Acoustic Analysis of Postvocalic /l/ in Chinese Learners of German in the Context of an Overall Perception Experiment

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Abstract

A foreign accent involves discrete phonetic features which can be acoustically analyzed. However, these phonetic features are often masked perceptually by other features, such as prosodic features. This study presents an acoustic analysis of the postvocalic /l/ in Chinese learners, as an example, and puts these results into context with a perception test, which targets the overall aspects of an audible foreign accent.

Mandarin Chinese does not allow consonant finals except /n/ and /ng/ which leads to the question, how well can Mandarin speakers of German produce a clear /l/ in syllable final position. This study investigates 490 German speech tokens with embedded postvocalic /l/ produced by 12 Mandarin speakers from three different proficiency levels, as well as two native German reference speakers. The acoustic analysis indicates that the /l/ productions of Mandarin speakers are darker than those of native Germans. No relationship could be found between darkness of /l/ and proficiency levels. The data reveals that preceding back vowels favour dark realization and vocalization of /l/.

A perception test involving the produced tokens with 10 native German listeners suggests that dark realization of /l/ contributes to foreign accent, while other factors - such as expectation and previous knowledge of listeners or overall accent strength and prosodic quality – influence the postvocalic /l/ assessment.

Index Terms: Foreign language acquisition, Chinese, German, postvocalic /l/, acoustic analysis, perception test

1. Introduction

As a lingua franca, English is taught as the first foreign language in schools in China. Most Mandarin students begin to learn German as a second foreign language at universities.

Non-native language acquisition has been generally studied in terms of second language acquisition. However, recent cross-linguistic studies have revealed that previously learnt foreign languages can also have impact on the phonetic performance of a third language, especially at the initial stage [1]. Thus we start with an analysis of the characteristics of the languages concerned.

The structure of the Chinese syllable is very simple: it ends either with a vowel or a nasal consonant /n/ or /ng/. German, however, can have consonant cluster codas of up to 4 consonants.

According to the phonetic implementation of /l/, languages can roughly be divided into three groups [2]:

(1) Languages which exhibit a strongly dark variety of /l/ in all positions, e. g. American English, Russian, Polish and Bulgarian;
(2) Languages in which larger acoustic differences occur as a function of syllable position, e.g. British English: clear [l] at word initial and dark [ɫ] at word final;
(3) Languages in which a clear [l] is reported in all syllable positions, e.g. German, Spanish and French.

Chinese learners of German do not have syllable final /l/ in their native language but they often acquire the dark realization of /l/ word finally in their first foreign language. Some students may have acquired a British accent while others may demonstrate an American accent. Both English varieties exhibit dark realization of postvocalic /l/. We are interested in their performance with regard to a German postvocalic /l/.

2. Examination Method

The following study addresses the following questions:

- Does an acquired phonetic knowledge of the dark realization of postvocalic /l/ in L2 have any phonetic transfer in learning L3 German?
- Are there any differences in /l/ realization between beginner, intermediate and advanced level learners?
- Is there any influence of the preceding vowel on the realization of the postvocalic /l/?
- Does the acoustic deviation of /l/ realization of Chinese speakers lead to foreign accent perception for native speakers?

2.1. Test database

We selected 29 different words and 3 sentences containing different V-/l/ combinations as reading material, which also facilitates the reading for beginners. Three words contain two postvocalic /l/s, resulting in 35 tokens for each subject.

2.2. Participants

The investigation includes two parts: productions of Chinese students, and perceptions of German native listeners.

The production experiment contains two male and two female speakers (age range 20-25) per level:

- Beginner level, who have learned German for 450 hours (18 weeks x 25 hours per week),
- Intermediate level, who have learned German for 900 hours (36 weeks x 25 hours per week),
- Advanced level, who are students in a German major and who have learned German for 5 years.

To obtain reference data, two female native German speakers participated in the production experiment. In the end we investigated 490 tokens (14 speakers x 35 tokens).

