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Determination of corrective optimals for Chinese university learners of English

Summary

In the expectation of investigating the nature of corrective optimals of the sounds of English for Chinese EFL learners, a small selection of problematic English vowel sounds (i.e. /ɪ/, /iː/, /e/, /æ/, /ʊ/ and /uː/) was explored. The present study investigated the corrective optimals for these sounds. To this end, an experiment was conducted. Thirty-seven first-year non-English major university EFL learners participated. Each student went through two diagnostic steps. First, each student's preferred center frequency (f_{center}) was determined for a particular vowel sound, beginning with exposure to the f_{center} of the traditional native-speaker optimal. Second, a combination of frequency bands that together form corrective optimals for each of the six vowels was determined for each individual student. Rather than consisting of single continuous 1-octave bands, corrective optimals for Chinese university EFL learners were found to be discontinuous multiple frequency bands that are both narrower and finer. The corrective optimals for Chinese university EFL learners were identified as discontinuous multiple band structures containing a bandpass filter narrower than one octave and, in addition, a significant low frequency component. In the light of this finding, it seems valuable to reorient the concept of corrective optimal away from a single octave frequency band and toward discontinuous multiband structures containing a significant low frequency component. Further research over a great number of vowels and consonants for various languages is desirable to confirm and extend this finding.

Key words: optimals, corrective optimals, verbotonal theory, language learning, Chinese learners of English

1. INTRODUCTION

The research reported in this paper is situated within a series of eight projects based in Asia (Thailand, China, Vietnam and Indonesia) whose purpose is to investigate ways of improving pronunciation, comprehensibility and fluency skills as well as, eventually, listening and other skills that depend on the perception of auditory signals or that are connected with auditory signals either explicitly or implicitly. All take the verbotonal theory of perception/production (Guberina, 1956, 1972; Guberina & Asp, 1981) as their research base.[1]

The first two studies were successfully completed in 2014 and 2016 respectively. The first study sought to teach Chinese adult learners of English (university students) the prosody of English as a way of increasing phonetic acceptability, comprehensibility and fluency (beyond simple pronunciation) (He, 2014; He & Sangarun, 2015; He, Sangarun, & Lian, 2015). The second study attempted to teach Chinese Grade 3 children (average age 9 years), not only the prosody of English but also general speaking skills (Yang, 2016; Yang, Wannaruk, & Lian, 2017). That study also examined the impact of the teaching approach on phonological working memory.

Both studies produced excellent, sometimes surprising, results beyond the original expectations of the researchers. Importantly, both studies drew on the range of techniques typically associated with phonetic correction in the verbotonal system e.g. low-pass filtering of intonation patterns, motoricity/synchronicity/"dancing" (coupled with preliminary relaxation exercises to reduce the impact of muscular/postural habits), other awareness-raising exercises based on the systematicity of intonation patterns as well as sensitivity to "tension". All procedures were conducted on the basis of each learner’s personal meaning-making mechanisms (in verbotonalism perception is an outcome of the ways in which people make sense of auditory signals – a form of meaning-making). In this sense, verbotonalism has always

1 The availability of low-cost modern technology together with the will and need to experiment conceptually with the notions of perception (a form of meaning-making), learning and teaching in the context of English language education in South-East Asia has led to a rebirth of interest in verbotonalism in the region, specifically in Thailand, China, Australia and Indonesia where studies have been conducted recently and continue to be conducted. Suranaree University of Technology is the primary source for all studies described here, with research teams active since 2012 under the leadership of Professor Dr. Andrew Lian. Chinese activity centres include Xin Yi Normal University for Nationalities (Professor Dr. He, Bi; He et al., 2015), Kunming University of Science and Technology (Associate Professor Dr. Yang, Yan; Yang et al., 2017), Kunming University of Medical Sciences (Mr. Cai, Cirui), Gannan Normal University (Mr. Wen, Fengwei) and, in Australia, another research team led by Dr. Ania Lian (Charles Darwin University) with specific projects in Indonesia (academic writing connected to rhythm and intonation) at IAIN Syekh Nurjati, Cirebon (Mr. Lala Bumela Sudimantara).

had a profound concern with the individual and the use of stimuli adapted to each learner's perceptions (i.e. understandings) as a starting point for correction of a person's or a group's system of errors (Lian, 1980).

The research reported here concerns the first half of the third study in the series. The second half will be reported separately. Traditionally, as implemented in the first two studies reported above, verbotonal intervention takes the form of an ensemble of techniques and procedures designed to support each other reciprocally so as to maximize their impact on the improvement of pronunciation. From a research perspective, if there is improvement, it is due to the entire system. In contrast to the first two studies, this third study seeks to focus primarily on corrective optimals rather than on the entire system of verbotonal corrective techniques. It singles out one of verbotonalism's more intriguing techniques for improving pronunciation: the use of electronic filtering of auditory signals to enhance perception of the phonemes under study. Specifically, in its entirety, the study seeks to discover whether repeated exposure to individually-diagnosed corrective optimals coupled only with simple repetition, is sufficient to bring about, per se, significant improvements in perception and production of the target phonemes. It also acknowledges that in the normal run of pronunciation learning, corrective optimals would be used, as per standard verbotonal practice, only to correct any residual problems following extensive training in the prosody of the language being learned (English in our case).

This is an important question to answer in both a theoretical and a practical perspective. It is important theoretically as, inter alia, it will help to identify more clearly the role of filtering and corrective optimals in terms of the balance of corrective techniques used in verbotonalism. It is also of practical relevance as, if significant/ sufficient improvement occurs, it may be possible to construct a system of corrective phonetics that functions more or less automatically, with no intellectualisation by the learner (in keeping with verbotonal principles) and, ideally, in a manner responsive to each individual learner's perceptual mechanisms, at low cost and with no teacher intervention. Should such a mechanism exist, language teachers will be released for other activities as the success of the intervention will not depend on teachers' skills but on the consistency of a rigorously-determined auditory signal repeatedly provided to learners under optimal, self-managed conditions. Eventually, this could give rise to teacher-less systems and is one area where NOT having a teacher may actually be of benefit to both learners and teachers. This is of special importance in today's mass

English language markets where respect for individual differences is often sacrificed because the market is both very large and significantly under-resourced.

