Chapter 7   The Acoustics of Rhotacization in Mandarin

7.1   Introduction

Through examining one or more linguistic variables in a speech community, studies of sociolinguistic variation arrive at an understanding of the social and linguistic constraints on the variation and reveal the ongoing change (Bayley, 2013; Bayley & Lucas, 2007; Meyerhoff, 2011). It is believed that speakers' choices among variable linguistic forms are systematically constrained by multiple linguistic as well as social factors. Those factors could reflect underlying grammatical systems and the social organization of the communities to which the speakers of the language belong. In sociophonetic studies, instrumental techniques, especially acoustic vowel analysis, have been used to analyze language variation and change quantitively (Baranowski, 2013; Kendall & Fridland, 2021).

The present chapter studies the variation and change in rhotacization in the Beijing speech community in order to reveal the social and linguistic constraints on rhotacization. As mentioned in Chapter 2, rhotacized syllables in Mandarin are not only auditorily salient, but, in some cases, they may express lexical meanings, such as diminutive, as well. As a consequence, a socio-phonetic study of rhotacization in Mandarin needs to take other linguistic factors into consideration as well.

The present chapter focuses on the following questions:

1) What are the most frequently used rhotacized rimes and what are their lexico-phonetic features? In the earlier chapters we looked at the frequency of tokens in general. Now we will focus on the individual rhotacization rimes themselves.
2) What are the variants of the rhotacized rimes most frequently used by speakers with different dialect backgrounds? How do social and linguistic constraints affect the variable?
3) Is there a duration difference in the realization of the rhotacized rime *ianr* across the groups? How do social and linguistic factors affect its duration?

In this chapter, we focus on the most frequent rhotacized rime *ianr* as the sociolinguistic variable. This chapter is structured as follows. After establishing that *ianr* is the most frequent rhotacized rime in our data in Section 7.2, we will, in Section 7.3, measure formant values of the rime *ianr* and compare the differences across groups, to obtain the variants of the rime *ianr* used by speakers with different dialect backgrounds. In Section 7.4, the duration of the rime *ianr* is measured, and we will compare the duration differences across the different groups to reveal the effects of linguistic and social factors on it. In the last section, we discuss and summarize the findings and results of the three experiments and draw conclusions.

7.2   Experiment 1: The occurrence of rhotacized rimes

This section about the occurrence of rhotacized rimes consists of three parts. First, we look at the frequency of the 37 Mandarin rhotacized rimes in our corpus to reveal the differences in instantiating rhotacization between rimes and between and within social groups. Then we determine which rime is the most frequently rhotacized across all social groups. Finally, we look at the lexical meanings of the morphemes and words that involve this most frequently rhotacized rime; the tonal realization of the rhotacized syllables will also be taken into consideration.

7.2.1   Results

The frequency of rhotacized rimes

Figure 7.1 shows the average of each rhotacized rime per dialect background.[21] The x-axis holds the categories, namely all (phonologically possible) 37 rhotacized rimes, and the y-axis holds the value of the average number of rhotacized rimes. There is a z-axis as well, which holds the three categories of dialect-background groups. The length of each column represents the average number of each rhotacized rime by a dialect group.
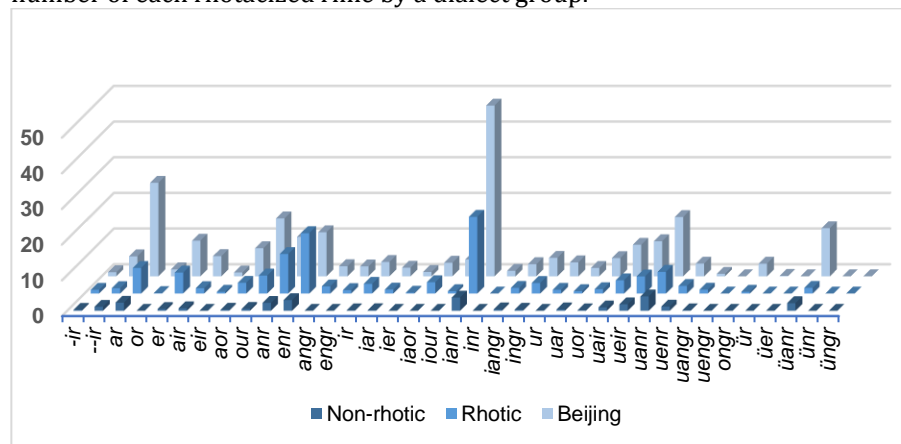
Figure 7.1 Overview of the average of each rhotacized rime used by three dialect groups.

As shown in Figure 7.1 (see also Appendix F), the occurrence of the 37 rhotacized rimes vary dramatically between and within dialect groups. The Beijing native

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[21] Appendix F provides an overview of the data in a table. Appendix G shows the complete lists of the total and average number of each rhotacized rime produced by three age groups of each dialect group.

speakers (Pn[22] = 31) used the highest number of different rhotacized rimes (Rt-n[23] = 33), more than the Rhotic speakers (Rt-n = 28) and the Non-rhotic speakers (Rt-n = 19). As can be seen in Appendix G, among the Beijing native speakers, the Old speakers (Pn = 8) used 33 different rimes in total, one more than the Middle-aged speakers (Pn = 8) and Young speakers (Pn = 16). In the Rhotic and Non-rhotic groups, the number of rhotacized rimes being used shows a slight downward tendency from Young to Old. Specifically, in the Rhotic group, we found that Young speakers used 28 different rhotacized rimes, while Middle and Old used 27 and 26 rimes, respectively. In the Non-rhotic group, Young speakers used 19 rimes, Middle-aged speakers used 18, and Old produced 7 in total.

Above all, in the three dialect groups, the Beijing native speakers used the largest number of rhotacized rimes, and for each rime, they also used it more frequently than the other two dialect groups, the Rhotic speakers in general finding themselves in the middle and the Non-rhotic speakers rhotacizing the least. In addition, there are also differences among the Age groups in each dialect group. In the Beijing native group, the number of rhotacized rimes decreased from the Old to the Young, while in the Rhotic and Non-rhotic groups, the number decreased from the Young to the Old, as we just saw.

Concerning the rhotacized rimes, in each dialect group, some of rhotacized rimes were used frequently, while others were barely used at all. For example, in the speech of the Beijing native speakers, some rimes, such as *ar, ianr*, and *uanr*, were used at least 15 times on average, while some rimes, like *uengr*, *ür*, *üer*, *ünr* and *üngr*, were not used at all.

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[22] *Pn* refers to the number of participants, same below.
[23] *Rt-n* refers to the number of rhotacized rime types; same below.

Most frequently used rhotacized rimes across groups

Table 7.1 The five most frequently rhotacized rimes used in natural speech of the three dialect groups.

	Beijing			Rhotic			Non-rhotic		
	rimes	*sum*	*avg.*	*rimes*	*sum*	*avg.*	*rimes*	*sum*	*avg.*
Young	ianr	221	15	enr	101	13	uanr	22	3
	enr	97	7	ianr	77	10	enr	17	2
	ar	65	4	anr	47	6	anr	12	2
	ueir	50	3	ar	34	4	ar	10	1
	anr	48	3	uenr	14	2	ianr	9	1
Middle	ianr	126	16	ianr	47	6	ianr	14	2
	ar	78	10	er	28	4	ueir	10	1
	our	68	9	anr	23	3	ar	7	1
	üanr	41	5	ar	22	3	uanr	6	1
	uanr	37	5	our	21	3	--ir	4	1
Old	ianr	139	17	ianr	36	6	ianr	4	1
	ar	97	12	uanr	17	3	uanr	3	0
	uanr	74	9	ueir	16	3	üanr	3	0
	üanr	44	6	anr	14	2	--ir	2	0
	er	41	5	er	12	2	anr	2	0

Note: '*rimes*' refers to five most frequently used rhotacized rimes in each group; '*sum*' and '*avg.*', respectively, refer to the total number of instances of a rime and its average per speaker in that Dialect–Age group. The *sum* and *avg.* of five rimes listed in each Dialect–Age group are arranged in descending order.

Table 7.1 shows the five most frequently used rhotacized rimes and the sum and average number of the rimes per Dialect–Age group (3 Dialect groups × 3 Age groups). It can be seen that the rime *ianr* is the most used in seven Dialect–Age groups, that is, all except the Rhotic-Young and Non-rhotic-Young groups. Nevertheless, in these two groups, *ianr* is still one of the five most frequently used rhotacized rimes. We also find that besides *ianr*, other rimes, belonging to the rhyming group *anr*, are also among the most frequently rhotacized rimes in several groups, such as *anr*, *uanr*, and *üanr*.