2.3. Data collection and analysis

The recordings were carried out in a quiet room using 16 kHz sampling frequency and 16 bit resolution. The students went through the reading list beforehand to make sure that they had no problem with the pronunciations.
The recordings were hand-labeled. Phonetic annotation and formant measurements were conducted using Praat [3]. All results were manually checked and corrected. F1 and F2 formant values were taken at the midpoint of the /l/ and vowel sounds in relatively stable formant phases.

3. Acoustic Analysis

Previous phonetic research [4, 5] suggests that darkness ought to be considered a gradual phonetic property, rather than a categorical attribute. It is commonly accepted that an increase in degree of velarization causes an F1 increase and F2 decrease, thus F2-F1 difference is inversely proportional to the degree of velarization [4]. In this study, we consider /l/ only and therefore F2-F1 as acoustic correlate of clearness/darkness, and we report on production and perception. To distinguish between the liquids /l/ and /r/, F3 was analyzed, too [6]. It has been reported that the strategies of Chinese students for dealing with German consonant codas can be divided into three categories: epenthesis, substitution and deletion [7]. An analysis of the data confirmed the findings. In the following analysis we just classify tokens with respect to realization and deletion. If realized a light [l] could be substituted by a dark [ɬ]; an additional schwa is also possible. The acoustic measurements were carried out on realizations of /l/.

3.1. Average F2-F1 difference

F2-F1 formant differences of all realized /l/ tokens were averaged for each speaker. The average values with standard deviations are presented in Figure 1:

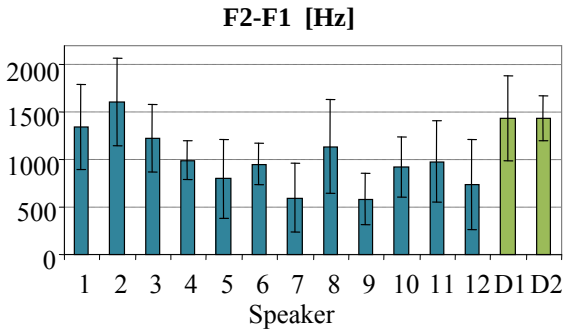

Figure 1: *Average F2-F1 difference with standard deviation (Chinese speakers 1-12 vs. German ref. speakers D1-D2).*

Except for speaker 2, all Chinese speakers have darker realization than both German speakers. Sproat & Fujimura [5] report F2–F1 measures at the midpoint of /l/ with a range from 904 Hz to 1316 Hz for 'light' productions and a range of 515 Hz to 909 Hz for 'dark' productions in high front vowel contexts. It seems that our values are comparatively higher than theirs, which may have resulted from from different linguistic contexts, and different speakers. However, we can still take this measurement as a rough reference in our analysis.

F2-F1 minima of the two German speakers are 993 Hz and 1061 Hz, which fall into the 'light' category. And four Chinese speakers have mean value between 585-799 Hz which belongs to 'dark' category. The other eight Chinese speakers with F2-F1 averages between 920-1606 Hz could be classified to 'light' area; some are slightly over the range, but they also belong to 'light' realization.

3.2. Proportion of light /l/

If the minimum threshold of light production is set at 909 Hz [5], both German speakers produce light variants of postvocalic /l/ with the lowest value of 993 Hz and 1016 Hz respectively. All Chinese speakers, however, have a variable rate of dark postvocalic /l/ production in German; the percentage of clear [l] among all 35 tokens of each speaker is illustrated in Figure 2.

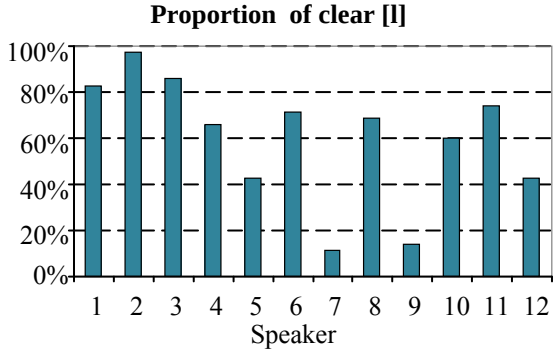

Figure 2: *Proportion of F2-F1 differences above minimal 'light' production threshold. Postvocalic /l/, chin. speakers.*

Figure 2 actually resembles Figure 1 and **it partially illustrates** the accuracy of light [l] production in German.

