

A Psycholinguistic Study of Postnuclear Glides and Coda Nasals in Mandarin

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Abstract

This paper mainly focuses on the syllable-structure status of glides in the postvocalic position and also discusses the issues of the postnuclear glide as opposed to coda nasals by examining a corpus of speech errors in Mandarin spoken in Taiwan. Evidence from speech errors shows that Mandarin displays an asymmetry in the syllable structure between glides and nasals in the postvocalic position. It further suggests that the postnuclear glides are more closely affiliated with nuclear vowels than coda nasals.

1. INTRODUCTION:

Given the centrality of the syllable in current phonological theory (Blevins 1995), it is not surprising that there has been much interest in the cognitive status of the syllable, both in terms of representation and processing (e.g., Treiman 1988, Derwing 1992). Research based on syllable structure in Mandarin or Chinese languages over the past several decades has become one of the major components of a long-overdue consideration of a controversial issue. Most researchers find evidence for an internal structure of the syllable, consisting of onset and rhyme, since the nucleus and coda of syllables are involved in errors as a unit more often than the onset and nucleus as a unit (MacKay 1972, Shattuck-Hufnagel 1983, Stemberger 1983, Anderson 1988).

Recently, the majority of related theoretical frameworks have focused on prenuclear glides, and reports of symposium on the syllable-structure status of prenuclear glides were summarized in the proceedings of the 7th International and 19th National Conferences on Chinese Phonology (e.g., Bao 2002, H. Lin 2002, Y. Lin 2002, Yip 2002, Huang 2002, Duanmu 2002, Ao 2002, Wan 2002a, and Myers 2002); however, there are a few reports in the literature which bear on the issue of the representation of postnuclear glides and nasal codas (e.g., Chung 1989, Y. Lin 1989, Bao 1990, Chiang 1992, and Wang & Kuo 2004).

The structural status of postnuclear glides and nasals in the Mandarin syllable is considered to be part of the rhyme; it assumes that a postnuclear glide and an ending nasal are both codas (i.e., C. Cheng 1973). However, evidence in some Chinese languages shows that postnuclear glides and coda nasals reveal schizophrenic

behavior as to the nucleus-coda affiliation, suggesting that postnuclear glides should be considered part of the nucleus instead of the coda (i.e., Chung 1989, Y. Lin 1989, Bao 1990, and Chiang 1992). The methodology that has been used to develop most of the phonological framework discussed here has tended to rely primarily on theory-internal consistency and speaker intuitions. Therefore, it should be noted that there is some doubt as to whether the methodological practice of such a phonological framework will allow it to reach its goal of accurately modeling the cognitive knowledge of real speakers regarding the structural representation of syllables in Mandarin.

One important source of evidence regarding the syllable has come from speech errors. Speech error studies have a long tradition of use for testing or examining the patterns and constraints observed in extensive collections of errors to argue both for the validity of phonological units as processing units, and for particular phonological theories or cognitive processing models (Fromkin 1973a, Stemberger 1983, Dell 1984, Shattuck-Hufnagel 1979, Levelt 1989, Bock & Levelt 1994). In the study of these one-time performance errors there is much support for the organizing status of the syllable in phonological processing, specifically the mapping from phonological representations to phonetic form, since in English, in segmental errors source and target elements nearly always come from identical locations in syllable; likewise syllable can be involved in errors as whole units, either as substitutions, deletions, or exchanges.

Recently, there has been much work which has attempted to determine the psychological validity of various linguistic claims ranging from the existence of certain units to the existence of particular rules. In particular, research on speech errors has been published regarding certain specific issues of the representation of Chinese languages (see Shen 1993, Chen 1993, 1999, Wan 1997, 1999, 2000, 2001, 2002b, 2003, Wan & Jaeger 1998, 2003, Yang 1997). Therefore, the purpose of this paper is to gather psycholinguistic evidence regarding co-occurrence patterns between the structural status of postnuclear glides and that of coda nasals, by looking at a corpus of speech errors made by native speakers of Mandarin spoken in Taiwan. Questions that will be addressed involve whether there is any evidence that postnuclear glides have syllable-structure status which is different from postvocalic nasals and whether postnuclear glides are more closely affiliated with nuclear vowels than with coda nasals, as listed below.

- (1) In syntagmatic errors involving substitution and exchange of a single segment, do the postnuclear glides interact more often with other glides, vowels, or consonants? That is, what kind of segments do they interact with?
- (2) In errors involving postnuclear glides, does the postnuclear glide interact more often with the onset consonant, prenuclear glide, vowel, other postnuclear glide, or coda nasal? That is, what position do they interact with?

This paper is organized as follows: in the following section there is a brief summary of the relationship between vowels and glides in Mandarin, and then lay out certain facts, including restrictions on the contextual occurrences of postnuclear glides and coda nasals. In addition, in this section, there is an investigation of two pieces of external evidence related to speech error and language games in English. In the third section, there is a presentation of the methodology for the collection of speech errors in detail. In the fourth section, the author will incorporate results of the analysis of speech-errors in terms of various competing hypotheses. In the fifth section, there is a summary of the study and a discussion of the phonological analysis which has been supported in detail in this study.

2. LITERATURE REVIEW

2.1 The relationship between vowels and glides

Mandarin is analyzed as having a range of possible phonetic syllables: V, CV, GV, VG, VN, CVG, CVN, CGV, GVG, GVN, CGVG, and CGVN. The maximal syllable is CGVX, with C a [+consonantal] segment, G a glide, V the nucleus vowel, and X either a nasal or a glide, as shown in (1).