Table 7.2 The total number of *ianr* and the average number per speaker from different dialect backgrounds (*N* = 895).

Dialect Background	Sum	Participants	Average
Beijing	613	31	19.7
Rhotic	260	22	11.8
Non-rhotic	21	22	1.0

The total number of *ianr* rimes in the corpus is shown in Table 7.2. In total, there are 895 tokens with *ianr* rimes produced by 74 speakers in the three dialect groups. The Beijing native speakers produced the most *ianr* rimes (*Tn* = 613), and the Non-rhotic *speakers* produced the fewest (*Tn* = 22), with the Rhotic speakers in between (*Tn* = 260). On average, as illustrated in the table, the Beijing native speakers produced 19.7 *ianr* rimes per person, the Rhotic speakers 11.8 and for the Non-rhotic speakers it was 1.2 per person.

Syllable types, meanings, and tones

As mentioned before, rhotacization is a lexico-phonetic phenomenon in Mandarin, rather than a purely phonetic affair. To do justice to all aspects involved in the rhotacized *ianr* syllables, we further categorized them based on syllable type,[24] meaning, and tone.

The pattern that we found in the 895 *ianr* syllables is shown in Table 7.3. Rather than occurring in many different syllable types, about 95% of the 895 *ianr* syllables occurs in five syllable types, namely *bianr*, *dianr*, *mianr*, *pianr*, and *tianr*. Among them, about half of the total (*n*=405, *Pct*=50.4%) occurs in the syllable *bianr.*[25] The second and third most frequently occurring are *dianr*[26] (*n*=266, *Pct*=29.7%) and *mianr*[27] (*n*=89, *Pct*=10%). These three syllable types account for about 90% of the total. The occurrence of the syllables *pianr* (*n*=26, *Pct*=3.9%) and *tianr* (*n*=16, *Pct*=1.8%) is dramatically lower, despite the fact that they take fourth and fifth place. All the other syllable types (*Nt*=47) with the rime *ianr* combined account for only 5.3% of the total.

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[24] Syllable types here refer to different "onset consonant + *ianr*" combinations.

[25] The morphemic meaning of *bian* (边) as a noun: 1. the edge or margin of an object; 2. the border or boundary of a region or a country; 3. side, nearby; 4. simultaneously; 5. indicating locality; etc.

[26] The morphemic meaning of *dian* (点): 1. a little, a bit; 2. some; 3. at all (used in negative sentence).

[27] The morphemic meaning of *mian* (面) as noun: 1. face; 2. the surface of an object; 3. measure word for an object which has flat surfaces such as drums, mirrors; 4. powder, flour; 5. aspect; 6. side; 7. indicating locality; etc.

Table 7.3 The number and percentage of the rhotacized rime *ianr*s by their syllable types, morphemic meanings, and tone realizations (*N*=895).

Syllable Type		Morphemic Meaning	Example	Or Tone	Beijing	Rho.	Non-rh.	Ot Tone	Beijing	Rho.	Non-rh.	Sum	Pct.
bianr	bianr 1	to indicate location	里边儿 li bianr 'inside'	T1	91	50	1	T0	194	65	4	405	45.3%
	bianr 2	edge; margin	路 边 儿 lu bianr 'roadside'	T1	31	15	0	-	-	-	-	46	5.1%
dianr	dianr 1	some, a little bit (of), at all	一点儿 yi dianr 'a little bit'	T3	81	68	7	T0	80	18	1	255	28.5%
	dianr 2	decimal; defined time/place	三点五 san dianr wu 'three point five' 景点儿 jingdianr 'attractions'	T3	3	7	1	-	-	-	-	11	1.2%
mianr	mianr 1	to indicate location	前面儿 qian mianr 'in front of'	T4	14	3	0	T0	27	4	2	50	5.6%
	mianr 2	surface	桌面儿 zhuo mianr 'on the desk'	T4	25	8	0	-	-	-	-	33	3.7%
	mianr 3	powder; flour	白面儿 bai mianr 'heroin'	T4	4	2	0	-	-	-	-	6	0.7%
pianr	pianr 1	a thin and flat thing; photo	纸片儿 zhi pianr 'card' 照片儿 zhao pianr 'photo'	T4	10	4	1	T1	1	2	0	18	2.0%
	pianr 2	to indicate location	那片儿 na pianr 'that part'	T4	2	5	0	T0	1	-	-	8	0.9%
tianr	tianr	day	聊天儿 liao tianr 'talk day; chat'	T1	14	1	1	-	-	-	-	16	1.8%
other	-	-	-	36	7	4	-	-	-	-	47	5.3%	
	Sum											895	

Note: Syllable type refers to the "onset consonant + *ianr*" combination. The numbers *1, 2*, and *3* marked after some syllable types are used to number the meanings of a syllable, if it has more than one meaning. *Morphemic Meaning* indicates the meanings of each syllable. *Or Tone* represents the citation tone of the syllable. *Ot Tone* represents some other tone realization based on the syllable's original tone in natural speech. *Beijing*, *Rho.,* and *Non-rho.* refer to the number of the syllable with the specified meaning and with the original tone (*Or Tone*) or other tone (*Ot Tone*) used by speakers respectively from Beijing, Rhotic, and Non-rhotic groups. *Sum* and *Pct.* refer to the total number of each syllable type and its proportion.

The citation tones of the three most frequent syllables are, respectively, T1 (*biānr*), T3 (*diǎnr*), and T4 (*miànr*). As shown in Table 7.3, on both *bianr* and *mianr*, when indicating the meaning of "location," the tone is neutralized in all three dialect groups (the syllable is often reduced in other respects as well, as we will see). Among them, the Beijing native speakers use the neutralized tone twice as often as the full form when they use *bianr*. The tone on *dianr* 'a little bit, some, at all', was realized equally often in its full form as in its neutralized form by the *Beijing* native speakers, *Nt*=81 and *Nt*=80, respectively. Both the Rhotic and the Non-rhotic speakers used the neutral tone (*Nt*=68; *Nt*=7) less frequently than the fully realized tone (*Nt*=18; *Nt*=1).

7.2.2   Summary

We investigated the 37 rhotacized rimes in our natural speech corpus and calculated the number of each rhotacized rime produced by the speakers from each dialect group. We found that rhotacized rimes were not used evenly. Some rimes occurred very frequently, while other rimes were never or almost never used. For the frequent rimes, the rimes in the rhyming group *anr* occurred the most frequently, including four rimes, *anr*, *ianr*, *uanr*, and *üanr*. Among them, the rime *ianr* turned out to be the most frequently used rime across all the Dialect–Age groups.

     Morphologically, one function of rhotacization in Mandarin is that of diminutive formation (Duanmu, 1990; B. Huang & Liao, 2017; Y.-H. Lin, 2007a). It should be noted that the results of this study show that the morphemic meanings of the most frequently used rhotacized syllables, *bianr* and *mianr,* have nothing to do with diminutive forms. Specifically, the syllables *bianr* and *mianr* usually occur in fixed words indicating location. The syllable *dianr* usually occurs in the fixed combination with *yi* 'one', *yi dianr* meaning 'a little bit'. As the focus of this study in not on revealing the grammatical or lexical function of rhotacization and possible changes in those respects, we will not discuss it further.

     The most frequently used rhotacized rime *ianr* is to be the focus in our sociolinguistic study. In Experiment 2 and Experiment 3, we will focus on the phonetics and acoustics of the rime *ianr* across social groups, to examine the

social and linguistic constraints in language variation and pronunciation norm formation.

7.3 Experiment 2: Acoustics of the rhotacized rime *ianr*

In Experiment 1, we found that *ianr* is the most frequently used rhotacized rime in our natural speech database across all social groups, and we looked at syllables containing the rime *ianr*, in terms of syllable type, meaning, and tone realization of such syllables. In the present experiment, based on the pattern and categories we obtained in Experiment 1, we study the rime *ianr* acoustically by comparing the formant trajectories of their first, second, and third formant contours and F2–F1 formant charts. The focus of this study is to explore the variants of the rime *ianr* in different social groups and to reveal the effects of both linguistic (e.g., tonal, segmental, and morphemic) factors and social factors on the variation in a specific rime.

7.3.1 Method

Categorizing ianr

In this acoustic experiment, all *ianr* rimes were pre-categorized into three types, namely *ianr* with Original Tone (OT *ianr*), with Neutral tone with the glide [j] (NT *ianr*) and with Neutral tone without the glide [j] (NG *ianr*).

