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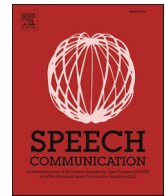
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Systematic review: The identification of segmental Mandarin-accented English features

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ABSTRACT

Background: The pronunciation of L2 English by L1 Mandarin speakers is influenced by transfer effects from the phonology of Mandarin. However, there is a research gap in systematically synthesizing and reviewing segmental Mandarin-accented English features (SMAEFs) from the existing literature. An accurate and comprehensive description of SMAEFs is necessary for applied science in relevant fields.

Aim: To identify the segmental features that are most consistently described as characteristic of Mandarin-accented English in previous literature.

Methods: A systematic review was conducted. The studies were identified through searching in nine databases with eight screening criteria.

Results: The systematic review includes nineteen studies with a total of 1,873 Mandarin English speakers. The included studies yield 45 SMAEFs, classified into Vowel and Consonant categories, under which there are multiple sub-categories. The results are supported by evidence of different levels of strength. The four frequently reported findings, which are 1) variations in vowel height and frontness, 2) schwa epenthesis, 3) variations in closure duration in plosives and 4) illegal consonant deletion, were identified and analyzed in terms of their potential intelligibility outcomes.

Conclusion: The number of SMAEFs is large. These features occur in numerous traditional phonetic categories and two categories (i.e. schwa epenthesis and illegal consonant deletion) that are typically used to describe features in connected speech. The study outcomes may provide valuable insights for researchers and practitioners in the fields of English Language Teaching, phonetics, and speech recognition system development in terms of selecting the pronunciation features to focus on in teaching and research or supporting the successful identification of accented features.

1. Introduction

In the past two decades, there has been a considerable increase in the number of Chinese nationals who are immigrants, students, and tourists in English-speaking countries, up to 445,646 in England and Wales in 2021, and 2.4 million in the U.S. in 2023, according to [Higher Education Student Statistics \(2021\)](#), [Higher Education Statistics Agency \(2023\)](#) and [Rosenbloom and Batalova \(2023\)](#). Most of these are L1 (first language) Chinese speakers. Along with 400 million Chinese learners of English at different levels in the education system in China ([Wei and Su, 2012](#)), they form the largest group of non-native English (NNE) speakers. The in-person and online communication needs of these speakers, who speak a wide range of L1s such as Mandarin and Cantonese, should be met with evidence-based English Language Teaching (ELT) practice, targeted

communication and repair strategies, and accurate automatic speech recognition systems. To enable these applications, it is necessary to identify the phonetic characteristics of English spoken by L1 Chinese speakers and to consider the potential impacts thereof on communication. Segmental accuracy plays a crucial part in the achievement of intelligibility ([Bradlow, 1995](#); [Field, 2005](#); [Gluszek and Dovidio, 2010](#); [Winters and O'Brien, 2013](#); [Suzukida and Saito, 2021](#)). The misinterpretation of segmental features may contribute to communication breakdown ([Jenkins, 2000](#)), which refers to a disruption in the continuous flow of turn-taking, according to [Brady and Halle \(2002\)](#). Accurate descriptions of segmental Mandarin-accented English features (SMAEFs), generated from synthetic research, are therefore essential to support the above applications. For example, they provide targeted ELT recommendations according to regional linguistic features, accurate

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phonetic descriptions of this particular language variety to improve speech recognition accuracy and insights to the development of regional language and education policies.

There has been considerable research in phonetics, second language acquisition, TESOL (Teaching English to Speakers of Other Languages) and related fields on the pronunciation of English by speakers from China (Xie and Jaeger, 2020; Wei and Gao, 2022). However, the inter-disciplinary nature of the topic and the large variety of theoretical and methodological frameworks used in different studies have led to a fragmented research landscape whereby scholars seeking a clear description of Mandarin-accented English for the applications above can easily be left overwhelmed. The present study therefore seeks to provide an accessible, data-driven account of the segmental features of Mandarin-accented English using a systematic review of previous literature, which has yet to be conducted to our knowledge.

A synthetic study of segmental Mandarin-accented English features (SMAEFs) is valuable for several reasons. First, systematic review is placed on the top of the *levels of evidence* hierarchy (Cochrane Consumer Network – Levels of Evidence, n.d.). While systematic reviews are prevalent in health sciences, including clinical linguistics (e.g. Dipper et al., 2021), they are also applicable and beneficial in phonetic science as demonstrated by research like Dallaston and Docherty (2020). Systematic review is secondary research that provides comprehensive, updated and unbiased results with rigorous and reproducible methods (Egger et al., 2001; Khan et al., 2003; Clarke, 2011; Tricco et al., 2011). Research outcomes generated from such bottom-up methods contribute to identifying outstanding and under-researched features. These findings are helpful in raising ELT practitioners' awareness of the need to adjust the selection of pronunciation features they recommend teachers to prioritize, address the overlooked or under-represented features in coursebooks, and guide future research directions in many relevant fields.

Secondly, the present study exclusively focuses on the English accent features produced by L1 Mandarin speakers, which distinguishes itself from other studies (e.g. Kirkpatrick, 2007) that investigate English pronunciation by speakers in China regardless of their L1 variety. This body of work has considered the putative existence of a pan-Chinese variety of English known as 'China English'. Given the enormous number of language varieties spoken in China, however, many of which are under-documented in English sources, the objective of identifying English accent features that are shared by all Chinese varieties seems unrealistic. This study thus focuses on the phonological properties of L2 English spoken by Northern Chinese speakers whose L1 is Standard Mandarin Chinese (Putonghua) or Mandarin varieties with northern regional variations. These speakers will be referred as Mandarin English (ME) speakers. Our focus on segmental features reflects that of much research on L1 phonological transfer (e.g. Flege, 1987; Ueyama, 2000; Winters and O'Brien, 2013), though that does not preclude the potential influence of supra-segmental features.

1.1. Standard mandarin and mandarin varieties

Chinese languages are grouped into seven dialect families. For example, Mandarin varieties in the Northern Mandarin family are spoken by about 70 % of the total Chinese population (Zhu, 2006; Tian and Bo, 2014). These speakers reside in areas of northern China, such as Beijing, Tianjin, and Hebei Province. It is worth noting that we agree with researchers (see Simmons, 2016) in terms of referring the Northern regional dialects as Mandarin varieties. In the current study, both Standard Mandarin Chinese and Northern Mandarin varieties are considered as speakers' L1, and English their L2. Speakers from different dialect families can be mutually unintelligible. Standard Mandarin (Putonghua), based on the phonology of Beijing and Tianjin dialects, was adopted as the official language of People's Republic of China in 1949. Mandarin, since then, has been broadly used in education, national radio, and everyday communication among Chinese speakers. The

actual realization of Standard Mandarin largely depends on the speaker's regional dialect. For example, for Beijing speakers, the word-initial [w] can alternate with [v], which does not exist in Standard Mandarin. In this section (1.1), only Standard Mandarin will be introduced.

1.1.1. Segments and syllables in Mandarin and English

Mandarin has a small vowel system. Although there are different schemes to classify Mandarin vowels (see Cheng, 1966; Lin, 1989; Duanmu, 2007; Wu and Shih, 2009), one of the most popular ones is the six-vowel scheme (Howie, 1976; Wu and Shih, 2009; Wheatley, 2011), involving [a], [o], [ɤ], [i], [u], [y]. Compared with Mandarin, English contains more vowels. Standard Southern British English and American English both have eleven monophthongs. There are some similar vowels in Mandarin and English, e.g. [i] and /i/, [a] and /ɑ/, [u] and /u/.

