. In terms of vowel harmony patterns, Laru has the same raising pattern as Rere: /ɛ ɔ/ → [i u] respectively, but in a [+ATR] plus

height harmony system with a vowel inventory lacking /e o/. The Talodi languages would raise /ɛ ɔ/ to their mid allophones [e o], but also differ from Rere in that they have a symmetric 2IU vowel system /i ɪ u ʊ ɛ ɔ ə a/, with contrasts among high front vowels, and exhibit a dominant [+ATR] harmony. Also, for Lumun, Smits (2017) noted that the ATR contrasts in the high vowels were weak or even absent, only remaining clear in minimal pairs, suggesting vowel harmony may be weakening. Rere is similar in this sense, for example, the high vowel contrasts were most obvious when articulating the minimal pair [kwîː] 'he will drink' versus [kwîː] 'he will wash'.

Finally, the state of Rere vowel quality is not always steady, especially in high front vowels, for example, [t̪ê] 'arm' is sometimes pronounced as [t̪î], [kîːɾù] 'small antelope' as [kêːɾù], to name a few. All languages have variation to some extent; however, the variable production of /e/ and /i/ in Rere leads to a disrupted vowel height harmony system. The distinction between the high and low vowels becomes blurred. This calls attention to the status of language sustainability and preservation, as brought up for Tabaq (Hellwig & Schneider-Blum 2014). Tabaq, another Nuba Mountains language, has substantial language contact with Arabic. The vowel system in that language was particularly hard to capture. For instance, the short vowel phonemes are subject to centralization, and the same word produced by the same speaker at different occasions could induce differences in acoustics and perception. In addition, Tabaq shows an inconclusive vowel harmony for a short unstressed suffix *-d̪u/ -d̪ʊ*, which is comparable to the instrumental suffix *-ki/ -ke* in Rere. Hellwig and Schneider-Blum assumed that the assimilations in vowel height were ad-hoc or local phenomena instead of remnants of an earlier vowel harmony system in Tabaq; however, the vowel raising process seems to be stronger in Rere, which I would treat more as a disrupted vowel harmony system.

The data so far might suggest that Rere is exhibiting signs of disintegration of its vowel harmony system, perhaps rooted in language contact with Arabic. However, Arabic also lacks a height contrast for back vowels. It is possible that during the language contact process, the front vowels in the "original" Rere vowel system are more unstable and subject to change than the back vowels. However, the underlying reason remains to be probed. Furthermore, the current vowel harmony system for this speaker is not as categorical as Quint suggested, since Quint insisted that the harmony pattern is pervasive even in loanwords Quint 2018. Yet, the speakers come from the same dialect and geographical area.

6 Conclusion

In this paper, I depict the current eight-vowel inventory in Rere with acoustic analysis on vowel distributions and characteristics. I show that the vowel height agreement patterns in Rere are not as robust as previous work has described due to variation seen in root-internal and word-internal disharmonic vowel combinations and noun suffixation with different realizations of the instrumental case. Moreover, I investigate the verbal conjugation under valence-changing constructions, discussed with regard to the vowel raising pattern: /ɛ a o ɔ/ raise to [i (ɪ) ɐ u ʊ], which has been shown to be more consistent with the features of height harmony. I further propose that the mid front vowel /e/ is likely shifting to a higher vowel [ɪ] in its phonological properties which explains its patterning with other high vowels. Future work could look closely into the impact of the syllable structure on the production of raised mid vowels and the implications of an alternative transcription ([ɪ] as [e], or [o] as [ʊ]). In addition, we should examine articulatory differences, in reference to the acoustic differences, such as the tongue root retraction, tongue height grooving, and/or constriction of the glottis for voice quality correlates (Starwalt 2008) for the potential ATR contrasts in high vowels (/i ɪ/). Lastly, although the current study did not make use of data from loanwords, it would be interesting to investigate in the future the vowel harmony patterns in a phonetic and phonological study on Rere loanwords.