This categorization was made based on the phonetic (segmental and tonal) and auditory features of syllables with *ianr* in our corpus. As we saw in Section 7.2, syllables with rime *ianr* are realized either with their original tone fully realized or with a neutral tone. In addition to losing their tone, *ianr* rimes occasionally also lose the glide [j].[28] So, *ianr* rimes carrying a neutral tone can be further divided into two subgroups, namely, Neutral tone with the glide [j] pronounced and Neutral tone without the glide [j] pronounced, according to the presence of the glide [j] or not.

To test the feasibility of this pre-categorizing method, a phonetician who is a Beijing native speaker was asked to test it. He did a trial on categorizing *ianr* rimes with this method, which is believed to be able to categorize *ianr* rimes based on their linguistic and auditory characteristics. Then this phonetician also helped to check all the pre-categorization results and to improve them.

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[28] Phonetic studies (Duanmu, 1990, 2004, 2014; Y.-H. Lin, 2007a) suggested that a neutral tone could change the quality of the syllable rime it affiliates with, as discussed in Chapter 2.

Recording conditions and data inclusion

Of the 37 rhotacized rimes, the most frequently used rhotacized rime *ianr* was selected for the acoustic analysis, as mentioned in Section 7.2. However, as mentioned in Chapter 3, the recording occurred at places familiar to the participants rather than a sterile studio. As a consequence, the conditions were different for each pair of speakers and were not always optimal. It turned out that not all recordings of the rime *ianr* were appropriate for an acoustic analysis, due to poor and unreliable formant information. The most frequent causes are listed here:

- Unexpected noise. Though the recordings were conducted in quiet rooms, such as the participants' study rooms at home or meeting rooms at their workplaces, unexpected noises inside of the room still occurred, such as speakers' rocking chairs and speakers clearing their throat or repeatedly rubbing their hands when they or their interlocutors were talking.
- Speech overlapping. While one speaker was talking, sometimes his/her interlocutor interrupted him/her. So, the rhotacized words with the rime *ianr* produced by one speaker could be partially or completely overlapped by the other interlocuter's speech. Consequently, the formant values extracted from Praat are not accurate and the original formant information of the rime *ianr* could thus not be precisely obtained any more.
- Fast and weak *ianr.* Some words with the rime *ianr*, especially those with neutral tone, were spoken too fast and soft, leading to limited formant information being recorded.

As a result, many *ianr*s (about one half) were excluded from further acoustic analysis. Table 7.4 shows the number of OT, NT, and NG *ianr*s before and after exclusion. In Appendix H, the average number of OT, NT, and NG *ianr*s per speaker per social group after the exclusion, is given respectively in Tables C1, C2, and C3.

Table 7.4 The number of *ianr*s obtained in the corpus (*N*=895), the actual number of *ianr*s in the formant analysis (*N*=460), and the actual average number of *ianr*s per speaker per social group.

Gender	Age	Beijing			Rhotic			Non-rhotic		
		ianr	*actl. ianr*	*actl. avg.*	*ianr*	*actl. ianr*	*actl. avg.*	*ian r*	*actl. ianr*	*actl. avg.*
Male	Young	161	91	11	45	32	8	6	4	1
	Middle	65	33	8	53	31	8	3	3	1
	Old	65	24	6	50	18	5	3	2	1
Female	Young	126	73	10	36	26	7	3	3	1
	Middle	74	36	9	44	24	6	7	4	1
	Old	122	45	11	32	13	7	0	0	0
	Total	613	302	10	260	144	7	22	16	1

Note: ianr refers to the number of *ianr* rimes obtained from all the speakers of each social group; *actl. ianr* refers to the actual number of *ianr* rimes that could be used in acoustic analyses of each social group; a*ctl. avg.* refers to the actual average number of *ianr* rimes per speaker per social group in the acoustics analysis.

Formant analysis and normalization

The formant analysis of this experiment consists of two parts: formant trajectory analysis and F2–F1 vowel chart analysis. The formant trajectory illustrates the first formant (F1), second formant (F2), and third formant (F3) movement contours of OT, NT, and NG *ianr* produced by speakers of each Gender–Age group in each dialect group. The F2–F1 vowel charts show the frontness and height of the tongue position of the normalized rime *ianr*. These two formant analyses aim to reveal formant differences, that is, vowel differences, of the variable *ianr*s produced by speakers in different social groups and to obtain the variants of *ianr* in the Beijing speech community.

Formant trajectories

In the present study, we focus on the acoustics of the variable *ianr*. The surface form of *ianr* is phonetically a combination of the glide [j] + rhotacized vowel [ar]. Being different from the vowel analysis in other variation studies, the variable *ianr* is neither a monophthong nor a diphthong. The common way to get the normalized midpoints of F1 and F2 on the monophthong, or 30 percent of the diphthong duration, do not completely apply to this variable *ianr*. Besides, this variable is a rhotacized sound and thus has a lower F3. The vowel-intrinsic

normalization methods would not produce an accurate measurement (Baranowski, 2013; Thomas & Typler, 2007). Moreover, the presence and absence of the glide [j] in the variable *ianr* plays an important role in this study of language choices and variation, so the presence of and realization of the glide [j] should be studied. For this reason, the common normalization methods do not apply to this study and examining the general formant trajectory (F1, F2, and F3) is a proper way to compare the differences in the realization of *ianr* across different social groups.

We sampled ten equidistant points on each formant of each *ianr* rime. The formant trajectories were obtained by averaging the ten formant values of the same type *ianr* produced by speakers in each Gender–Age group. This can to some extent eliminate the effects of vocal tract differences of speakers of different ages and gender on the vowel comparison. In addition, we are aware that averaging the formant values of different speakers in the same Gender–Age group could eliminate some micro-differences in the rime *ianr* across those speakers. However, the focus of this formant study is to reveal the differences of formant movements macroscopically across different Gender–Age groups and to obtain the variants of the rime *ianr* in different social groups. Formant trajectories were shown in line charts that were grouped by Gender–Age group.

Trajectory differences can be compared with multilevel regression models, such as growth curve analysis (GCA) or generalized additive mixed modeling (GAM). However, as illustrated in Table 7.4 and Appendix H, the actual number of variable OT, NT, and NG *ianr*s in each Gender–Age group that is usable in the formant trajectory analysis is less than it ideally should be. If random effects, such as the onset consonant and the phonetic context of variable *ianr*, are involved, the actual data size is not appropriate for conducting statistical tests, which would be necessary for such comparisons.

F2–F1 vowel charts

The midpoint value of F2 and F1 of each *ianr* was sampled and normalized using the Lobanov method (Lobanov, 1971). The results obtained with the Lobanov method are not Hertz-like values, so the normalized results were converted to Hertz-like values, and we plotted them on a chart of F1 (on the y-axis) against F2 (on the x-axis). The Lobanov method is believed to be one of the best normalization formulas and could optimally eliminate physiologically caused differences in vowel formant values produced by speakers of different ages and genders while preserving sociolinguistic differences (Adank et al., 2004; Thomas

& Typler, 2007). The Lobanov vowel normalization[29] and scaling[30] in this study were done using the vowels package in R (R Core Team, 2020). The F2–F1 formants are shown per *ianr* type per Dialect–Age group.

Both format trajectory and F2–F1 vowel charts were made using the ggplot2 package (Wickham, 2016) in R (R Core Team, 2020).

7.3.2   Results
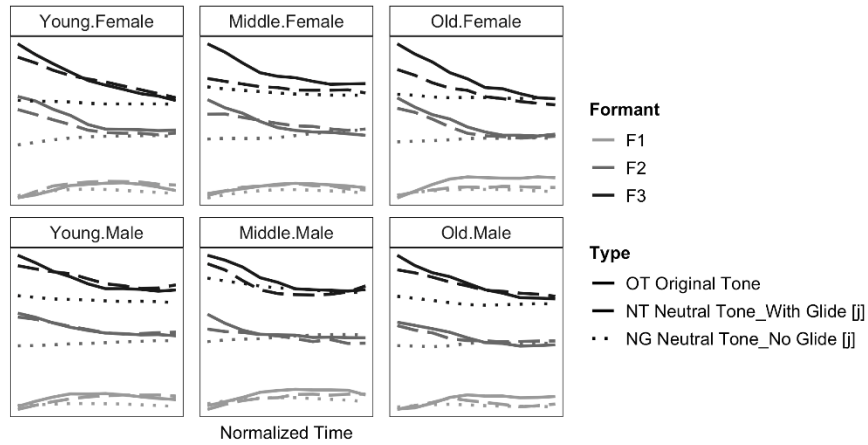
Formant trajectories of ianr

Beijing native speakers

Figure 7.2 Averaged formant contours of rhotacized rime *ianr* produced by Beijing native speakers. F1, F2, F3 (bottom to top).
The x-axis represents the normalized time, and the scale of y-axis is in Hz. Three different line types— solid, dashed, and dotted lines—are used to differentiate the three types of the rime *ianr* with the Original tone or a Neutral tone with the glide [j] being pronounced or without the glide.

