ISSN 1798-4769
Journal of Language Teaching and Research, Vol. 13, No. 3, pp. 541-549, May 2022
DOI: https://doi.org/10.17507/jltr.1303.10

Integration of Perceptual Similarity With Faithful Mapping of Phonological Contrast in Loanword Adaptation: Mandarin Chinese Adaptation of English Stops

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***Abstract*—In loanword phonology, perceptual similarity and faithful mapping of phonological contrast are two main factors which influence loanword adaptation. Previous studies observe that English phonological voicing contrast is mapped to Mandarin Chinese (hereafter, Mandarin) phonological aspiration contrast, indicating faithful mapping of phonological contrast. Nevertheless, the role of perceptual similarity in adaptation of English stops to Mandarin has not been fully explored. The current study investigates the influence of perceptual similarity on loanword adaptation by examining how English voiced and voiceless stops are adapted in Mandarin Chinese using a data set of 1427 novel Mandarin loanwords from English. The results show consistent adaptation of English voiced stops as Mandarin unaspirated stops and English aspirated voiceless stops as Mandarin aspirated ones, while inconsistent adaptation patterns are found for the English unaspirated voiceless stops. In particular, English post-/s/ unaspirated voiceless stops which occupy a similar voice onset time (VOT) region to Mandarin unaspirated stops are adapted as Mandarin unaspirated ones, whereas the rest are mapped to aspirated stops in Mandarin. The overall adaptation patterns provide partial support to faithful mapping of phonological contrast and provide robust evidence for an integration of perceptual similarity with faithful mapping of phonological contrast in loanword adaptation.**

***Index Terms*—loanwords, consonant adaptation, Mandarin Chinese, perceptual similarity, phonological contrast**

I. Introduction

When a word is borrowed by one language (the borrowing language) from another language (the donor language), sound adaptation of the word must conform to the segmental inventory, prosodic patterns and phonotactic constraints of adapters' native language while trying to maintain faithfulness to the words in the donor language (Kenstowicz & Suchato, 2006).

Various accounts have been put forward with regard to the ways in which loanwords are adapted. Currently, three main approaches have been proposed, namely the phonological approach (e.g. Jacobs & Gussenhoven, 2000), the perceptual approach (e.g. Boersma & Hamann, 2009; Peperkamp & Dupoux, 2003) and the phonetics-phonology approach (e.g. Yip, 1993, 2006). The major difference between the first two approaches lies in whether the foreign inputs to adaptation are processed at the phonological level to maintain faithful mapping of phonological contrast, or at the perceptual level where perceptual similarity matters. Taking an intermediate position, the third approach integrates perceptual similarity with phonological contrast to obtain the best match of the foreign inputs in adaptation.

In the current study, we examine how a native speaker of Mandarin Chinese (hereafter, Mandarin) adapts English voiced and voiceless stops, aiming to investigate the influence of perceptual similarity on loanword adaptation revealed by the adaptation patterns of English stops to Mandarin. We use a new and larger data set of Mandarin loanwords from English than those in previous studies which mainly collected a limited number of established Mandarin loanwords from English in dictionaries.

In the segmental inventory of English, there are three pairs of stop phonemes /p, b/[1], /t, d/ and /k, g/. The oppositions within each pair are distinguished by the distinctive feature of voicing. In different contexts, the voiceless stops are either aspirated or unaspirated. Aspiration, meaning "voiceless interval consisting of strongly expelled breath between the release of the plosive and the onset of a following vowel" (Cruttenden, 2014, p.163), is a nondistinctive feature in

[1] Slash brackets / / are used to refer to underlying or phonological representations of sounds while square brackets [ ] represent the surface forms (phonetic realisation) of the sounds.

English but a distinctive one in Mandarin (Table 1). With regard to voice onset time (VOT), which is "the interval between the release burst and the onset of voicing" (Cruttenden, 2014, p.164), English post-/s/ unaspirated voiceless stops occupy a similar VOT region to Mandarin unaspirated stops.

