Er-suffixation in Chinese monophthongs:
phonological analysis and phonetic data

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Among the seven (not counting /er/) single vowels in standard Chinese [i, y, z̩, z̺̩, u, ɤ, a] (where [z̩, z̺̩] stand for the high vowels following dentialveolars and retroflexes), previous studies have analyzed the surface forms of *er*-suffixed /u, ɤ, a/ as the original vowel followed by either [ɹ] (Chao, 1968; Cheng, 1973; Pulleyblank, 1984; Lin, 1989; among others) or [ɭ] (i.e. [z̺̩], Li, 1986), while the *er*-suffixed non-back vowels are said to surface as a concatenation of the original vowel or its glide counterpart (if there is an underlying vowel) and [əɹ]. However, Duanmu (2007) offers a different analysis, where [ɚ] is the final component in the surface forms of all seven monophthongs.

To evaluate these accounts, the present study investigated the production of the plain and *er*-suffixed monophthongs by eight native speakers from Beijing. Our data show (1) that there is no evidence for a separate [ɹ] coda in the surface forms, (2) that in addition to lowering of F3, *er*-suffixation has a centralizing effect on all monophthongs, and (3) that there is significant interaction between *er*-suffixation and vowel quality. The analysis of the Chinese *er*-suffixed monophthongs is thus revised as: [jɚ, ɥɚ, ɚ, ɚ; uˑ; ɤˑʵ, aˑʵ]. Our results also call for more careful phonetic study of similar processes cross-linguistically: while there is evidence for a coda /r/ in Scottish English (Wells, 1982), in other languages the underlying rhotic segment or syllable seems to be realized only as "*r*-coloring" on the preceding vowel (and perhaps an [ɚ] off-glide). If this is true, then for cases such as Yanggu (Lin, 2004) one may not have to posit surface syllables with both a complex onset (e.g. [tl]) and an /r/ coda.

1. Introduction

Chinese being impoverished in morphology, the rare phenomenon of *er*-suffixation (or *erhuay* 儿化) observed across many dialects has attracted linguists' attention from early on (e.g. Wang, 1963; Chao, 1968; Cheng, 1973; T. Lin, 1982; Wang & He, 1983; Li, 1986; Y. Lin, 1989, 2004, 2007; Duanmu, 2007). Historically, the retroflex suffix /-ɚ/[1]

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[1] Notational conventions: (1) I shall also use "/-ɚ/-suffixation" and "er-suffixation" interchangeably. (2) Where an exact phonetic transcription is not necessary, I shall use Pinyin with superscript tone description (e.g. /er^{35}/ 'son'). The numbers indicate pitch heights on a five-point scale (Chao, 1930), and Chao's (1968) description of the tones (i.e. tone 1 = 55, tone 2 = 35, tone 3 = 214, and tone 4 = 51) is adopted here. (3) Where an exact phonetic transcription is not necessary and for ease of typesetting, I may use "V+r"/"Vr"/"V-r" to indicate an *er*-suffixed vowel (e.g. [cha^{35}.jir^{55}] 'tea table'). (4) V may be used in short for 'vowel'.

originated mainly from four morphemes (Chao, 1968; Li, 1986): (1) the diminutive /er/儿; (2) /ri/日 "day"; (3) the locative /li/里 "inside"; and (4) the perfective /le/了. (There are also a few isolated lexical items that employ rhoticity to convey specific meanings. See, e.g., T. Lin, 1982.) The diminutive /er/ 儿 is the most productive synchronically. Chao (1968) has a fairly detailed discussion on the types of morpheme or word to which it can attach and how it alters the original meanings of those morphemes or words in Beijing Mandarin. The /-ɚ/ suffix derived from /ri^{51}/ 日 "day" occurs in a small set of frequently occurring colloquial words and appears to be fossilized: e.g. in /jin^{55}-ri^{51}/ 'today', /zuo^{35}-ri^{51}/ 'yesterday' and /ming^{35}-ri^{51}/ 'tomorrow', /ri/ is deleted and the words surface as monosyllables with rhotic vowels (where /n/ in /jin^{55}/ is also lost, while the engma in /ming^{35}/ is deleted with nasality preserved on the vowel). The same can be said of the locative /li/ 里: e.g. /zhe^{51}-li^{214}/ 'here', /na^{51}-li^{214}/ 'there', /na^{214}-li^{214}/ 'where', and /wu^{55}-li^{214}/ 'inside the house' (as in [jin^{51}.wur^{55}.zuo^{51}.ba] 'come in and sit down'). The perfective (/lə/了) surfaces as rhoticity in a few dialects (but not in Beijing Mandarin) (see Li, 1986).