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[29] According to (Adank et al., 2004; Nearey, 1977; Thomas & Typler, 2007), the Lobanov formula is:

$$F_{n[V]}^N = (F_{n[V]} - MEAN_n)/S_n$$

[30] The NORM's formulas for the scaling algorithm are:

$$F'_1 = 250 + 500 (F^N_1 - F^N_{1MIN}) / (F^N_{1MAX} - F^N_{1MIN})$$

$$F'_2 = 850 + 1400 (F^N_2 - F^N_{2MIN}) / (F^N_{2MAX} - F^N_{2MIN})$$

where F^N_i is a normalized value for formant i and F^N_{iMIN} and F^N_{iMAX} are the minimum and maximum normalized formant values for formant i.

In Figure 7.2, the trajectories of the first three formants of the rime *ianr* produced by the Beijing native speakers in three different Age groups are shown. In total, there are six *Age–Gender* subgroups, and thus the six graphs in Figure 7.2 show the formant movements of *ianr* in each subgroup. The Beijing native speakers produced all three types of *ianr*.

As shown in Figure 7.2, there are four general findings. First, in all six *Age–Gender* groups, a steep fall of F2 and F3 and a slightly arched F1 are observed on the OT (solid line) and NT *ianr* (dashed line), though the fall of F3 contours of OT *ianr* is steeper than that of NT *ianr*. Second, the formant contours of NG *ianr* (dotted line) have a very different pattern. Instead of a falling F3, the F3 contours of NG *ianr* have a rather low onset and show only mild rising or falling, compared to the F3 of OT and NT *ianr*. Third, the F1 movement of three types of *ianr* in the same *Age–Gender* subgroup is quite similar. However, the F1 contours of NG *ianr* are less arched. Fourth, the three formants of the three types of *ianr* in all *Age–Gender* groups have a consistent ending target respectively, though their onsets are varied. Last but not the least, the formant endings of *ianr* usually keep the downward tendency.

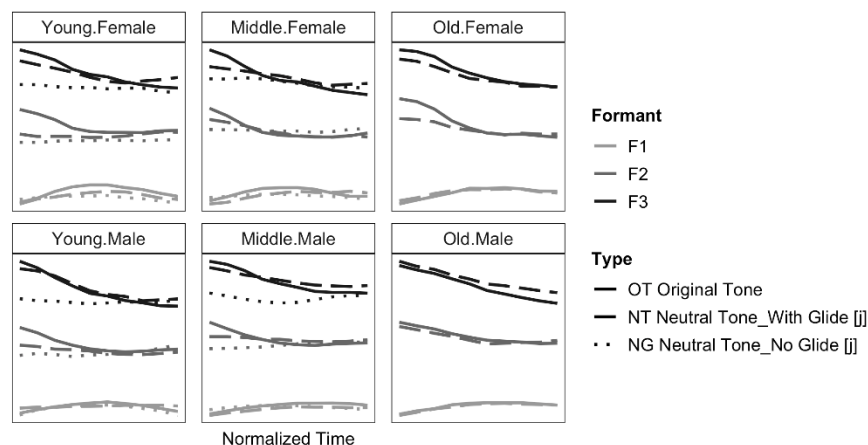*Non-native speakers: Rhotic speakers*

Figure 7.3 Averaged formant contours of the three types of rhotacized rime *ianr* produced by Rhotic speakers.[31]

With respect to the *Non-native:* Rhotic speakers, Figure 7.3 shows that, here too, there are four general findings. First, like Beijing native speakers, in the six *Age–Gender* groups, the formant movement of OT *ianr* and NT *ianr* shows a similar

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[31] The group of *Old* speakers produced few rhotic words/didn't produce NG *ianr*, so no contours of NG *ianr* can be shown in this figure.

appearance in general. That is, slightly arched F1 and falling F2 and F3; but the F3 contours of OT *ianr* start higher and fall more steeply, while the F3 onset of NT *ianr* is lower and its F3 fall is milder than that of NT *ianr*. Second, the formant contours of NG *ianr* have a very different pattern. Instead of falling, the F3 contours of NG *ianr* have a quite low onset and then show only mild rising or falling. Third, the three formants of the three types of *ianr* in all groups, in general, have consistent ending targets respectively but their onsets are varied, as can be seen. Fourth, the F1 contour movements of three types of *ianr* in each subgroup are quite similar, compared to the differences on F2 and F3 contours. In addition, the formant endings of *ianr* of different types produced by speakers from different groups are, to some extent, observed to go upwards, instead of keeping the tendency of going downwards.

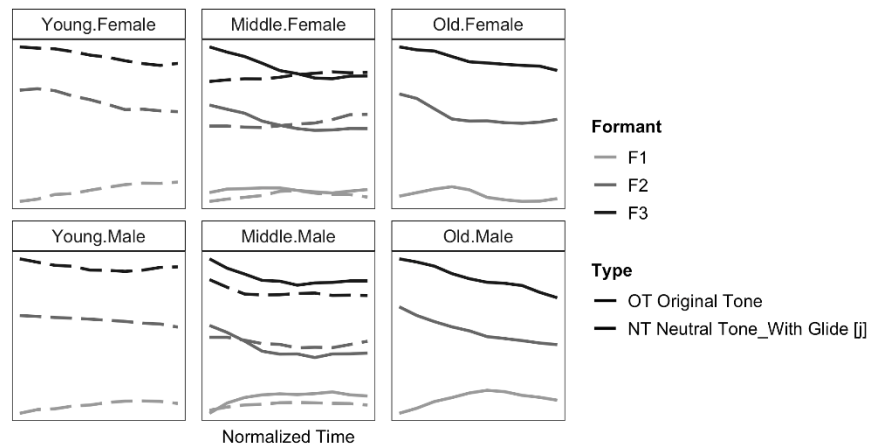*Non-native speakers: Non-rhotic speakers*

Figure 7.4 Averaged formant contours of two types (OT and NT) of rhotacized rime *ianr* produced by *Non-rhotic speakers*.[32]

Turning to the *Non-native:* Non-rhotic speakers, we see in Figure 7.4, that there are three general findings. First, *Young* speakers only produced one type of *ianr*, that is, NT *ianr*. The F3 and F2 contours produced by them show a slight decline and F1 is arched. F3 shows a slight rising at the end. Second, the *Middle-aged speakers* produced two types of *ianr*, OT and NT *ianr*. For the OT *ianr* time, F2 and F3 contours both show a fall followed by a slight rise. As for NT *ianr*,

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[32] Non-rhotic speakers didn't produce any NG *ianr* rime. Furthermore, none of the speakers in the six *Age–Gender* groups produced five tokens and not all subgroups produced both OT and NT *ianr*. Therefore, in this figure we show all concerned data we have in the corpus: the plotted contours are based on one to four *ianr* tokens produced by one or more speakers in each subgroup.

speakers show different patterns. The F2 and F3 contours produced by *Female* speakers have a lower onset and then rise, while the two contours produced by *Male* speakers show a decline. Third, the *Old* speakers only produced one type of *ianr* rime, namely OT *ianr*. The F2 and F3 contours show a decline for both *Female* and *Male* speakers. Moreover, like what we saw with respect to the Rhotic speakers, the formant endings of *ianr*, especially as produced by *Young* and *Middle* speakers, go upwards, instead of staying flat or going downwards.