TABLE 1
DIFFERENCE IN PHONOLOGICAL CONTRAST AND PHONETIC SIMILARITY BETWEEN ENGLISH AND MANDARIN STOPS

	[±voice]	[±aspirated]	Phonetic similarity
English	• ***phonological contrast*** • voiceless vs. voiced • e.g. **p**ie /**p**aɪ/ vs. **b**uy /**b**aɪ/	• ***allophonic variation*** depending on different contexts • allophones for English voiceless stops • e.g. **p**ot [**p**^{h}ɔt], su**p**er ['su.**p**ə], s**p**y [s**p**aɪ]	Similar VOT values between English post-/s/ unaspirated voiceless stops and Mandarin unaspirated stops
Mandarin	(not applicable)	• ***phonological contrast*** • aspirated vs. unaspirated • e.g. 塔 [**t**^{h}ǎ] "tower" vs. 打 [**t**ǎ] "to beat"	

Note: post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"

The different phonological contrasts between English and Mandarin stops, and neutralised distinction between English unaspirated voiceless stops and Mandarin unaspirated stops in terms of perceptual similarity, warrant examination from the perspective of the three approaches which differ in what kind of information matters in loanword adaptation. In particular, Mandarin has a phonological aspiration contrast, whereas in English voicing is a phonologically contrastive feature and aspiration is a nondistinctive feature. Paradis and Tremblay (2009) find a consistent mapping of English phonological voicing contrast to Mandarin phonological aspiration contrast in adaptation of English stops to Mandarin, supporting the phonological approach. Kim (2012) and Hui and Oh (2015), however, report a few observations of adapting English unaspirated stops to Mandarin unaspirated ones, indicating that perceptual similarity plays a role.

The current study extends the previous research in that we not only examine the general adaptation patterns for English voiced and voiceless stops to Mandarin, but also separate English unaspirated voiceless stops by different surrounding contexts into post-/s/ and single stops to further explore the issue of perceptual similarity and phonological contrast in loanword adaptation.

II. BACKGROUND

This section first introduces three major approaches regarding the ways in which loanwords are adapted. Next, the phonological features and phonetic properties of English and Mandarin stops are introduced. On the basis of previous studies, research questions of the study are proposed.

A. Approaches to Loanword Adaptation

1. The Phonological Approach

Jacobs and Gussenhoven (2000) argue for a "universal phonological vocabulary" that native grammar of the hearers of a language plays a crucial role in adaptation of foreign segments. For instance, native speakers of Cantonese (a dialect of Chinese) perceive the voiced stop coda /b/ in the English word "club" /klʌb/, but they just don't allow [+voice] in their native language. Paradis and Tremblay (2009), in favour of the phonological approach, report that English voiceless stops are adapted as Mandarin aspirated voiceless stops regardless of aspiration. They conclude that English stop aspiration which is a phonetic cue doesn't influence Mandarin phoneme categorisation. Stress-to-tone mapping of Mandarin loanwords from English is also found "to be constrained by tonal feature model of native phonology, while acoustic similarity plays a very limited role" (Li, 2017). In short, according to the phonological approach, speakers of the borrowing language identify segmental contrasts in the donor language as phonologically equivalent sounds in their native language that stand for similar contrasts.

2. The Perceptual Approach

On the other hand, Silverman (1992) proposes "Perceptual Level" and "Operative Level" for the rule-based account of loanword phonology. At the Perceptual Level, the inputs are not processed at the phonological level but have a phonetic status that conforms to the borrowing language's segments and tones. For instance, English stop aspiration is predictable and hence it is not in the underlying representation but in the phonetic form. Because of perceptual similarity in aspiration, English "pie" [p^{h}aɪ] is adapted into [p^{h}ay] in Cantonese while English "motor" ['məʊ.tə] into Cantonese [mɔ.ta]. In other words, the adapters process the inputs based on aspiration which is phonemic in Cantonese. In addition, Silverman (1992) notes that less salient segments are deleted because they are less likely to be detected than the salient ones at the Perceptual Level. Furthermore, Peperkamp and Dupoux (2003) state that the adaptation of an illicit input follows an idea of "phonetically minimal transformation" where phonetic distance matters. Paradis and Tremblay (2009), though argue against the perceptual approach, admit that the perceptual approach correctly predicts the adaptation of English voiced stops as Mandarin unaspirated ones based on similar VOT regions between them. To sum up, according to the perceptual approach, speakers of the borrowing language map the sounds in the donor

language to the perceptually closest ones in their native language and faithful mapping of phonological contrast does not play a role.