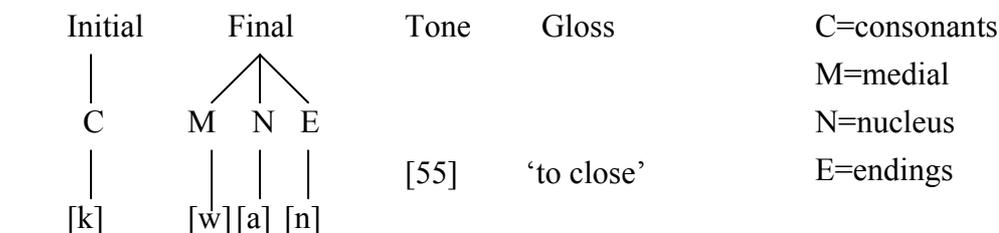
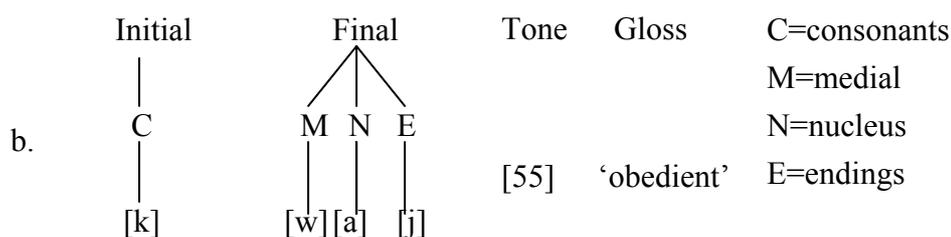
(1)

Syllable structures	Phonetic transcription	Gloss
V	[u55]	houses
CV	[ma55]	mother
GV	[ja55]	ducks
VG	[aj55]	to endure
VN	[an55]	safe
CVG	[taj55]	to stay
CVN	[tiŋ55]	tacks
CGV	[pʰjɿ55]	biased
GVG	[jɿw55]	to invite
GVN	[wan55]	to bend
CGVG	[tʰjɿw55]	to pick
CGVN	[kwan55]	to close

Traditionally, the Chinese syllable is viewed as being comprised of three parts (i.e., R. Cheng 1966, Chao 1968, C. Cheng 1973): the first part is the *initial*, which can be a consonant or a nasal; the second part is the remainder of the segmental sequence, which is labeled the *final*; and the third part is the pitch, called *tone*. Moreover, the final can be divided into three parts: the segment preceding the main vowel or nucleus is called the medial, which is a glide, and the segment following the nucleus is called the ending, which can be a glide, called a vocalic ending, or a nasal, called the consonantal ending, as illustrated in (2a, b).

(2) Mandarin syllable structure

a.



Regarding the status of prenuclear glides, a number of researchers including Bao (1990), Duanmu (1990), Y. Lin (1989, 1990) and Wan (1997, 1999, 2003) suggest that the glides are derived from the vowels in the underlying representation in Mandarin. This claim is supported by the following speech-error data (Wan, 1999),

as shown in (3)-(4).

(3) $j^{35}-y^{21} \rightarrow$
maybe

$j^{35}-i^{21}$

'maybe' \rightarrow meaningless

Example (3) shows a case where the postnuclear glide [j] is perseverated and replaces the high vocalic segment [y], and then since there is no nonhigh nuclear vowel adjacent to [j], [j] then changes to its vocalic allophone [i].

(4) $xo^{55}pu^{51}kan^{55} \rightarrow$

heat not dry

$xo^{55}pu^{51}kw^{an}^{55}$

'(the heater) does not work well' \rightarrow meaningless

Similarly, in example (4), the high vocalic segment [u] is perseverated and added after the onset [k] in the following syllable [kan]. Then since there is an adjacent nonhigh nuclear vowel [a], [u] changes to its glide allophone [w].

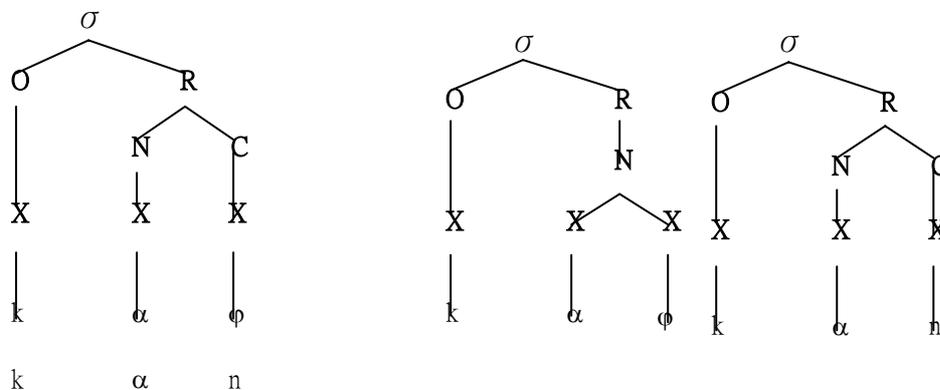
Evidence from speech-error data can support the claim that all surface glides in Mandarin come from underlying vowels since the high nuclear vowels and glides interact with each other frequently.

2.2 The structure status of postnuclear glides

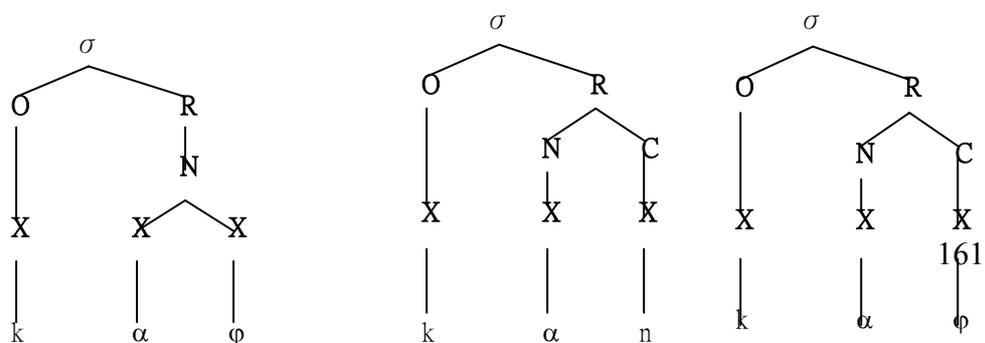
Traditional analysis treats postnuclear glides and coda nasals as in the same structure position, and the framework can be converted in terms of X-tier structure, as shown in (5a). However, if one treats postnuclear glides structurally as different from ending nasals in the postnuclear position, postnuclear glides will then be considered to be structurally part of the nucleus, and ending nasals will be treated as in the coda position, as shown in (5b).