F2–F1 formant chart of rime ianr

Beijing Native speakers
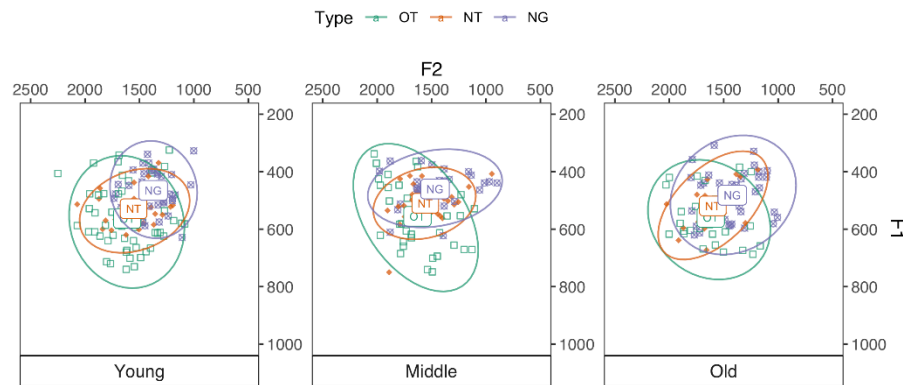
Figure 7.5 F2–F1 formant charts of OT, NT, and NG *ianr* produced by Beijing native speakers using the Lobanov method (scaled).
Note: The results are grouped into three graphs by three *Age* groups. The X-axis on each graph represents F2 in Hertz, and the y-axis represents F1 (same below).

Let's now turn to the F2–F1 formant chart of the rime *ianr*, considering the Beijing Native speakers first. As shown in Figure 7.5, compared to NT and NG *ianr*, the OT *ianr* covers the largest space in the charts and OT, NT, and NG *ianr* overlap mostly in the close-mid (height) and near-back (frontness) area. Specifically, in height, OT *ianr* takes the near-close, mid, and near-open position, NT *ianr* takes the space between the close-mid and the open-mid, and NG *ianr* takes the space between the near-close and the mid. In frontness/backness, OT, NT, and NG *ianr* usually occur in the area between the near-front and near-back.
        In addition, similarities and differences across *Age* groups are observed. The vowel spaces of OT, NT, and NG *ianr* go from a lower and central position to higher and more back position relatively, in all *Age* groups. OT, NT, and NG *ianr* in *Old* speakers overlap greatly with each other, while NT and NG *ianr* overlap with each other in the group of *Middle* speakers. *Young* speakers' OT, NT, and NG *ianr* occur in more specific areas and clearer clusters can be seen in the chart.
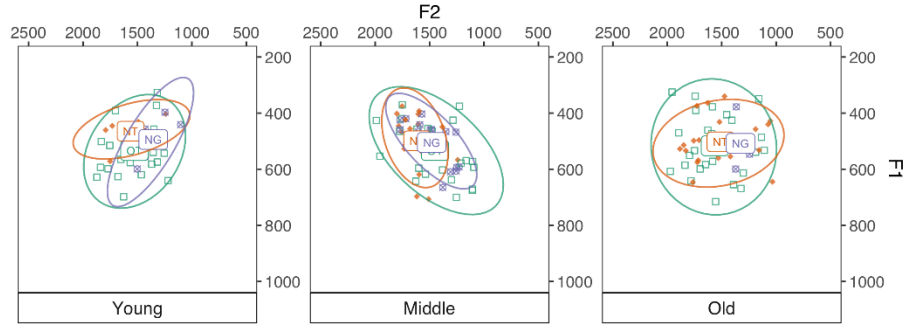
Non-native speakers: Rhotic speakers

Figure 7.6 F2–F1 formant charts of OT, NT, and NG *ianr* produced by Rhotic speakers using the Lobanov method (scaled).

For *Non-native:* Rhotic speakers, as can be seen in Figure 7.6, like Beijing native speakers, the vowel space of OT *ianr* produced by Rhotic speakers, compared to NT and NG *ianr*, covers the largest space in the charts. Furthermore, OT, NT, and NG *ianr* usually overlap with each other between the near-close and mid area. Specifically, in height, OT *ianr* takes the area between the near-close and open-mid, and NT and NG *ianr* mostly occur in the near-close and mid position. In frontness/backness, OT, NT, and NG *ianr* occur between the near front and near back area. Across *Age* groups, no obvious differences are observed.

　　Moreover, compared to Beijing native speakers, the vowel space of OT *ianr* seems similar to that of Beijing speakers, while the vowel space of NT and NG *ianr* are less low and less back than with Beijing speakers.
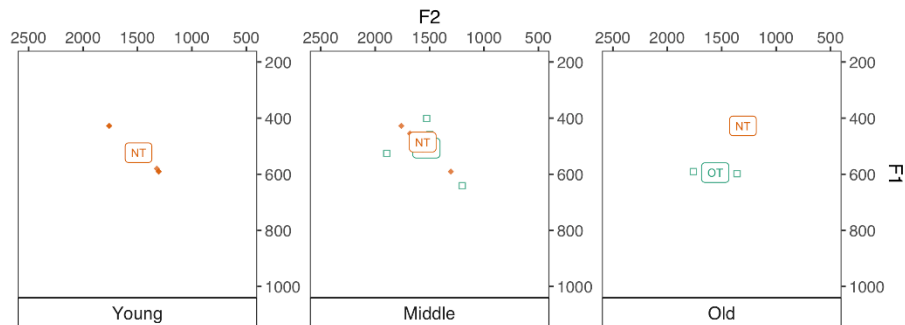
Non-native speakers: Non-rhotic speakers

Figure 7.7 F2–F1 formant charts of *ianr*s produced by Non-rhotic speakers using the Lobanov method (scaled).

Turning our attention, finally, to the *Non-native:* Non-rhotic speakers, let's consider Figure 7.7, which shows the F2–F1 formant charts of OT and NT *ianr*s produced by Non-rhotic speakers; we also see that no NG *ianr* is produced. However, as mentioned above, Non-rhotic speakers produced few *ianr* tokens anyway. On the one hand, the small number of *ianr* tokens reveals that Non-rhotic speakers do not use rhotacized rimes as frequently as the other two dialect groups. On the other hand, the results based on such a small data set would not provide us with adequate information about the vowel space of *ianr* produced by Non-rhotic speakers. For this reason, it is not discussed here.

Variants of rime ianr

Beijing native speakers

Our next topic is the variants of *ianr*, and once again we start with the *ianr*s produced by the Beijing native speakers. As we have already seen in Figures 7.2 and 7.5, the rhotacized rime *ianr* produced by Beijing speakers comes in three different variants, Original tone (OT), Neutral tone with the glide [j] (NT), and Neutral tone without the glide [j] (NG). Let's look at the details of the categorical differences now.

   OT   *ianr* The segmental elements of the rime are articulated approximately in its complete form, the acoustic evidence of which can be recognized on its formant trajectories (solid lines in Figure 7.2). The F1 contours of OT *ianr* have a low onset, the F2 contours have a high onset and fall steeply proceeding to a slight decline, and the F3 contours fall steeply. With such formant movements, the glide [j] is well pronounced. A low onset of F1 represents a high tongue position, and a high F2 onset indicates that the tongue is in the front of the mouth. A high F3 onset also indicates that the tongue is not curved yet. These are the acoustic features of the glide [j].[33] The remaining part of the three formant contours indicates the realization of the rhotacized vowel [ar]. In addition, as shown in the F2–F1 vowel space charts in Figure 7.5, there exists a height difference of the midpoints of OT *ianr*, which covers the space from the close-mid to the near-open (height), and we can transcribe the vowels in this area as [ɘ-ə-ɛ-ɐ]. Therefore, the phonetic variants of OT *ianr* uttered by native Beijing speakers can be transcribed as [jɘɹ], [jəɹ], [jɛɹ], and [jɐɹ].

   NT *ianr* NT *ianr* bears a Neutral tone and the segment [j] is realized. As mentioned above, the Neutral tone can centralize the vowel to which it affiliates, and thus the segmental elements of *ianr* can also be neutralized. This can be seen in Figure 7.2, where the formant contours (dashed lines) of NT *ianr* become shrank in general, compared to that of OT *ianr*. To be specific, F2 and F3 contours of NT *ianr* have a lower onset and a smoother decline and the F2 value is lower,

[33] Glide [j] is semi-vocalic equivalent of the close front unrounded vowel [i]. Thus, they have acoustic similarities.

which means that the glide [j] is articulated backwards and thus centralized than that of OT *ianr*. As shown in Figure 7.5, NT *ianr* take mostly the vowel space between the close-mid and open-mid in height (F1) and take the central position in front–backness (F2). Thus, the phonetic variants of NT *ianr* could be [jəɹ], [jəɹ], [jɛɹ].

NG *ianr* NG *ianr* bears a Neutral tone and the glide [j] is completely absent. The tonal and segmental elements of such rimes are further neutralized, and the vowel quality is also changed. The evidence can be found in Figure 7.2 (dotted line). Different from the arched F1 contour and falling F2 and F3 contour of OT and NT *ianr*, its F1, F2, and F3 contours are quite flat. Besides, the F3 contour has a very low onset and stayed low through the whole rime. As shown in Figure 7.5, most *ianr*s in NG take the central and near-back position for F2 and the near-close and the mid position for F1. In short, the phonetic variants of NG *ianr* can be [ʊɹ], [əɹ], and [əɹ].