3. The Phonetics-phonology Approach

Neither the phonological nor perceptual approach is sufficient to explain variable loanword adaptation. Alternatively, the phonetics-phonology approach believes that both perceptual and phonological factors matter in loanword adaptation and tries to integrate perceptual similarity with phonological equivalence. Silverman (1992) favours the perceptual approach but proposes that perceptual similarity is within the scope of the borrowing language's phonology. Yip (2006) notes that perception alone can't explain loanword adaptation and grammatical factors also play a role. The loanword adaptation model in Yip (2006) is "L2 source → Perceptual module → non-native percept → L1 grammar → Adapted loanword". Moreover, Hsieh et al. (2009) also argue that perceptual salience forms an important dimension of phonological faithfulness. Furthermore, perceptual similarity seems to be mediated by phonological system of the adapters. Kang and Schertz (2021) investigate the role of Korean listeners' phonological knowledge of a non-native language in cross-language mapping and find that though they are sensitive to perceptual similarity between the foreign input and native output, their loanword adaptation is constrained by "the (perceived) phonological categories of the [non-native] input". In a study of Mandarin loanwords from English, Chen and Lu (2020) investigate the effects of vowel duration, syllable duration and nasalization on loanword adaptation and report that phonotactic constraints play a more crucial role than phonetic cues do in accounting for adaptation of singleton nasals over nasal geminates.

In a nutshell, the phonological approach argues that the inputs of adaptation come from underlying representation in the donor language, namely the phonological contrast. The perceptual approach claims that the inputs are phonetic details and emphasises perceptual salience of segments. Yet neither of the two approaches can perfectly predict patterns of loanword adaptation. An intermediate approach is thus proposed that both perceptual similarity and phonological contrast in adapters' language play important roles in loanword adaptation.

B. English and Mandarin Stops

Differences in segmental inventory and similarities in phonetic properties between English and Mandarin stops will be introduced below, which can provide a window into the investigation of the influence of perceptual similarity on adapters' phonemic categorisation in loanword adaptation.

1. Phonological Features of Stops in English and Mandarin

English stops are categorised according to voicing and the place of articulation, namely labial voiceless /p/ and voiced /b/, dental voiceless /t/ and voiced /d/ and velar voiceless /k/ and voiced /g/ (Table 2). Voicing is contrastive in English such that a voiceless stop and a voiced stop are two phonemes in the same place of articulation. For example, /t/ and /d/ are two phonemes in English and contrast word meanings like "tuck" /tʌk/ versus "duck" /dʌk/.

TABLE 2
INVENTORY OF ENGLISH CONSONANTS (GIEGERICH, 1992, P.41)

Labial	Dental	Velar
p b	t d	k g

Note: voiceless phonemes on the left and voiced ones on the right within a cell

For each voiceless stop, there is a classification of aspiration. Aspirated and unaspirated allophones of the English voiceless stops do not contrast word meanings and only differ in phonetic manifestation. The environment for aspirated stops is either (1) at the beginning of a syllable and before a stressed nucleus, e.g. [pʰ] in the word "companion" [kʰəm.'pʰæ.njən] or (2) at the beginning of a word, e.g. [pʰ] in the word "pot" [pʰɔt] (Rogers, 2013, p.50), whereas unaspirated stops are found in other contexts such as before an unstressed nucleus or after the fricative /s/ (Hayes, 2009, p.122), e.g. [p] in the word "super" ['su.pə] and the word "spy" [spaɪ], respectively (Table 3).

TABLE 3
ALLOPHONES FOR ENGLISH VOICELESS STOPS (CRUTTENDEN, 2014, P.173)

Context	[±aspiration]	Example
Syllable initial, accented	aspirated	**p**ot [pʰɔt]
Syllable initial or final, unaccented	unaspirated to slightly aspirated	su**p**er ['su.pə]
Post-/s/, accented	unaspirated	s**p**y [spaɪ]

Note: post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"

In Mandarin, all the stops are voiceless and are categorised according to aspiration and the place of articulation (Table 4). The two phonemes /t/ and /tʰ/ can distinguish words carrying the same lexical tone, 塔 /tʰǎ/ "tower" and 打 /tǎ/ "to beat", whereas the sounds [t] and [tʰ] which belong to the same phoneme /t/ in English do not contrast word meanings.