(5) a

b



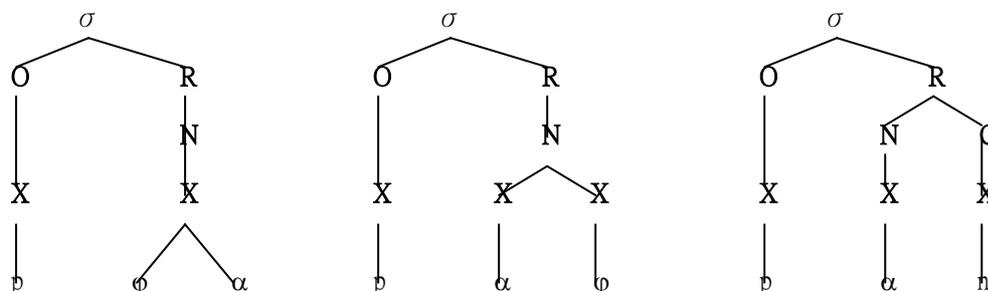
As discussed above, the traditional analysis divides the syllable structure into the initial, which is the onset consonant, and the final which includes prenuclear glides, nuclear vowels, and either postnuclear glides or nasals. This suggests that the postnuclear glide and the final nasal should both be treated as codas. However, since in the traditional analysis, all glides are predictably considered to be derived from underlying vowels, one might suggest that postnuclear glides should be a component of the nucleus.



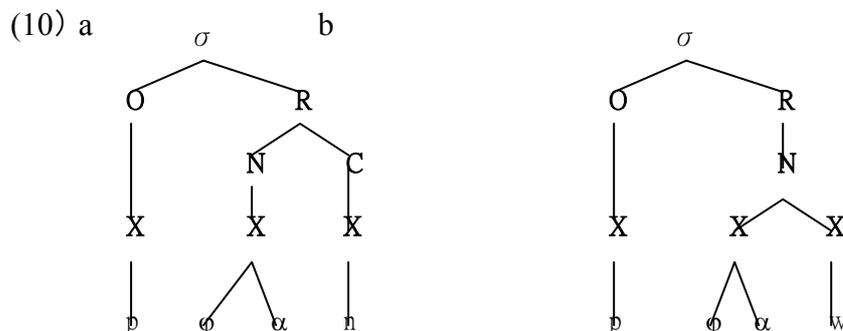
In this proposal, either the nucleus or rhyme branches can be possible in Hakka, but not both.

Chung thus proposed that there are three possible syllable structures in Hakka, as shown in (9).

(9) a. Rising diphthong b. Falling diphthong c. Branching rhyme



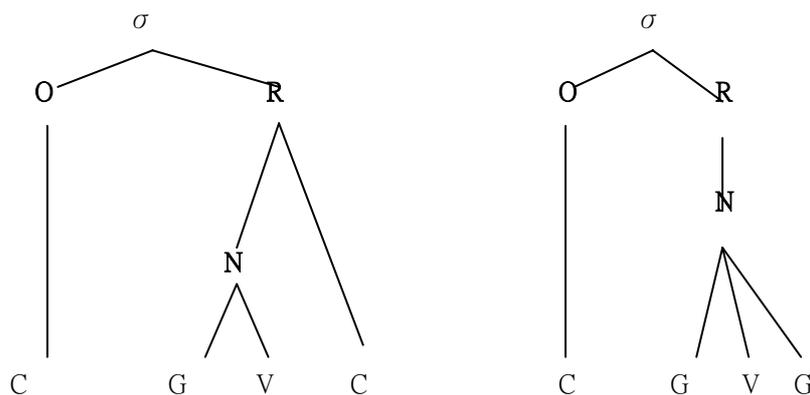
The structure in (9a) has two skeletal slots, while in (9b-c) there are three skeletal slots. Examples (9a) and (9b) have the same phonetic elements, but different phonological skeletons. The reason to posit different phonological structures for (9a) and (9b) is because Chung suggests that one to three X-slots are the only allowed skeletal slots in structure (9b), and there is no possibility of there being another skeletal slot in N (i.e. *[pajn]). Chung does not mention what a possible structure may be for a sequence such as [pjaw] or [kwan], but presumably these two other possibilities can also be accounted for by this framework, as shown in (10a-b). Note that at most three X-slots are allowed.



It is also true that in Mandarin, a sequence such as [pajn] is not possible; this is one of the reasons that in the traditional analysis, the postnuclear glide and the nasal are nearly always treated as codas, since if the postnuclear glide is treated as being in the nucleus and the nasal in the coda, a sequence such as [pajn] would be theoretically possible. Therefore, Chung's treatment would seem to solve this problem by disallowing co-occurrence of a branching nucleus and rhyme.

In summary, regarding the status of postnuclear glides, Chung (1989) proposed that postnuclear glides and postnuclear nasal consonants do not have an equal syllable-structure status. Y. Lin (1989) also suggested a similar pattern based on Taiwanese language games. Therefore, if the postnuclear glide has a greater relationship with the nuclear vowel than the nasal consonant has with the nuclear vowel, the possible structure could be proposed as follows.

(11)



Evidence from language games in Taiwanese and rhyming structure in Hakka lead Chung and Y. Lin to suggest a structure where postnuclear glides and ending nasals show asymmetrical behavior; postnuclear glides being considered as part of the nucleus instead of the coda in Taiwanese and Hakka. Therefore, the question of whether postnuclear glides and ending nasals have the same syllable-structure status in Mandarin spoken in Taiwan may follow the same pattern.