The /-ɚ/ suffix can be combined with any rhyme in Beijing Mandarin other than the rhotic rhyme /er/, as in /er^{35}/ 'son', /er^{214}/ 'ear', etc. (see also Chao, 1968 and Li, 1986), producing many *r*-colored surface vowels (or *erhuayin* 儿化音). This paper focuses on how /-ɚ/-suffixation affects the seven monophthongs (i.e. single vowels; not counting the rhotic vowel /er/): [i, y, ʐ̩, ʐ̩, u, ɤ, a] (Cf. Chao, 1968). The fricative vowel [ʐ̩] only occurs after the dentialveolars /ts, ts^{h}, s/, while the other fricative vowel [ʐ̩] is found only after the retroflex sibilants /tʂ, tʂ^{h}, ʂ, ʐ/. These monophthongs do not have the same phonological status in the sound inventory (see Duanmu, 2007 for a phonological analysis of the vowels). However, since the /ɚ/ suffix has different effects on these sounds, all seven of them will be examined and discussed separately.

2. Previous studies

Different surface forms of /ɚ/-suffixed single vowels in Beijing Mandarin have been proposed by various researchers. Some are cited in (1) below.

(1) Surface forms proposed by various researchers for [i, y, ʐ̩, ʐ̩, u, ɤ, a] + /ɚ/

    a. Pulleyblank (1984):   [jər, jwər, ər, ər, ur, ɤr/ər, ar]

    b. Li (1986):   [iˀɭ, yˀɭ, əɭ, əɭ, uˡ, əɭ, aˡ],
       (where [ɭ] is Karlgren's symbol, equivalent to IPA [ʐ̩]; Cf. the analyses of Cheng (1973) and T. Lin (1982))

    c. Y. Lin (1989):   [iər, yər, ər, ər, ur, ɤr, ar]

    d. Duanmu (2007):   [jəɚ, ɥəɚ, əɚ, əɚ, uɚ, ɤɚ, aɚ]

Notational differences aside, these analyses differ most noticeably in the surface forms of *er*-suffixed /i, y/: Li (1986) and Lin (1989) treat them as mostly unchanged in quality (with a schwa off-glide), whereas Pulleyblank (1984) has a rule that allows /i, y/ to lax into glide+schwa before /r/ (1984:56). Although Duanmu (2007) also has the high front vowel laxing rule, his surface rhymes derived from /i, y/ consist of a non-rhotic schwa as the nucleus and a rhotic schwa off-glide. In addition, Li (1986) uses [ɻ] (IPA [ʐ]) in his analysis. or Li (1986) claims, perhaps in agree-ment with Pulleyblank (1984) and Lin (1989), that in *er*-suffixed /u, a/ rhoticity is fused with the original vowels rather than being realized as an off-glide, whereas Duanmu (2007) has a rhotic schwa off-glide after the [u, a] nuclei. One notes further that for Pulleyblank (1984) and Lin (1989) *er*-suffixed /ɤ/ seems to also be analyzed as unchanged in vowel quality, whereas Duanmu (2007) again has a rhotic schwa off-glide after the nucleus.

The goal of the present study is to examine the surface monophthong rhymes acoustically and to compare them with their plain counterparts (i.e. surface monoph-thongs without the *er*-suffix) to see how rhoticity affects each of them. It is hoped that the results from this study will help us to better understand the *er*-suffixation process and to achieve more accurate phonological analysis.[2]

3. Methodology
3.1 Recording
Six (6) female and six (6) male speakers from the city of Beijing, average age 28, were recorded in a sound-attenuated booth, with a head-mounted Shure® SM-10A microphone and a Marantz® solid state recorder. The speakers read a semi-randomized list of 350×2 disyllabic words, balanced for rhyme and tone, with the second syllable containing the target plain rhyme or *er*-suffixed rhyme. The whole list consists of about 350 words and 38 sentences. Only the results for the single vowels from eight (four male and four female) speakers will be discussed here.

3.2 Data tagging and taking measurements
After the recordings were transferred to a computer, they were segmented into words (and sentences), and saved as individual files using Praat (Boersma, 2001). The target vowels were then further segmented into the first 20-milisecond, last 20-milisecond and center portions and labeled with Praat (see Figure 1).

Measurements of the first four formants (i.e. F1, F2, F3 and F4) were taken from the center point of each of the three labeled segments in the target vowel (i.e. at 10ms from the vowel onset, mid point of vowel and 10ms from the vowel offset) with a Praat script (adapted from one originally written by Mietta Lennes). The LPC parameters were adjusted for each individual speaker. In general, five (5) formants under 5000Hz were

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[2] There were earlier acoustic studies (Wang & He, 1983; Lin, Zhou & Cai, 1998; Shi, 2003) on –r suffixation in Chinese, all of which used only one speaker.

specified for male speakers and five (5) formants under 5500Hz for female speakers. In an *er*-suffixed form, due to the presence of the rhoticity, formants may change drastically, with the frequency range for the first five formants lowered by 500 to 1000Hz. As can be seen in the right panel of Figure 1, the F3, normally around 3100Hz for this speaker, is lowered to below 1900Hz and an extra fifth formant is now visible under 5000Hz. Accordingly, the LPC parameters were set to look for five (5) formants under 4500Hz for male and under 5000Hz for female in the *er*-suffixed forms. In some cases, further finer-tuned adjustments were made to get the correct measurements. The formant measurement data were then read into a text file and plotted using PlotFormant, a computer program developed by the late Peter Ladefoged of UCLA.