TABLE 4
INVENTORY OF MANDARIN CONSONANTS (DUANMU, 2007, P.26)

Labial	Dental	Velar
p pʰ	t tʰ	k kʰ

Note: unaspirated phonemes on the left and aspirated ones on the right within a cell

2. Phonetic Properties of English and Mandarin Stops

Acoustically, an aspirated stop has a long positive VOT and an unaspirated stop a short VOT in English (Table 5). Among unaspirated voiceless stops, syllable-initial post-/s/ stops show similar VOTs to voiced stops (Cho et al., 2014). On the other hand, VOTs of single unaspirated voiceless stops preceding an unstressed vowel are slightly longer than those of post-/s/ stops (Antoniou et al., 2010). For instance, [p] in the word "super" ['su.pə] has a longer VOT than that in the /sC/ clusters in the word "spy" [spaɪ]. With regard to places of articulation, labial stops have shorter VOTs than those of dental stops which are shorter than those of velar ones (Menyuk & Klatt, 1975).

TABLE 5
MEAN VOTS (MS) OF ENGLISH STOPS IN THE LITERATURE (JONES & MEAKINS, 2013; KLATT, 1975)

	voiced			voiceless					
	[b]	[d]	[g]	[p]	[t]	[k]	[pʰ]	[tʰ]	[kʰ]
single	11	17	27	22	38	39	47	65	70
post-/s/	n.a.	n.a.	n.a.	12	23	30	n.a.	n.a.	n.a.

Note: single stops = single stops before an unstressed vowel, such as [p] in "super"; post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"; n.a. = not applicable

Furthermore, English and Mandarin stops fall in the similar VOT regions. The VOT values of English voiced stops and unaspirated voiceless stops are similar to those of Mandarin unaspirated stops while VOTs of English aspirated stops are relatively shorter than those of Mandarin aspirated stops (Tables 6 and Fig 1).

TABLE 6
MEAN VOTS (MS) OF MANDARIN STOPS (RAN & SHI, 2007)

unaspirated			aspirated		
[p]	[t]	[k]	[pʰ]	[tʰ]	[kʰ]
13	14	30	106	104	112

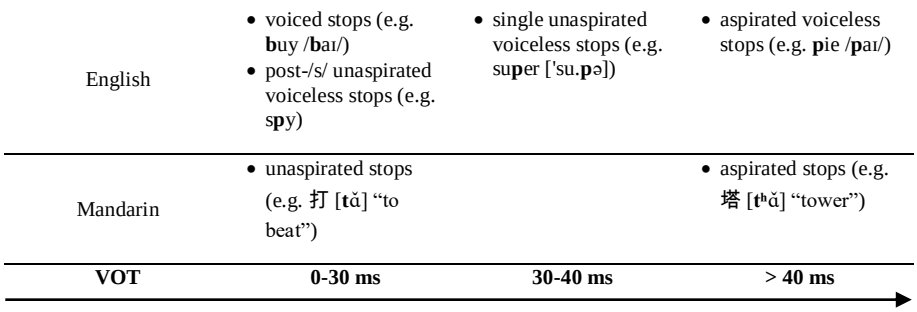

Figure 1. Comparison of VOTs of Stops in English and Mandarin

In sum, there exists an overlap of VOTs between voiced stops and post-/s/ stops in English as well as similarity in VOTs between English and Mandarin stops. Thus, the current study collects a new and larger novel loanword data set to investigate the influence of perceptual similarity on adapting English words into Mandarin, from the perspective of the three approaches to loanword adaptation.

C. Research Questions

Three specific research questions will be addressed:

(1) Is voiceless-vs-voiced contrast for English stops adapted as aspirated-vs-unaspirated stops for Mandarin? (If yes, it supports the phonological approach which favours faithful mapping of phonological contrast.)

(2) Are English aspirated and unaspirated voiceless stops adapted as Mandarin aspirated and unaspirated stops respectively? (If yes, it supports the perceptual approach which favours perceptual similarity and disfavours faithful mapping of phonological contrast.)