2.3 External evidence

Using speech-error data or language games (i.e., ‘external evidence’; Ohala 1986) to test phonological theories or hypotheses in English has a long tradition. For example, external evidence from language games can shed light on the structure status of syllables. Davis & Hammond (1995) argue that onglides (or prenuclear glides), [w, j] in CGV sequences in English do not exhibit symmetrical behavior through analysis of patterns found in the language game, Pig Latin. In Pig Latin, forms are derived from their corresponding English words by moving the initial consonant or consonant clusters of the English words together to the end, and adding the vowel [e] in the syllable-final position. Examples are provided as follows:

(12)	English	Pig Latin
a.	sat	[\rightarrow tse]
b.	tip	[\rightarrow ptē]
c.	criminal	[\rightarrow m★n★lkre]

Based on the output, in examples (12a-c), the initial consonant or consonant clusters have been moved together to the end; the moved consonant(s) include [s], [t], and [kr]. The following examples show the different output patterns in Pig Latin when the word begins with glides [w] and [j].

(13)	English	Pig Latin
a.	queen	[inkwe]
b.	twin	[\rightarrow ntwe]
c.	sway	[eswe]

Examples (13a-c) show that the glide [w] moves with the initial onset consonant as part of consonant clusters. However, in Pig Latin, words beginning with the glide [j] are somewhat complicated as there is dialectal variation with the output, as shown in (14).

(14)	English	Pig Latin (Dialect A)	Pig Latin
(Dialect B)			
a.	cute	[jutke]	[utke]
b.	puke	[jukpe]	[ukpe]
c.	mute	[jutme]	[utme]
d.	fuse	[juzfe]	[uzfe]

In Dialect A, the glide [j] does not move with the preceding consonant, and in Dialect B, the glide [j] does not show up in the output form.

Data from Pig Latin lead Davis & Hammond (1995) to suggest that the glide [w] and [j] in English behave asymmetrically in that the glide [w] moves with the initial onset consonant, acting more like consonants whereas the glide [j] does not move with the preceding consonant and stays in the same position, behaving more like vowels.

Fromkin (1973b) and Stemberger (1983) used data from speech errors to examine the psychological reality of postvocalic glides and consonants in English. They both found that glides and consonants do not behave in a parallel fashion postvocally in speech errors, as shown in (15-17)¹.

(15) **Thap**'s **stupid**. 'That'

Example (15) shows a case where the vowel [ɔ] and the following consonant [t] are split by the anticipation of the consonant [p] from the following word. However, fewer cases show that a vowel and the following consonant behave as a single unit, as shown in (16).

(16) **Luck Huck**y drink 'let'

In contrast, example (16) shows a case in which the whole rhyme [ɛk] of the following word is substituted for the rhyme [et]. However, the postvocalic glides nearly always move with the vowel as a single unit, as shown in (17).

(17) **how** clides 'high clouds' ([h*ai* klɪudz])

Example (17) shows a case where the vowel-glide sequences [ai] and [ɪu] exchange their position, and they move together as a whole unit.

Given the external evidence found in English, it is interesting to note that the prevocalic glides [w, j] function differently in Pig Latin. The glide [w] is treated as part of the onset, behaving more like a consonant, and the glide [j] is treated as part of the diphthong, acting more like a vowel. However, in postvocalic positions, the two glides [w, j] behave the same in speech-error data, and thus are treated as part of the diphthong whereas the postvocalic consonants are treated in coda position so postvocalic glides are not parallel to the postvocalic consonants in speech production. Most researchers in this area look at sound patterns in terms of specific theoretical viewpoints; however, using external evidence to test some phonological claims will provide more psychological validity.

3. Methodology.

The current study is based on 247 speech errors involving postnuclear glides and coda nasals, selected from a corpus of approximately 4500 speech errors collected by the author from native speakers of Mandarin spoken in Taiwan between 1995 and the present. The speech error data are derived from thousands of tape-recorded brief excerpts of natural speech. These excerpts were taken from free conversation, conference discussions, broadcasts, lectures, and interviews with students. Speech errors were collected from over 100 different speakers whose ages range from 20 to 50 years old. For each error in the corpus, the complete utterance, including self-

¹ The speech-error data in English are drawn from Stemberger (1983).

corrections, and relevant contextual information were all tape-recorded with portions were written in IPA phonetic transcription as appropriate. Thus the errors will be reported below in terms of the actual pronunciation subjects produced during the utterance of the error.

Notice that the subjects in this study are all native speakers of a dialect of Mandarin spoken in Taiwan. The main difference among subjects is that some speakers' dialects reflect a general sound change currently taking place in Taiwan, whereby the retroflex affricates [t^ɻ, t^ɻɰ, ɻ] are being lost and replaced by dental affricates [ts, ts^ɰ, s], and whereby the velar nasal following the high front vowel such as [i^ɰ] is being dropped and replaced by the dental nasal after the high front vowel such as [in]. However, certain speakers in the subject group continue to distinguish dental from retroflex affricates or to distinguish dental from velar nasals.

One might argue that obtaining such data under naturalistic conditions does not have the overriding advantage of giving insight into the psychological structures and processes actually used by native speakers in the generation of speech. Even if evidence may be derived from psychological constructs, it is not always clear at which level of analysis the speakers were operating on. In addition, the traditional methodology in collecting speech error data is to rely on the native-speaker linguist's intuitions as to what categories in the native language were heard by the native listener (Fromkin 1973a). This method is subject to a certain listener bias (Cutler 1982). In order to eliminate the context-effect applying in naturalistic speech performance, Dell & Reich (1980) and Stemberger (1985) conducted a number of experiments, trying to reduce all anticipated potential distortions that might render evidential value of the slips ambiguous. Furthermore, Mowrey & MacKay (1990) found that in speech errors induced in the laboratory by having speakers repeat 'tongue twisters' several times in succession, some phonetic differences between erroneously produced and intentionally produced consonants could be detected using electromyography. However, Stemberger (1989) gathered a naturalistic corpus to examine some issues related to speech errors in early child language production, suggesting that there should not be great differences between an experimentally elicited corpus and a natural/spontaneous corpus. In addition, Fromkin (1973b, 1980) and Ohala (1986) suggested that speech errors collected in a naturalistic setting have a cognitive validity in terms of the representation of speakers' minds during processing. Therefore, in order to prove that the perception by a native speaker that a segment was spoken with a particular sound is a more valid psycholinguistic measure than the actual phonetic properties of the utterance, Wan (1999, 2003) and Wan & Jaeger (2003) subjected several instances of erroneously produced sounds and the same sounds produced intentionally in the same environments in order to formant value analysis. It was found that there were no significant differences in analysis between the erroneously produced sounds and the same sounds produced intentionally in the same environment. Therefore, the slips collected in a naturalistic setting for this study may be taken as evidence reflecting the psychological constructs in the language structure, and the data to be discussed below are thus sufficiently reliable to provide matter for analysis.