In terms of consonants, Mandarin and English plosives are similar. In the actual realization of word-initial plosives, similar to American and British English, the distinctions of Mandarin plosives are mostly shown in aspiration (Docherty, 1992; Ladefoged, 1999; Roach, 2004; Zhao and Li, 2009). Mandarin and English fricatives differ primarily in number. Mandarin contains five fricatives, [f], [s], [ɕ], [ʃ], and [x] (Lee et al. 2012). English has nine, /f, v, θ, ð, s, z, ʃ, ʒ, h/.

Compared to the varied syllable structures in English (e.g. CVC, CCVC, and CVCCVC), Mandarin syllable structures are restricted to CV (Consonant Vowel), V, VC and CVC, with CV being the overwhelmingly common structure (Nogita and Fan, 2009). In Mandarin VC and CVC structures, the final consonant is either [n] or [ŋ]. Additionally, there are no consonant clusters in Mandarin, while English contains complex codas and clusters.

In Mandarin and many northern Mandarin varieties, strong syllabic rhotics are permitted, albeit infrequently. This feature is similar to American rhotic accents, yet not to many British English varieties.

1.2. Research Question

Literature investigating Chinese-accented segmental features exists but some considers a pan-Chinese English variety, and most were conducted across diverse disciplines within the umbrella term of linguistic research. A system review of segmental Mandarin-accented English features is needed to consolidate research and inform practice. The aim of this study is to identify SMAEFs in all relevant existing research. This objective yields the research question 'What are segmental Mandarin-accented English features (SMAEFs)?'. We will also discuss whether these features are unique to Mandarin English speakers and the intelligibility or communication impacts of the frequent findings in Section 4.

2. Methods

The systematic literature review method was chosen to identify all SMAEFs in existing studies. Apart from wide adoption in medical and clinical experiments (Petticrew, 2001), systematic review is also employed in the fields of accent, bilingualism and education (e.g. Hambly et al., 2013; Subhash and Cudney, 2018; Gu and Shah, 2019).

Following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) protocol, we first established a list of criteria (see Fig. 1. and 2.1) to control variables such as L1, age, and language domain, to further determine the evidence base. After obtaining the evidence base, the first author extracted information, including participant information, study designs, data elicitation tasks, measurement methods and data analysis methods involved in the included studies, and the SMAEFs, and finally accessed the reliability of the data extraction procedures and results (see 3.1 for details).

2.1. Search methods

Nine databases (Academic Search Complete, CINAHL Complete,

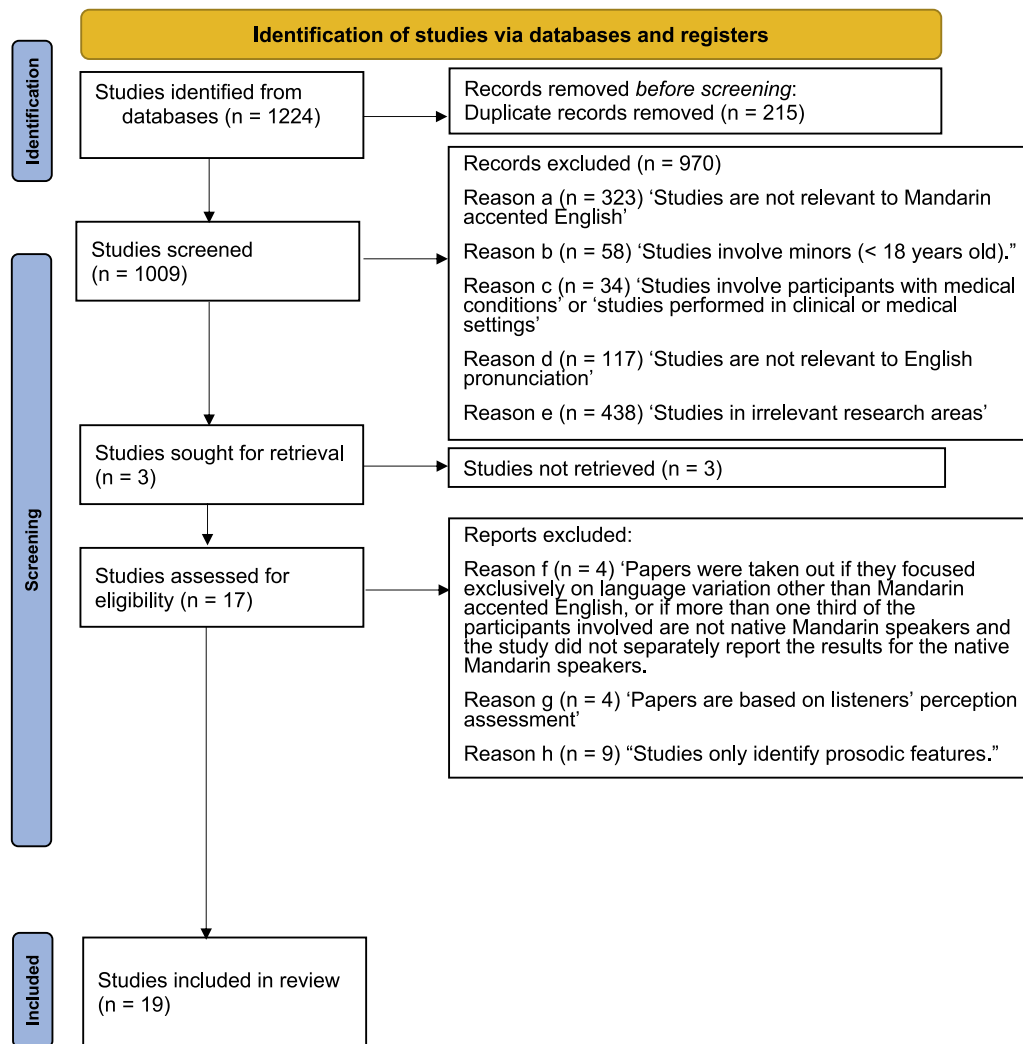


Fig. 1. PRISMA flow diagram showing the systematic screening process.

Communication Source, Medline Complete, APA PsycInfo, Teacher Reference Centre, Embase 1974–2021, Ovid Emcare; Turning Research into Practice or TRIP) on three platforms (EBSCO Host, Ovid Online and TRIP) were searched, on 9th September 2021, using eleven combinations of the search terms (see the full list in [Appendix A](#); e.g. Mandarin English, Mandarin accented English, Mandarin, Putonghua, Beijing dialect, L1 or first language, accent*, characteristics or features or patterns). After removing the duplicates, the following eight screening criteria or exclusion criteria were applied to select relevant papers for the review:

- (a) Studies were not relevant to Mandarin-accented English.
- (b) Studies involved minors (< 18 years old).
- (c) Studies involved participants with medical conditions or studies being performed in clinical or medical settings.
- (d) Studies were not relevant to the language domain of English pronunciation.
- (e) Studies were in irrelevant research areas.
- (f) Studies focused exclusively on language variation other than Mandarin-accented English, or more than one-third of the participants in a study were not L1 Mandarin speakers and the study did not report the results for the L1 Mandarin speakers separately.
- (g) Studies were based on listeners' perception.
- (h) Studies only identified prosodic features.

Criterion (a) was set to control the language variety investigated, i.e. English spoken with Mandarin accent. This criterion was used to exclude studies that only investigated other languages, such as Japanese and Cantonese.