The general spirit of this investigation is in line with the notion of Precision Language Education (Lian, 2016, 2018; Lian & Sangarun, 2017; Lian & Sussex, 2018) and, more generally, Precision Education (Cook, Kilgus, & Burns, 2018) both of which seek to avoid a one-size-fits-all approach to the solution of educational problems and actually meet learners' individual needs more effectively.

This third study can be split into two parts: (a) determination of individualised corrective optimals and (b) testing of the impact of these optimals. The remainder of this paper will deal exclusively with the first of these two parts in the context of learning English as a Foreign Language for speakers of Putonghua (Mandarin) in China.

2. CONTEXT AND BACKGROUND

In the age of globalization, as an important medium for communication among people from different countries and sociolinguistic groups, the English language has now moved to a new status as a global language and worldwide lingua franca (Galloway, 2017; Pan, 2015; Rose & Galloway, 2019; Sung, 2016). As a result, the need for learners to be effective users of English has become a basic requirement for nearly everyone. English is now (since 2001) a compulsory school subject from primary school (Grade 3) onward in China. However, despite studying English for years and passing a variety of English tests, Chinese EFL learners remain particularly weak in pronunciation (Qiang & Wolff, 2011). They are unable to produce some key English sounds and English sound contrasts adequately and, as a result, are often unintelligible (there are other reasons too). The difficulties encountered include vowel contrasts such as the ones that we focus on in this study: /ɪ/-/iː/, /e/-/æ/ and /ʊ/-/uː/ (Chang, 2001; Han, 2013; Wang & van Heuven, 2004; Zhang & Yin, 2009; Zheng & Liu, 2018). Given the inefficiency of current approaches to pronunciation development, there is a need to develop new remedies for this situation. This opens up interesting and valuable research opportunities to investigate original or unexplored approaches.

One such approach to phonetic correction with great but still largely unrealized potential is the verbotonal approach (VTA). The verbotonal approach, an auditory rather than an articulatory approach, was developed by Petar Guberina in the 1950s. According to him, each language has its own set of optimal frequency bands for its sound repertoire. The theory further postulates that segmental articulation is relatively problem-free if the optimal quality of the sound has been perceived by the language learner. As pointed out above, one of the characteristic research-based techniques of verbotonalism is to seek to improve learners' pronunciation by exposing/sensitizing them to optimized materials using digital audio filtering (Asp, 1972, 2006; Asp & Kline, 2012; Hang, 2012; He, 2014; Lian, 1980; Mildner & Bakran, 2001; Mildner & Tomić, 2007; Wu, 2013; Zhang, 2006).

The process of filtering involves the removal of certain frequency bands from a naturally-produced sound (e.g. a single phoneme) or sequence of sounds (e.g. a sentence).

Verbotonal theory postulates that identification and production of phonemes is based on the selection/recognition of frequency bands embedded in the complexity of the sound spectrum. Under this assumption, all sounds carry all other sounds within them so that the perceiving ear, once triggered, may seek or "find" familiar frequency bands from its first language and/or other languages that it knows, inside the sound that they hear. Language learners may therefore incorrectly "recognise" not the quality of the target foreign language sound but construct a cognate sound from their first or other languages. This defective perceptual model is then used as the basis for the internal generation of a production model for the sound that they are trying to produce. Because their production model is inadequate, they fail to pronounce target sounds acceptably. This is a simplification of the process but it will suffice for the moment.

Restricting the frequency bands to which the learner is exposed removes the possibility of making "wrong" selections by eliminating any "wrong" frequency bands from which to choose as only the "correct" bands are left behind. Learners can only physically hear what they were meant to be hearing: the critical elements of the target sound. However, given that we do not hear or see "reality" as it is, this process is not sufficient to ensure correct perception as each brain imposes its own structuring mechanisms on input sound to "distort" received auditory signals in accordance with its own perceptual habits (Lian & Sussex, 2018). For example, the monolingual speakers of a "tense" language might create an internal perceptual representation that is tenser than that which a competent speaker of the language being learned might create and, as a result, might produce "tense" sounds that are distorted in accordance with the parameters of their "tense" first language. The opposite would be true of a "lax" language. Typical verbotonal intervention might be to offer learners some perceptual models which "go in the opposite direction" to the errors detected, in a kind of push-pull compensatory process. As enacted by certain verbotonal practitioners, the nature of these perceptual models is often intuitive, approximate and short-lived rather than precise and extended over time (e.g. Boureux, 2020; Intravaia, 2015).

Developing the above according to verbotonal theory, the optimal quality of a sound is embodied in what Guberina called an optimal frequency band. This is generally described as the 1-octave band that yields the best identification score for a specific speech sound (phoneme) (Asp, 2006)[2]. There are native-speaker optimals (at which native-speakers best identify the sound in question) and corrective optimals to assist learners of foreign languages. Corrective optimals are different from native-speaker optimals in that they are designed to compensate for the non-native-speaker learners' perceptual mechanisms.[3]

Until now, the notion of corrective optimal has been insufficiently explored in the case of Chinese EFL learners (and, arguably, for other learners too). The advent

[2] There are other possible optimal frequencies, e.g. the optimal frequency of intonation which is regularly set as a low-pass filter with a cutoff frequency of about 320 Hz. A low-pass filter removes all frequencies above the cutoff frequency i.e. it passes frequencies BELOW the cutoff frequency, hence its name. A high-pass filter removes all frequencies below the cutoff frequency i.e. it passes frequencies ABOVE the cutoff frequency, hence its name. A bandpass filter has two cutoff frequencies, high and low. It maintains the frequencies between the two cutoff frequencies. Low-pass, high-pass and band-pass filters may be combined with one another.