(3) Is voiceless-vs-voiced contrast for English stops adapted as aspirated-vs-unaspirated stops for Mandarin, with an exception that English unaspirated voiceless stops with two different surrounding contexts (post-/s/ and single) are adapted as different segments in Mandarin? (If yes, it supports the phonetics-phonology approach which integrates perceptual similarity with faithful mapping of phonological contrast.)

III. METHOD

A. Data Collection

The source of the data is a vocabulary book covering English vocabulary written and released by a user at www.topsage.com, an online education resources sharing forum in China. The book includes the English vocabulary in secondary school textbooks in China. The author made an adaptation form on each word from English to Mandarin to help readers (secondary school students in China) to memorise English pronunciations and word meanings in the following way:

English word: spider
Mandarin sentence: **四伯的**儿子花四百块钱买了一只蜘蛛。
Pinyin: **si.bo de** er.zi hua si.bai.kuai.qian mai.le yi.zhi zhi.zhu
IPA: **szz.p^{w}oo tɤɤ** ər.tszz x^{w}aa szz.pai.k^{hw}ai.tɕ^{h}an mai.lɤɤ jii.tʂrr tʂrr.tʂ^{w}uu
Gloss: **fourth uncle of** son pay four hundred buy one spider
English sentence: "The son of the fourth uncle pays four hundred for a spider."

The novel Mandarin loanwords from English in the data set are nonwords and are rarely used in real life, which means most of them are not found in formal loanword corpora or dictionaries containing established loanwords such as Mandarin loanwords from English brand names. Therefore, it provides new data for Mandarin loanwords from English which is less affected by non-phonological factors such as analogy (Paradis & Tremblay, 2009).

The data set consists of 1465 stops in 1427 Mandarin loanwords from English after removing irrelevant words. The novel words which were not adapted solely on the English pronunciation were not relevant to this study, and hence were not included. There were 645 (44%) aspirated voiceless stops, 301 (20%) unaspirated voiceless stops and 519 (36%) voiced stops. The procedures of processing each English word and its made-up Mandarin word are as follows.

English words were automatically transcribed in International Phonetic Alphabet (IPA) by one of the largest online dictionary service providers "youdao.com" using *The 21st Century Unabridged English-Chinese Dictionary* (Li, 2003). Pinyin was added on the Mandarin words and segments were transcribed in IPA based on the phonological forms of Mandarin syllables in Duanmu (2007).

B. Different Predictions by the Three Approaches

The three approaches predict different adaptation patterns of English stops to Mandarin. The predictions are as follows (See Figures. 2-4). We expect that the data set will provide evidence to support one or more of the predictions.

(1) The phonological approach predicts the mapping of English phonological voicing contrast to Mandarin phonological aspiration contrast. For instance, both English [p] and [p^{h}] are adapted as Mandarin [p^{h}] and English [b] is adapted as Mandarin [p].

(2) The perceptual approach predicts the mapping of English stops to Mandarin stops based on perceptual similarity and perceptual salience, regardless of faithful mapping of phonological contrast. For instance, English [p^{h}] is adapted as Mandarin [p^{h}], whereas English [p] is adapted as Mandarin [p]. English [b] is adapted as Mandarin [p] as well.

(3) The phonetics-phonology approach predicts the mapping of English phonological voicing contrast to Mandarin phonological aspiration contrast while perceptual similarity plays a role in salient context such as post-/s/ stops. For instance, English [p^{h}] is adapted as Mandarin [p^{h}]. English single [p] preceding an unstressed vowel or at a syllable-final position is adapted as [p^{h}] as well, whereas [p] in /sC/ clusters is adapted as Mandarin [p]. English [b] is also adapted as Mandarin [p].

