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Original Paper

Prenasal Vowel Production by Chinese-Speaking Beginners of Japanese: A Cross-Language Acoustic Study

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Abstract

This study aims to describe the five Japanese prenasal vowels produced by beginning Chinese-speaking learners and identify which are acoustically closer to their Mandarin vowels or to native Japanese vowels. Sixteen native speakers of Chinese with approximately six months of Japanese study read Japanese and Mandarin words, and two native speakers of Japanese read the Japanese words. Vowel quality was compared using F1 and F2 measurements. The learners' Japanese /i/ and /e/ distributions overlapped, as did /ɯ/ and /o/. On average, their /e/ was closer to the pooled Japanese reference than to the Mandarin vowels in [ən] and [əŋ]. In the group whose home dialects retained the /n/-/ŋ/ distinction, Japanese /ɯ/ was closer to the vowel in Mandarin [uən], and /a/ to those in [an] and [aŋ], than to the Japanese reference. Japanese /o/ had comparable mean distances to the Japanese and Mandarin vowels. These patterns suggest addressing contrasts between neighboring Japanese vowels together with similarities to familiar Mandarin vowels in pronunciation teaching.

Keywords

Japanese pronunciation, native Chinese speakers, prenasal vowels, cross-language similarity, speech learning model

1. Introduction

Native speakers of Chinese learning Japanese may pronounce the vowel before /N/ differently from native speakers of Japanese. The difficulty involves vowel quality as well as the duration of the nasal mora. Japanese /N/ forms an independent mora and varies phonetically with its environment (Maekawa, 2023; Vance, 2008). Chinese nasal rhymes provide familiar vowel-plus-nasal patterns, but their vowels differ with the nasal ending and other segments in the rhyme (M. Y. Chen, 2000; Lin, 2007). For a

learner, a Japanese sequence such as /ɯN/ may therefore resemble one Mandarin rhyme more than another. Comparing the learner's productions in both languages can help identify these relationships.

The Speech Learning Model (SLM) relates second-language pronunciation to perceived similarities between first- and second-language sounds. Equivalence classification can link an L2 sound to an existing L1 category and affect the formation of a new phonetic category (Flege, 1995). The revised model, SLM-r, gives greater attention to individual differences in L1 category precision, perceived cross-language dissimilarity, and L2 input (Flege & Bohn, 2021). Bilingual production research also shows that L1 and L2 phonetic systems can influence each other (Flege et al., 2003). These accounts make the learner's L1 production relevant to the interpretation of L2 pronunciation (S. Chen, 2023).

Studies of Japanese /N/ have examined how learners perceive nasal duration and distinguish Japanese durational categories (Toda, 1998; Uchida, 1995). Production research has also documented difficulties with the preceding vowel. Sun et al. (2022) measured prenasal vowels and obtained native listeners' naturalness judgments. Their learners' /u/ and /e/ distributions overlapped, and /u/ received the lowest naturalness ratings. Their /u/ denotes the Japanese high nonfront vowel transcribed /ɯ/ here. Sun and Jin (2025) extended this work with acoustic and ultrasound data from beginning and advanced learners and native Japanese speakers. They found vowel patterns that varied with the preceding consonant and interpreted some productions as resembling Chinese vowels. Other studies report difficulties in Japanese vowel sequences (Sun & Hayashi, 2025) and palatalized sequences, including /juN/ productions resembling Chinese [yn] (Liu, 2024). Articulatory differences among Chinese rounded sounds and variation in Japanese vowel articulation further indicate that segmental context matters when proposing an L1 explanation (Kawahara et al., 2017; Zhu & Wu, 2021).

The aim of this study is to describe the five Japanese prenasal vowels produced by beginning Chinese-speaking learners and identify which vowels are acoustically closer to their Mandarin rhyme vowels and which to native Japanese vowels.

Two research questions guide the study: (1) What vowel-quality differences and overlaps occur among the five Japanese prenasal vowels after approximately six months of study? (2) For each Japanese vowel, are the learners' productions acoustically closer to native Japanese vowels or to vowels in their Mandarin rhymes?

The study records both languages from the same learners, adding a measured Mandarin reference to previous Japanese production studies. Comparisons also describe variation between learners from home-dialect backgrounds with and without the /n/-/ŋ/ distinction. The SLM provides a framework for interpreting the resulting cross-language similarities.