Another language-related criterion is (f), which was used to control the speakers' L1, including regional dialects, in the evidence base. This is necessary considering that this systematic review is based on the general assumption that the first language of native Chinese speakers affects their English productions, and that Chinese regional dialects can be markedly different from each other and from Standard Mandarin ([Duanmu, 2007](#)). This criterion excluded studies on speakers whose L1 was not Standard Mandarin or a Northern Mandarin variety, such as Cantonese speakers and Taiwanese Mandarin speakers. However, many papers in the search results did not specify their Chinese participants' L1 and simply reported them as Mandarin speakers, among whom there are potentially Northern Chinese speakers. An operational decision was taken to allow studies involving general Mandarin speakers whose L1 was not specified as long as they constituted no more than a third of the total number of Chinese participants, so that this group would not overwhelm the data. The L1 information of each included study is presented in [Table 1](#) (see [Section 3.2.1](#)).

The criterion (b) was established to ensure that only adult speakers were included. This is because this review attempts to capture consistent accented features. Given that adults, compared to minors, are less able to change their articulatory patterns, or more prone to preserve their

Table 1
The number of Northern Mandarin speakers and research focus of the nineteen studies.

Study	Type of study	Research focus	Number of L1 Chinese speakers involved	Chinese participants' first language(s) (number of speakers of such L1)
Barkana & Patel (2020)	Descriptive research	Segmental and prosodic similarities and differences between ME and AE	32	Standard Chinese Mandarin (32); other potential Chinese languages not specified
Robb & Chen (2008)	Descriptive research	Investigating the differences between the vowel space areas by ME and NE speakers	40	Beijing Mandarin variety (40)
Robb & Chen (2009)	Descriptive research	Investigating the gender and L1 effects on the articulation of /h/ and examining the influence of /h/ production on subsequent vowel articulation	40	Beijing Mandarin variety (40)
Xie & Fowler (2013)	Descriptive research	Examine the interlanguage speech intelligibility benefit in Mandarin English speakers	30	Beijing Mandarin variety (number of speakers not specified); other potential Chinese languages not specified
Hansen (2011)	Multiple-case study	Investigating Mandarin English learners' acquisition of English /t, d/ deletion patterns in word-final consonant clusters	7	Standard Chinese Mandarin (5); Taiwan Mandarin and/or Min dialect (2)
Flege et al. (1997)	Descriptive research	Investigating the effects of experience on non-native speakers' production and perception of English vowels	20	Standard Chinese Mandarin (20); other potential Chinese languages not specified
Liu & Lee (2020)	Descriptive research	Investigating the nasalance values in English productions by L1 Mandarin speakers	16	Standard Chinese Mandarin (16); other potential Chinese languages not specified
Thomson (2005)	Descriptive research	Investigating the relationship between English vowel perception and production by adult L1 Mandarin speakers in Canada	32	Standard Chinese Mandarin (32); other potential Chinese languages not specified
Hansen (2001)	Multiple-case study	Investigating the acquisition of English syllable coda by ME speakers	3	Beijing Mandarin variety (3)
Eckman (1981)	Descriptive research	Presenting evidence for two phonological rules in the interlanguage of Mandarin English learners	2	Standard Chinese Mandarin (2); other potential Chinese languages not specified
Luo et al. (2020)	Descriptive research	Investigating the native and non-native production differences in relation to speech planning	45	Standard Chinese Mandarin (45); other potential Chinese languages not specified
Sangwan & Hansen (2012)	Descriptive research	Developing an accent analysis system that automatically accesses Mandarin accent	37	Standard Chinese Mandarin (37); other potential Chinese languages not specified
Hansen et al. (2010)	Descriptive research	Developing an automatic system that identifies accents with VOT in unvoiced stops	4	Beijing Mandarin variety (3) and Cantonese (1)
Pua et al. (2019)	Descriptive research	Collecting normative nasalance values for bilingual Mandarin/English speakers and examining the social variables' effects on nasalance levels	45	Standard Chinese Mandarin (45); other potential Chinese languages not specified
He & van Heuven (2010)	Descriptive research	Investigating which pronunciation standard (AE or RP, Received Pronunciation) is approximated best by ME accent	16	Tianjin Mandarin variety (16)
Huang et al. (2004)	Descriptive research	Addressing the accent-related issues in large vocabulary continuous speech recognition	1500	Beijing Mandarin variety (1500)
Chen (2015)	Descriptive research	Investigating the timing patterns of Chinese English speech	10	Beijing Mandarin variety (10)
Arslan & Hansen (1997)	Descriptive research	Identifying acoustic features in accented English	Not specified	Standard Chinese Mandarin (number of speakers not specified); other potential Chinese languages not specified
Olmstead et al. (2021)	Experimental study	Investigating how mismatches at the phonetic level affect speech adjustments in mixed versus shared language pairs	34	Standard Chinese Mandarin (34); other potential Chinese languages not specified
Number of Northern Mandarin speakers	1564			
Number of L1 Chinese speakers	1873			

accentedness (Kalikow and Swets, 1972; Flege, 1987), all studies involving minor participants were excluded.

Criterion (c) was used to exclude studies that involve participants with clinical or medical conditions, such as cleft palate and aphasia. These participants displayed various types and degrees of speech difficulties, which were vastly different from the speech of participants who were free from medical conditions and illness. Considering the research interest of this systematic review lies on healthy ME speakers with typical articulator anatomy, this criterion was established.

Criterion (g) was developed to exclude studies that identified SMAEFs through perception assessments. The perception assessments here refer to 1) ME speakers' productions being perceived by untrained listeners and 2) ME speakers' perception of NE productions. The studies that involved the former perception task in SMAEFs identifications were excluded due to the concern that the subjectiveness of untrained listeners might affect the accuracy of the SMAEF results. The studies that used the latter type were excluded because ME speakers' perception is not the topic of interest of the current research.

The complete screening procedures were documented in the PRISMA

flow chart below (see Fig. 1).

3. Results

The screening process yielded nineteen papers. A total of 1873 Mandarin English speakers were included in these nineteen studies. The SMAEFs were extracted and divided into two groups: Vowel and Consonant. There are in total 45 Mandarin-accented English features reported, among which 30 are vowel features and fifteen are consonant features. All SMAEFs are shown in Appendix B.

3.1. Data extraction and reliability

SMAEFs extraction was performed by the first author and reviewed by an anonymous researcher to assess the reliability of the current review. The first author performed a complete data extraction from the nineteen articles through screening the full articles.

A form was developed to organize the following extracted information: publication details, type of study design, research foci, number of

participants, participants' L1(s) and their L2 English proficiency, age, gender, occupation, residency, study procedures (i.e. stimuli, conversation partners, data elicitation tasks, measurement methods), and findings (i.e. statistically significant findings of segmental Mandarin-accented English features). An anonymous reviewer with phonetics expertise later performed data extraction from four randomly selected papers (> 20 %) and compared her SMAEFs with those extracted by the first author. After the initial reliability check of the reviewer and further discussion, the reviewer and the first author agreed on all extracted data from the four papers. The reliability score of the current review reaches 100 %.