3.3. Language levels and production of dark /l/

If we compare the German proficiency level with the proportion of dark [ɬ] production, there seems to be no correlation between them. The Chinese speakers 1-12 (either 'm' -male or 'f' - female) were selected from different levels:

- Elementary: 3(w), 6(m), 10 (w), 12(m);
- Intermediate: 1(w), 5(m), 7(w), 8(m);
- Advanced: 2(w), 4(w), 9(m), 11(m).

Among the four "darkest producers" (7, 9, 5, 12) two speakers (5, 7) belong to the intermediate level, one (12) to elementary and one (9) to the advanced level. Three speakers (5, 9, 12) are male, and one speaker (7) is female.

3.4. Effect of preceding vowel on /l/

The previous study [5] has shown that a preceding long vowel is likely to be followed by higher levels of velarization than a preceding short vowel. The problem is that the vowel productions of Chinese students were not accurate enough to be classified into long or short groups. We thus compared all the duration values of the preceding vowel and F2-F1 values of /l/ of each speaker, the correlation coefficients of all speakers are below 0.35, including both German speakers. The vowel length effect can hardly be observed in our data.
A detailed investigation revealed that the preceding vowels before dark productions [ɬ] are usually back and mid vowels. Therefore we calculated the Pearson correlation coefficient for

F2 values of the preceding vowels and the F2-F1 of /l/s of each speaker, as shown in Table 1.

Table 1. *Correlation F2 (preceding vowel) vs. F2-F1 (/l/).*

Speaker	Pearson corr. Coeff.	p-value
1	**0.715**	**0.01**
2	**0.586**	**0.01**
3	**0.808**	**0.01**
4	**0.587**	**0.01**
5	**0.804**	**0.01**
6	0.380	0.05
7	0.340	0.05
8	**0.849**	**0.01**
9	0.202	-
10	**0.816**	**0.01**
11	**0.723**	**0.01**
12	0.460	0.05
D1	**0.491**	**0.01**
D2	**0.577**	**0.01**

F2-F1 measurements of /l/ have a high correlation with F2 values of the preceding vowels at 0.01 significance levels for 9 Chinese speakers and two German speakers. This implies a back vowel will be probably followed by a dark [ɬ], a front vowel by a light [l]. The speakers who have lower correlation coefficients are 6, 7, 9 and 12, among them 3 speakers (7, 9, 12) are those who have darkest realizations of /l/. They seem to be producing a dark /l/ word finally even after a front vowel. Dark /l/s of Chinese speakers sometimes resemble [w] or [ɤ̯], which is also defined as vocalized /l/. It has been observed in [8] that back vowels favor vocalization, and front vowels disfavor vocalization of /l/. Our results coincide with this report. For example, after high front [I] in German word *Milch* (*milk*), most speakers keep a high F2 and low F1 to produce a clear [l]. Speaker 7, however, makes more effort to lower F2 to produce a dark [ɬ]. After the back vowel [ɔ] in the German word *Golf* (*Golf*), most Chinese speakers continue to keep F2 low to produce a dark [ɬ]. A native German speaker, however, raises F2 to realize a light [l].

4. Perceptive Analysis

We presented 10 German words or phrases incl. postvocalic /l/ (*Merkmal, Floskeln, Kessels, Vollmilch, Gehalts, mithilft, Floskeln, Spielfilms, gib mir bitte mal die Zeitung, zum Schnitzel*) from 16 speakers (12 Chinese, 2 Germans, 1 Russian, 1 Turkish) in three test parts (total of 118 utterances):

(1) 16 phrases (w/o text, unknown to listener). Evaluation of intelligibility & accent strength 1-5 ('no' - 'very strong').
(2) 32 phr. (incl. text). Estimate of L1, accent strength and prosodic quality 1-5 ('excellent' to 'insufficient').
(3) 70 phr. (incl. text) from Chinese and German speakers. Evaluation of /l/ quality 1-5 ('excellent' to 'insufficient'.