Figure 1. Sound files were segmented and labeled with Praat. Pinyin was used and tones indicated with numbers 1, 2, 3, and 4 (for T55, T35, T214 and T51, respectively). The letters 'e', 'm' and 'l' stand for 'early', 'mid' and 'late', respectively. The left panel shows the word /fei^{55}.ji^{55}/ 'airplane' containing a plain /i/ in the second syllable, and the right panel the word /cha3^5.jir^{55}/ 'tea table' containing a rhotic /i/. The vertical lines mark the vowel onset, 20ms from the onset, 20ms from the vowel offset, and the end of vowel.

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4. Results and Discussion
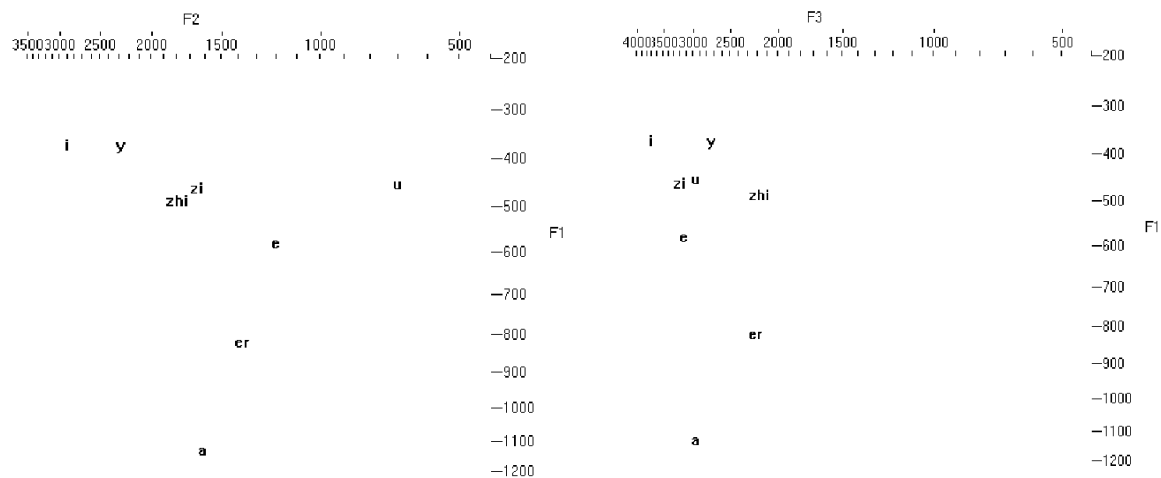
4.1 Beijing plain monophthongs

Figure 2. Beijing plain monophthongs (female speakers). Formants were taken at the mid-points in vowels. The left panel shows the F1 vs. F2 plot, and the right one F1 vs. F3.

Figure 2 shows the steady state values of the seven monophthong vowels in Beijing Mandarin (female speakers), with the rhotic vowel *er* also plotted for comparison. The left panel shows our familiar vowel space. The vowels are fairly well separated from each other, differing somewhat along either the F1 or F2 dimension or both, except for [ʐ̩] (labeled "zhi" in the chart) and [z̩] (labeled "zi"). (Note that "e" stands for the back mid vowel [ɤ].) But in the right panel, a large difference between [ʐ̩] and [z̩] is seen along the F3 dimension. Note also that F3 in /y/ is noticeably lower than /i/, obviously to help maintain a perceptual distance from /i/; or one may say that F3 in /i/ is particularly high for the same purpose. The F3s in "zhi" (i.e. [ʐ̩]) and "er" are considerably lower, due to the presence of rhoticity. The F3 values in other vowels are very similar and are around 3000Hz for the female Beijing Mandarin speakers.