In this paper, only those errors involving the phonological unit will be examined. Errors were classified as 'phonological' if some non-meaningful phonological units were involved such as phonetic features, single consonants or vowels, clusters of segments (including consonant clusters, rhymes, etc.), whole syllables, or tones. Phonological errors, unlike semantic errors, frequently violate lexical category and

have no semantic relationship to the target word; thus they typically produce an ungrammatical or meaningless utterance.

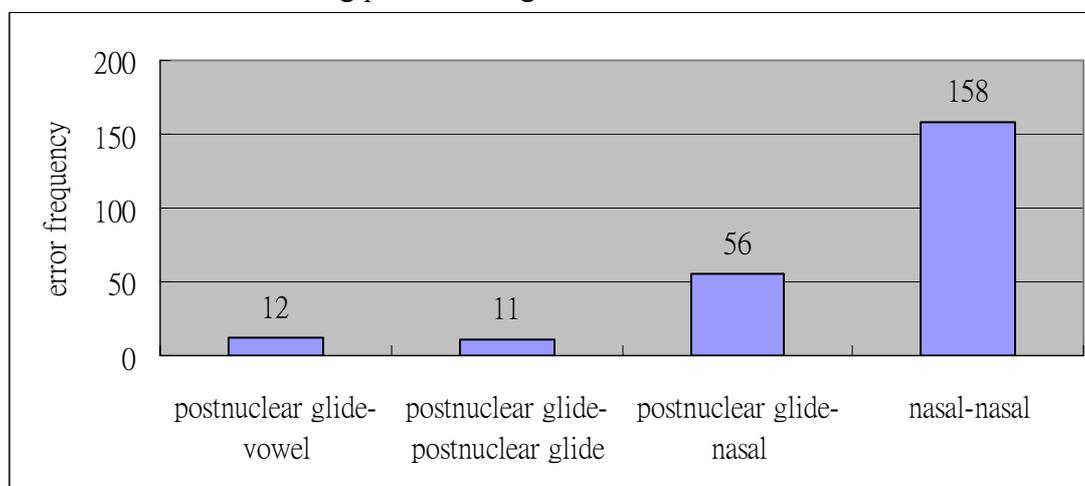
Throughout the paper, when each example of an error is presented, the first line will be the intended utterance (in surface phonetic transcription); the second line will provide a morpheme-by-morpheme gloss. The third line will be the error utterance, again in phonetic transcription, and the fourth a translation into English of the intended utterance. The element to the left of the arrow is the target, and the element to the right of the arrow is the error. A single-headed arrow indicates ‘is replaced by’, and a double-headed arrow indicates ‘exchange’. In both of the intended and error utterances, the source units and the error units will be in underlined boldface. The term ‘meaningless’ following the gloss of the intended utterance means either that the error utterance violates syntactic rules of Mandarin, or that the error utterance contains a semantic anomaly that renders it meaningless.

4. FINDINGS AND RESULTS

The main issue involving the syllable-structure status of postnuclear glides is whether they are codas, as in the traditional analysis, or are a component of the nucleus, such that the postnuclear glide and coda nasal do not have the same syllable-structure status.

Regarding the relationship between postnuclear glides and other segments in the postvocalic syllable position, there are 79 errors in the corpus involving postnuclear glide substitutions, and 158 errors involving nasal substitutions. A comparison of errors involving postnuclear glides or coda nasals is shown in the following table.

TABLE 1: Errors involving postnuclear glides or coda nasals



Chi-square tests were done to compare the frequency of the postnuclear glide-vowel, postnuclear glide-postnuclear glide, postnuclear glide-coda nasal, and nasal-nasal interactions. It was found that the error distribution among the four sub-groups of errors is significantly different ($\chi^2(3) = 241.734, P < .01$). There are in total 79 errors involving postnuclear glide substitutions. In 12 errors, a postnuclear glide interacts with a vowel, as exemplified in (18). In 11 errors, a postnuclear glide substitutes for another postnuclear glide, as exemplified in (19). In 56 errors, a postnuclear glide interacts with a coda nasal, as shown in (20).

- (18) pei51 ko55-pu51 →
 by announce
 pei51 ko55-pi51
 ‘(it was) announced’ → meaningless

In example (18), the postnuclear glide [j] is perseverated and replaces the vowel [u]. Since there is no nonhigh vowel adjacent to the glide [j], [j] is then realized as the vowel [i].

- (19) tʰw₃₅-ts₇ tsaj₅₁ tʰaj₃₅ tʰi₅₅ tʰn₅₁ →
 Tao-zi in TSMC
 tʰw₃₅-ts₇ tsaj₅₁ tʰw₃₅ tʰi₅₅ tʰn₅₁
 ‘Tao-zi (was) in TSMC’ → meaningless

In example (19), the postnuclear glide is perseverated and replaces another postnuclear glide [j], and note that the vowel [a] is phonetically realized as [ʷ].

- (20) tʰj_{n35}-i₅₅ xow₅₁-kw₂₁ →
 cause effect
 tʰj_{n35}-i₅₅ xoi₅₁-kw₂₁
 ‘cause and effect’ → meaningless

In example (20), the coda nasal [ŋ] is perseverated and replaces the coda glide [w].

One might take the 79 errors involving the postnuclear glides as evidence that the postnuclear glides and coda nasals should both be considered to be in the coda position given that the interaction between the postnuclear glide and coda nasal occurs slightly more often than the interaction between the postnuclear glide and vowel or postnuclear glide. However, of the 237 errors where a single consonant substitution occurs postvocally, there are 158 (67%) errors in which one nasal interacts with another, as exemplified in (21).