[3] It is arguable that a native-speaker optimal is only a perceptual construct and that native speakers in need of correction are functionally similar to foreign language learners and therefore should be exposed to corrective rather than native-speaker optimals. However, there are instances where native-speaker optimals appear to have been used successfully to correct the defective pronunciation of native speakers (e.g. Mildner & Bakran, 2001). In these cases, presumably, the learner's ear was able to perceive within the native-speaker optimal the necessary compensatory features for correct production to ensue. Alternatively, as an ensemble of processes were used (Mildner & Bakran, 2001, pp. 152–153), the correction may have come, effectively, from other corrective processes and not from exposure to the native-speaker optimal.

of modern technology provides new opportunities for reviewing the assumptions underpinning the classical view of corrective optimals in the Chinese context. This study therefore investigated the corrective optimals of specific English vowels for Chinese EFL learners. Corrective optimals identified would then be used in further experimentation. In order to investigate the issue, three pairs of problematic vowels for Chinese EFL learners were selected.

3. AIMS

As a consequence of the above reasoning, the present study attempted to answer the following question:

What are the corrective optimals for Chinese non-English major university EFL learners for the following English vowels: /ɪ/, /iː/, /e/, /æ/, /ʊ/ and /uː/?

4. STIMULI AND FILTERING

The stimuli used for diagnosis of the corrective optimals of the target vowels were a list of six digitally-recorded monosyllabic words (i.e. ship, sheep, bed, bad, soot, suit). The words were selected because they are common, simple, and easy to produce. The recorded words were pronounced by a male English native speaker of British English and were played to learners in accordance with the protocol below.

In the present study, the target vowel sounds and only the vowel sounds in the recordings were filtered using either classical native-speaker optimal bands or enriched optimals (see below). This approach was devised in order to maximize the intelligibility of the sentences used and also to avoid distorting any sounds not under study. This approach would not have been possible without the use of digital technology and may represent an improvement over approaches that filter the entire words or sentences, thus rendering them unintelligible (He, 2014; Lian, 1980, 2014; Yang, 2016). Taking the word "bed" as an example, only the vowel /e/ was filtered and the remaining phonemes were left untouched. This resulted in the following recording (underlined part represents filtering): "bed". The word therefore consisted of a mix of filtered and unfiltered sounds, with filters applied only to the sound under study, thus maximizing intelligibility while imposing auditory restrictions on the target phoneme. In the present study, the audio-editing program Audacity (Version 2.1.2; Audacity Team, 2016) was used for digital filtering of the sounds under study.

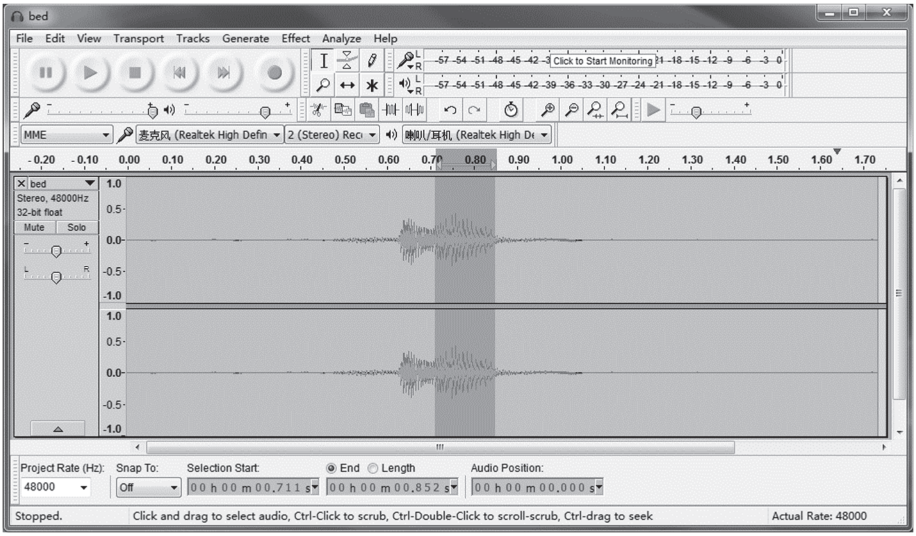

Figure 1. Sound selection for the vowel /e/ in "bed" – selection is unfiltered /e/

Slika 1. Zvučni primjer za vokal /e/ u riječi "bed" – označeni odsječak je nefiltriran glas /e/

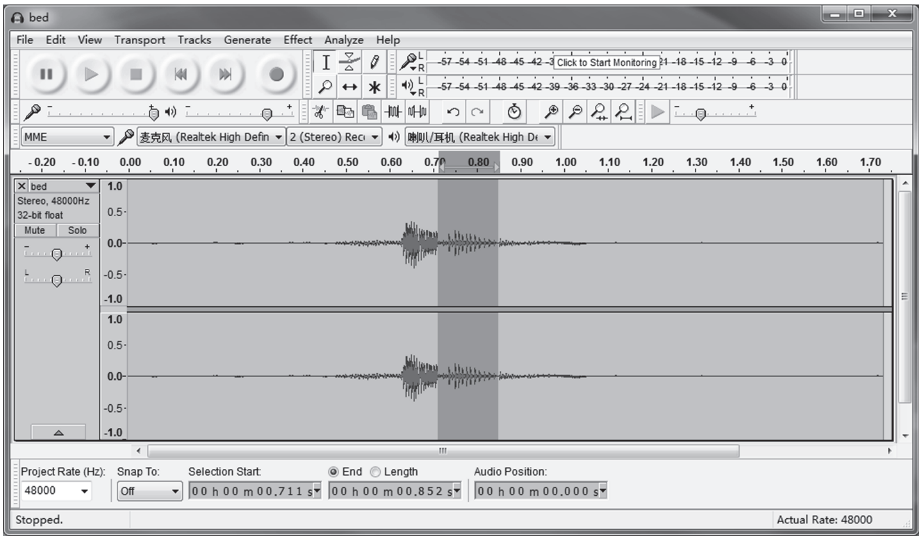

Figure 2. Filtering for the sound /e/ in "bed" (2,419–3,048 Hz) – selection is filtered /e/

Slika 2. Filtriranje glasa /e/ u riječi "bed" (2 419 – 3 048 Hz) – označeni odsječak je filtriran glas /e/

5. PARTICIPANTS

Thirty-seven first-year Chinese non-English major EFL university students were chosen to participate in this study. They were between 17–21 years of age, with a mean age of about 19 years. All participants reported having normal hearing at the time of the college entrance physical exam. According to the paper-based college English placement test, these students were within a similar proficiency range. Ethics clearance was secured from Gannan Normal University. The procedures and processes of the study were carefully explained to all students who explicitly signified their assent to participate.