4.2 Beijing rhotacized monophthongs

Recall that formant measurements were taken at three points in the target vowel. In the "early" measurement data taken at 10ms after V onset (left panel of Figure 3), the vowel space already starts to shrink (Cf. Figure 2). Thus, the effects of rhoticity kick in from early on. Only the front and back high Vs maintain a separation both in F1 and F2 from the rest of the Vs.
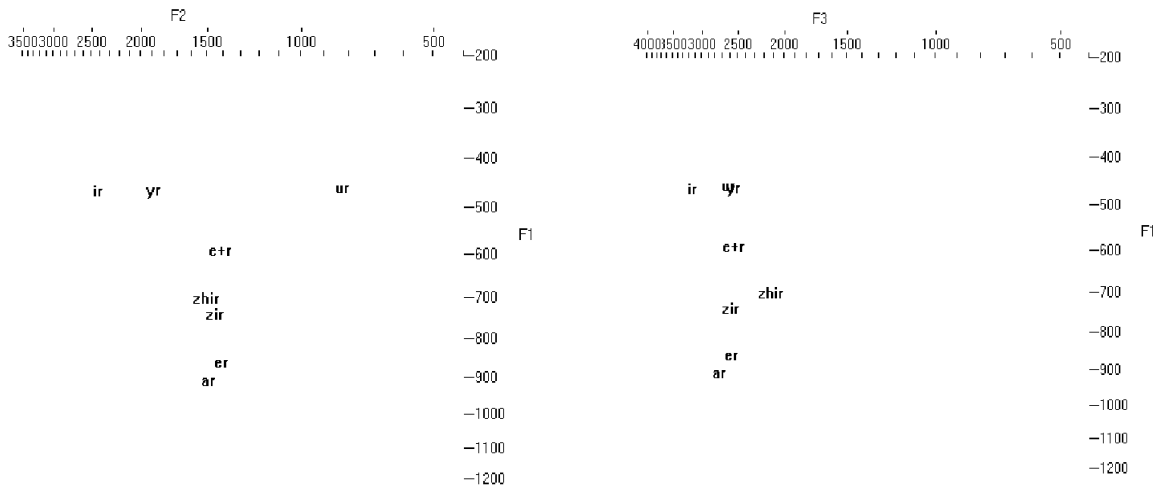
Figure 3. Plot of "early" formant measurements for Beijing rhotacized monophthongs (female speakers). (Note that "er" denotes the inherent rhotic vowel while "e+r" stands for /ɤr/.)

In the plot of measurements taken from the mid points of the Vs (Figure 4), all vowels huddle together, except for /u-r/, which still maintains its height. Along the F3 dimension, it is obvious that rhoticity is present in all Vs. At 10ms from the vowel offset (Figure 5), things crowd even closer together, except, again, for [ur]. Along the F3 dimension, heavy rhoticity is observable in all Vs.

Figure 4. Plot of "mid" formant measurements for Beijing rhotacized monophthongs (female speakers).
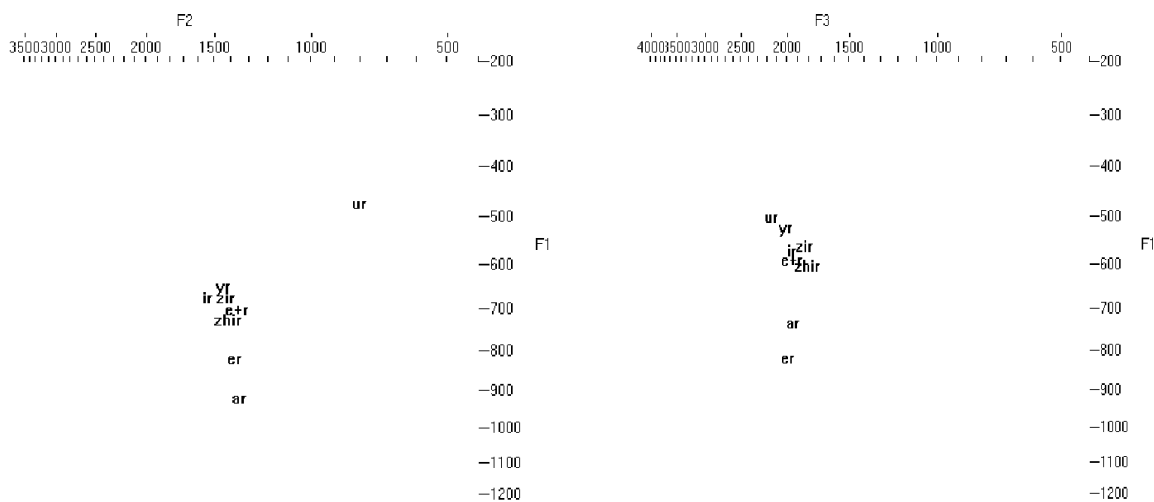
Figure 5. Plot of "late" formant measurements for Beijing rhotacized monophthongs (female speakers).