Abbreviations

1, 2, 3	first, second, third person	HAB	habitual
IPFV	imperfective	TAM	tense/aspect marker
ACC	accusative	PASS	passive
SBJV	subjunctive	DEM	demonstrative
PFV	perfective	SUF	suffix
PROG	progressive	ATR	advanced tongue root
CAUS	causative	F1	first formant
CL	classifier	F2	second formant
		F3	third formant

Acknowledgements

The author is grateful to one anonymous reviewer, Sharon Rose, Marc Garellek, and the audience at ACAL 51.52 for very constructive feedback and comments.

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Appendix

Representative word list for vowel acoustics
(All the examples used in the paper can be searched and accessed at rere.ucsd.edu)

File	Word	V	F1	F2	F3	IPA
TK01112019-2	place of gathering	ɐ	542.50	1612.63	2885.87	èm̀ərè
TK01112019-2	place of gathering	ɐ	539.22	1610.52	2640.64	èm̀ərè
TK04262019-YH1	knife	ɐ	538.33	1909.28	2559.49	kɛ́ɳɖèŋ
TK04262019-YH1	sheath	ɐ	505.47	1844.08	2356.40	kɛ̂ɭ
TK04262019-YH1	with the lie	ɐ	426.78	1856.35	2154.33	ŋèɭúŋè
TK04192019YHSC-2	liar	ɐ	445.29	1235.86	2594.94	kwèɭùŋ
TK02082019-1	body	ɐ	502.66	1418.02	2557.57	áŋgnà
TK02082019-1	body	ɐ	606.60	1637.08	2506.46	áŋgnà
TK02082019-1	body	ɐ	480.10	1588.05	2389.88	áŋgnà
TK04262019-YH1	seed-hole	e	397.19	2236.46	2862.12	kɛ̂ɭ
TK04262019-YH1	seed of gourd	e	368.48	2329.55	3016.24	ɭè:rè

TK04262019-YH1	seed of gourd	e	321.09	2272.09	2910.68	l̩èːɾè
TK02012019-6	girl	e	360.84	2353.52	3047.55	t̪èːl̩à
TK02012019-6	girls	e	356.30	2270.92	3178.12	ɲèːɾà
TK05102019-YH	girl	e	355.14	2248.38	2853.53	t̪èːl̩à
TK02082019-1	arm	e	373.95	2340.49	3220.97	t̪ê
TK05102019-YH	arm	e	332.69	2409.21	3080.12	t̪ê
TK04262019-YH1	termite	e	371.42	2309.61	3268.79	l̩èːl̩è
TK02082019-7	to come	e	351.94	1625.58	2751.31	êːlà
TK05102019-YH	to come	e	347.52	2315.09	3102.45	t̪èːl̩à
TK05012019-1	to dance	e	394.68	2151.90	2811.66	t̪èrt̪è
TK04192019YHSC-2	lower back	e	381.21	2397.92	2983.28	kèːrèɲ
TK04192019YHSC-2	lower back	e	408.26	2162.81	2881.44	kèːrèɲ
TK04192019YHSC-2	lower back	e	375.59	2253.44	2932.54	kèːrèɲ
TK04192019YHSC-2	lower back	e	428.58	2214.14	2735.20	kèːrèɲ
TK02062019-7	kill	e	369.73	2219.16	2980.48	ʈéɲè
TK05102019-YH	be cold	ɛ	440.08	2125.77	2705.47	ðê
TK04122019YHSC-2	sky	ɛ	498.17	1962.04	2854.94	l̩ɛ́ːɾɛ̀
TK04122019YHSC-2	sky	ɛ	489.10	1833.28	2696.22	l̩ɛ́ːɾɛ̀
TK02082019NKJGQX-3	one	ɛ	497.09	1726.61	2535.54	kwɛ́ʈɛ̀
TK02082019NKJGQX-3	one	ɛ	448.60	2184.04	2949.30	kwɛ́ʈɛ̀
TK05102019-YH	go	ɛ	507.30	2164.75	3172.16	ɛ̂lɛ̀
TK04172019-5	be strong	ɛ	545.42	1965.04	2664.64	pɛ́rl̩ɛ̀
TK04172019-5	feel better	ɛ	530.82	1839.98	2684.26	pɛ́rl̩ɛ̀
TK20190308SCARYH-3	wipe	ɛ	433.89	2023.76	2812.16	pɛ́ɾt̪ɛ̀
TK05312019-YH	finish!	ɛ	504.58	2085.14	2563.16	èrnà
TK05312019-YH	hit lightly	ɛ	523.34	1989.15	2732.68	ɛ́rt̪ɛ̀
TK05312019-YH	hit lightly	ɛ	449.09	2096.63	2825.83	ɛ́rt̪ɛ̀
TK02202019-5	bowl	ɛ	513.01	2072.46	3016.89	l̩ɛ̀ːɖɛ̀r
TK02202019-5	bowl	ɛ	562.24	1930.61	2660.06	l̩èːɖɛ̀r
TK02202019-5	bowls	ɛ	502.01	1894.03	2559.93	ŋwèːɖɛ̀r
TK01162019-2	clouds	ɛ	538.04	2121.05	2835.88	ŋwàblɛ̀t̪ʼ
TK02062019-7	kill	ɛ	483.49	2235.63	3005.37	ʈéɲè
TK05312019-YH	dance	ɛ	435.24	1977.83	2663.80	ɛ̀rt̪ɛ̀
TK05312019-YH	dance	ɛ	417.25	2142.24	2758.48	ɛ̀rt̪ɛ̀
TK20190308SCARYH-3	be clean	o	384.62	944.84	2542.55	ɕóːɾè
TK20190308SCARYH-3	be dry	o	401.43	1071.92	2608.28	ónn̪ì
TK02012019-6	star	o	404.41	906.87	2236.87	t̪òːròm
TK02012019-6	star	o	424.12	755.85	2137.84	t̪òːròm
TK02152019-8	child	o	449.19	909.62	2472.54	ʈôr
TK01252019-11	man	o	431.73	770.98	2422.21	kwôr
TK01252019-11	men	o	470.06	926.53	2268.17	lôr
TK01252019-12	fish	o	440.33	1029.93	2586.43	l̩óm