Non-native speakers: Rhotic speakers

As for the variants of *ianr* produced by Rhotic speakers, we saw earlier on (in Figures 7.3 and 6.6), that they display categorical differences as well.

OT *ianr* As was the case with OT *ianr* produced by the Beijing native speakers, it is articulated in a complete form by the Rhotic speakers as well. The acoustic features of the segmental elements [j] and [ar] can be observed on the Figure 7.3 (solid line). The F1 contour has a low onset, the F2 contour has a quite high onset and then went down and the F3 contour falls dramatically. A low onset of F1 means a high tongue position, and a high F2 onset indicates that the tongue is in front of the mouth. A high F3 also indicates that the tongue is not curved yet. These are the acoustic features of the glide [j]. The remaining part of formant contours indicates the realization of the rhotacized part [anr]. As shown in the F2–F1 formant charts in Figure 7.6, OT *ianr* usually takes the near-close and open-mid position in height (F1) and takes the near-front and near-back position in front–backness (F2). Thus, the vowels of rime *ianr* in such space are [ɘ-ə-ɛ]. Therefore, the phonetic variables of OT *ianr* from Rhotic speakers are [jɘɹ], [jəɹ] or [jɛɹ].

NT *ianr* Similar to what we saw above (Beijing native speakers), NT *ianr* produced by Rhotic speakers bears a Neutral tone and the glide [j] is present as well, but the segmental elements of rime *ianr* are neutralized. The acoustic evidence is shown on Figure 7.3 (dashed line). If the formant contours of OT *ianr* are set as a reference, the amplitude of the three formants in NT *ianr* shrank. Specifically, both F2 and F3 contours in NT have lower onsets and went down more mildly. The F2 value is in general lower than that of OT *ianr*, which means that the tongue position of the high-front glide [j] goes backwards and thus centralized. As shown in Figure 7.6, NT *ianr* takes the near-close and mid position in height (F1) and takes the near-front and near-back position in front–backness (F2). Therefore, the phonetic variants of NT *ianr*s are [jəɹ] and [jəɹ].

NG *ianr*[34] NG *ianr* bears a Neutral tone and the glide [j] is absent. That is, the tonal and segmental elements are further neutralized. The corresponding evidence can be found on the formant trajectories in Figure 7.3 (dotted line). The F1, F2, and F3 contours are all quite flat, which are dramatically different from that of OT and NT *ianr*. The F2 onset surprisingly has lower values, compared to the remainder of the contours. This means that the tongue body is at the central position from the beginning of the rime while it is supposed to be the high-front position of semi-vocalic [j]. F3 contours also have very low onsets and stayed low through the whole rime. Thus, the appearance of formant contours is basically that of a rhotacized monophthong. As shown in Figure 7.6, the NG *ianr* takes mostly the near-close and mid position in height (F1) and takes the near-front and near-back position in front–backness (F2). Therefore, the phonetic variants of NG *ianr* can be represented with [əɹ] and [əɹ].

Non-native speakers: Non-rhotic speakers

Finally, when it comes to the Non-rhotic speakers, as mentioned in Section 7.3.1, there is only a small number of *ianr*s (*N*=22) produced by this group, and only two types, namely OT and NT. The phonetic variants summarized below are based on the results of the available data (*N*=16).

OT *ianr* Such *ianr* is articulated in a complete form, which can be recognized on the formant trajectories (solid lines in Figure 7.4). The arched F1 contours has a low onset, which represents a high tongue body position. The F2 and F3 contours start high and fall steeply. A high F2 onset indicates that the tongue is in the front of the month. A high F3 onset also indicates that the tongue is not curved yet. Thus, the glide [j] is present. The remainder part of formant contours is the realization of the rhotacized vowel. In addition, as shown in Figure 7.7, OT *ianr* take the mid position in height (F1) and central position in front–backness (F2). Thus, the variant is labeled as [jəɹ].

NT *ianr* The glide [j] of this *ianr* is present, and the rime bears a Neutral tone. However, compared to that of the Beijing native and the Rhotic speakers, the segmental elements of such *ianr* are further neutralized. The F1 contour is quite flat and F2 and F3 contours fall smoothly. However, we can still see the F1 contour has a lower onset, the F2 and F3 contours have a slight high onset, which indicates the acoustic features of glide [j]. As shown in Figure 7.7, the *ianr* rimes take the mid position in height (F1) and central position in front–backness (F2). Thus, the phonetic variant of this type is transcribed as [jəɹ].

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[34] Old speakers didn't produce enough tokens of NG *ianr*. So, the discussion here is based on the tokens produced by *Young* and *Middle* speakers.

Table 7.5 Phonetic variants of the rhotic rime *ianr* in three segmental–tonal types produced by Beijing, Rhotic, and Non-rhotic speakers.

Dialect Background	OT ianr	NT ianr	NG ianr
Beijing	[jəɹ], [jəɹ], [jɛɹ], [jɐɹ]	[jəɹ], [jəɹ], [jɛɹ]	[ʊɹ], [əɹ], [əɹ]
Rhotic	[jəɹ], [jəɹ], [jɛɹ]	[jəɹ], [jəɹ]	[əɹ], [əɹ]
Non-rhotic	[jəɹ]	[jəɹ]	-

With the results of the formant trajectory and F2–F1 vowel space, we obtain the phonetic variants of the variable *ianr* produced by speakers from three dialect backgrounds. The results are shown in Table 7.5. The Beijing native speakers produced the greatest number of phonetic variants, which are OT *ianr* [jəɹ], [jəɹ], [jɛɹ], and [jɐɹ], NT *ianr* [jəɹ], [jəɹ], and [jɛɹ], and NG *ianr* [ʊɹ], [əɹ], and [əɹ]. The Rhotic speakers used a smaller number of the phonetic variants, namely OT *ianr* [jəɹ], [jəɹ], and [jɛɹ], NT *ianr* [jəɹ] and [jəɹ], and NG *ianr* [əɹ] and [əɹ]. The Non-rhotic speakers produced the fewest phonetic variants, namely [jəɹ] with OT and with NT. The Beijing native speakers make use of the area from the near-close to the near-open, the Rhotic speakers the from near-close to the open-mid and the Non-rhotic speakers only use the mid.

7.3.3   Summary

In this study, we examined the effects of linguistic and social factors on the phonetic realization of rhotic rime *ianr*. Below we have summarized such effects on mainly two aspects, namely the formant trajectory of *ianr* and the vowel space of *ianr*.

Formant trajectories of ianr

In this experiment, we primarily compared the differences of *ianr* formant trajectories by different types and by speakers' dialect backgrounds. Different *ianr* types show different formant contours patterns. In general, OT *ianr* and NT *ianr* show similarities. However, OT *ianr* has a higher F2 and F3 onset, and the F2 and F3 contours fall more dramatically than that of NT *ianr*. Furthermore, NG *ianr* has three flat formant contours with very mild fluctuation, which are different from OT and NT *ianr*. This suggests that the *ianr* rime with OT and NT is articulated approximately in its complete form, namely, with the presence of both the glide [j] and the rhotacized vowel. However, due to the centralization effect of neutral tone on the *ianr* rime with which it affiliates, the glide [j] of NT *ianr* starts less front (lower F2 onset) and the speaker's tongue is probably curved earlier (lower F3 onset) than that of OT *ianr*. As for NG *ianr*, due to the further centralization effects of the neutral tone, it shows that no glide [j] but

only the rhotacized vowel is pronounced on its formant trajectories. In terms of the differences in trajectory according to dialect background, speakers with Beijing and *Rhotic dialect* backgrounds have similar formant movements for *ianr* in general, while that of Non-rhotic speakers shows different formant trajectory appearances (if we can say anything about them, in view of the small number of data available for this group) of the available rime *ianr* of the two types, namely OT *ianr* and NT *ianr*. Furthermore, we also observed a rise at *ianr* formants endings with the *Rhotic* and the Non-rhotic speakers. This suggests that non-native speakers do rhotacize the rime, but the rhotacization is probably not sufficiently realized and the speaker's tongue is de-retroflexed at the rime ending.

Vowel space of ianr

We also looked at the vowel space of *ianr* in three segmental–tonal types and that of speakers in different Dialect–Age groups. The *ianr* rimes of the same type are clustered, in general. OT *ianr* takes the largest space in the vowel charts, which covers the area between near-close and near-open. NT *ianr* and NG *ianr* take a smaller space, which is usually above the mid-central area. NG *ianr* can also take the near-close and near-back area.