4.3 Comparison of plain vs. rhotacized monophothongs in Beijing Mandarin

An analysis of variance (ANOVA) was run on the measurement data with "gender of speaker" as the between-subjects variable, and "vowel quality", "presence (or absence) of er-suffix" and "measurement point" as within-subject variables. ANOVA main effects were significant (p< .001) for all variables. The four-way interaction of *gender * vowel * er-suffix * measurement point* was not significant for any of F1, F2 and F3, indicating that the female and male speakers behave very similarly – with the normal difference in frequency range across genders noted. This is not surprising, given that speakers of either gender can produce *er*-suffixed forms and be correctly understood by all fellow speakers of the language, who can always tell whether an *er*-suffixed form or a plain V was intended by the speaker. Thus, data patterns for F1, F2 and F3 from the mid point of the vowel, aggregated across genders, are presented here. As can be seen in the left-most panel, changes induced by the *er*-suffix in F1 (except for [u] and [u-r]) and F3 (except for [ʐ] and [ʐ-r], labeled "zhi") are significant across the board. For /ɤ/ (labeled "e"), the overlap of F2 measurements was only 5Hz. For [z̩] and [z̩-r] (labeled "/zi/") the overlap was 35Hz. So, these changes are marginal. Furthermore, as noted before, these changes under the effect of *er*-suffixation made the vowels less distinctive from each other. Indeed, F2 (except for /u/) and F3 values are very similar in all *er*-suffixed vowels.
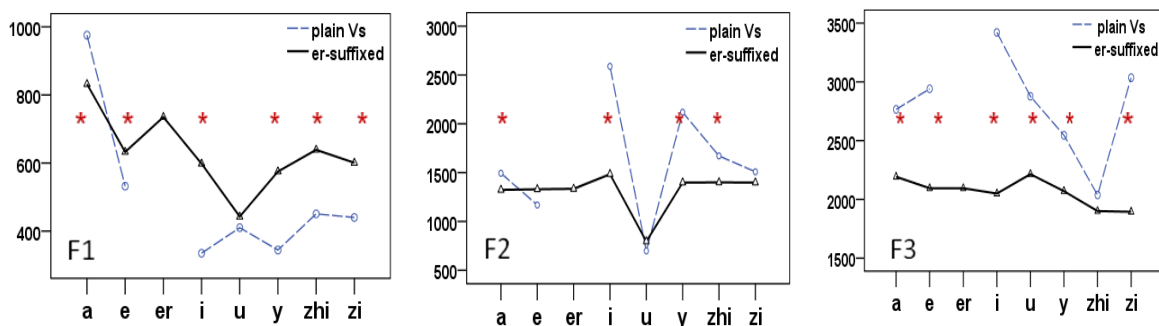
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Figure 6. Comparison of formant values in Beijing Mandarin plain (circles with dashed lines) versus *er*-suffixed (triangles with solid lines) vowels. (Again, "e", "zhi" and "zi" stand for [ɤ], [ʐ̩] and [z̩], respectively.) An asterisk marks a significant change. Formant values of the inherent rhotic vowel /er/ are also plotted as a reference.

4.4 Patterns of change observed in *er*-suffixed vowels

In sum then, one may make the following general observations about *er*-suffixed vowels from the data presented here:

(i)   F3 is lowered significantly (p < .05) across the board, except for [z̩].

(ii)   In the non-back high Vs [i, y, z̩, ʐ̩], F1 is significantly (p < .05) raised ↑, while F2 is significantly (p < .05) lowered ↓.

(iii) In the back mid vowel [ɤ], F1 and F2 are raised ↑ (marginally significant).

(iv)   In the low vowel [a]: F1 and F2 are lowered ↓.

(v)   In the high back vowel [u], no significant changes in F1 and F2 were observed.

Thus, for some vowels, esp. /i, y/, all three formants may be affected significantly by *er*-suffixation, while in others, e.g. /ɤ/ and the rhotic and the dental fricative vowels, only two of F1, F2, F3 may be affected. And then, there is /u/, whose F1 and F2 are unaffected by *er*-suffixation. (Recall that Pulleyblank (1984), Li (1986), Lin (1989) and Duanmu (2007) all posit a surface vowel with unchanged /u/ quality.) While some of the participants in this study reported that *er*-suffixed /u/ was hard to pronounce, they did produce some with heavy rhoticity. How is it then that its formant structure seems unaltered acoustically and perceived by native speakers and researchers as maintaining the quality of the original (i.e. plain) /u/? A closer look at the plain and *er*-suffixed /u/ samples (see Figure 7) revealed that its formant structure did change but that because there is plenty of space between its second and third formants, a rhotic formant appears to be super-imposed onto the original formant structure. Or alternatively, one may say that its original F3 is lowered under the effect of rhoticity but that its original F4 is lowered to where the F3 in a plain /u/ would normally be. Table 1 lists the formant values from these examples. Indeed, one notices that F5 in *er*-suffixed /u/ takes place of the plain /u/ F4.
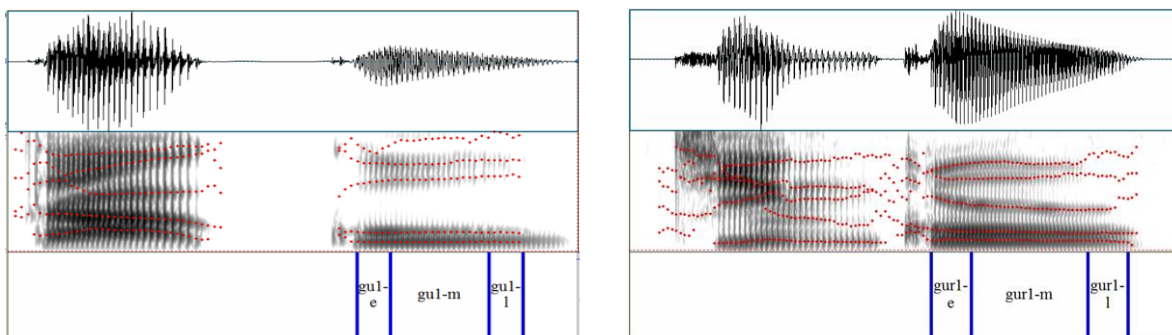
Figure 7. Examples of [u] (left panel) and [u˞] (right panel).The formant structure of /u/ is mostly preserved, with the *r*-formant "super-imposed".