- (21) kwan₅₅ m_{n35} tʰŋ₅₅-in₅₅ tʰn₂₁ →
 close door careful little
 kwa₅₅ m_{n35} tʰŋ₅₅-in₅₅ tʰn₂₁
 ‘be careful to shut the door’ → meaningless

In example (21), the coda nasal [ŋ] is anticipated and replaces the coda nasal [n]. Note that the vowel changes to its correct allophone [ʷ]. The fact that coda nasals interact with each other much more often than with postvocalic glides suggests that nasals and glides may not have the same syllable-structure status as each other.

In summary, of 79 syntagmatic errors involving postnuclear glides, postnuclear glides interact with coda nasals in 56 errors, with the vowel in 12 errors, and with the postnuclear glide in 11 errors.

A number of error types are pertinent to the issue of the relationship between the prenuclear glide, postnuclear glide, and vowel nucleus. The following table and figure show the interaction between postnuclear glides, and vowels, prenuclear glides, coda nasals, postnuclear glides or onset consonants, with nasal-nasal and prenuclear glide-vowel interactions as a comparison.

TABLE 2: Postnuclear glides interacting with all possible elements

Postnuclear glides - vowels	N=12
Postnuclear glides - prenuclear glides	N=10
Postnuclear glides - onset consonant	N=0
Postnuclear glides - postnuclear glides	N=11
Postnuclear glides - coda nasals	N=56
Prenuclear glides - vowels	N=81
Nasal-nasal	N=158
Total	N=328

In this table, it can be shown that there are 89 errors in which postnuclear glides interact with other segments. Of 89 errors in which one of the elements is the postnuclear glide, the postnuclear glides interact with the coda nasals in 56 errors, with the vowel in 12 errors, and with the postnuclear glide in 11 errors, and with the

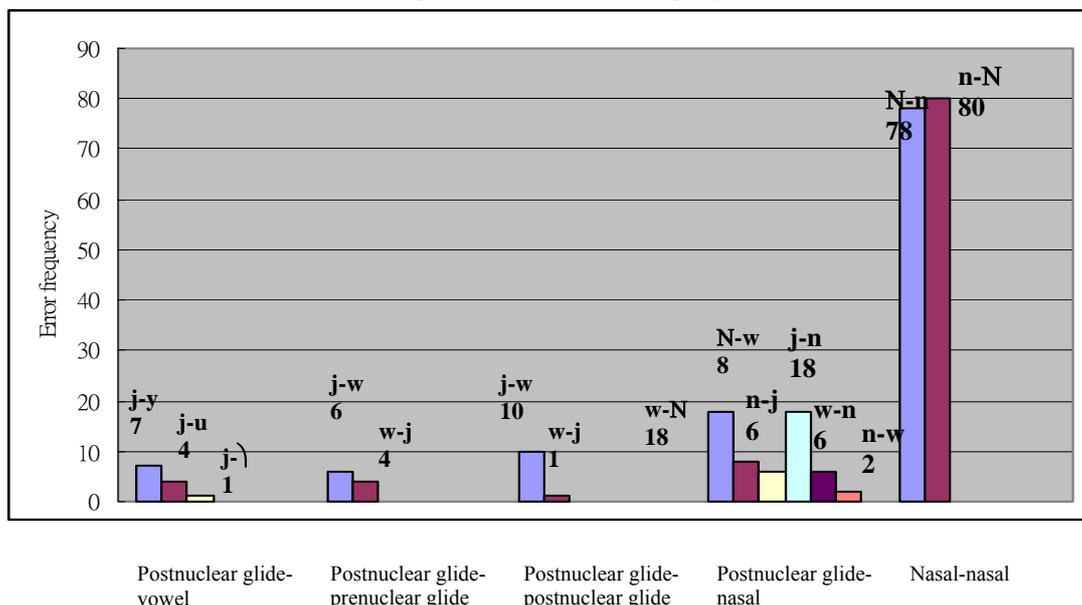
prenuclear glide in 10 errors. Based on Table 2, 81 cases show pre-nuclear glide-vowel interactions, as exemplified in (22), and only 12 cases show post-nuclear glide-vowel interactions. This may suggest that pre-nuclear glides are more closely affiliated with nuclear vowels than post-nuclear glides are in the nucleus position.

(22) tʰa55-m★n wej51-□ 35-m →
 she-PLUR why
 tʰu55-m★n wej51-□ 35-m
 ‘why did they’

Example (22) shows a case where the pre-nuclear glide [w] is anticipated and replaces the high vocalic segment [a], and then since there is no non-high nuclear vowel adjacent to [w], [w] thus changes to its vocalic allophone [u].

The following table shows details of the error distribution which falls into each sub-category.