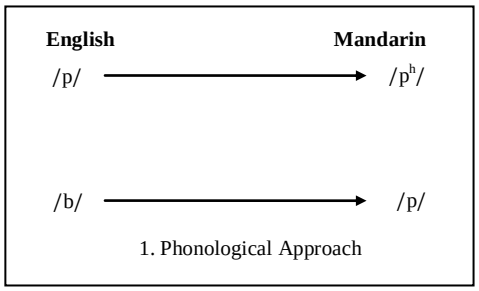

Figure 2. Predictions of Adaptation of English Stops Into Mandarin by the Phonological Approach

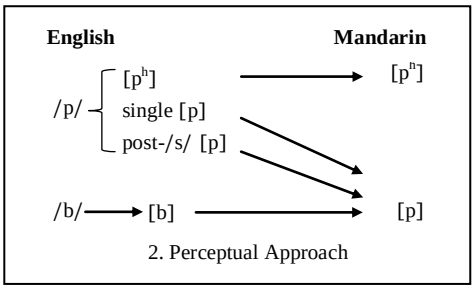

Figure 3. Predictions of Adaptation of English Stops into Mandarin by the Perceptual Approach.
Note: single stops = single stops before an unstressed vowel or at a syllable-final position, such as [p] in "super"; post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"

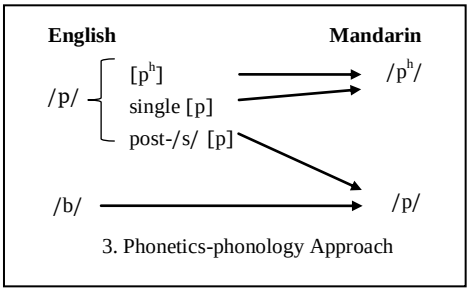

Figure 4. Predictions of Adaptation of English Stops Into Mandarin by the Phonetics-phonology Approach.
Note: single stops = single stops before an unstressed vowel or at a syllable-final position, such as [p] in "super"; post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"

IV. Results

A. General Adaptation Patterns of English Voiced and Voiceless Stops

As shown in Table 7, English aspirated voiceless stops are all adapted as Mandarin aspirated ones, and English voiced stops are all adapted as Mandarin unaspirated voiceless stops. English unaspirated voiceless stops are more often adapted as Mandarin aspirated stops than unaspirated stops, implying a less significant role of perceptual similarity. Nonetheless, there is still inconsistent adaptation of English unaspirated voiceless stops. Chi-square tests were conducted to compare the number of words being adapted as aspirated stops and the number of words being adapted as unaspirated stops in Mandarin. There are significant differences between the two adaptation patterns across different English stops.

TABLE 7
NUMBER OF ASPIRATED AND UNASPIRATED STOPS IN MANDARIN ADAPTED FROM ENGLISH STOPS

	Voiceless stops in English		Voiced stops in English
	aspirated	unaspirated	
Aspirated stops in Mandarin	301 (100%)	536 (83%)	0
Unaspirated stops in Mandarin	0	109 (17%)	519 (100%)
Sum	301	645	519
Chi-square	$\chi^2 = 301$, df = 1, $p < .001$	$\chi^2 = 282.7$, df = 1, $p < .001$	$\chi^2 = 519$, df = 1, $p < .001$

Examples of the adaptation patterns for English voiced and voiceless stops are listed in Table 8. For the adaptation of English unaspirated voiceless stops, the two distinct patterns are found where the pre-unstress single stop in (2) and the post-/s/ stop in (3) are adapted as the aspirated and unaspirated stops in Mandarin respectively. It appears that different surrounding contexts may affect the adaptation of English unaspirated voiceless stops.

TABLE 8
ADAPTATION OF ENGLISH STOPS TO MANDARIN

	Adaptation	English word	Context	IPA	Mandarin word	IPA
(1)	[pʰ] → [pʰ]	**p**ublish	accented	['**pʰ**ʌb.lɪ̞ʃ]	怕薄利士	[**pʰ**aa pʷoo lʲii ʂrr]
(2)	[p] → [pʰ]	car**pet**	single	['kɑː.**p**it]	卡**皮**特	[ka **pʰʲ**ii tʰɤɤ]
(3)	[p] → [p]	s**p**ot	post-/s/	[s**p**ɔt]	石**宝**他	[ʂrr **p**au tʰaa]
(4)	[b] → [p]	**b**itter	n.a.	['**b**i.tə]	**比**他	[**p**ii tʰaa]

Note: single stops = single stops before an unstressed vowel, such as [p] in "super"; post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"; n.a. = not applicable

B. Adaptation of Single and Post-/s/ English Unaspirated Voiceless Stops

A closer examination of adaptation of English unaspirated voiceless stops with different surrounding contexts shows two distinct patterns. English post-/s/ stops in /sC/ clusters, such as [sp] in "spy", mostly yield unaspirated adaptation as Mandarin [p], whereas single stops before an unstressed vowel or at a syllable-final position, such as [p] in "super", tend to be adapted as the Mandarin aspirated stop [p^h] (Table 9). Chi-square tests reveal that the number of words being adapted as aspirated stops and the number of words being adapted as unaspirated stops are significantly different across surrounding contexts and places of articulation.