3.2. Summary of evidence base

3.2.1. Participant information

The participants in the nineteen papers vary in terms of the reference L1 English accent, the number of participants, and grouping criteria. Of the nineteen papers included, six papers (Eckman, 1981; Hansens, 2001; Huang et al., 2004; Thomson, 2005; Hansen, 2011; Pua et al., 2019) analyzed Mandarin English (ME) utterances without a comparison with L1 English speakers'. Of the nineteen papers, fourteen conducted comparisons between ME and American English (AE), including one paper (He and van Heuven, 2010) that compared ME and AE, as well as ME and British English (BE). One paper (Luo et al., 2020) compared ME and Canadian English. Of the nineteen papers, five (Arslan and Hansen, 1997; Huang et al., 2004; Hansen et al., 2010; He and van Heuven, 2010; Sangwan and Hansen, 2012) adopted ME and L1 speech data from readily available corpora rather than collecting their own L1 English data. The number of ME speakers involved in said corpora ranges from three to 1500. The number of NE speakers in said corpora ranges from four to 270. In the fifteen papers that collected empirical data, the number of ME speakers ranges from two to 55 and that of the NE speakers ranges from 0 to 51. Studies also included data from multiple language groups (e.g. Hindi and Spanish). The nineteen papers also followed different grouping criteria for their participants: usually participants were grouped according to their L1 or gender, but two papers (Flege et al., 1997; Luo et al., 2020) further divided ME speakers according to their length of residence in an English-speaking country (LoR) and their level of English proficiency respectively.

Table 1 reports the number of L1 Mandarin speakers in each of the nineteen studies and the research focus of each study. Table 1 provides the necessary information for readers concerned with the L1 control of each study to determine the strength of evidence of the SMAEFs extracted from a specific study.

3.2.2. Types of study

Of the nineteen studies, sixteen are descriptive studies. More specifically, most of the sixteen are acoustic research. The other three are experimental research (Olmstead et al. 2021) and multiple-case study (Hansen, 2001, 2011). Detailed information can be found in Table 1.

3.2.3. Data elicitation tasks

Read-aloud tasks with three levels of stimuli (i.e. words, sentences, and passages) were used in thirteen papers (Eckman, 1981; Arslan and Hansen, 1997; Flege et al. 1997; Thomson, 2005; Robb and Chen, 2008; Robb and Chen, 2009; He and van Heuven, 2010; Sangwan and Hansen, 2012; Chen, 2015; Barkana and Patel, 2020; Liu and Lee, 2020; Luo et al., 2020; Olmstead et al., 2021). Repetition tasks with three levels of stimuli (i.e. words, non-words and speech) were used in three studies (Eckman, 1981; Xie and Fowler, 2013; Pua et al., 2019). In two studies (Hansen, 2001, 2011), interviews were employed to elicit natural ME speech. Some papers employed multiple methods to elicit ME productions. Additionally, one paper (Huang et al., 2004) adopted L2 speech data from an unsourced corpus and did not specify the elicitation method used in said corpus.

3.2.4. Measurements and data analysis methods

Frequently used measurement methods include acoustic analysis in ten studies (Arslan and Hansen, 1997; Flege et al. 1997; Robb and Chen, 2008, 2009; He and van Heuven, 2010; Xie and Fowler, 2013; Chen, 2015; Barkana and Patel, 2020; Luo et al., 2020; Olmstead et al., 2021), phonetic transcription in two studies (Eckman, 1981; Hansen, 2011) and native English speaker rating or expert rating in four studies (Flege et al. 1997; Sangwan and Hansen, 2012; Liu and Lee, 2020; Luo et al., 2020). Five studies employed other methods to analyze accented features: Xie and Fowler (2013) used orthographic transcription to identify the voicing variations in non-word consonant codas; Liu and Lee (2020) and Pua et al. (2019) used instrumental analysis to assess nasalance values; two studies adopted ME speech from corpora as input for accent identification algorithms. It is worth noting that it is common for research to adopt more than one measurement or analysis method.

3.2.5. Study aims and research questions in the nineteen studies

Fifteen papers had the common aim of investigating the ME speakers' vowel variations (Eckman, 1981; Flege et al. 1997; Hansen, 2001; Thomason, 2005; Robb and Chen, 2008; He and van Heuven, 2010; Sangwan and Hansen, 2012; Pua et al., 2019;

Barkana and Pate, 2020; Liu and Lee, 2020) and consonant variations (Flege et al. 1997; Hansen, 2001; Robb and Chen, 2009; Hansen et al., 2010; Hansen, 2011; Sangwan and Hansen, 2012; Xie and Fowler, 2013; Liu and Lee, 2020; Luo et al., 2020). Other studies (Arslan and Hansen, 1997; Huang et al., 2004; Chen, 2015; Olmstead et al., 2021) were conducted to identify both segmental and prosodic features, or to explore the possibility of utilizing ME features in developing accent identification algorithms.

The most frequent research question, shared by six papers, was 'What are the differences between the vowel productions of native English speakers and non-native speakers?'. The ten researched vowels include /ɪ, ɪ, ε, æ, ʌ, u, ʊ, o, ɔ, ɑ/. Despite the moderately large number of vowels researched, some studies focused on a small number of vowel contrasts, such as /i - ɪ/ contrast in Olmstead et al. (2021). Robb and Chen (2008) compared the vowel space of six vowels (/i, u, ɑ, ɪ, ʊ, ɔ/) between ME and AE speakers to test Second Language Acquisition hypotheses related to vowel space. He and van Heuven (2010) set out the study to answer the question 'Which pronunciation standard is approximated best by the typical Mandarin Chinese accent?' by investigating the acoustic variations between the vowel space of sixteen ME speakers, and of in total 270 AE and BE speakers, and conclude that ME vowel productions are closer to BE.

Another popular aim shared by studies focusing on consonant productions was related to plosive features in ME. There are three papers that investigated the voicing features in ME speakers' plosive productions. Luo et al. (2020) aimed to identify the production patterns of ME and NE language groups in cross-word consonant cluster coproduction (e.g. producing /pk/ sound in *keep calm*). Other aspects of plosives such as voice onset time (VOT) and closure duration were also researched. Hansen et al. (2010) examined the VOT in /p, k, t/ production to develop an automatic accent classification system. Arslan and Hansen (1997) conducted their research to achieve a similar goal of formulating accent identification algorithms by studying various acoustics features, including VOT and word-final plosive closure duration of ME utterances. The feature of consonant deletion was a less researched topic, with only one study (Hansen, 2011) dedicating to investigating L1 Mandarin speakers' acquisition of English /t, d/ deletion patterns in word-final consonant clusters. Another two studies (Hansen 2001; Chen, 2015) confirmed the occurrence of illegal consonant deletion feature in ME speech.

The rest of the study aims were varied, from identifying the L1 effects on /h/ articulation, to the assessment of ME speakers' nasalance values in vowels. Numerous aspects of Mandarin-accented English were identified, and segmental variations were reported in the nineteen studies.

3.3. Frequent findings

The authors determined the strength of evidence by evaluating the frequency of occurrence of segmental Mandarin-accented English features across the nineteen studies. Additionally, other factors such as the number of participants involved in a study, the L1 of the ME speaker participants, and the measurement methods are also recommended for consideration based on individual interest. Table 2 presents the findings in descending order of frequency.

Four frequent findings were identified: two related to vowel productions and two to consonant productions, as elaborated below (3.3.1 and 3.3.2).

Discussion involving the strength of evidence criteria will be presented in Section 4, where the strongest findings are discussed and appraised.

From the dispersion of the SMAEFs, it can be observed that the following categories were not explicitly investigated: degree of lip-rounding was not explicitly described, although potentially related to F2 frequencies reported in some vowel features; diphthongs; affricate productions; Place of Articulation features. Additionally, few fricative productions were reported, apart from /h/ and /s/.