6. CORRECTIVE OPTIMALS

To determine the Chinese non-English major EFL learners' corrective optimals for the target English vowels, all 37 participants took part in an individual diagnostic intervention. As mentioned, six stimuli were involved (i.e. ship, sheep, bed, bad, soot, suit). The diagnosis was individually carried out in a language laboratory at Gannan Normal University. We acknowledge that each learner's perceptual problems are individual in nature and that the procedure adopted here would have to be refined in order to be entirely individualized so as to (a) tune it to each learner and (b) cover a greater range of prosodic and phonetic contexts than was possible here. However, we felt that at this stage of the study this procedure would be satisfactory for our purpose and would provide sufficiently accurate evidence to test the general parameters of the corrective optimals. One of the researchers (Chinese) and another experienced English teacher (also Chinese) assessed the production quality of the target vowel sounds. Each student went through two diagnostic steps as follows.

First, as a starting point, in order to determine each individual student's preferred center frequency (f_{center}) for a particular vowel sound, the procedure began with exposure to the f_{center} of the traditional native-speaker optimals. That is, the target vowel sounds in the above-mentioned six monosyllabic words were filtered initially according to the settings of the classical 1-octave frequency range: /ɪ/ = 1,600–3,200 Hz (f_{center} = 2,263 Hz); /i:/ = 3,200–6,400 Hz (f_{center} = 4,525 Hz); /e/ = 1,600–3,200 Hz (f_{center} = 2,263 Hz); /æ/ = 1,200–2,400 Hz (f_{center} = 1,697 Hz); /ʊ/ = 300–600 Hz (f_{center} = 424 Hz); /u:/ = 200–400 Hz (f_{center} = 283 Hz) (Asp, 1972; Koike, 2012).

Learners listened three times to each filtered word and their pronunciation was checked in terms of acceptability of the target vowel sound. Generally, exposure to the native-speaker optimal did not result in acceptable production of the sound, presumably because the student's perceptual mechanisms were not similar to those of native speakers. When the students failed to produce the sounds acceptably (or where it was thought they were likely to do better), a different (higher or lower) f_{center} was presented according to the student's performance. For example, if the student pronounced /ɪ/ instead of /i:/, his/her pronunciation was deemed to be "lower" than the target and needed to be remedied by using an f_{center} higher than the initial one. On the contrary, if the erroneous pronunciation was /i:/ instead of /ɪ/, the pronunciation was deemed to be "higher" and needed to be "lowered".

As a result, a set of optimal $f_{centers}$ for all six vowels was determined for each student according to where the student had best been able to produce vowel sounds that were close to the target sounds.

Second, various filters were constructed around the diagnosed center frequencies so as to produce sets of finer, in some cases discontinuous, frequency bands as specified below. In the case of discontinuous filters, a lowpass frequency band (< 320 Hz) was added and the width of the center frequency band was narrowed from 1 octave to $\frac{1}{2}$ octave or $\frac{1}{3}$ octave. Together with the 1-octave filter determined above, every vowel under study was enhanced using six different filter settings (i.e. 1 octave, $\frac{1}{2}$ octave, $\frac{1}{3}$ octave, 0–320 Hz + 1 octave, 0–320 Hz + $\frac{1}{2}$ octave and 0–320 Hz + $\frac{1}{3}$ octave).

After a student listened to each specific filter three times, he/she was then required to try to repeat the word. At some point in the process, the student was able to best produce the target vowel sound. When the student produced the sound correctly or produced a sound that was the best that he/she could, the combination of frequency bands was noted and this was deemed to be that particular student's corrective optimal. In the end, corrective optimals for each of the six vowel sounds were determined for each individual student. In a second phase, these individual corrective optimals were then used (a) to sensitize students to the characteristics of the sound under study and then (b) to provide a stimulus for simple self-managed listen-repeat exercises. Full details of this second phase will be reported separately.

7. RESULTS

The following table shows the composition of the corrective optimals of the six target vowels. To help readers better understand the corrective optimals identified, their octave type, center frequency and percentages of best production are also displayed.

Table 1. Corrective optimals for the target English vowels for Chinese EFL learners as identified in this study

Tablica 1. Eksperimentalno određena korektivna optimala za izgovor vokala engleskog jezika kod kineskih govornika koji uče engleski jezik u ovom istraživanju