2. Method

2.1 Participants

Seventeen first-year university students in Tianjin were recruited after approximately six months of Japanese study. One was excluded because a bilingual background did not meet the study's L1 criteria, leaving 16 native Chinese-speaking learners of Japanese. Eight reported a home-dialect background retaining the /n/-/ŋ/ distinction and eight reported a background without it. They are called the contrast-retaining and non-contrast groups below. Grouping was based on reported upbringing and dialect background, without a separate test of each participant's dialect pronunciation.

Participants reported no hearing impairment, speech-related disorder, extended Japanese immersion, or professional voice training. All gave written informed consent for recording and anonymized phonetic research and received compensation. Two native Japanese teachers, J01 and J02, supplied the Japanese reference recordings: a woman from Kumamoto and a man from Mie, both accustomed to using standard Japanese in teaching.

2.2 Materials and Recording

The Japanese task used 15 real words, three for each of /aN, iN, ɯN, eN, oN/. The consonant after /N/ was labial, alveolar, or velar (Table 1), covering environments in which /N/ has different realizations (Maekawa, 2023; Vance, 2008). Participants read the words in これは__です and were asked to use a level accent pattern. The target vowel and nasal were in the first syllable.

Table 1. Japanese Target Words by Vowel and Following-Consonant Place

Vowel-nasal context	Labial	Alveolar	Velar
/aN/	看板 (かんばん)	観覧 (かんらん)	歓迎 (かんげい)
/iN/	勤勉 (きんべん)	近年 (きんねん)	金魚 (きんぎょ)
/ɯN/	文脈 (ぶんみゃく)	分散 (ぶんさん)	文豪 (ぶんごう)
/eN/	厳密 (げんみつ)	限定 (げんてい)	原告 (げんこく)
/oN/	今晩 (こんばん)	根底 (こんてい)	根源 (こんげん)

Note. Place labels describe the consonant following /N/. The measured portion is the vowel preceding /N/.

The Mandarin task used nine words: 看门 [an], 康复 [aŋ], 拼图 [in], 乒乓 [iəŋ], 昆仑 [uən], 军队 [yn], 奔驰 [ən], 登山 [əŋ], and 空降 [oŋ]. Participants read them in 这个词是__; the first syllable of each word had a first tone. The comparisons paired Japanese /aN/ with Mandarin [an] and

[aŋ], /iN/ with [in] and [iəŋ], /ɯN/ with [uən] and [yn], /eN/ with [ən] and [əŋ], and /oN/ with [oŋ]. These rhyme labels follow the stimulus coding. Throughout the paper, comparisons between /VN/ sequences and Mandarin rhymes concern the vowel before the nasal.

Recordings were made in an acoustically treated studio in Tianjin with a Neumann microphone and an Antelope Zen Tour audio interface at 44.1 kHz. Participants read instructions and practiced before recording. Each word was read three times, with additional readings when a participant requested a correction. The 16 learners completed both tasks; the two native Japanese speakers completed only the Japanese task. After exclusions for misreadings or unsuitable recordings, the data comprised 708 Japanese vowel tokens and 431 Mandarin vowel tokens from the learners, plus 89 Japanese vowel tokens from the native Japanese speakers. This yielded 1,228 of the 1,242 planned tokens; 14 were unavailable.

2.3 Acoustic Measurements

Vowel intervals and the onset of nasalization were manually annotated in Praat. Measurement points were selected in the stable oral vowel portion before nasalization by listening to the recording and inspecting the TextGrid, waveform, and wideband spectrogram (Boersma & Weenink, n.d.). The same criterion was applied to Japanese /VN/ sequences and Mandarin rhymes, including [uən] and [iəŋ]. Points lay at a median of 24.8% of the full annotated vowel interval (5^{th}-95th percentiles: 9.9%-40.8%). F1 and F2 were extracted with Burg analysis using five formants, a 5,500-Hz ceiling, a 25-ms window, an automatic time step, and pre-emphasis from 50 Hz.

Formants were normalized separately for each speaker using the Lobanov transformation, $z = (F - \mu)/s$, where μ and s are that speaker's mean and sample standard deviation (Lobanov, 1971). For each learner, these parameters were calculated from the combined Japanese and Mandarin recordings; for each native Japanese speaker, they were calculated from the Japanese recordings. Normalization reduces differences related to speaker anatomy and facilitates comparison of vowel quality (Adank et al., 2004). The vowel inventory used to estimate the parameters affects such comparisons (Fabricius et al., 2009; Flynn & Foulkes, 2011).