3.3.1. Frequent findings in vowel production

Four papers (Flege et al. 1997; He and van Heuven, 2010; Sangwan and Hansen, 2012; Barkana and Patel, 2020) contributed to the frequent finding in the vowel height and frontness of individual vowels /i, ɪ, e, æ, u/ and the /i-ɪ/, /e-æ/, /u-ʊ/ vowel contrasts. Specifically, the directions of the variations on height and frontness were as follows: compared with AE and BE, /i/ was lower and more back and /ɪ/ was higher and more front, thus threatening the contrast between the two vowels; compared with AE and BE, /e/ was too low and /æ/ was lower and more back, the distinction between /e-æ/ is too small, thus reducing the distinction between /e/ and /æ/; compared with AE and BE, /u/ was lower and often perceived as /ʊ/ and /o/, and the distinction between /u-ʊ/ was smaller. There is a clear indication that ME speakers produced each pair of tense-lax vowels more closely to each other, sometimes leading to misperception, as evidenced by Thomson (2005).

This finding is considered a frequent finding as it was reported by four studies with noticeable sample sizes. Three (Flege et al. 1997; Sangwan and Hansen, 2012; Barkana and Patel, 2020) of these studies involved in total 89 ME speakers who L1 was either not specified or documented as Standard Mandarin and the other one (He and van Heuven, 2010) involved 20 L1 Tianjin speakers. In total, the four studies involved data from 215 AE speakers from two databases and 55 BE speakers from three RP databases.

Another frequent vowel finding is the occurrence of schwa epenthesis, reported by three studies. Two of these studies (Hansen, 2001; Chen, 2015) involved in total thirteen Beijing ME speakers. The other study (Eckman, 1981) involved two ME speakers who spoke Standard Mandarin as L1.

3.3.2. Frequent findings in consonant production

Consonant features are scattered in different sub-categories, e.g. voicing in /h/, substitution, and syllable-final /r/, each of which was reported by one study only, as shown in Table 2. There are two frequent findings: 1) variations in closure duration in plosive productions were reported in two papers (Arslan and Hansen, 1997; Luo et al., 2020), although the direction is inconclusive; 2) illegal consonant deletion was reported by three studies (Hansen, 2001, 2011; Chen, 2015), showing a tendency of deleting /t, d/ against the pronunciation rules in AE. The studies that reported frequent finding 1) together involved 45 English speakers of L1 Standard Mandarin Chinese, a relatively large sample size, though Arslan and Hansen (1997) did not specify the number of participants. The three studies yielded frequent finding 2), in total, involved eighteen ME speakers: thirteen were L1 Beijing speakers and five were L1 Standard Mandarin speakers.

4. Discussion

This review includes nineteen studies across different fields, with data from 1873 ME participants and 568 L1 English participants in total. Across all the studies, 45 Mandarin accented English features were extracted and synthesized, among which 30 were vowel features and fifteen were consonant features. From the dispersion of the SMAEFs and the evaluation of the strength of evidence, the most frequent findings were identified: 1) variations in vowel height and frontness; 2) schwa epenthesis; 3) variations in closure duration in plosives; 4) illegal consonant deletion.

The discussion of each frequent finding will unfold in relation to Lingua Franca Core (LFC, see Jenkins, 2000; Dauer, 2015 Deterding, 2013; Walker, 2021) and Functional Load (FL; Catford, 1987; Brown, 1988, 1991). LFC provides a finite set of 'core features' as features that are important for intelligibility between global speakers and therefore are recommended to teach, acquire, or accommodate (Jenkins, 2000). The functional load of phonemic contrasts, generated based on the frequency of phoneme occurrence in speech and the number of minimal pairs, provides the ranking of each pair of contracted phonemes in comparison with others (Brown, 1988). EFL practitioners worldwide adjust their pronunciation teaching focus, especially when they select the pronunciation features that are 'worth' teaching, based on the LFC and FL recommendations (Munro and Derwing, 2006; Suzukida and Saito, 2021). This section will also involve discussion about the uniqueness of some of the frequent findings.

4.1. Vowel height and frontness

This investigation enables us to understand ME speakers' realization of English vowels. In total, four studies (Flege et al. 1997; He and van Heuven, 2010; Sangwan and Hansen, 2012; Barkana and Patel, 2020) reported fifteen results on ME variations for individual vowels /i, ɪ, e, æ, u/ and vowel contrasts /i - ɪ/, /e - æ/, /u - ʊ/. ME speakers showed a general tendency of producing contrasted phonemes very close to each other, threatening intelligibility.

The fifteen SMAEFs together indicate significant variations in height

Table 2

Prevalence of segmental Mandarin-accented English features in nineteen studies.

Findings	Number of studies reporting the features
/e - æ/ contrast	3
schwa epenthesis	3
closure duration in plosive productions	3
illegal consonant deletion	3
/i/	2
/ɪ/	2
/i - ɪ/ contrast	2
/e/	2
/æ/	2
/u/	2
other vowels (/ʌ, o, ɔ, ɑ/)	2
vowel space	2
vowel duration in isolated words	2
voice onset time	2
/u - ʊ/ contrast	1
durations of stressed and unstressed vowels	1
using vowel length to distinguish sounds	1
voicing errors	1
voicing of plosives	1
voicing in /h/	1
substitution	1
duration of fricative /h/	1
duration ratio of fricative /h/	1
syllable-final /r/	1
/l, w/	1

and frontness between the monophthong productions of Mandarin English and L1 English. This agrees with the findings of previous research (e.g. Chen et al., 2001; Ji et al., 2013; Wang and van Heuven, 2018; Gong et al., 2020.) that investigates Mandarin-accent English vowel variations. Flege et al. (1997) reported that ME speakers exhibited similar degrees of frontness and little distinction in tense-lax pairs /i-ɪ/ and /e-æ/. They also specifically pointed out the impact of such SMAEFs: decreased intelligibility and bi-directional confusion. These impacts of the finding align with the study outcomes in Xie and Jaeger (2020), and Ji et al. (2013), where acoustic confusion in identifying the tense-lax vowels was reported.

Although this finding and the LFC both include tense-lax vowel contrasts as key features to intelligibility, this finding does not agree with the LFC claims that vowel quality is not important to intelligibility and that vowel quantity (i.e. vowel length) distinctions in the tense-lax vowel contrasts are (see Jenkins, 2000, Deterding, 2013). The current review has shown that ME variations in vowel quality may lead to the loss of contrast between the pairs of vowel phonemes, which may affect intelligibility (Flege et al., 1997; Wang, in progress). This outcome is aligned with the empirical study results in Deterding (2013), where he ran a perception study on South-east Asian English speakers' vowel productions and revealed that their /æ/ productions were often heard as /e/. The frequent finding in the tense-lax vowels and contrasts challenges the LFC recommendation of focusing on teaching the vowel length aspect, which is not one of the key identifiers for a vowel, within limited teaching hours. It is also possible that teachers misinterpret the LFC recommendations and highlight the strategy of exaggerating vowel duration distinctions to allow listeners' discrimination of the tense-lax vowels. In fact, He and van Heuven (2010) and Olmstead et al. (2021) both reported ME speakers' employment of this strategy, potentially under the impact of LFC, while L1 English listeners do not use duration as a cue in vowel identification. This finding, however, agrees with FL to a larger degree, in terms of the importance of distinguishing /i-ɪ/ and /e-æ/ (see Brown, 1988; Deterding, 2013). According to Brown's studies in FL and ELT (1988, 1991), /i-ɪ/ and /e-æ/ have high functional load, while /u-ʊ/ has a low one. The current research partly supports LFC and FL that ELT and speech learning priority should be given to the contrasts with higher importance in intelligibility and provides more insights in terms of the features that should be focused on.