Vowel / Vokal	Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
/ɪ/	0–320 Hz + 2,419–3,048 Hz	0–320Hz + $\frac{1}{3}$ octave	2,715 Hz	33 (89.2%)
	0–320 Hz + 1,815–2,286 Hz	0–320Hz + $\frac{1}{3}$ octave	2,037 Hz	4 (10.8%)
/i:/	0–320 Hz + 4,838–6,096 Hz	0–320Hz + $\frac{1}{3}$ octave	5,431 Hz	32 (86.5%)
	0–320 Hz + 4,567–6,459 Hz	0–320Hz + $\frac{1}{2}$ octave	5,431 Hz	4 (10.8%)
	0–320 Hz + 4,435–5,588 Hz	0–320Hz + $\frac{1}{3}$ octave	4,978 Hz	1 (2.7%)
/e/	0–320 Hz + 2,419–3,048 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,715 Hz	34 (91.9%)
	0–320 Hz + 2,016–2,540 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,263 Hz	2 (5.4%)
	0–320 Hz + 1,613–2,033 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,811 Hz	1 (2.7%)
/æ/	0–320 Hz + 1,512–1,905 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,697 Hz	30 (81.1%)
	0–320 Hz + 1,209–1,523 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,357 Hz	4 (10.8%)
	0–320 Hz + 1,815–2,286 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,037 Hz	3 (8.1%)
/ʊ/	0–320 Hz + 214–269 Hz	0–320 Hz + $\frac{1}{3}$ octave	240 Hz	31 (83.8%)
	0–320 Hz + 415–523 Hz	0–320 Hz + $\frac{1}{3}$ octave	466 Hz	3 (8.1%)
	0–320 Hz + 303–382 Hz	0–320 Hz + $\frac{1}{3}$ octave	340 Hz	2 (5.4%)
	0–320 Hz + 542–682 Hz	0–320 Hz + $\frac{1}{3}$ octave	608 Hz	1 (2.7%)
/u:/	0–320 Hz + 302–381 Hz	0–320 Hz + $\frac{1}{3}$ octave	339 Hz	32 (86.5%)
	0–320 Hz + 277–349 Hz	0–320 Hz + $\frac{1}{3}$ octave	311 Hz	5 (13.5%)

(Note: on average, 13.5% of participants did not use the most "popular" corrective optimal)

As can be seen, the target vowel sounds were best produced when filtered through discontinuous multiband filters (i.e. 0–320 Hz + $\frac{1}{2}$ octave or 0–320 Hz + $\frac{1}{3}$ octave). This was true for all target vowels.

The most "popular" corrective optimal identified was as follows: for /ɪ/ it was 0–320 Hz + 2,419–3,048 Hz (f_{center} = 2,715 Hz); for /i:/ it was 0–320 Hz + 4,838–6,096 Hz (f_{center} = 5,431 Hz); for /e/ it was 0–320 Hz + 2,419–3,048 Hz (f_{center} = 2,715 Hz); for /æ/ it was 0–320 Hz + 1,512–1,905 Hz (f_{center} = 1,697 Hz); for /ʊ/ it was 0–320 Hz + 214–269 Hz (f_{center} = 240 Hz) and for /u:/ it was 0–320 Hz + 302–381 Hz (f_{center} = 339 Hz).

In addition, a variety of other corrective optimals were found to be effective for a small percentage of participants. Apart from the abovementioned, 0–320 Hz + 1,815–2,286 Hz (f_{center} = 2,037 Hz) was determined for /ɪ/. Filters 0–320 Hz + 4,567–6,459 Hz (f_{center} = 5,431 Hz) and 0–320 Hz + 4,435–5,588 Hz (f_{center} = 4,978 Hz) were determined for /i:/. Filters 0–320 Hz + 2,016–2,540 Hz (f_{center} = 2,263 Hz) and 0–320 Hz + 1,613–2,033 Hz (f_{center} = 1,811 Hz) were determined for /e/. Filters 0–320 Hz + 1,209–1,523 Hz (f_{center} = 1,357 Hz) and 0–320 Hz + 1,815–2,286 Hz (f_{center} = 2,037 Hz) were determined for /æ/. Filters 0–320 Hz + 415–523 Hz (f_{center} = 466 Hz), 0–320 Hz + 303–382 Hz (f_{center} = 340 Hz) and 0–320 Hz + 542–682 Hz (f_{center} = 608 Hz) were determined for /ʊ/. The filter 0–320 Hz + 277–349 Hz (f_{center} = 311 Hz) was determined for /u:/.

From the above findings, it can be concluded that the corrective optimals identified in this study are both narrower (smaller than 1 octave) and richer (containing more than one frequency band) than the original native-speaker optimals. Moreover, the corrective optimals were found to be less uniform and more diverse in comparison to the native-speaker optimals.

8. DISCUSSION

Based on the above results, there are interesting findings worth pointing out. First, a list of corrective optimals was determined.

Second, it was verified that changing the input changed the output and suggested that the best changes in production resulted from discontinuous filtering consisting of a low-frequency component and a narrow bandpass filter.

Third, while most students favored a particular configuration of input which varied from vowel to vowel, a significant minority (13.5% on average) were distributed over up to three other input configurations, thus demonstrating that although each sociolinguistic group raised its members to construct similar perceptual mechanisms as a result of social interaction, some significant, currently unexplained, learner differences in the perception of the target sounds actually do exist even within the same sociolinguistic group. There may be optimal configurations scattered in small numbers throughout the Chinese EFL learner population. Clearly, then, apparently similar learners can be significantly different from one another in terms of perception/production thus demonstrating that corrective intervention based on a one-size-fits-all statistical model of perception/production is not the best approach. Individual diagnosis and intervention is needed. Having said that, results also indicate that, further research with finer settings may reveal greater differences than those identified in this study.

Fourth, it was clear that the discontinuous multiband filters were more effective than the single bandpass filters, indicating the value of the bi-modal use of low-frequency bands associated with narrow, smaller-than-octave bands. Further refinement of the frequency bands discovered for Chinese EFL learners may be necessary and valuable to accommodate more precisely to their perceptual mechanisms. This study, however, seems to be a good first step in the correct direction.

Fifth, it is worth noting that a low-frequency component, provided by low-pass filtering (F_0), actually makes a significant contribution to corrective optimals and should be taken into consideration when developing corrective optimals in the future. These findings, in turn, open up a new set of research questions such as the more precise determination of cutoff points for both bandpass and low-pass filters, including their personalization. As part of the tradition of the verbotonal approach, low frequencies are often incorporated into speech treatment in order to help improve learners' speech perceptions. According to Asp (2006), low frequencies can be easily felt and are optimal for processing speech rhythm and intonation patterns. Similarly, Lian (1980) reminds us that the target vowels could be made more salient using lowpass filtering, since the body is more sensitive to low frequencies.