2.4 Comparisons of Vowel Production

Separate linear mixed-effects models assessed normalized F1 and F2 in the learners' 708 Japanese vowel tokens. Vowel, the place of the consonant following /N/, and dialect group were additive fixed effects with sum-to-zero contrasts; speaker was a random intercept. Models were fitted by restricted maximum likelihood in R 4.5.1 using lme4 1.1-38 and lmerTest 3.2-0 (Bates et al., 2015; Kuznetsova et al., 2017). Fixed effects were evaluated with Type III F tests using Satterthwaite denominator degrees of freedom. Each vowel-by-place combination contained one word, so lexical and place effects were not independently estimated. The models did not include interactions. Both models converged without singular fits. Residual plots showed heavy tails and unequal dispersion across vowels; the tests provide supplementary evidence about average effects under the random-intercept specification.

Euclidean distances in normalized F1-F2 space compared each Japanese vowel token produced by a learner with two reference means. The Japanese reference was the mean of all available tokens of the relevant vowel produced by the two native Japanese speakers. The Mandarin reference was the mean of all available tokens of the relevant rhyme vowel produced by learners in the same dialect group. For each token, dJP and dCN denote the distances to these Japanese and Mandarin means. The distance between the two reference means is b. The index I = (dCN - dJP)/b is negative when the learner's Japanese vowel is closer to the Mandarin vowel and positive when it is closer to the native Japanese vowel. Zero indicates equal distances. Group summaries average the token-level distances and indices; the Mandarin reference is shared within each group.

Table 3 includes dJP, dCN, and b alongside the index. Figure 2 shows individual learners' mean indices as well as group means. A small b magnifies a difference between dJP and dCN, so the index is interpreted together with these distances. The analysis describes acoustic similarity in production; its relation to perceptual similarity requires separate evidence (Barreda, 2021).

2.5 Checks of Normalization and One Unstable Measurement

Distances were also calculated using normalization parameters estimated from each learner's Japanese recordings alone and applied to both languages. The same tokens and distance formula were used, and normalization of the native Japanese recordings was unchanged. A further check excluded one Mandarin token with an unstable formant track before recalculating normalization and distances. The complete set of measurements was retained in the main analysis.

3. Results

3.1 Japanese Vowel Distributions

The Japanese vowel space showed higher F1 for /aN/, higher F2 for /iN/ and /eN/, and lower F2 for /ɯN/ and /oN/ (Figure 1). The learners' productions differed across vowels in F1, $F(4, 686.42) = 537.02$, $p < .001$, and F2, $F(4, 686.02) = 348.97$, $p < .001$ (Table 2). Neither following-consonant place nor dialect group had a significant average main effect.

Table 2. Fixed Effects in Models of Learners' Japanese F1 and F2

Outcome	Fixed effect	df1	df2	*F*	*p*
F1	Vowel	4	686.42	537.02	< .001
F1	Following place	2	686.53	.73	.483
F1	Dialect group	1	14.10	.27	.612
F2	Vowel	4	686.02	348.97	< .001
F2	Following place	2	686.09	.28	.753
F2	Dialect group	1	13.83	.27	.614

Note. Outcomes are Lobanov-normalized F1 and F2. Models use REML estimation and a speaker random intercept. Type III F tests use Satterthwaite denominator degrees of freedom. Speaker-intercept/residual variances are .00218/.21005 for F1 and .01233/.35301 for F2.

The distributions overlap for /iN/ and /eN/, and for /ɯN/ and /oN/. In particular, /iN/ has a broad F1 range. Learners thus produced different average vowel qualities, with overlap between these neighboring vowels across their recordings. The Japanese reference speakers differed in /ɯN/ F2 (-.785 and -.082 z for J01 and J02) and /aN/ F1 (1.206 and 1.713 z); Figure 1 shows their individual and pooled means.