TK04102019-7	hole in the tree	o	513.27	891.07	2692.80	l̩ùbòŋ
TK02152019NDYC-1	elephant	o	485.54	936.31	2715.77	ʈ̪óŋôr
TK02152019NDYC-1	elephant	o	417.42	853.46	2320.26	ʈ̪óŋôr
TK04122019YHSC-2	rich person	o	437.32	841.36	2249.44	kwórtò
TK04122019YHSC-2	rich person	o	407.61	1056.22	2642.01	kwórtò
TK04122019YHSC-2	rich person	o	425.07	820.59	2331.18	kwórtò
TK04122019YHSC-2	rich person	o	436.16	1005.20	2642.41	kwórtò
TK04122019YHSC-2	group	o	415.50	1085.75	2498.19	ɗòŋ
TK04122019YHSC-2	government	u	359.01	1003.71	2596.89	ʈ̪úrùm
TK04122019YHSC-2	government	u	355.22	895.20	2476.52	ʈ̪úrùm
TK04192019YHSC-2	manure	u	346.35	994.66	2700.18	l̩ùr
TK02152019-8	silo	u	375.62	929.26	2507.29	ʈ̪úl̩ùŋ
TK02152019-8	silo	u	369.47	1018.80	2538.95	ʈ̪úl̩ùŋ
TK04102019-7	hole in ground	u	324.14	760.42	2615.82	l̩ùbùŋ
TK01162019-2	smoke	u	307.55	722.39	2622.59	kû:l̩ù
TK01162019-2	smoke	u	365.36	919.43	2197.12	kû:l̩ù
TK01162019-2	much smoke	u	317.93	777.60	2242.40	kú:l̩ù kû:ɾù
TK01162019-2	much smoke	u	310.80	777.53	2305.24	kú:l̩ù kû:ɾù
TK01162019-2	much smoke	u	343.56	523.20	2215.43	kú:l̩ù kû:ɾù
TK04172019-6	money	u	364.96	888.94	2442.86	gúɾùʃ
TK02152019-8	hammer	ɔ	572.95	1115.55	2465.84	ʈ̪ôr
TK04262019-YH1	with cup	ɔ	536.51	1103.56	2272.18	ʈ̪ɔ̀:ɲérì
TK02012019-6	boy	ɔ	546.30	1080.35	2212.47	ʈ̪ɔ́:ŋɔ̀r
TK02012019-6	boy	ɔ	525.31	915.05	2121.98	ʈ̪ɔ́:ŋɔ̀r
TK04122019YHSC-2	beetle 1	ɔ	569.86	1157.85	2366.67	l̩ɔ́rl̩ɔ́l̩ɔ̀
TK04122019YHSC-2	beetle 1	ɔ	558.15	1097.63	2868.95	l̩ɔ́rl̩ɔ́l̩ɔ̀
TK04122019YHSC-2	beetle 1	ɔ	544.99	1192.23	2631.05	l̩ɔ́rl̩ɔ́l̩ɔ̀
TK04122019YHSC-2	beetle 1	ɔ	605.38	1203.23	2891.92	l̩ɔ́rl̩ɔ́l̩ɔ̀
TK04122019YHSC-2	beetle 1	ɔ	587.87	1050.26	2467.03	l̩ɔ́rl̩ɔ́l̩ɔ̀
TK04122019YHSC-2	blacksmith	ɔ	537.80	979.22	2359.84	kwɔ́rtɔ̀
TK02082019NKJGQX-3	three	ɔ	529.81	938.08	2391.32	ʈ̪ɔ́:ɽɔ̂l̩
TK04192019YHSC-2	vocal tract	ɔ	551.44	851.72	2279.99	kwɔ́:rɔ̀
TK04172019-5	become	ɔ	545.20	874.59	2292.89	ɔ́rɔ̀
TK04172019-5	become	ɔ	591.90	912.17	2640.50	ɔ́rɔ̀
TK04122019YHSC-2	back of skull	ɔ	547.39	1028.42	2488.97	ɗɔ̀ŋ
TK04122019YHSC-2	beetle 2	ɔ	545.13	1057.77	2553.14	l̩ɔ̀mnɔ́kɔ̀
TK04122019YHSC-2	beetle 2	ɔ	493.73	932.88	2542.14	l̩ɔ̀mnɔ́kɔ̀
TK02202019-5	gourd	ɔ	548.86	711.41	2520.81	ʈ̪ɔ́:ɲò