4.2. Schwa epenthesis

Another vowel-related finding, supported by evidence in three papers (Eckman, 1981; Hansen, 2001; Chen, 2015), is that ME speakers tended to insert a schwa-like vowel after a word-final consonant (e.g. [tægə] for *tag*), and more frequently so when the word ends with /t/ or /d/. Although this realization is suggested to be a ME-specific trend by researchers (McAndrews and Thomson, 2017; Ding and Hoffmann, 2013; Deterding, 2006) amongst other investigated speaker groups (e.g. L1 Slavic speakers), vowel epenthesis seems to be a feature of a number of L2 accents of English, typically from languages that do not permit coda consonants or consonant clusters. However, it is unclear whether other groups exhibit this feature in the same way as ME speakers. For example, Japanese English speakers tend to insert /o/ after /t, d/ consonant clusters, and /u/ after various other consonants, breaking up the clusters and avoiding closed syllable structure (Funatsu et al., 2008; Yazawa, et al. 2015; Nomura and Ishikawa, 2018). Similarly, Spanish English speakers show the tendency of inserting a short, audibly perceptible front mid vowel, close to schwa, in word-initial clusters, e.g. sC in *spring* (Hancin-Bhatt and Bhatt, 1997; Lopez, 2024). Researchers (e.g. Hansen, 2001; Nogita and Fan, 2009; Yun, 2016) propose that vowel epenthesis may be a result of L1 structure transfer. This means that L1 speakers of Mandarin, Japanese and Spanish prefer open syllable structures, which are common in their L1s, and carry this preference over to their L2 English productions. Though schwa epenthesis may not be completely unique to Mandarin English, it may be combined with

other accented features (including supra-segmental ones) to form Mandarin-accented English.

Although no intelligibility impact was mentioned in the evidence base, previous research (e.g. Zielinski, 2008; Dahmen et al., 2023) suggests that schwa epenthesis may cause the misperception of an additional syllable such as an *-er* suffix, which consequently leads to misunderstanding at grammatical level. It is also possible that schwa epenthesis combined with other factors, such as variation in vowel quality, prosodic voice quality, or pronunciation rules in connected speech, can attenuate intelligibility. For example, all L1 English listeners in Zielinski's study (2008) perceived the 'I have /hævə/ been ...' accented L2 English production with schwa epenthesis as 'I haven't /hævənt/ been ...', considering that an extra syllable was produced and the /t/ in *haven't* is often omitted in L1 English connected speech. This misperception in Zielinski's (2008) led to a major grammatical change and communication breakdown. On the contrary, if adjectives *fast* and *strong* are pronounced with schwa epenthesis, they might be perceived as their comparatives (i.e. *faster* and *stronger*), changing the grammatical meaning. However, it is less likely that this feature will cause communication breakdown, as the intended and perceived words (i.e. *fast* and *faster*) are semantically highly similar. This suggests that the combination of an accented-feature and other factors or the combination of two or more features may increase the possibility of unintelligibility.

Since this finding seems common among L2 speakers whose L1s prefer open syllable structure, the English syllable structures is recommended to highlight in classrooms to help learners avoid such realization. Guided discovery task is recommended for the teaching of syllable structures. Although guided discovery approach is mostly used to teach grammar, due to its strength of encouraging learners to learn rules by identifying patterns independently under guidance or with scaffolding, it can also be used to teach pronunciation (Caprario, 2013). This approach also may contribute to a lasting retention of the target rules that students 'discover' by themselves (Ellis et al., 2002). In the task, the teacher can give instructions such as 'Make a list of all the English syllable structures in the underlined words in text. For example, CV for *my*, and CVC for *cat*.' to help learners notice the varied syllable structures.

4.3. The variations in the closure features of plosives

There are in total four SMAEFs reported by three studies in the plosive sub-category, making the variations in the closure of plosives a frequent finding. One focused on word-final plosive variations (Arslan and Hansen, 1997), one on word-initial plosive variations (Hansen et al., 2010) and two (Luo et al., 2020) on cross-word consonant coarticulation.

The SMAEF focusing on word-final plosive variations only reported variations in closure duration. It is less likely to cause unintelligibility, considering that closure variations are hard to detect by human ears and that word-final plosives are not important for plosive identification and international intelligibility, according to LFC (Jenkins, 2000; Walker, 2010). Considering the similarity between Mandarin [b, d, g, p, t, k] and English /b, d, g, p, t, k/, including the fact that aspiration is the main cue to distinguish plosives in both Mandarin and in English, especially in word-initial position (Davidson, 2016), the occurrence of the following SMAEF is not entirely surprising: ME speakers tended to replace English word-initial /p, t, k/ with their Mandarin counterparts (Hansen et al., 2010). For similar reasons why this SMAEF may have happened, it is not likely to cause unintelligibility.

Finally, the realization of cross-word consonant or consonant cluster, e.g. ME speakers' production of /lɪp bəm/ for *lip balm* where /p/ would not be released in L1 English, although not native-like and rarely appear in connected speech, technically is not an error. It may contribute to increased perceived accentedness, yet it is not likely to lead to misunderstanding. In the source research, Luo et al. (2020), the two groups of ME speakers with different LoR (length of residence in target language speaking countries) displayed different degrees of non-nativeness.

Unlike AE speakers and experienced ME speakers, the less experienced ME speakers did not produce cross-word coarticulation, i.e. releasing /p/ in *lip balm* and /t/ in *diet guide*. The less experienced ME speakers were also reported (Luo et al., 2020) to produce little closure overlap in cross-word consonants, which confirms the absence of consonant coarticulation. Experienced ME speakers produced a fair amount of overlap, although less than AE speakers, which indicates a certain degree of deviation in coarticulation. It is plausible that the acquisition of cross-word consonant coarticulation becomes more successful as LoR increases. However, only one paper looked at the LoR effect in this category, therefore the evidence is not strong enough to support the correlation between SMAEFs and LoR. Since there are mixed findings in existing studies that access the impacts of LoR on the degree of accentedness (e.g. Wang, 2013; Saito, 2015; Flege and Fletcher, 1992) and there is little research that specially investigates the accentedness in the feature of plosives, future research is needed to further explore whether LoR indeed affects this feature.

4.4. Illegal consonant deletion

Consonant deletion or elision refers to the non-articulation of a consonant, or a consonant cluster (Jenkins, 2000; Hansen, 2011). Huang et al. (2004) pointed out that deletion can occur with consonants in any position, yet it happens more frequently with word-final consonant(s). Although consonant deletion is common in L1 English (e.g. weak form *and* /ən/ in speech, and absence of medial /t/ in three-consonant cluster /sts/ in 'It lasts two hours. '), as a result of phonological rules, it is difficult for L2 English speakers to fully acquire the complex rules of consonant deletion. To distinguish the consonant deletion features that occur in L1 English and those that are atypical omissions in L2 English, the latter is referred to as illegal consonant deletion.

Three studies (Hansen, 2001, 2011; Chen, 2015) reported in total three ME variations in the sub-category of illegal consonant deletion. One SMAEF focuses on the frequency of illegal consonant deletion in ME. The other two are related to the potential factors that contribute to this feature. All three studies confirmed that ME speakers did produce illegal consonant deletion. Chen's study (2015) reveals a smaller amount of consonant deletion by ME speakers compared to Canadian English speakers, which supports Hansen's (2011) prediction of the incomplete acquisition of the rules. These findings agree with the outcomes of existing research, including Lin (2001), who investigates Chinese speakers' word-initial consonant cluster articulation in L2 English, and He (2014), who studies Chinese speakers' English final /l/.