The evaluation was carried out by 10 native German speakers (gender-balanced) with an average age of 43.0 +/- 12.6. Some phrases were repeated to measure the decision confidence.

4.1. Assessment of /l/ quality

In part 3 of the test, we presented ten different phrases with one or two postvocalic /l/s (81 randomly ordered tokens produced by 12 Chinese speakers and 15 tokens by German speakers). Dividing the tokens into three groups by their /l/ quality, the 12 deleted /l/ tokens receive the worst assessments (mean 4.41), and the 34 tokens with a lower F2-F1 average of 863Hz perform worse than the 35 remaining tokens (mean scores: 3.65, 2.54 respectively), as shown in Table 2.

Table 2. /l/ Assessment range versus F2-F1 difference.

Assessment range	No. of tokens	F2-F1 (mean)
1.7-3.0 (mean 2.54)	35	1210 Hz
3.1-4.6 (mean: 3.65)	34	863 Hz
4.1-4.8 (mean: 4.41)	12	Deletion

The results suggest that tokens with a better assessment are mostly lighter /l/s, and those with worse assessment are mostly darker /l/s. Some darker tokens are followed by dark vowels, and those lighter tokens with assessments below 3 are usually followed by front vowels.

4.2. Overall assessment

In addition, we examine results from parts 1 and 2 of the test. Figure 3 shows the relation between the mean perceived accent strength 1-5 ('no accent' to 'very strong') of a phrase and the proportion of 'unintelligible' judgments in part 1. The mean accent strength of 4.25 with a proportion of 70% unintelligible phrases confirms the last entry of Table 2.

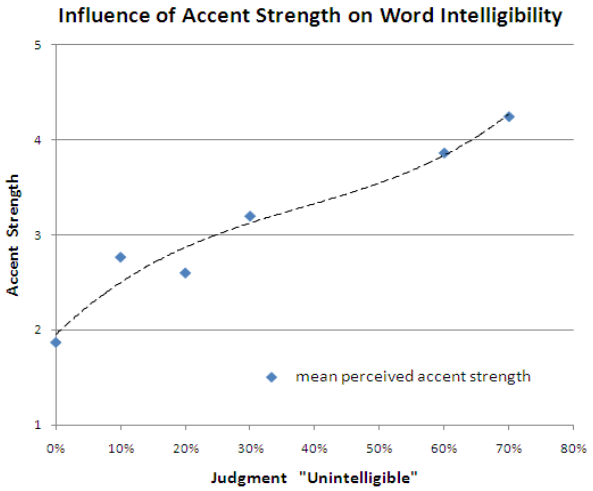

Figure 3: *Influence of accent strength on word intelligibility.*

To test the listener's perceptual adaptation to the samples, part 1 provided four different words, repeated in a cycle four times. Figure 4 shows that the unintelligibility rate decreases from 37.5% (after one word cycle) to 10.0% - while passing three more learning cycles. It is likely that this learning process influences the discrete assessment of the /l/ quality. Comparing the results of test part 2 and 3, an interaction between accent strength, prosodic quality and /l/ quality can be observed. Table 3 summarizes the correlation coefficients for the assessments of 32 tokens from part 2 (accent/prosody) plus 14 repeated tokens in part 3 (/l/ quality).

Table 3. *Accent strength, prosodic quality, /l/ quality.*

Comparison	Pearson correlation coefficient
Accent strength vs. prosodic quality	0.873
Accent strength vs. /l/ quality	0.900
Prosodic quality vs. /l/ quality	0.880

Listeners' perception of accent strength is probably affected to a high extent by prosodic deviations from the German reference. Listeners are not able to classify a postvocalic /l/ independently from prosodic quality or accent strength. The average prosodic assessment is around 18% lower, and the average /l/ assessment around 9% higher than the mean accent strength. To visualize the interrelations, the prosodic and /l/ assessments are normalized on the accent strength with the corresponding factors.

Figure 5 shows the normalized assessments of all 14 word examples which are available in both test parts 2 and 3. These examples were uttered by four Chinese speakers. The lower bars (accent strength lower than 2.0) originate from German reference speakers.