TK02082019-7	to come	a	830.90	1910.62	2566.47	êːlà
TK02082019-1	body	a	747.37	1474.69	2473.66	áŋgnà
TK02082019-1	head	a	750.88	1673	2366.24	ɳɖà
TK02012019-6	girl	a	762.99	2089.55	2598.32	ʈèːɾà
TK02082019-2	foot	a	769.30	1551.40	2092.08	káːɤà
TK02082019-2	leg	a	841.88	1631.32	2598.63	l̪àːɾà
TK02082019-2	leg	a	739.51	1851.85	2569.85	l̪àːɾà
TK02082019-2	finger	a	704.49	1633.13	2185.43	l̪áːmìn
TK02082019-2	finger	a	846.85	1667.03	2461.74	l̪áːmìn
TK02082019-2	finger	a	702.88	1681.21	2725.73	l̪áːmìn
TK02082019-2	day (short)	a	759.03	1744.38	2527.67	ʈáːmìn
TK02222019-4	cook	a	538.26	1451.32	2550.30	máːnì
TK03062019-1	meat	i	321.37	2371.55	2999.95	jíːðì
TK03062019-1	meat	i	265.46	2315.29	2897.44	jíːðì
TK04192019YHSC-2	warthog	i	301.06	2357.34	2462.10	kìːɾìŋ
TK04192019YHSC-2	warthog	i	301.57	2224.04	2925.84	kìːɾìŋ
TK01162019-6	drink	i	277.85	2435.63	3267.88	îː
TK05032019-4	rabbit	i	303.53	2400.55	3209.52	ʈíɲì
TK05032019-4	rabbits	i	319.56	2325.07	3062.60	ɲíɲì
TK03152019-YH1	hit	i	293.68	2316.45	2990.98	pî
TK03152019-YH1	fly	i	274.44	2517.08	3160.95	dĭːɽî
TK03152019-YH1	fly	i	286.15	2361.03	3103.54	dĭːɽî
TK05032019-4	catch	i	260.72	2478.75	3189.06	íːðì
TK02082019-2	thumb (ox)	i	330.12	2275.51	2657.18	ɲíðrì