Table 1. Formant values in plain /u/ and *er*-suffixed /u/. (Formant values were taken from mid vowel.)

	u	u + ɚ
F5		3630
F4	3635	3025
F3	2975	1760
F2	800	795
F1	390	445

As mentioned in §1, the researchers also posit mostly unchanged vowel quality for *er*-suffixed /ɤ, a/. Although changes in formant values have been observed, they may not be as great as changes found in other vowels (esp. in comparison with /i, y/). Figure 8 shows spectrograms of plain (left panel) vs. *er*-suffixed /ɤ/ (right panel). One notices that just as in for *er*-suffixed /u/, if one "took away" the F3 from the *er*-suffixed /ɤ/, its formant structure would be similar to that of the plain /ɤ/.
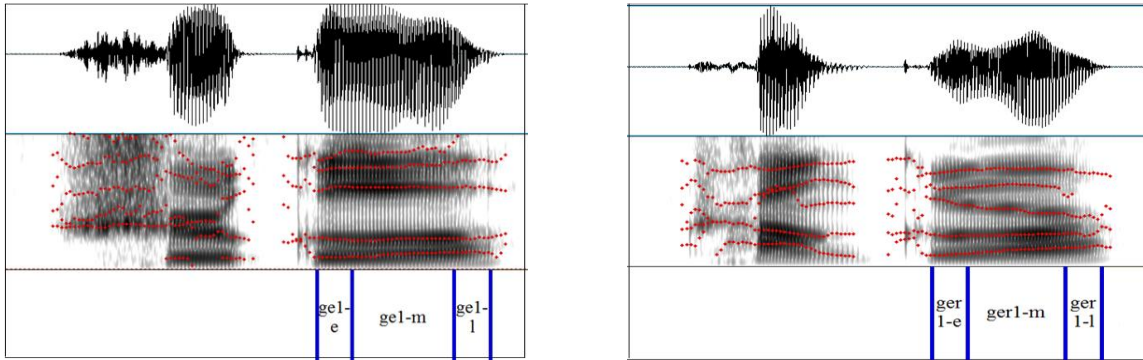
Figure 8. Examples of plain (left panel) vs. *er*-suffixed /ɤ/ (right panel).

The story with *er*-suffixed /a/ is different. Instead of having a super-imposed rhotic F3, all of the first three formants were affected. However, they seem to be affected proportionately so that the formant structure is still preserved but with "overlaid" *r*-coloring (see Figure A1 in the Appendix). It may also be true that rhoticity starts slightly later in *er*-suffixed /a/ in comparison to, for instance, the non-back high vowels.

The researchers cited in §1 all seem to be in agreement as to the phonetic realization of the retroflex and the dental fricative vowels, analyzing them as losing their original quality from vowel onset and surfacing as a rhotic schwar when *er*-suffixed. Drastic changes were observed in F1 and F2 in the rhotic fricative vowel, and in F1 and F3 in the dental fricative vowel. (See Figures 2, 3, 4 and 5 in §4 and Figures A2 and A3.)

But the analyses are inconsistent with regard to *er*-suffixed /i, y/. Some consider the original quality preserved with additional schwar off-glide (Li, 1986 and Lin, 1989), while others treat the surface nuclei as schwa (Pulleyblank, 1984 and Duanmu, 2007). As reported earlier (see Figures 2, 3, 4 and 5), changes – indeed the largest changes among all seven vowels discussed here – are observed in all of the first three formants in /i, y/. However, the formant structures are somewhat preserved for the first one-third or so of the vowel duration (see Figures 1 and A4).