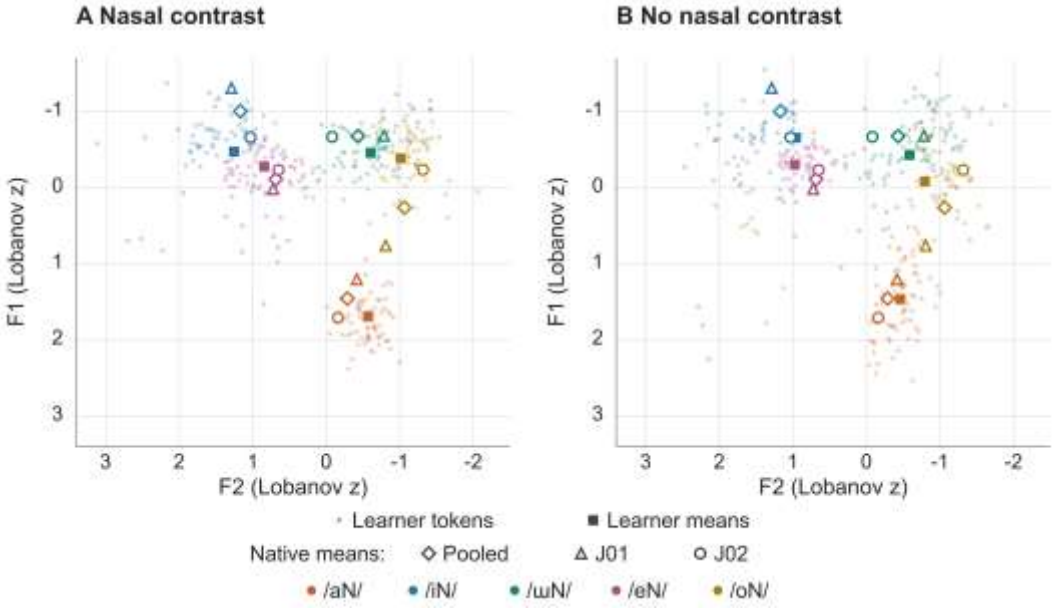


Figure 1. Japanese Prenasal Vowel Spaces by Dialect Group

Small dots show the learners' 708 Japanese vowel tokens; filled squares show token-pooled learner means. Open diamonds show the native Japanese reference pooled over 89 tokens; open triangles and circles show the means for J01 (45 tokens) and J02 (44 tokens), respectively. F1 and F2 are normalized separately for each speaker. Both panels repeat the same native reference and use identical, reversed axes. A: contrast-retaining group; B: non-contrast group.

3.2 Similarity to Japanese and Mandarin Vowels

Japanese /eN/ was closer to the native Japanese /e/ than to the learners' Mandarin vowels in [ən] and [əŋ] in both groups. Its indices were .751 and .784 in the contrast-retaining group and .842 and .812 in the non-contrast group. The complete distances appear in Table 3; Figure 2 shows how the comparisons varied across learners.

Table 3. Cross-Language Distances and Relative Proximity

Group	Vowel	Rhyme	n	b	dJP	dCN	I
C	aN	an	72	0.249	0.513	0.483	-0.123
C	aN	aŋ	72	0.551	0.513	0.425	-0.160
C	iN	in	72	0.029	0.885	0.880	-0.195
C	iN	iəŋ	72	0.193	0.885	0.939	0.281
C	ɯN	uən	69	0.385	0.551	0.472	-0.207
C	ɯN	yn	69	1.148	0.551	1.509	0.834
C	eN	ən	70	0.771	0.439	1.017	0.751
C	eN	əŋ	70	0.952	0.439	1.185	0.784
C	oN	oŋ	71	0.980	0.822	0.767	-0.056
NC	aN	an	72	0.390	0.514	0.625	0.286
NC	aN	aŋ	72	0.605	0.514	0.653	0.230
NC	iN	in	70	0.661	1.094	1.285	0.290
NC	iN	iəŋ	70	0.619	1.094	1.261	0.271
NC	ɯN	uən	71	0.543	0.573	0.583	0.020
NC	ɯN	yn	71	1.141	0.573	1.360	0.689
NC	eN	ən	71	0.701	0.477	1.067	0.842
NC	eN	əŋ	71	0.606	0.477	0.969	0.812

Group	Vowel	Rhyme	n	b	dJP	dCN	I
NC	oN	oŋ	70	0.798	0.794	0.814	0.025

Note. C = contrast-retaining group; NC = non-contrast group. Rhyme = Mandarin rhyme; n = Japanese vowel tokens from learners. dJP and dCN are mean distances to native Japanese and Mandarin vowel means; b is the distance between those means. I = (dCN - dJP)/b. Values are dimensionless.