This is evidenced, for example, in Hillenbrand and Gayvert's (1993) understanding of vowel perception. According to them, "perceived vowel quality is strongly correlated with the frequencies of the two or three lowest formants" (p. 694). Referring to acoustic analysis, fundamental frequency is viewed as the main correlate of the pitch patterns of the linguistic prosodic systems of tone and intonation

(Abberton & Fourcin, 1997). Similarly, Honorof and Whalen (2005) declare that the fundamental frequency carries information about many different aspects of the speech signal, including both linguistic and paralinguistic aspects. In other words, the fundamental frequency necessarily embodies characteristics of the vowel that we are trying to produce. This is because, simply put, the fundamental frequency is an integral part of all vowels and voiced consonant sounds and is responsible for actually generating them. Without F_0, there would simply be no vowel or voiced consonants. Thus, the fundamental frequency is necessarily heavily responsible for the characteristics of the vowels that it helps to produce. Change the quality of the fundamental frequency and you change the quality of the resulting vowel or consonant. This is why when the intonation of each vowel (F_0) is corrected, it is expected that the other formants (i.e. F_1, F_2, F_3 etc.) will adjust themselves to and become harmonious with the fundamental frequency.

However, one of the long-standing problems of English pronunciation learning is that we have been trained in academic courses (e.g. BA, MA), and therefore in our habits of mind, to separate phonemes and intonation from one another and to focus initially and primarily on phonemes with intonation then added as a kind of decoration. This seems based on the simplistic assumption that spoken language consists of individual sounds strung together. Phoneticians have long-known, however, that this is simply not the case and that single sounds rarely occur in isolation but are constantly in transition: everything is moving, everything is dynamic. Thus, in the world of English language teaching, we are usually taught to focus first on individual sounds, and then to move on to intonation, even though, in reality, individual sounds cannot be separated from their accompanying intonation: they are actually the same thing and embodied in one another. Exposure to lowpass filtering not only helps to emphasize the individual sounds and intonation but also helps to give sounds some of their dynamic characteristics. As a result, if a significant, perhaps enhanced, intonative component is added to auditory stimuli, learners can be made much more aware of the typical qualities/attributes and production range of the sounds that they are studying, thus enhancing their perception and, ultimately, their production.

9. CONCLUSION

This study investigated the determination of corrective optimals for Chinese non-English major university EFL learners for a set of six vowels. A set of discontinuous multiband filters (corrective optimals) were identified for Chinese non-English major EFL learners. Not surprisingly, these corrective optimals were different from native-speaker optimals despite the fact that, in some contexts, native-speaker optimals have been used in other contexts for correction. Considering the research findings, the study suggests that it may be valuable to reorient the mindset connected to corrective optimals toward that of discontinuous multiband structures containing a significant low frequency component. These findings are important for verbotonal theory and research in foreign language learning and teaching. However, the sample size of the present study might not be large enough for generalizable results. There may also be additional factors relating to right-brain functionality of Chinese learners (who speak a tonal language) that may need to be taken into account (Rozin, Moscovitch, & Imada, 2016). Future research will therefore need to enlarge the sample size and perhaps provide a more nuanced experimental structure comparing the performances of speakers of tonal and non-tonal languages.

The present study also presents a new way of dealing with individual differences in the context of language-learning by performing as precise a diagnosis as possible on each language learner, thus creating the possibility of triggering optimal interventions designed to target and respond to each individual's specific pronunciation problems of the target vowels. The concept of optimality is in agreement with the concept of precision language education (Lian & Sangarun, 2017) as well as the notion of autonomy (including rhizomatic systems) (Lian, 2011; Lian & Pineda, 2014).

Results have strong implications for the teaching of pronunciation from both a practical and a theoretical perspective. From a practical perspective, traditional group pronunciation lessons and exercises could be replaced with a short diagnostic session followed by a lengthier, self-managed teacher-free, period of listen-repeat exercises: a simple self-learning process that would be teacher-proof, financially economical and linguistically effective. Such a study has already been performed as a follow-up to the current research. It has met with positive results and will be reported separately.

From a theoretical perspective, teacher-education programs with a focus on pronunciation may need to change their approach, moving away from the notion of individual phonemes enriched by intonation as a decoration and moving toward a more integrated approach where the distinction between prosody and individual phonemes is effaced. This will give rise to a more accurate conceptualization of perception/pronunciation leading to a better understanding of the workings of both perception and pronunciation and result in improved pronunciation outcomes for learners of foreign languages.

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APPENDIX / PRILOG

Table 1. Corrective optimals for the vowel /ɪ/ as tested in this study
Tablica 1. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /ɪ/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
1,280–2,560 Hz	1 octave	1,811 Hz	0 (0.0%)
1,440–2,880 Hz	1 octave	2,037 Hz	0 (0.0%)
1,600–3,200 Hz	1 octave	2,263 Hz	0 (0.0%)
1,760–3,520 Hz	1 octave	2,489 Hz	0 (0.0%)
1,920–3,840 Hz	1 octave	2,715 Hz	0 (0.0%)
1,713–2,422 Hz	$\frac{1}{2}$ octave	2,037 Hz	0 (0.0%)
2,283–3,229 Hz	$\frac{1}{2}$ octave	2,715 Hz	0 (0.0%)
1,815–2,286 Hz	$\frac{1}{3}$ octave	2,037 Hz	0 (0.0%)
2,419–3,048 Hz	$\frac{1}{3}$ octave	2,715 Hz	0 (0.0%)
0–320 Hz + 1,713–2,422 Hz	0–320 Hz + $\frac{1}{2}$ octave	2,037 Hz	0 (0.0%)
0–320 Hz + 2,283–3,229 Hz	0–320 Hz + $\frac{1}{2}$ octave	2,715 Hz	0 (0.0%)
0–320 Hz + 1,815–2,286 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,037 Hz	4 (10.8%)
0–320 Hz + 2,419–3,048 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,715 Hz	33 (89.2%)