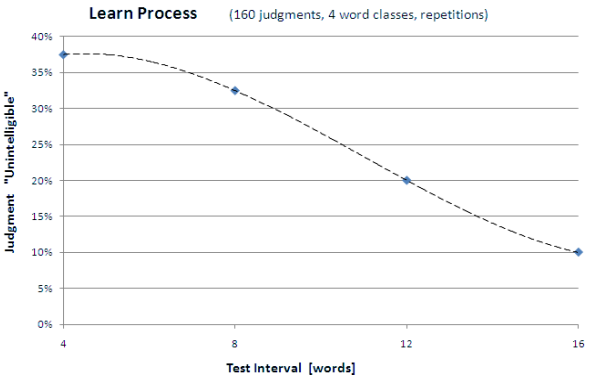

Figure 4: Perceptual adaptation ("*learn process")* *over 16 words (Test part 1 with 4 different words, repeated 4 times)*

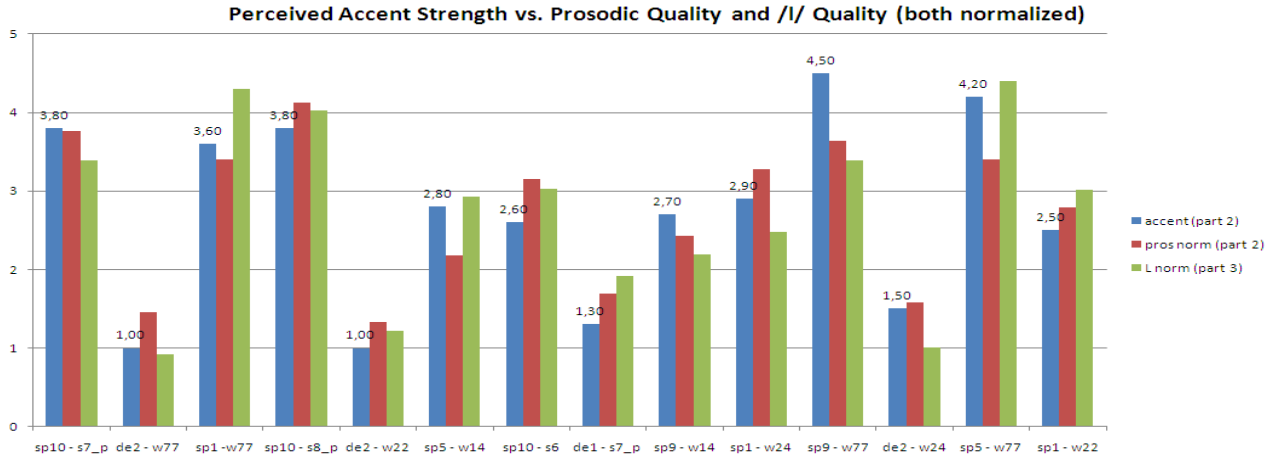

Figure 5: *Interrelation of accent strength vs. prosodic quality and /l/ quality (14 available test phrases in parts 2 and 3).*

Discussion and Conclusion

Regarding our analysis of the postvocalic /l/s, we want to summarize the following:

- Some students employ dark [l] in English at word final position instead of producing German light [l].
- The number of participants is not large enough to shed light on overall performance between different language levels but we can conclude that some beginners can produce light [l]s, and advanced learners still retain dark [ɫ]s. If beginners' errors are transferred from L2, those of advanced learners are usually from native language. Chinese CV structure also favors vocalization of syllable finals.
- Preceding back vowels favor dark [ɫ], front vowels favor light [l] in both production and perception. In terms of duration our data did not show a minimal pair contrast: the long/short vowel effect can hardly be observed.
- Deletion of postvocalic /l/s degrades the pronunciation performance considerably, darker realization of light [l] in German only results in perception of a slight foreign accent.

The discrete assessment of postvocalic /l/s contrasts with the overall results of the perception test. In particular, the listener's perceptual adaptation to the presented samples (cf. Fig. 4) but also the interrelation between accent strength, prosodic assessment and /l/ assessment are critical for the interpretation of a discrete /l/ contribution to foreign accent perception and should hence receive more attention in future.

5. References

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