Since the VOT of a post-/s/ stop is relatively shorter than that of a single stop, the two distinct patterns imply the role of perceptual similarity in mapping post-/s/ stops to Mandarin unaspirated ones while single stops to Mandarin aspirated ones. Furthermore, the English unaspirated voiceless stops in the two types of structures have identical features of [+aspiration] and [-voice], indicating that perceptual similarity overrides the faithful mapping of phonological contrast in the adaptation of English unaspirated voiceless stops in Mandarin.

Among the three English post-/s/ unaspirated voiceless stops, the percentage of being adapted as Mandarin aspirated stops increases as the place of articulation for the stops goes from labial to velar.

TABLE 9
NUMBER OF ASPIRATED AND UNASPIRATED STOPS IN MANDARIN ADAPTED FROM ENGLISH UNASPIRATED VOICELESS STOPS

	[p]		[t]		[k]	
	single	post-/s/	single	post-/s/	single	post-/s/
Aspirated stops in Mandarin	79 (98%)	0	277 (98%)	6 (12%)	170 (98%)	4 (17%)
Unaspirated stops in Mandarin	2 (2%)	34 (100%)	7 (2%)	43 (88%)	4 (2%)	19 (83%)
Sum	81	34	284	49	174	23
Chi-square	$\chi^2 = 73.2$, df = 1, $p<.001$	$\chi^2 = 34$, df = 1, $p<.001$	$\chi^2 = 256.7$, df = 1, $p<.001$	$\chi^2 = 27.94$, df = 1, $p<.001$	$\chi^2 = 158.4$, df = 1, $p<.001$	$\chi^2 = 9.8$, df = 1, $p<.01$

Note: single stops = single stops before an unstressed vowel or at a syllable-final position, such as [p] in "super"; post-/s/ stops = stops in /sC/ clusters such as [sp] in "spy"

V. DISCUSSION

The current study examined the adaptation patterns of English words into Mandarin based upon novel Mandarin loanwords from English, aiming to investigate the influence of perceptual similarity on loanword adaptation. Overall, the results reject the perceptual approach but provide partial support to the phonological approach and provide robust evidence for the phonetics-phonological approach.

The answer to the first research question is partly YES. The results show that English voiced stops [b, d, g], and English aspirated voiceless stops [p^h, t^h, k^h] are adapted as Mandarin unaspirated and aspirated stops respectively, indicating the partial preservation of phonological contrast.

The answer to the second research question is NO. There is no consistent adaptation of English aspirated voiceless stops to Mandarin aspirated ones and English unaspirated voiceless stops to Mandarin unaspirated ones.

The answer to the third research question is YES. English unaspirated voiceless stops [p, t, k], however, are either adapted as Mandarin aspirated or unaspirated stops, suggesting integration of perceptual similarity with faithful mapping of phonological contrast. Compared with the unaspirated segments [p], the segments [k] and [t] have relatively lower percentages of being adapted as Mandarin unaspirated stops.

In what follows, we further discuss partial preservation of phonological contrast, and integration of perceptual similarity with faithful mapping of phonological contrast.

A. Partial Preservation of Phonological Contrast

English phonological voicing contrast is mapped to Mandarin phonological aspiration contrast, which echoes the previous studies (Hui & Oh, 2015; Kim, 2012; Paradis & Tremblay, 2009) which report adaptation of English voiced stops to Mandarin unaspirated and English voiceless stops to Mandarin aspirated stops. Underlying phonological contrasts are preserved in adaption of English stops into Mandarin stops. The "voiced versus voiceless" contrast in English is preserved as "unaspirated versus aspirated" contrast in Mandarin in loanword adaptation, since voicing in English and aspiration in Mandarin are both phonemic categorisation. The results partially confirm the predictions by the phonological approach (Jacobs & Gussenhoven, 2000; LaCharité & Paradis, 2005; Paradis & Tremblay, 2009).