Legal consonant deletion, as an outstanding feature of fluent native English connected speech, seems to be challenging to acquire, not just for L1 Mandarin learners, but also for global learners. Illegal consonant deletion is shared by speakers from diverse L1 language backgrounds. For example, Cantonese English speakers deleted syllable-final plosives (Wong et al., 2019), Korean English speakers simplified consonant cluster in codas (Yun, 2023) and Malaysian English speakers reduced final consonant clusters (Pillai, 2015).

Unintelligibility is less likely to occur when ME speakers preserve consonants against the rules (i.e. producing the consonants that would be deleted in native English natural speech). However, according to LFC researchers (Jenkins, 2000, 2002, 2007; Walker, 2010; Deterding, 2013; O'Neal, 2015), illegal consonant deletion can attenuate intelligibility in natural communication, especially in clusters and syllable codas. Additionally, when illegal deletion occurs on the consonants that carry grammatical function (e.g. past tense and past participle /d/ and /t/, and plural form and third person /s/), intelligibility is also likely to be affected.

The knowledge that the illegal consonant deletion feature is common globally and the LFC finding that this feature is a threat to intelligibility urge corresponding actions. Yet, due to the complex and challenging nature of English pronunciation rules and how they affect consonant deletion, explicit instruction may not be practical. Therefore, allowing

illegal consonant deletion, teaching the adjusting, repairing, and accommodation communication strategies from both speaker and listener should be enforced, to increase and restore intelligibility and contribute to the success of communication (O'Neal, 2015).

5. Conclusion and limitations

5.1. Conclusion

Mandarin-accented English has attracted an increasing number of studies across varied disciplines, engaging different theoretical foundation and methodological frameworks, in the last four decades. The evidence base is constrained by the diversity in research design, focus, L1 control, and outcome measurement, which proposes challenges to achieve a comprehensive synthesis of segmental Mandarin-accented English features. Despite this, this systematic review yields ME vowel variations in the following phonemes: /i, ɪ, ε, æ, u/ and their corresponding contrasts, schwa epenthesis, as well as variations in closure duration of plosives and consonant deletion.

These findings hold significant implications for various professionals and individuals. They benefit fellow researchers exploring Mandarin-accented English, speech and language therapists and English teachers working with L1 Mandarin speakers. Additionally, they are valuable for developers of speech recognition systems that identify accents and transcribe speech content, and for L1 English listeners and global listeners who have frequent interlocutions with Mandarin English speakers.

5.2. Limitations

The topic of this review was limited to the identification of SMAEFs. There were efforts to highlight L1 transfer and the LoR. However, they were not thoroughly considered due to insufficient evidence. Further investigation of the factors requires a separate database search with different search terms.

This systematic review excludes non-native Mandarin speakers, such as speakers of other Chinese varieties, by establishing the accent control criteria (see Criteria (a) and (f) in 2.1) in the screening procedure. However, part of the evidence base is limited in terms of involving Standard Mandarin Chinese speakers and not specifying their L1 or regional dialect (as shown in Table 1 in 3.2.1). Future studies of Mandarin-accented English are strongly encouraged to be clearer about the linguistic background of their participants.

Similarly, no restrictions were applied to control native reference accents. Three native accents, American, Canadian, and British accents, were adopted in studies as reference models, although there seems to be few inconsistent findings resulted from such heterogeneity.

It is also acknowledged that this systematic review does not aim to define Mandarin-accented English with features unique to ME speakers, and that many of the features identified here are shared by other L2 accents of English as discussed above. It is possible that this review may not capture some ME-specific features for various reasons, such as excluding papers for criteria related to the age of participants.

We also excluded studies that only reported prosodic features and all prosodic features reported in the nineteen included studies. Considering the different nature of prosodic MAFEs, an investigation focusing on prosodic ME variations deserves separate attention.

CRedit authorship contribution statement

Hongzhi Wang: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Rachael-Anne Knight:** Resources, Supervision, Visualization, Writing – review & editing. **Lucy Dipper:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Roy Alderton:** Supervision,

Visualization, Writing – review & editing. **Reem S. W. Alyahya:** Supervision, Visualization, Writing – review & editing.

interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of competing interest

The authors declare that they have no known competing financial

Appendix A. Eleven search term combinations used in database searching

Search terms combinations	EBSCOhost	Ovid Online	TRIP	*Note: No 'NOT' condition was applied on TRIP database because all results of search terms with NOT condition, from previously run scoping search, were 0; the results with 'NOT' conditions also excluded a paper later identified as important for this research.
	S1 (Search 1) 'Mandarin English'	S1 'Mandarin English'	S1 'Mandarin English'	
	NOT (speech disorders or language disorders or language impairment)	NOT (speech disorders or language disorders or language impairment)	AND	
	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	S2 'characteristics or features or patterns'	
	AND	AND	features or patterns'	
	S2 'characteristics or features or patterns'	S2 'characteristics or features or patterns'		
	S1 'Mandarin accented English'	S1 'Mandarin accented English'	S1 'Mandarin accented English'	
			English'	
	S1 Mandarin	S1 Mandarin	S1 Mandarin	
	NOT (speech disorders or language disorders or language impairment)	NOT (speech disorders or language disorders or language impairment)	AND	
	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	S2 (L1 or first language)	
	AND	AND		
	S2 (L1 or first language)	S2 (L1 or first language)		
	NOT (child* or infan*)	NOT (child* or infan*)		
	S1 Mandarin	S1 Mandarin	S1 Mandarin	
	AND	AND	AND	
	S2 accent*	S2 accent*	S2 accent*	
	AND	AND	AND	
	S3 (characteristics or features or patterns)	S3 (characteristics or features or patterns)	S3 (characteristics or features or patterns)	
	S1 Mandarin	S1 Mandarin		
	NOT (speech disorders or language disorders or language impairment)	NOT (speech disorders or language disorders or language impairment)		
	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)		
	AND	AND		
	S2 accent*	S2 accent*		
	AND	AND		
	S3 English	S3 English		
	S1 Putonghua	S1 Putonghua	S1 Putonghua	
	AND	AND	AND	
	S2 accent*	S2 accent*	S2 accent*	
	S1 Putonghua	S1 Putonghua	S1 Putonghua	
	NOT (speech disorders or language disorders or language impairment)	NOT (speech disorders or language disorders or language impairment)	AND	
	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	NOT (hearing loss or deafness or hearing impairment or deaf or hard of hearing)	S2 accent*	
	AND	AND	AND	
	S2 accent*	S2 accent*	S3 (characteristics or features or patterns)	
	AND	AND		
	S3 (characteristics or features or patterns)	S3 (characteristics or features or patterns)		
	S1 Putonghua	S1 Putonghua	S1 Putonghua	
	AND	AND	AND	
	S2 (L1 or first language)	S2 (L1 or first language)	S2 (L1 or first language)	
	AND	AND	AND S3 (characteristics or features or patterns)	
	S3 (characteristics or features or patterns)	S3 (characteristics or features or patterns)		
	S1 'Beijing dialect'	S1 'Beijing dialect'	S1 'Beijing dialect'	
	AND	AND	AND	
	S2 accent*	S2 accent*	S2 accent*	

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(continued)