5. Concluding remarks

The present study attempted to address the details and the inconsistency found in previous analyses of *er*-suffixed monophthong vowels in Beijing Mandarin. It has been found that F3 is lowered across the board in *er*-suffixed vowels (except for the rhotic fricative vowel, whose F3 is inherently low, as rhoticity is present in the vowel without the *er*-suffix). This is characteristic of *r*-colored vowels observed cross-linguistically (see, e.g., Aungst & Frick, 1964). Changes in F1 and F2 basically manifest a centralizing effect on the vowels, with F1 raised in high vowels and lowered in the low vowel /a/, and with F2 lowered in front vowels and raised in the back vowel /ɤ/. Since the dental fricative vowel can be considered mostly central, rhoticity incurred little change in its F2. Note that the inherent underlying rhotic vowel *er*, although a central vowel, is lower than

a schwar. Indeed, when produced in the high falling tone, as in /er^{51}/ 'two', its phonetic properties are close to those of *er*-suffixed /a/. Cf. Figure 3, 4 and 5, where "er" and "ar" are close to each other. Therefore, although the *er*-suffixed vowels all appear to move toward a certain central and mid target point in the vowel space (see Figures 3, 4 and 5), they never actually coincide with the underlying rhotic vowel *er*. Although Li (1986) uses [ʟ] (IPA [ʐ]) in his analysis to denote the rhotic component in the *er*-suffixed vowels, there is no evidence that this rhotic component contributes to raise vowel height. One can only conjecture that perhaps he intended for it to be vocalic and different from the underlying rhotic vowel *er*.

Due to the strong effect of lip rounding in /u/, rhoticity has essentially no effect on its F1 or F2. But F4 and F5 in *er*-suffixed /u/ are greatly affected to the extent that they now assume the frequency ranges of the F3 and F4 in the plain /u/. Meanwhile, F3 in the *er*-suffixed /u/ is considerably lowered to the middle of the antiformant range between F2 and F3 in a plain /u/ to become a super-imposed extra rhotic formant, giving the perceptual impression of a vowel with simultaneous /u/ quality and *r*-coloring. A super-imposed F3 may also be offered to account for the seeming unaffected perception of the original vowel quality in the *er*-suffixed /ɤ/. Changes in *er*-suffixed /a/ are relatively small and proportionate, making it possible to maintain a fairly good /a/ quality.

Changes in F1 and F3 of the dental fricative vowel, and in the F1 and F2 of the rhotic fricative vowel set on early with *er*-suffixation, rendering them effectively rhotic schwars for most of their vocalic duration.

Although significant changes have been observed in *er*-suffixed /i, y/ from the onset of the vowels, their formant structures are somewhat preserved initially. Perhaps for some one-third of the vowel (with rhoticity already affecting the formants) is too brief to give the impression of an intact vowel /i/ or /y/. Yet, for others these initial, somewhat altered perceptions are still qualified to be labeled /i/ or /y/.

It is hard to take a position in the controversy found in the previous analyses: after all, phonological analysis and phonetic description are based on the listener's perception of the sound in question. Given the acoustic data presented here, we would like to propose that the description of the Chinese *er*-suffixed monophthongs be revised as: [jɚ, ɥɚ, ɚ, ɚ; uˠ; ɤˠˀ, aˠˀ]. This is mostly consistent with Duanmu's (2007) analysis. Of course, it is understood that there is even rhoticity present in [j, ɥ]. The superscript schwar in [ɤˠˀ, aˠˀ] captures the native intuition that vowel quality is preserved with an [ɚ] off-glide. And [uˠ] indicates that the *r*-coloring is "superimposed" on /u/ with no [ɚ] off-glide.

Our results also call for more careful phonetic study of similar processes cross-linguistically: while there is evidence for a rhotic consonantal coda in Scottish English (Wells, 1982), in other languages the underlying post-vocalic rhotic segment or syllable seems to be realized only as "*r*-coloring" on the preceding vowel and perhaps a schwar [ɚ] off-glide (see, e.g., Harris (1994) for analysis on American English). If this is true,

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then for cases such as Yanggu (Lin, 2004) one may not have to posit surface syllables with both a complex onset (e.g. [tl]) and a rhotic coda.