In the contrast-retaining group, Japanese /ɯN/ was closer to the Mandarin vowel in [uən] than to the native Japanese /ɯ/: mean distances were .472 and .551, respectively (I = -.207). It was farther from the Mandarin vowel in [yn] (I = .834). In the non-contrast group, Japanese /ɯN/ was at almost equal mean distances from native Japanese /ɯ/ and the Mandarin vowel in [uən] (I = .020), and closer to native Japanese /ɯ/ than to the vowel in [yn] (I = .689). Similarity to Mandarin [uən] therefore differed from similarity to [yn].

For /aN/, the contrast-retaining group's productions were closer to both Mandarin rhyme vowels than to native Japanese /a/: I = -.123 for [an] and −.160 for [aŋ]. The mean distances were .483 to [an], .425 to [aŋ], and .513 to native Japanese /a/. The non-contrast group's productions were closer to native Japanese /a/ than to either Mandarin vowel (I = .286 and .230). For /oN/, mean distances to native Japanese /o/ and the Mandarin vowel in [oŋ] were comparable in both groups (I = -.056 and .025). Individual learners' means fell on both sides of zero.

For /iN/, the native Japanese /i/ and Mandarin [in] vowel means were particularly close in the contrast-retaining group: b = .029. Learners' Japanese /iN/ had nearly equal mean distances to the Mandarin and Japanese means (.880 and .885), yielding I = -.195. It was closer to native Japanese /i/ than to the vowel in [iəŋ] (I = .281). In the non-contrast group, /iN/ was closer to native Japanese /i/ than to either Mandarin vowel (I = .290 for [in] and .271 for [iəŋ]).

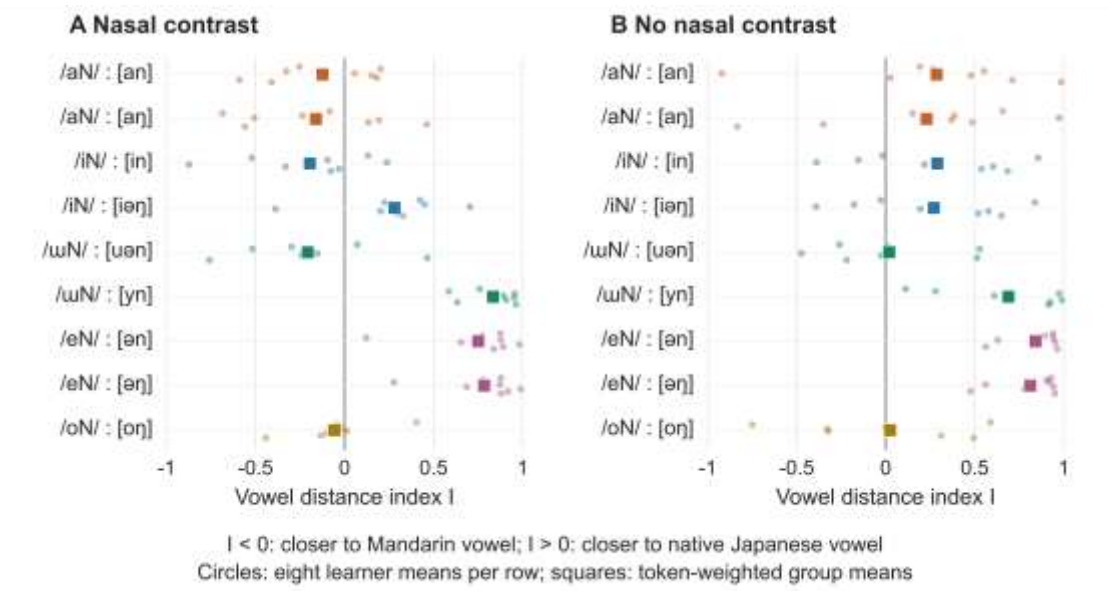


Figure 2. Relative Proximity of Learners' Japanese Vowels to Japanese and Mandarin References

Rows pair a Japanese vowel with a Mandarin rhyme. Circles show each learner's mean index; squares show group means pooled over Japanese tokens. Negative values indicate a shorter distance to the Mandarin vowel, and positive values a shorter distance to the native Japanese vowel. Mandarin vowel means are pooled within each group. A: contrast-retaining group; B: non-contrast group.