Table 2. Corrective optimals for the vowel /i:/ as tested in this study
Tablica 2. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /i:/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
2,559–5,118 Hz	1 octave	3,619 Hz	0 (0.0%)
2,879–5,758 Hz	1 octave	4,072 Hz	0 (0.0%)
3,200–6,400 Hz	1 octave	4,525 Hz	0 (0.0%)
3,520–7,040 Hz	1 octave	4,978 Hz	0 (0.0%)
3,840–7,680 Hz	1 octave	5,431 Hz	0 (0.0%)
4,186–5,920 Hz	$\frac{1}{2}$ octave	4,978 Hz	0 (0.0%)
4,567–6,459 Hz	$\frac{1}{2}$ octave	5,431 Hz	0 (0.0%)
4,435–5,588 Hz	$\frac{1}{3}$ octave	4,978 Hz	0 (0.0%)
4,838–6,096 Hz	$\frac{1}{3}$ octave	5,431 Hz	0 (0.0%)
0–320 Hz + 4,186–5,920 Hz	0–320 Hz + $\frac{1}{2}$ octave	4,978 Hz	0 (0.0%)
0–320 Hz + 4,567–6,459 Hz	0–320 Hz + $\frac{1}{2}$ octave	5,431 Hz	4 (10.8%)
0–320 Hz + 4,435–5,588 Hz	0–320 Hz + $\frac{1}{3}$ octave	4,978 Hz	1 (2.7%)
0–320 Hz + 4,838–6,096 Hz	0–320 Hz + $\frac{1}{3}$ octave	5,431 Hz	32 (86.5%)

Table 3. Corrective optimals for the vowel /e/ as tested in this study
Tablica 3. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /e/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
1,280–2,560 Hz	1 octave	1,811 Hz	0 (0.0%)
1,440–2,880 Hz	1 octave	2,037 Hz	0 (0.0%)
1,600–3,200 Hz	1 octave	2,263 Hz	0 (0.0%)
1,760–3,520 Hz	1 octave	2,489 Hz	0 (0.0%)
1,920–3,840 Hz	1 octave	2,715 Hz	0 (0.0%)
1,523–2,154 Hz	$\frac{1}{2}$ octave	1,811 Hz	0 (0.0%)
1,903–2,691 Hz	$\frac{1}{2}$ octave	2,263 Hz	0 (0.0%)
2,283–3,229 Hz	$\frac{1}{2}$ octave	2,715 Hz	0 (0.0%)
1,613–2,033 Hz	$\frac{1}{3}$ octave	1,811 Hz	0 (0.0%)
2,016–2,540 Hz	$\frac{1}{3}$ octave	2,263 Hz	0 (0.0%)
2,419–3,048 Hz	$\frac{1}{3}$ octave	2,715 Hz	0 (0.0%)
0–320 Hz + 1,523–2,154 Hz	0–320 Hz + $\frac{1}{2}$ octave	1,811 Hz	0 (0.0%)
0–320 Hz + 1,903–2,691 Hz	0–320 Hz + $\frac{1}{2}$ octave	2,263 Hz	0 (0.0%)
0–320 Hz + 2,283–3,229 Hz	0–320 Hz + $\frac{1}{2}$ octave	2,715 Hz	0 (0.0%)
0–320 Hz + 1,613–2,033 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,811 Hz	1 (2.7%)
0–320 Hz + 2,016–2,540 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,263 Hz	2 (5.4%)
0–320 Hz + 2,419–3,048 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,715 Hz	34 (91.9%)

Table 4. Corrective optimals for the vowel /æ/ as tested in this study
Tablica 4. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /æ/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
960–1,920 Hz	1 octave	1,357 Hz	0 (0.0%)
1,080–2,160 Hz	1 octave	1,527 Hz	0 (0.0%)
1,200–2,400 Hz	1 octave	1,697 Hz	0 (0.0%)
1,320–2,640 Hz	1 octave	1,867 Hz	0 (0.0%)
1,440–2,880 Hz	1 octave	2,037 Hz	0 (0.0%)
1,141–1,614 Hz	$\frac{1}{2}$ octave	1,357 Hz	0 (0.0%)
1,427–2,018 Hz	$\frac{1}{2}$ octave	1,697 Hz	0 (0.0%)
1,713–2,422 Hz	$\frac{1}{2}$ octave	2,037 Hz	0 (0.0%)
1,209–1,523 Hz	$\frac{1}{3}$ octave	1,357 Hz	0 (0.0%)
1,512–1,905 Hz	$\frac{1}{3}$ octave	1,697 Hz	0 (0.0%)
1,815–2,286 Hz	$\frac{1}{3}$ octave	2,037 Hz	0 (0.0%)
0–320 Hz + 1,141–1,614 Hz	0–320 Hz + $\frac{1}{2}$ octave	1,357 Hz	0 (0.0%)
0–320 Hz + 1,427–2,018 Hz	0–320 Hz + $\frac{1}{2}$ octave	1,697 Hz	0 (0.0%)
0–320 Hz + 1,713–2,422 Hz	0–320 Hz + $\frac{1}{2}$ octave	2,037 Hz	0 (0.0%)
0–320 Hz + 1,209–1,523 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,357 Hz	4 (10.8%)
0–320 Hz + 1,512–1,905 Hz	0–320 Hz + $\frac{1}{3}$ octave	1,697 Hz	30 (81.1%)
0–320 Hz + 1,815–2,286 Hz	0–320 Hz + $\frac{1}{3}$ octave	2,037 Hz	3 (8.1%)