	S1 'Beijing dialect' AND S2 English	S1 'Beijing dialect' AND S2 English	S1 'Beijing dialect' AND S2 English
	S1 Beijing AND S2 accent*	S1 Beijing AND S2 accent*	S1 Beijing AND S2 accent*
	AND S3 English	AND S3 English	AND S3 English
Number of results	919	260	45
In total	1224		

Appendix B. Segmental mandarin accented English features (SMAEFs) from the nineteen studies

Variation category	Variation sub-category	Studies that report significant results	Results
Vowel	Vowel height and frontness		
	/i/	He & van Heuven, 2010 Barkana & Petal, 2020	ME /i/ productions were lower, compared to AE. Male ME speakers /i/ productions were too far back.
	/ɪ/	He & van Heuven, 2010 Sangwan & Hansen, 2012 Flege et al., 1997	ME /ɪ/s were largely different from AE /ɪ/s on both height and frontness. ME speakers produced /ɪ/ too low and back. Experienced ME speakers, compared with inexperienced ME speakers, made a significantly clearer distinction between /i - ɪ/ contrast.
	/i - ɪ/ contrast	He & van Heuven, 2010	The spectral contrast between /i - ɪ/ in ME was smaller than those in AE and BE.
	/e/	He & van Heuven, 2010; Barkana & Petal, 2020	ME /e/s were lower than AE and RP.
	/æ/	Barkana & Petal, 2020 He & van Heuven, 2010	ME /æ/s were lower than AE /æ/s. ME /æ/s were too low and too far back, compared with AE in Peter & Barney's (1952) and in Hillenbrand's (1995) corpora.
	/e - æ/ contrast	He & van Heuven, 2010 Flege et al., 1997	ME /æ/s were too far back, compared with RP in Wells' (1962) and Deterding's (1997) corpora. Five out of 20 of ME speakers (both inexperienced and experienced) produced /e/ and /æ/ with similar frontness, showing little distinction, contributing to bidirectional confusion between /e/ and /æ/.
	/u/	He & van Heuven, 2010; Barkana & Petal, 2020 He & van Heuven, 2010	There is less distinction in the contrasted vowels in ME /e - æ/, compared with AE and BE. ME /u/s were not high enough, compared to AE /u/ productions. This made the ME productions closer to /ʊ/.
	/u - ʊ/ contrast	Thomson, 2005 He & van Heuven, 2010	ME /u/s were frequently perceived as both /ʊ/ (41%) and /o/ (27%). The spectral contrast between /u - ʊ/ in ME was smaller than those in AE and BE.
	Other vowels (/ʌ, o, ɔ, ɑ/)	Barkana & Petal, 2020 Barkana & Petal, 2020 He & van Heuven, 2010 He & van Heuven, 2010	ME /ʌ, o, ɔ/ productions were lower and more back than AE productions. ME /ɑ/ were higher and more back than AE. ME /o/s were too low.
	Vowel space	Robb & Chen, 2008 Robb & Chen, 2008 He & van Heuven, 2010	ME /ʌ/ productions were different from AE /ʌ/. ME speakers had a smaller vowel space than AE speakers for /i, u, ɑ/ productions. ME speakers had a bigger vowel space than AE groups for the productions of /ɪ, ʊ, ɔ/. In general, ME vowel space was relatively closer to RP vowel space, and far less similar to AE vowel space.
	Vowel length		
	Vowel duration in isolated words	Robb & Chen, 2008 He & van Heuven, 2010	ME speakers had shorter vowel duration for /i, u, ɑ, ɔ/ productions, and a longer duration for /ʊ/ productions, compared with AE speakers. ME speakers produced much larger duration ratios between /e-e/, /e-æ/, /i-ɪ/, /u-ʊ/ than AE speakers do, suggesting that ME speakers tend to over-emphasise this feature strategically potentially to distinguish /e/ and /æ/.
	Durations of stressed and unstressed vowels Using vowel length to distinguish sounds	Chen, 2015 Olmstead et al., 2021 Olmstead et al., 2021	The length deviation between stressed and unstressed ME vowels twice as long as that in AE. ME speakers had acquired the native pattern of utilising longer vowel durations to indicate and distinguish the voicing features in the preceding plosives. ME speakers used longer vowel duration as a primary strategy to distinguish similar vowels, e.g. /i, ɪ/, unlike NE speakers who primarily used spectral contrast to make distinctions between similar vowels.
Schwa epenthesis	Hansen, 2001; Eckman, 1981; Chen, 2015 Hansen, 2001; Eckman, 1981; Chen, 2015 Hansen, 2001	ME speakers tended to insert a schwa-like vowel after the word-final consonant. Schwa epenthesis occurred most frequently when the word ends with /t/, then /d/.	
Consonant	Voicing features		
	Voicing errors	Xie & Fowler, 2013	Epenthesis was the most common type of variation for two-member codas, e.g. [hel.də] for held Most of the incorrect responses of NE listeners' transcription of Me speakers' productions (approximately 94%) were voicing errors rather than manner (approximately 4%) or place (less than 2%) errors.
	Voice onset time	Arslan & Hansen, 1997; Hansen et al., 2010	The VOT values for word-initial /p, t, k/ in ME natural speech were shorter than those in AE natural speech.
	Voicing of plosives	Xie & Fowler, 2013	In /b, p, d, t, g, k/ productions, ME speakers' coda stop voicing was less separable than NE speakers.

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(continued)

Variation category	Variation sub-category	Studies that report significant results	Results
	Voicing in /h/ MoA: Plosive productions	Robb & Chen, 2009	NE speakers produced voiced /h/ (i.e. [h]) more than ME speakers did.
	Closure duration in plosive productions	Arslan & Hansen, 1997 Luo et al., 2020	ME speakers produced longer closure durations for /t, d/ codas. In cross-word consonant clusters (i.e. C1#C2, such as /pk/ sound in <i>keep calm</i>), Canadian English speakers did not release C1 (e.g. the /d/ in <i>good</i> in the <i>phrase good day</i>), while ME speakers with lower proficiency tended to release C1
	Substitution	Luo et al., 2020 Hansen et al., 2010	ME group with lower proficiency produced no closure overlap in C1#C2 clusters. In ME productions of words that contained word-initial /p, t, k/, ME speakers replaced the plosive-vowel syllable with a Mandarin syllable that contained <i>equivalent</i> Mandarin plosive-vowel phonemes. For example, Mandarin /tʰ/ (or [ta] in Mandarin Pinyin) would be used to replace English syllable /ta/ in <i>target</i> /tagit/.
	MoA: Fricative productions		
	Duration of fricative /h/ Duration ratio of fricative /h/	Robb & Chen, 2009 Robb & Chen, 2009	ME speakers produced longer durations for /h/ than AE speakers. Male ME speakers produced larger duration ratio than male AE speakers.
	MoA: Approximant productions		
	Syllable-final /r/ /l, w/	Arslan & Hansen, 1997 Sangwan & Hansen, 2013	ME speakers had different F2 and F3 frequencies in /r/, compared with AE speakers. ME speakers exhibited differences in the articulator motion and duration in /l, w/ productions.
	Illegal consonant deletion	Hansen, 2001 Hansen, 2001; Hansen, 2011 Chen, 2015	For ME speakers, consonant deletion was favored in their production of three-member codas (i.e. codas with three consonants, such as /t/ in /sts/ as in <i>lasts</i>) The appearance of /t, d/ deletion in ME. Beijing ME speakers exhibited less consonant deletion than AE speakers.

Data availability

No data was used for the research described in the article.

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