Table 3: Error distribution falling into each sub-category

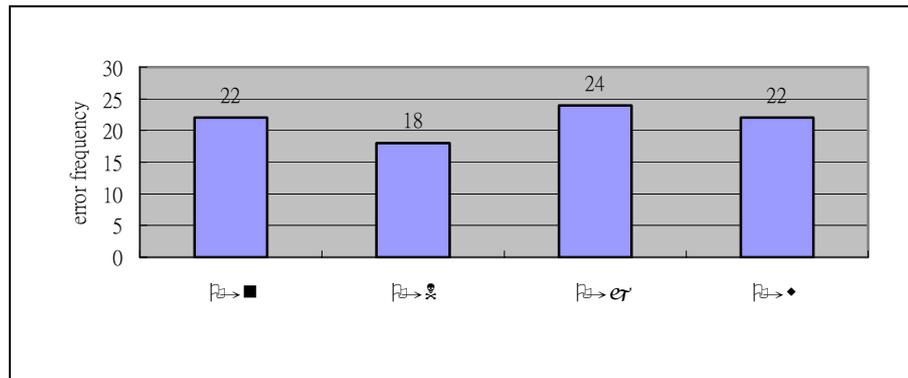


Chi-square tests along with Yate's correction for continuity were done to compare the interaction between post-nuclear glides and vowels, pre-nuclear glides, coda nasals, post-nuclear glides, or onset consonants. The results show that within the post-nuclear glide-vowel interaction, there is no significant difference among [j]-[y], [j]-[u], and [j]-[ɿ] interactions ($\chi^2(2) = 3.125, p > .01$)². Within the post-nuclear glide-prenuclear glide and post-nuclear glide-post-nuclear glide interactions, the results again show that there is no significant difference between [w]-[j] and [j]-[w] interactions ($\chi^2(1) = 0.008, p = .929$). Finally, within the nasal interactions, the results do not show a remarkably significant difference between [ŋ]-[n] and [n]-[ŋ] interactions ($\chi^2(1) = .025, p = .874$). However, within the post-nuclear glide-nasal interactions, the results show a highly significant difference among [w]-[ŋ], [ŋ]-[w], [n]-[j], [j]-[n], [w]-[n], and [n]-[w] interactions ($\chi^2(5) = 25.429, p < .01$). It is noted that phonetic units within the post-nuclear glide-nasal interactions are more significant than the other types, supporting the finding where one segment, which violates phonetic features the least, is more likely to interact with one another. Possible explanations which might be formulated to account for the results found here will be described in the following section.

² Wan & Jaeger (2003) suggest that the vowel phones [i] and [ɿ] belong to the same vowel phonemes [i]. Therefore, it is not surprising that [j]-[ɿ] interactions are found in this study.

The above data are drawn from substitution errors in the postvocalic position. The following table shows the error distribution of addition and omission errors involving the elements in a postvocalic position.

TABLE 4: Addition errors in postvocalic position



Chi-square tests were done to compare which element is more likely to be added into the postvocalic syllable position. The results show that all of the four elements [n, ɲ, j, w] are equal to be inserted in the postvocalic position in that there is no significant difference among the sub-categories ($\chi^2(3) = .884, p = .829$). The relevant examples are provided as follows.

- (23) tjən51-tɲi55 ɲi51 →
 Electrical Engineering Department
 tjən51-tɲi55 ɲi51
 ‘Department of Electrical Engineering’ → meaningless

Example (23) shows a case in which the ending nasal [n] is perseverated and added to the postvocalic position in the following syllable.

- (24) pu51 xɔ35 fa21 tɔ in55 ɲi51 →
 not suit law LINK sound system
 pu51 xɔ35 fa21 tɔ in55 ɲin51
 ‘illegal sound sequences’ → meaningless

Example (24) shows a case where the ending nasal [n] is perseverated and added to the postvocalic position in the following syllable.

- (25) ɲjɔ21 tɔa55 ta55 →
 want transfer university
 ɲjɔ21 tɔa55 ta55
 ‘(she) wants to transfer to a university from a college’

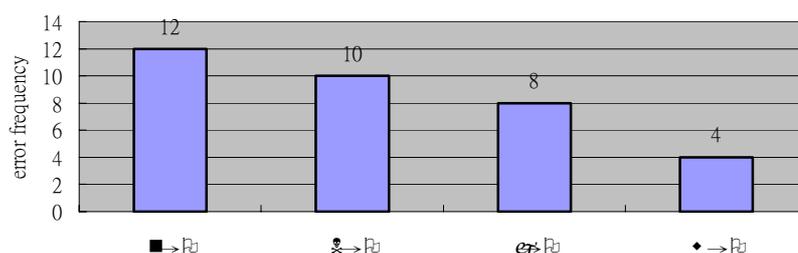
Example (25) shows an example where the prenuclear glide [j] is perseverated and added to the postvocalic position in the following syllable.

- (26) tɔa55-tjən21 tɲjw51 tɔa55 →
 almost name become
 tɔa55-tjən21 tɲjw51 tɔa55
 ‘(he was) almost named as...’ → meaningless

Example (26) shows a case in which the postnuclear glide [w] is anticipated and added to the postvocalic position in the preceding syllable, and the vowel [a] changes to its correct allophone [ɔ].

The following table shows the omission errors in a postvocalic position.

TABLE 5: Omission errors in postvocalic position



Chi-square tests were done to compare which element is easier to be deleted from a postvocalic syllable position and again there is no significant difference among the sub-categories ($\chi^2(3) = 4.118, p=.249$). The results show that all four elements have an equal opportunity to be involved in omission errors in the postvocalic position. The relevant examples are listed in (27)-(30).

- (27) k★n55 tsʔ51-tʃi21 pʰi55 →
 with self compare
 k★n55 tsʔ51-tʃi21 pʰi55
 ‘compare with yourself’ → meaningless

In example (27), the ending nasal is omitted and the resultant form [pʰi] is much more similar to the preceding syllable [tʃi].

- (28) iʔ21-mi51-ʃiʔ51 x★n21 kʷ55 →
 privacy very good
 iʔ21-mi51-ʃiʔ51 x★n21 kʷ55
 ‘(the room) is very private’ → meaningless

In example (28), the ending nasal [ʔ] is dropped from the syllable and the resultant form [ʃi] is much more similar to the preceding syllable [mi].

- (29) ʃi55-taj51 tʰa51-tan51 →
 carry bomb
 ʃi55-ta51 tʰa51-tan51
 ‘carry the bomb’

In example (29), the ending glide [j] is dropped from the syllable and the resultant form [ta] is much more similar to the following syllable [tʰa].

- (30) jow21 xwa51 xʷ21 ʰʃʔ55-ljʷʔ35 →
 have words good negotiate
 jow21 xwa51 xa21 ʰʃʔ55-ljʷʔ35
 ‘let’s talk about (this issue) nicely’

In example (30), the ending glide [w] is dropped from the syllable, and the vowel [ʷ] changes to its correct allophone [a].