      The factor Dialect background also shows an effect on the vowel space of the rime *ianr*. The Beijing speakers' *ianr*s gather into a cluster in each type. The OT *ianr* of the Beijing native speakers and Rhotic speakers take similar positions on the F2–F1 vowel charts. Concerning the effects of the social factor *Age*, it is more obvious among the Beijing speakers. The younger the speakers are, the clearer the clusters of three *ianr* types in different positions can be seen.

Based on the two analyses above, we obtained the variants of *ianr* of three types from speakers from three dialect backgrounds. Across dialect groups, we found that the Beijing native speakers have the largest number of variants of *ianr,* and the Non-rhotic speakers use the smallest number. Articulatorily, this difference mainly results from the differences in tongue height, that is, the vowel height of speakers from different dialect groups. Across age groups, all three types of *ianr* produced by the Beijing old speakers have the same tongue height span, while the young speakers show three obvious clusters of *ianr* in three types. The effect of age is not obvious among non-native speakers. In addition, the variants of *ianr* in three types are also constrained by linguistic factors, such as the segmental and suprasegmental realization of *ianr*.

7.4   Experiment 3: Duration of the rhotacized rime *ianr*

In this section, we will study the duration of the rhotacized rime *ianr* of three types produced by speakers in different social groups, to investigate the relationship of linguistic and social factors on the duration of the rhotacized rime.

In Section 7.4.1 we will first examine the duration of the rime *ianr* produced by speakers with different dialect backgrounds. Then a linear mixed-effects model will be fitted to the data from all speakers, to examine the effects of linguistic and social factors on the duration of the rime *ianr*. The results of Experiment 3 are summarized in Section 7.4.2.

7.4.1   Results

Beijing

Table 7.6 Duration (in ms) of the rhotacized rime *ianr* of three different types produced by Beijing native speakers (n=613). Number of speakers: 31.

ianr Type	*n*	*mean*	*median*	*min*	*max*	*stddev*
Original Tone	293	157	146	52	389	58
Neutral Tone_With glide [j]	236	114	106	48	275	39
Neutral Tone_Without glide [j]	84	106	94	48	287	48

Investigating the variation in duration in the realization of *ianr*, we start with the Beijing native speakers. Table 7.5 shows the duration of rhotacized rime *ianr* with Original Tone (OT) and Neutral Tone with the glide [j] (NT) and without glide the [j] (NG) uttered by the Beijing native speakers. The ranges of the rimes' duration in the three types mostly overlap with each other, and the differences of min and max durations are also quite large, due to their occurrence in natural and spontaneous speech. To give a better picture of the data distribution, both the mean and the median of the duration are shown in the table (same below).

The differences between the OT *ianr* and non-OT *ianr* are clear: the average length of *ianr*s with neutral tone (both NT and NG) is roughly 70% of that of *ianr*s with OT. As we can see in the table, the duration of OT *ianr* is the longest, that of NT *ianr* comes second, and that of NG *ianr* is the shortest. Phonetically, it is known that the length of a rime in its full tonal and complete segmental realization is greater than in its neutralized forms; the length of a rime with more segments is bigger than that with fewer segments. To test this interpretation, a linear mixed-effects model was run with *ianr* duration as its dependent variable. Speaker and item were included as random effects, while the fixed effects included were *ianr* Type (Original tone, Neutral tone with the glide [j], and Neutral tone without the glide [j]) and social factors, namely Age and Gender. An overview of the results is given in Table 7.7. Significant differences were tested for with Satterthwaite's method using the lmerTest Package (Kuznetsova et al., 2017); *p*-values from these are included in the final column of the table.

Table 7.7 Summary of a linear mixed-effects regression predicting *ianr* duration in different types in the Beijing subcorpus. The intercept corresponds to an OT *ianr* for a young female speaker. Number of observations = 613.

Random effects	Variance	Std Deviation	N	
speaker	167.6	12.95	31	
item	101.7	10.09	11	
Fixed effects	Estimate	Std Error	t	p
(intercept)	151.00	7.791	19.380	.000
type: NT	-37.06	4.523	-8.193	.000
type: NG	-42.62	6.636	-6.422	.000
gender: male	3.71	7.407	0.500	.620
age: middle	3.01	9.123	0.330	.744
age: old	6.70	8.961	0.748	.460

The model shows that there are significant differences in the duration between OT *ianr* (mean: 156 ms) and NT *ianr* (mean: 120 ms), as well as between OT *ianr* and NG *ianr* (mean: 110 ms). However, the difference between NT *ianr* and NG *ianr* is not significant (t=1.904, p=.057).[35] The social factors Gender and Age are not significant.

Rhotic

Table 7.8 Duration (in ms) of the rhotacized rime *ianr* in three different types produced by Rhotic speakers (n= 260). Number of speakers: 21.[36]

ianr Type	n	mean	median	min	max	stddev
Original Tone	164	129	125	53	336	45
Neutral Tone_With glide [j]	75	116	112	49	292	40
Neutral Tone_Without glide [j]	21	96	94	51	165	26

As for the Rhotic speakers, Table 7.8 shows the duration of the rime *ianr* of three different types produced by speakers with a *Rhotic dialect* background. Similar to that of the Beijing native speakers, the ranges of the rimes duration in the

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[35] Results from refitting the model such that the intercept corresponds with NG *ianr*.
[36] There were 22 speakers with a Rhotic background in total, but there was one speaker producing no syllables with the rime *ianr*. This is why there are 21 speakers in the calculation here.

three types mostly overlap with each other and the differences between min and max duration are quite large.

The duration differences of rime *ianr* in different types are obvious. OT *ianr* is the longest, NT *ianr* is in the middle, and NG *ianr* is the shortest. To predict the duration of *ianr* for the different types, such as that for the Beijing speakers, a linear mixed effects model was run with speaker and item as random effects, and *ianr* types and social factors (gender and age) as fixed effects.

Table 7.9 Summary of a linear mixed-effects regression predicting *ianr* duration in different types in the Rhotic subcorpus. The intercept corresponds to an OT *ianr* for a young female speaker. Number of observations = 260.

Random effects	Variance	Std Deviation	N	
speaker	71.71	8.468	23	
item	360.23	18.98	11	
Fixed effects	*Estimate*	*Std Error*	*t*	*p*
(intercept)	154.01	9.45	16.30	.000
type: NT	-3.02	6.26	-0.48	.630
type: NG	-21.93	9.58	-2.29	.023
gender: male	-23.26	6.29	-3.70	.002
age: middle	-10.98	7.85	-1.40	.185
age: old	5.56	7.78	0.72	.484

Table 7.9 shows the results from the linear mixed-effects model. It shows that there are significant differences in the duration between OT *ianr* (mean: 129 ms) and NG *ianr* (mean: 96 ms), as well as between NT *ianr* (mean: 116 ms) and NG *ianr* (t=1.969, p=.05)[37]. However, OT *ianr* and NT *ianr* (mean: 116 ms) shows no significant difference. The social factor Gender is significant. Female speakers produce significantly longer *ianr* than male speakers (t=3.07, p=.002). The social factor Age, however, is not significant.

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[37] Results from refitting the model such that the intercept corresponds with NG *ianr*.

Non-rhotic

Table 7.10 Duration (in ms) of the rhotacized rime *ianr* in three different types produced by speakers with Non-rhotic dialect background (n=22). Number of speakers: 16.[38]

ianr Type	*n*	*mean*	*median*	*min*	*max*	*stddev*
Original Tone	15	130	114	70	239	50
Neutral Tone_With glide [j]	6	99	90	64	162	37
Neutral Tone_Without glide [j]	1	105	105	105	105	NA

Finally, turning to the Non-rhotic speakers, Table 7.10 shows the duration of the rime *ianr* of three different types produced by Non-rhotic speakers. As can be seen in Table 7.10, the average duration of NT *ianr* is shorter than that of OT *ianr.* To test the observation, a linear mixed effects model was fitted with speaker and item as random effects, and *ianr* types and social factors (gender and age) as fixed effects.[39]

Table 7.11 Summary of a linear mixed-effects regression predicting *ianr* duration in different types [40] in the Non-rhotic subcorpus. The intercept corresponds to an OT *ianr* for a young female speaker. Number of observations = 260.