3.3 Results under Alternative Normalization

Using only Japanese recordings to calculate the learners' normalization parameters left the main /aN/, /ɯN/, /eN/, and /oN/ comparisons unchanged (Figure 3). In the contrast-retaining group, /ɯN/ remained closer to the Mandarin vowel in [uən] (I changed from -.207 to -.097), while its comparison with [yn] remained positive (.834 to .839). Both /aN/ indices remained negative in this group and positive in the non-contrast group. All /eN/ indices remained positive, and /oN/ remained at comparable distances from the Japanese and Mandarin vowels.

The contrast-retaining group's /iN/ comparison with [in] changed from -.195 to .415. Its apparent greater similarity to the Mandarin vowel therefore depended on normalization. In the non-contrast group, the same index was nearly unchanged (.290 to .289).

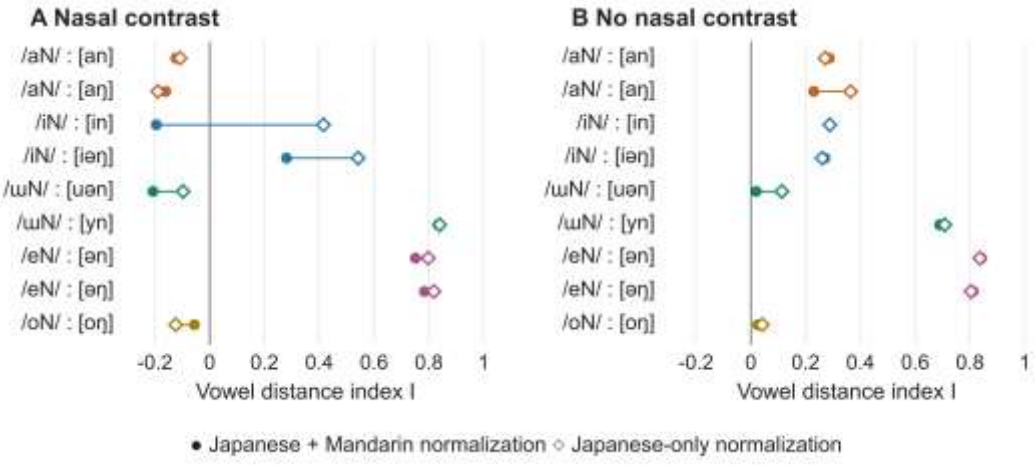


Figure 3. Sensitivity of Cross-Language Proximity to the Normalization Inventory

Filled circles use parameters calculated from each learner's Japanese and Mandarin recordings; open diamonds use parameters calculated from Japanese recordings alone and applied to both languages. Lines join the two values for the same Japanese vowel and Mandarin rhyme. The tokens and distance formula are unchanged. A: contrast-retaining group; B: non-contrast group.

Excluding the unstable Mandarin [yn] measurement left the signs of all 18 indices unchanged. In the affected non-contrast group, /ɯN/ indices changed from .689 to .756 for [yn] and from .020 to .062 for [uən]; its two /eN/ indices became .847 and .818. The main Japanese-Mandarin comparisons were preserved.

4. Discussion

4.1 Prenasal Vowel Pronunciation and L1 Similarity

After approximately six months of Japanese study, these native Chinese-speaking learners produced different average qualities for the five prenasal vowels. Overlap between /iN/ and /eN/ and between /ɯN/ and /oN/ nevertheless shows variation in the realization of neighboring vowels. Cross-language similarities also differed by vowel. Japanese /eN/ was closer to native Japanese /e/ than to the two Mandarin rhyme vowels examined, whereas /ɯN/ and /aN/ in the contrast-retaining group were closer to particular Mandarin vowels. Japanese /oN/ was at comparable distances from the Japanese and Mandarin vowels. These results describe which aspects of the learners' Japanese pronunciation resembled their L1 productions.

The /ɯN/ comparison is relevant to the interpretation of pronunciation errors. Liu (2024) reports palatalized Japanese sequences resembling Chinese [yn]. The present words did not have those palatalized onsets, and their /ɯN/ vowels were consistently farther from the Mandarin vowel in [yn] than from native Japanese /ɯ/. The contrast-retaining group's /ɯN/ instead resembled the vowel in

[uən]. Identifying the Mandarin rhyme as well as the Japanese onset context is therefore necessary when describing the proposed L1 relationship.

The SLM predicts that the relationship between particular L1 and L2 sounds affects phonetic learning (Flege, 1995; Flege & Bohn, 2021). The similarities observed for /ɯN/ and /aN/ are compatible with an L1 contribution to these learners' Japanese vowel quality. The /eN/ result shows that the same description does not apply across all five vowels. Acoustic similarity by itself cannot establish equivalence classification or a shared perceptual category. Those processes require perception data (Best & Tyler, 2007). Because bilingual phonetic interaction can also affect L1 production (Flege et al., 2003), the present recordings identify similarities at one stage of Japanese learning; they do not determine how either language changed over time.