Regarding the addition and omission errors, it is found that the four elements [n, ŋ, j, w] have an equal opportunity to be added or deleted in the postvocalic position. This suggests that no particular element interact more easily with one than with another; every element involved [n, ŋ, j, w] has an equal chance to be involved in the error interaction. However, when the element in the postvocalic position interacts with another element either within the same syllabic positions or in different syllabic positions, it does not show an equal rate of occurrence in substitution errors. Substitution errors favor nasal-nasal interactions over the other sub-categories, including postnuclear glide-vowel, postnuclear glide-postnuclear glide, and postnuclear glide-nasal interactions.

5. Discussion and Conclusion

Evidence from the interaction between postnuclear glides and vowels, prenuclear glides, onset consonants, postnuclear glides, and coda nasals shows that postnuclear glides do not have the same syllable-structure status as postvocalic nasals. If the postnuclear glide and ending nasal are both considered to be in the coda position, then one would expect to find that postnuclear glide-nasal interactions would occur as frequently as nasal-nasal interactions.

It is generally accepted that in speech errors, one segment is more likely to be substituted for another if they differ by fewer phonetic features, and the ‘place of articulation’ is the most commonly violated feature, whereas ‘nasality’ is rarely violated (Jaeger 1992, 2004). This property has been shown to occur in speech errors in every language for which data are available (e.g., Dell 1984, Fromkin 1973a, Fromkin 1980, Shattuck-Hufnagel & Klatt 1979, Stemberger 1983, Wan 1999). One might take such phonetic similarity as a factor to suggest that the reason that nasal interactions outnumber the other sub-categories is because the nasals [n] and [ŋ] are highly similar in terms of phonetic features, compared with [w] vs. [ŋ] and [j] vs. [n]. Nasals [n, ŋ] differentiated from each other by only one feature; that is, they are different by the place feature. However, [w] vs. [ŋ] and [j] vs. [n] differentiated from each other by one and a half features; that is, they are different by the nasality and place features, but for the place feature, they partially share the same place of articulation. Since [n] and [ŋ] are phonetically more similar from each other than [j] and [n] or [w] and [ŋ] are, phonetic similarity should be taken account as a major factor in the substitution phenomenon. In addition, based on 81 cases involving the prenuclear glide-vowel interactions and only 12 cases involving the postnuclear glide-vowel interactions, prenuclear glides are more closely affiliated with the nuclear vowel than the postnuclear glides are. These two pieces of evidence might lead one to suggest that the postnuclear glides and coda nasals are in the same position. However, if one-feature difference is the major factor enabling us to predict which phonetic elements are more likely to interact, we might expect to find great number of substitution errors involving one-feature difference in syllable-initial position. In syllable-initial position, Wan (1999) has found that 54% of the consonant pairs differentiate from each other by one feature and 46% of the consonant pairs differentiated from each other by more than one feature in Mandarin speech errors. Therefore, phonetic similarity will predict there to be a slightly higher chance of [n] vs. [ŋ] than [j] vs. [n] or [w] vs. [ŋ] interactions since [n] and [n] are differ by one feature and [j] vs. [n] or [w] vs. [ŋ] are differ by one and a half feature. However, the nasal-nasal interactions far outnumber postnuclear glide-nasal interactions by a ratio of 3 to 1 (N=158 vs. N=56). This is greater than what would be expected by chance. In addition, if one-feature difference would predict which phonetic elements are more likely to interact, the glides [j] and [w] would have more error frequencies in that they are phonetically different by one feature. However, the coda nasals interact with each other more often than the postnuclear glides interact with one another (N=158 vs. N=10), so it is unlikely that they share the same syllable-structure position. Moreover, compared with English speech errors, most examples involve the case where a vowel and the following consonant split apart, and fewer cases show that a vowel-consonant combination is substituted for another vowel-consonant combination, behaving more like a vowel-glide sequence since a vowel-glide sequence is nearly always substituted for another vowel-glide sequence. This asymmetrical behavior suggests that postvocalic consonants and postvocalic glides in English are not treated in the same coda position, and no researchers would have taken the fewer cases to support that consonants and glides in the postvocalic position

should be treated in the same syllable position in English. Therefore, the phonetic similarity is a tendency, but not the major factor to aid in predicting which phonetic elements are more likely to interact in the syllable-final position. Thus, for phonetic reasons it is likely that the nasals [n] and [ŋ], which differ only by place of articulation, would interact with each other more often than either would interact with the glides. However, this argument does not entirely explain the findings of this present study, since it would predict that postvocalic glides would interact with each other much more often than they do, and it would predict that glides would not interact often with vowels. Thus the phonetic explanation can only partially account for the findings presented under this present study.

In addition and omission errors, it is found that all the four elements [n, ŋ, j, w] have an equal chance of being added or deleted in postvocalic position. However, in substitution errors, nasal-nasal interactions are more common than postnuclear glide-nasal interactions or postnuclear glide-postnuclear glide interactions. The fact that coda nasals are involved in many more errors than are postnuclear glides indicates that the nasals are true consonants, whereas the glides behave more like vowels by being involved in fewer errors, since cross-linguistically consonantal errors are found to always outnumber vowel errors. Thus it is reasonable that postnuclear glides are more closely linked to the nucleus than to the coda position.

In summary, coda nasals interact with each other in 158 errors, which is much more frequently than the 56 errors in which they interact with postnuclear glides. The fact that coda nasals are involved in many more errors than postnuclear glides indicates that the nasals are true consonants, whereas the glides behave more like vowels by being involved in comparatively few errors. Postnuclear glides interact with other glides or vowels in 33 cases (12 errors in postnuclear glide-vowel, 10 errors in postnuclear glide-prenuclear glide, and 11 errors in postnuclear glide-postnuclear glide interactions), and this finding supports an analysis in which postnuclear glides are derived from vowels, and remained affiliated with the vowel in phonetic form as the right branch of the nucleus.

In conclusion, the psychological reality of postvocalic glides in speech errors in Mandarin can best be accounted for by assuming that these glides are derived from underlying vowels. Although they occur in the same postvocalic position as coda nasals, they are not as robustly associated with the coda structure as nasals are, in that they retain some association with the nuclear vowel. These data support the hypothesis that postnuclear glides in Mandarin form a structural constituent with the nuclear vowel, and are in fact situated at the right-most branch of the nucleus.

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