B. Integration of Perceptual Similarity with Faithful Mapping of Phonological Contrast

Firstly, distinct patterns are found in English unaspirated voiceless stops in different places of articulation. The English post-/s/ dental and velar stops [t] and [k] have a relatively higher percentage of being adapted as Mandarin aspirated stops than the velar stop [p], which echoes Hui and Oh (2015) who report a larger ratio of aspirated adaptations for both English unaspirated [t] and [k] than [p]. This is explained by the facts that the segments [t] and [k]

have longer VOTs than that of the segment [p]. As the place of articulation moves from the labial to the velar, the ratio of adapting English post-/s/ stops as Mandarin aspirated ones also increases.

Secondly, the current study finds that English post-/s/ unaspirated voiceless stops are adapted as Mandarin unaspirated ones while the single ones are adapted as Mandarin aspirated stops. The distinct adaptation patterns between single and post-/s/ stops are accounted for by differences in VOT values. Since English post-/s/ unaspirated voiceless stops occupy the 0-30 ms VOT region where is also occupied by English voiced and Mandarin unaspirated stops, it is expected that hearers of the borrowing language perceive the shorter VOTs and map the sounds as unaspirated in their native grammar. Despite belonging to the same phonological category, post-/s/ stops have shorter VOTs than those of single stops, which means that they are more likely to be perceived as English voiced stops and Mandarin unaspirated stops than single stops. In contrast, , English single unaspirated voiceless stops are consistently assigned to Mandarin aspirated stops since they normally have longer VOTs than those of the post-/s/ stops, and more importantly, their surface phonetic details are less salient than those of post-/s/ stops. It is speculated that the degree of perceptual saliency interacts with perceptual similarity in loanword adaptation. When it is less salient, adapters tend to preserve faithful mapping of phonological contrast rather than try to achieve the best match to the surface phonetics of the inputs.

The variable adaptation patterns for English unaspirated voiceless stops are not explicitly examined in Paradis and Tremblay (2009) who report consistent mapping of English unaspirated voiceless stops to Mandarin aspirated ones. Though Kim (2012) and Hui and Oh (2015) show a few cases where English unaspirated stops are adapted as Mandarin unaspirated stops, they do not differentiate post-/s/ stops from the single ones and treat them as the same category, which might be a confounding factor.

These results confirm the predictions in the phonetics-phonology approach (Hsieh et al., 2009; Kenstowicz, 2012; Kim, 2012; Yip, 1993, 2006). Perceptual similarity plays a role because it overrides preservation of phonologically contrastive feature in the adaptation of post-/s/ English stops. Nonetheless, English phonological voicing contrast is consistently preserved in the mapping to the phonologically equivalent aspiration contrast in Mandarin, indicating that perceptual similarity is mediated by phonological factors (Chen & Lu, 2020; Kang & Schertz, 2021).

VI. Conclusion

Through a study of the adaptation of English novel loanwords in Mandarin, this study attempts to answer the questions of how English voiced and voiceless stops are adapted to Mandarin and whether perceptual similarity plays a role in adapting English words into Mandarin, from the perspective of the three approaches to loanword adaptation.

Firstly, the results show that English voiced are adapted as Mandarin unaspirated stops and English aspirated voiceless stops as Mandarin aspirates stops, which disfavours the perceptual approach but provides partial support to the faithful mapping of phonological contrast proposed by the phonological approach.

Secondly, for English unaspirated voiceless stops, the single stops are adapted as Mandarin aspirated stops and the post-/s/ stops as Mandarin unaspirated stops, providing robust evidence for the phonetics-phonological approach which integrates perceptual similarity with phonological contrast in loanword adaptation.

Future research can include more data of adaptation of English stops to Mandarin from various sources. Users of China's social media have produced some loanwords from English. Also, the findings show that the adaptation patterns of English unaspirated voiceless stops are complex. An English unaspirated voiceless stop can have more than one segment mapping in Mandarin. An analysis with OT (Optimality Theory) may offer more insights into the various adaptation patterns.

Acknowledgements

This article is the revised version of a part of Mosi He's Master's thesis at University College London. Mosi He collected the data and wrote the draft of the paper. Jianing He reviewed and edited the draft.

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