Table 5. Corrective optimals for the vowel /ʊ/ as tested in this study
Tablica 5. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /ʊ/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
170–340 Hz	1 octave	240 Hz	0 (0.0%)
199–398 Hz	1 octave	282 Hz	0 (0.0%)
241–482 Hz	1 octave	340 Hz	0 (0.0%)
270–540 Hz	1 octave	382 Hz	0 (0.0%)
300–600 Hz	1 octave	424 Hz	0 (0.0%)
330–660 Hz	1 octave	466 Hz	0 (0.0%)
359–718 Hz	1 octave	508 Hz	0 (0.0%)
400–800 Hz	1 octave	566 Hz	0 (0.0%)
430–860 Hz	1 octave	608 Hz	0 (0.0%)
202–285 Hz	$\frac{1}{2}$ octave	240 Hz	0 (0.0%)
286–404 Hz	$\frac{1}{2}$ octave	340 Hz	0 (0.0%)
392–554 Hz	$\frac{1}{2}$ octave	466 Hz	0 (0.0%)
511–723 Hz	$\frac{1}{2}$ octave	608 Hz	0 (0.0%)
214–269 Hz	$\frac{1}{3}$ octave	240 Hz	0 (0.0%)
303–382 Hz	$\frac{1}{3}$ octave	340 Hz	0 (0.0%)
415–523 Hz	$\frac{1}{3}$ octave	466 Hz	0 (0.0%)
542–682 Hz	$\frac{1}{3}$ octave	608 Hz	0 (0.0%)

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
0–320 Hz + 202–285 Hz	0–320 Hz + $\frac{1}{2}$ octave	240 Hz	0 (0.0%)
0–320 Hz + 286–404 Hz	0–320 Hz + $\frac{1}{2}$ octave	340 Hz	0 (0.0%)
0–320 Hz + 392–554 Hz	0–320 Hz + $\frac{1}{2}$ octave	466 Hz	0 (0.0%)
0–320 Hz + 511–723 Hz	0–320 Hz + $\frac{1}{2}$ octave	608 Hz	0 (0.0%)
0–320 Hz + 214–269 Hz	0–320 Hz + $\frac{1}{3}$ octave	240 Hz	31 (83.8%)
0–320 Hz + 303–382 Hz	0–320 Hz + $\frac{1}{3}$ octave	340 Hz	2 (5.4%)
0–320 Hz + 415–523 Hz	0–320 Hz + $\frac{1}{3}$ octave	466 Hz	3 (8.1%)
0–320 Hz + 542–682 Hz	0–320 Hz + $\frac{1}{3}$ octave	608 Hz	1 (2.7%)

Table 6. Corrective optimals for the vowel /u:/ as tested in this study
Tablica 6. Vrijednosti korektivnih optimala korištenih u istraživanju za vokal /u:/

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
160–320 Hz	1 octave	227 Hz	0 (0.0%)
180–360 Hz	1 octave	255 Hz	0 (0.0%)
200–400 Hz	1 octave	283 Hz	0 (0.0%)
220–440 Hz	1 octave	311 Hz	0 (0.0%)
240–480 Hz	1 octave	339 Hz	0 (0.0%)
262–370 Hz	$\frac{1}{2}$ octave	311 Hz	0 (0.0%)
285–403 Hz	$\frac{1}{2}$ octave	339 Hz	0 (0.0%)
277–349 Hz	$\frac{1}{3}$ octave	311 Hz	0 (0.0%)

Corrective optimals / Korektivna optimala	Octave type / Vrsta oktave	Center frequency / Središnja frekvencija	Best production (%) / Najbolje ostvarenje (%)
302–381 Hz	$\frac{1}{3}$ octave	339 Hz	0 (0.0%)
0–320 Hz + 262–370 Hz	0–320 Hz + $\frac{1}{2}$ octave	311 Hz	0 (0.0%)
0–320 Hz + 285–403 Hz	0–320 Hz + $\frac{1}{2}$ octave	339 Hz	0 (0.0%)
0–320 Hz + 277–349 Hz	0–320 Hz + $\frac{1}{3}$ octave	311 Hz	5 (13.5%)
0–320 Hz + 302–381 Hz	0–320 Hz + $\frac{1}{3}$ octave	339 Hz	32 (86.5%)

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Određenje korektivne optimale za učenje engleskog jezika kod govornika kineskog jezika

Sažetak

Vokali koji u engleskom jeziku čine jezgru sloga uzrokuju brojne poteškoće u izgovoru neizvornim govornicima engleskog jezika, primjerice kineskim učenicima engleskog, zbog čega je njihov govor, u najboljem slučaju, djelomično nerazabirljiv. Verbotonalna teorija korekcije izgovora upućuje na uporabu korektivnih optimala, koje mogu pomoći pri postizanju boljeg izgovora na stranom jeziku. U nastojanju da se ispita učinkovitost korektivne optimale u istraživanju je korišten određen broj vokala engleskog jezika koji predstavljaju poteškoće kineskim učenicima (/ɪ/, /i:/, /e/, /æ/, /ʊ/ i /u:/). Cilj istraživanja bio je utvrditi vrijednosti korektivnih optimala za spomenutih šest vokala. U istraživanju je sudjelovalo 37 studenata prve godine koji uče engleski jezik, ali ga ne studiraju. Svaki ispitanik sudjelovao je u dijagnostičkom postupku koji se sastojao od dva koraka. Prvi korak je uključivao određivanje individualne središnje frekvencije (f_{center}) za određeni vokal. Na početku je ispitanik izložen tradicionalnoj frekvencijskoj optimali za izvornoga govornika. Drugi korak je uključivao kombinaciju frekvencijskih pojaseva koji zajedno čine individualnu korektivnu optimalu svakog od ispitivanih vokala. Korektivne optimale za kineske govornike koji uče engleski jezik nisu bile kontinuirani pojasevi širine jedne oktave, već diskontinuirane višepojasne strukture unutar kojih su pojasnopropusni filtri bili uži od jedne oktave te s dodatno prisutnom nisko-propusnom komponentom. Za potvrdu ovih rezultata potrebno je ponovljeno istraživanje s većim brojem ispitanika te većim brojem ispitivanih glasova, vokala i konsonanata, ne samo za engleski jezik, nego i za druge jezike.

Ključne riječi: optimala, korektivna optimala, verbotonalna teorija, učenje jezika, kineski govornici koji uče engleski jezik