Random effects	Variance	Std Deviation	N	
speaker	0.00	0.03	22	
item	0.00	0.00	7	
Fixed effects	*Estimate*	*Std Error*	*t*	*p*
(intercept)	125.78	26.68	4.71	.000
type: NT	-31.70	25.47	-1.25	.227
gender: male	7.48	22.23	0.34	.740
age: middle	4.36	25.47	0.17	.866
age: old	11.39	37.64	0.30	.765

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[38] There were 23 speakers with a Non-rhotic dialect background in total, but only 16 of them produced syllables with rime *ianr*.

[39] Only one NG *ianr* produced by a Non-rhotic speaker was observed in the subcorpus. For this reason, the NG *ianr* and its duration is excluded from in the linear mixed-effects model. Only the duration of OT *ianr* and NT *ianr* is considered.

[40] As seen in Table 6.8, the number of NG *ianr*s produced by Non-rhotic speakers is 1. This is a small sample size, and we excluded it when we ran a linear mixed-effects model.

As the linear mixed-effects model summarized in Table 7.11 shows, there are no significant differences between *ianr*s of the different types. Social factors also show no significant differences.

The effect of linguistic and social factors

Table 7.12 Duration (in ms) of the rhotacized rime *ianr* in three different types by all speakers from three dialect backgrounds (n= 895). Number of speakers: 68.[41]

ianr Type	n	mean	median	min	max	stddev
Original Tone	472	146	138	52	389	55
Neutral Tone_With glide [j]	317	114	107	48	302	39
Neutral Tone_Without glide [j]	106	104	94	48	287	45

Table 7.12 shows the average of the duration of *ianr* produced by all the speakers. As shown in this table, the mean and median together show categorical differences in the duration of *ianr* in the three different types. The length of OT *ianr* is the longest, NT *ianr* is in the middle, and NG *ianr* is the shortest. Lateral comparisons across dialect groups of the average durations and the ranges of *ianr* also show differences. As seen in Tables 7.6, 7.8, and 7.10, the ranges of *ianr* in three types overlap with each other. And the average length of *ianr* in the three types shows a similar pattern in the three different dialect backgrounds. That is, the length of OT *ianr* is the biggest, the NT *ianr* comes in second, and NG *ianr* is the smallest. However, both the mean and median of *ianr* rimes of the three types produced by the Beijing native speakers are somewhat larger than that produced by the Rhotic speakers; the range of each type of *ianr* uttered by Beijing native speakers is also larger. In addition, the mean and median of the duration of *ianr* of the three types uttered by the Non-rhotic speakers are somewhat smaller than that of both the Beijing and the Rhotic speakers; the range of *ianr* of the three types produced by the Non-rhotic speakers is the smallest. To test the observation, a linear mixed-effects model was fitted to the duration data from all speakers. The type of *ianr* rimes and social factors (dialect background, age, and gender) were considered for inclusion in the model. Adding the effect of age or gender of speakers did not improve the fit of the model, nor did the random slopes within speakers. The model is summarized in Table 7.13.

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[41] As explained in footnotes 2 and 4, one Rhotic speaker and seven Non-rhotic speakers produced no syllables with the rime *ianr.* It is for this reason that there are 68 speakers in total here.

Table 7.13 Summary of a linear mixed-effects regression predicting *ianr*. The intercept corresponds to an OT *ianr* for a young female Beijing native speaker. Number of observations = 895.

Random effects	Variance	Std Deviation	N	
speaker	282.3	16.80	68	
item	172.6	13.14	11	
Fixed effects	Estimate	Std Error	t	p
(intercept)	153.646	5.995	25.629	.000***
dialect background: Rhotic	-12.595	6.074	-2.074	.043*
dialect background: Non-rhotic	-17.639	11.036	-1.598	.110
type: NT	-27.022	3.745	-7.215	.000***
type: NG	-35.974	5.551	-6.481	.000***

What the model shows is that Dialect background and Type of rime *ianr* have major effects on the duration of *ianr*. The difference of *ianr* duration between the Beijing native speakers and the Rhotic speakers is significant ($t=-2.07$, $p=.043$). However, no significant difference was observed between the Beijing native speakers and the Non-rhotic speakers ($t=-1.60$, $p=.110$), as well as the Rhotic speakers and the Non-rhotic speakers ($t=-0.443$, $p=.658$). OT *ianr* is significantly longer than NT *ianr* ($t=-7.22$, $p=.000$) and NG *ianr* ($t=-6.48$, $p=.000$). However, there was no significant difference between NT *ianr* and NG *ianr* ($t=1.687$, $p=.092$). In sum, the duration of *ianr* is significantly influenced by its Type and by the Dialect background of speakers.

7.4.2   Summary

In this section, we first examined the average duration of OT, NT, and NG *ianr* within each Dialect background and the effects of social factors (Age and Gender) on it. We found that for the Beijing and the Rhotic speakers, only the Type of *ianr* has effects on the duration of *ianr*, and none of the social factors show effects on it. However, for Non-rhotic speakers, neither linguistic nor social factors show effects. Then we examined the average duration of *ianr* across all speakers. Social factors (Dialect background, Age, and Gender) and the one linguistic factor (Type) were included. It was found that Dialect background and Type of *ianr* do have effects on the duration of *ianr* in the speech community of Beijing.

7.5   Discussion and conclusion

An ongoing change in a rime

This sociolinguistic study on the rime *ianr* shows that both linguistic and social variables have an effect on the variation of the rime.

In terms of linguistic variables, we found that *ianr* of the three different types affects its variants. The *ianr* types were pre-categorized on the basis of its possible tone realization (original tone and neutral tone) in a syllable and the effect of neutral tone on rime neutralization.

The sociolinguistic factor of dialect background proves to be a very important variable. Speakers from different dialect backgrounds use different variants of rime *ianr*, which lies mostly in the area of the vowel height. Despite the mid height, the Beijing native speaker also produces *ianr* with near close and near-open tongue height, while non-native speakers, especially Non-rhotic speakers mostly use mid height. In the group of the Beijing native speakers, we found that there is a generational change among speakers. The old speakers show consistent tongue height, that is, vowel height with the three different *ianr* types, while the young speakers tend to produce *ianr* by using different tongue heights. In addition, the difference of variants of *ianr* across dialect groups lies mainly in the area of the vowel height.

New light on studying rhotacization in Mandarin

In the sociolinguistic variation and change studies on rhotics in Western languages, except common sociolinguistic variables, such as age, gender, and socioeconomical class, linguistic contexts and variables of the rhotics examined are also often specified. For example, stress and prepausal were specified as two related linguistic parameters in the sociophonetic study of coda-r in Scottish Standard English (Schützler, 2010); Sankoff & Blondeau (2007, 2010) investigated the change in the two canonical variants—[r] and [R]—in different phonological contexts in Montreal French; Schiller (1998) used Articulatory Phonology to describe the different variants uvular /r/ in German, in which targeted words of the same phonological structure were embedded in full sentences; the /r/ on the non-prevocalic position was specified in Dickson & Hall-Lew's (2017) study of *r* in Edinburgh Speech; /r/ in different base words and following segmental environments in New Zealand English were considered in data collection and analyses (Preston & Niedzielski, 2010); and the variants of /r/ in different contexts were examined for Dutch *r* (Sebregts, 2015). However, linguistically, Mandarin rhotacization is at the same time similar to and different from the rhotics in Western languages in many respects. As we have seen in this chapter, in a study on sociolinguistic variation and change in rhotacized rimes in Beijing Mandarin, the linguistic and non-linguistic constraints must both be taken into consideration. After all, as mentioned in Chapter 2, Mandarin

rhotacization is not only salient auditorily but can also have grammatical functions and lexical meaning. In addition, Mandarin syllable and word structure determines that rhotacization occurs together with other linguistic elements, such as tone and morphemic meanings, which could affect the realization of rhotacization and its variation. Therefore, possible linguistic elements should be considered when linguistic constraints/variables are determined.

In this study, we focused on the sociophonetics of the most frequently used rhotacized rime *ianr*. The word and syllable contexts where *ianr*s occur were first examined, including their lexical meanings and the segmental and suprasegmental information. Rime *ianr*s were pre-categorized into three types. The results of acoustic measurements proved that the phonetic variants of the rime *ianr* produced by speakers are varied in different linguistic contexts because the suprasegmental (tonal) and segmental realization of *ianr* have an influence on its variants.

Above all, in variationist studies on Mandarin rhotacization, the possible linguistic variables should be carefully sorted out, which could contribute to a better understanding of how it changes. In the case of rime *ianr*, linguistic variables, like the tone and segments, can affect its variation and change. However, indiscriminately applying the linguistic variables to other rhotacized rimes may not work, because other Mandarin rhotacizations may have their own linguistic features and be constrained by those linguistic factors.