4.2 Comparison with Previous Studies

Sun et al. (2022) found overlap between Japanese /u/ and /e/ and low naturalness ratings for /u/. In the present data, overlap was more apparent for /iN/ with /eN/ and /ɯN/ with /oN/. Their learners had more Japanese experience and read /s/-initial materials. They located the formant measurement point within the first quarter of the combined vowel-plus-nasal interval, whereas the present study sampled the stable oral vowel portion before nasalization. A time point defined by the duration of the combined interval has no fixed relation to the onset of vowel nasalization. The studies therefore differ in the temporal definition of prenasal vowel quality as well as in learning experience and segmental context.

Sun and Jin (2025) measured formants at the temporal midpoint of the vowel interval and examined a broader range of onsets using acoustic and ultrasound recordings. They interpreted some /e/ productions as resembling Chinese en or eng. In the present word set, the learners' /eN/ was closer to native Japanese /e/ than to their Mandarin vowels in [ən] or [əŋ]. Here the proposed Chinese relationship was assessed against Mandarin recordings from the same learners. Further comparisons across onset contexts could determine where these different /e/ realizations occur.

The /iN/ result illustrates why a small distance difference needs care in interpretation. For the contrast-retaining group, native Japanese /i/ and the Mandarin vowel in [in] were already close, and changing the normalization inventory reversed which was slightly closer to the learners' Japanese /iN/. Normalization studies show that the sampled inventory affects the vowel relationships preserved by an analysis (Adank et al., 2004; Barreda, 2021; Fabricius et al., 2009). In this study, the greater similarity of /ɯN/ and /aN/ to Mandarin vowels in one group, and of /eN/ to native Japanese /e/ in both groups, persisted under both normalization choices.

4.3 Implications for Pronunciation Teaching

Pronunciation work on /N/ should include the preceding vowel as well as nasal timing. The overlap of /ɯN/ with /oN/ and of /iN/ with /eN/ provides specific contrasts to examine in learners' recordings. For /ɯN/, a teacher can compare the learner's Japanese production with native Japanese /ɯ/ and the learner's Mandarin vowel in [uən]. For /eN/, the current results favor examining its relation to

neighboring Japanese vowels instead of assuming a substitution with Mandarin [ən].

Listening to recordings and comparing vowel-space displays can help learners and teachers discuss vowel quality in the relevant words. Such activities can build on self-monitoring approaches used in Japanese vowel-length instruction (Park et al., 2006). Their effectiveness for prenasal vowel quality remains a question for teaching research.

4.4 Limitations and Further Research

The two groups of eight learners and the two native Japanese speakers provide a small sample. Dialect background was self-reported; differences between the groups in the distance analysis are descriptive, and the mixed-effects models found no average dialect effect. Each Japanese vowel-by-place combination and each Mandarin rhyme was represented by one word. More speakers and words, together with models of speaker-specific contextual variation, would help assess how widely the observed patterns occur (Barr et al., 2013).

Measurements at one point in the vowel describe its quality at that location. Formant trajectories and nasalization measures would show how vowel quality changes as the nasal approaches. Nasalization has spectral correlates beyond F1 and F2 (M. Y. Chen, 1997), and the timing of coarticulatory information affects the distribution of vowel and nasal cues (Beddor, 2009). Since postvocalic nasals can also affect vowel perception (Nozawa & Wayland, 2021), combining production and perception tasks would help explain which acoustic differences matter to listeners.

5. Conclusion

Among native Chinese speakers with approximately six months of Japanese study, prenasal vowel production showed overlap between /i/ and /e/ and between /ɯ/ and /o/. Group mean distances to the pooled Japanese and Mandarin references differed by vowel: /eN/ was closer to Japanese /e/ in both groups, while /ɯN/ and /aN/ in the contrast-retaining group were closer to particular Mandarin rhyme vowels. Japanese /oN/ had comparable distances to the Japanese and Mandarin vowels, and the contrast-retaining group's /iN/ comparison with [in] depended on normalization. Recording both languages from the same learners helped specify these similarities and identify vowel contrasts for Japanese pronunciation teaching.

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