ACKNOWLEDGEMENTS

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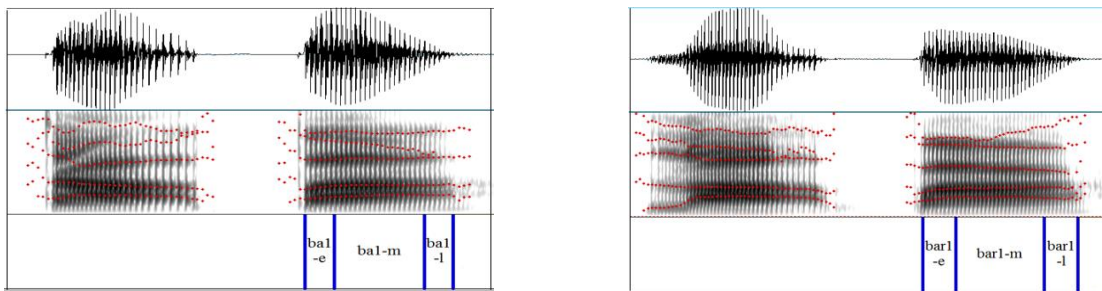
APPENDIX

Figure 1A. Examples of plain (left panel) and *er*-suffixed (right panel) /a/. Changes are observed in F1, F2 and F3. But as changes are relatively small and gradual, the original vowel quality is preserved.
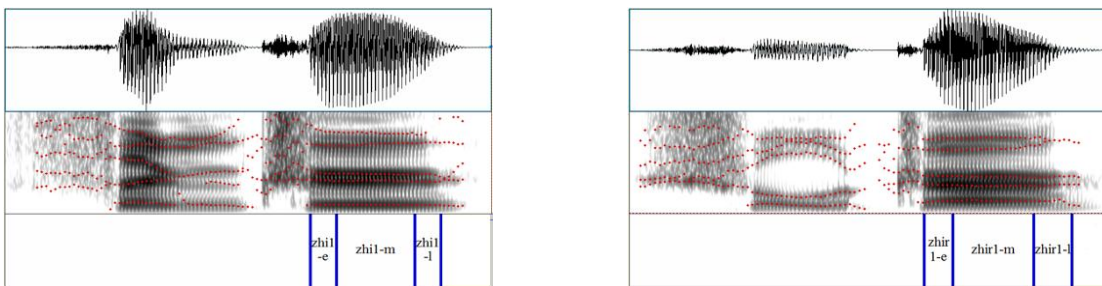

Figure A2. Examples of plain (left panel) and *er*-suffixed (right panel) rhotic fricative vowel [ʐ̩].
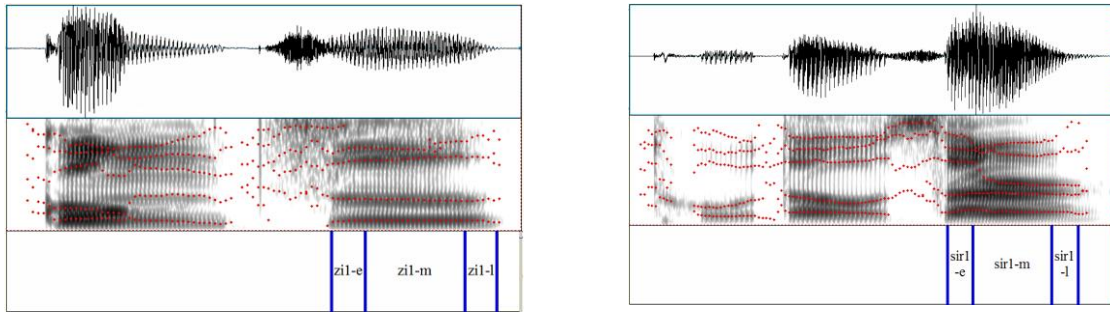
Figure A3. Examples of plain (left panel) and *er*-suffixed (right panel) dental fricative vowel [ẓ].
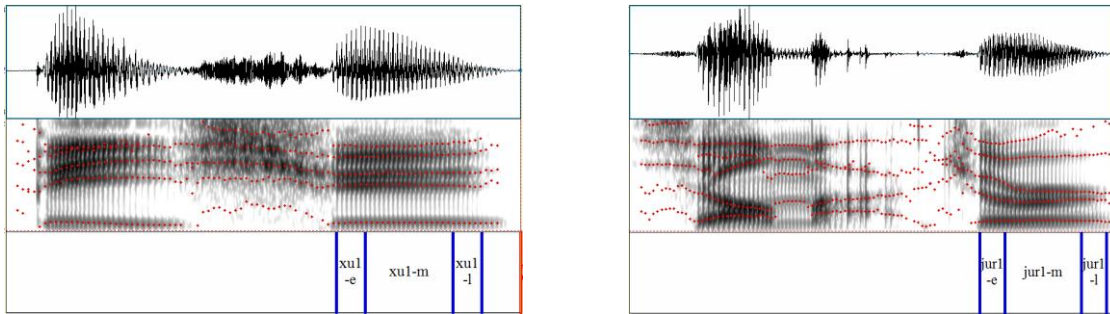

Figure A4. Examples of plain (left panel) and *er*-suffixed (right panel) /y/. Rhoticity induced formant changes are noticeable from onset of vowel, although the initial portion still somewhat maintains the vowel quality.