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The Treatment Effect of Lingual Control Therapy on Disordered Putonghua Consonant Initials: A Single-Case Experimental Design

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Abstract

This case study examined the effect of a lingual control therapy based on motor learning principles in a 5; 30-year-old monolingual Putonghua-speaking girl with functional speech sound disorder (SSD). The participant received 1240-minute individual therapy sessions once a week over 6 months, wherein the spatiotemporal instruction for lingual training integrating auditory and visual feedback was given. Fisher's exact test and linear regression model were fitted to examine the differences in response accuracy between time points. The accuracy of training- (at phoneme and syllable level) and test-probes (at word and sentence level) both demonstrated positive change, indicating generalization of the treatment gains to larger linguistic units. Additionally, the place of articulation was found to mediate the treatment outcomes based on the linear regression with interaction results. Finally the possible underlying deficits in internal speech processing mechanism of the tongue musculature and the corresponding implications are explored. Findings from this study suggest that training in lingual motor control could improve distorted syllable-initial apical consonants in Putonghua-speaking children with SSD. Future research should investigate the generalization effect in a larger sample size.

Keywords

Speech Sound Disorder, Lingual Control, Distorted Apical Consonants, Place of Articulation, Putonghua, Feedback

1. Background

Speech sound disorder (SSD), which is among the most prevalent of childhood communicative impairments, constitutes over 70% of pediatric speech-language pathology caseloads worldwide (Jesus et al., 2019). SSD can be characterized as delayed speech sound acquisition, articulatory errors and phonological development difficulties such as substitutions, omissions, distortions, additions and atypical prosody (American Speech-Language-Hearing Association, 2021; Bowen, 2015; Jesus et al., 2019; Shriberg, 2003). The preschool history of unintelligent speech may increase the risk of children being disadvantaged for future social, academic and psychological performance, particularly if SSD persists into school age. (Dodd, 2014; Gačnik et al., 2018; Gierut, 1998; Rvachew et al., 2007; Square et al., 2014; Tambyraja et al., 2022). Deviant phonological errors are resistant to spontaneous change unless these deficits are targeted in specific intervention programs. In light of this, it is crucial to investigate the effect of SSD intervention in early childhood (Dodd, 2014; Gačnik et al., 2018; Gierut, 1998; Rvachew et al., 2007; Tambyraja et al., 2020).

To date, SSD among the English-speaking population has been relatively well-documented. An estimated 48,000 children per year in the UK are referred to speech-language pathologists (SLPs), accounting for 6.4% of the total child population aged 2 - 16 years (Broomfield & Dodd, 2004). National Institute on Deafness and Other Communication Disorders (NIDCD) reported that approximately 10% of American preschoolers and school-age children are diagnosed with primary speech and language problems (Gierut, 1998). However, research on speech-sound development in Chinese-speaking children is under investigation (Li & To, 2017; Shi & Yang, 2020), even with no access to the official statistics on the number of SSD children speaking Putonghua (the official standard spoken form of modern Mandarin Chinese) (Duan & Zhang, 2020).

Given the fact that both the linguistic features and the phonological processes vary between logographic and alphabetic languages (e.g., Chinese vs. English), the production and treatment response of the speech sound errors may be different in children speaking distinct language systems (Jeng, 2011; Li & To, 2017; Zhu & Dodd, 2000). Error patterns of disordered speech sounds are language-specific (Dodd, 2014). Compared with English, Putonghua phonology distinguishes itself with salient features that should be referred to when the relevant dimension is targeted (Zhu & Dodd, 2000; Liu & Chien, 2020; Peng & Chen, 2020). For instance, with respect to the proportion of phonemes, the ratio of vowels to consonants in Chinese is 1:3.6, higher than 1:1.8 in English (Wan & Jaeger, 2003), thereby more consonant errors than vowel errors are identified in the Chinese disordered population (Wan, 2007). Additionally, in regard to the disordered position, the atypical phonological process affects syllable-initial consonants the most in Putonghua-speaking children with SSD, whilst for their English-speaking counterparts the omission of final consonants is a common error pattern (Gierut, 1998). Moreover, concerning the syllabic structure processes, the simplification of consonant clusters is absent in Putonghua-speaking children with SSD because no consonant clusters were present before vowels were constrained by Chinese syllabic structure. Rather, consonant cluster reduction is commonly reported in English-speaking children with SSD as the English syllable structure allows multiple consonants before the vowel (Jeng, 2011). Further, regarding the segmental impairment, backing was reported as the second most frequent atypical phonological process among Putonghua-speaking children, whereas it is rarely reported among English-speaking children. This cross-linguistic disparity is possibly due to the fact that there are many more apico-dentals in Putonghua than in English in terms of place of articulation (Jeng, 2011). Even within the Chinese language system, due to varied phonological processes, discrepancies concerning discrimination abilities, rhotacisation, weak stress and tone have been demonstrated among Cantonese-, Taiwan Mandarin-, and Putonghua-exposed children with SSD. These variations may lead to diverging diagnoses regarding the same phonetic realization and implied differential diagnosis and treatment on account of distinct ambient language (Peng & Chen, 2020). Yet studies on the treatment of Putonghua-speaking children with SSD are much scarcer in contrast to ample studies in Mandarin/Cantonese-speaking SSD children. Therefore, given the large population in the world (more than 1.19 billion), it is important to investigate the effectiveness of SSD intervention in Putonghua-speaking preschoolers.

Existing empirical research, clinical case studies and service delivery reports have accumulated a broad range of treatment approaches addressing preschool SSD. Therefore, speech-motor control and learning has been found the most effective in improving speech intelligibility in the trained and untrained items (Square, 2014). This approach targets parameters like the place, manner, timing and amplitude of the movements of speech articulators (e.g., lips, jaw and tongue) via visual, auditory and kinesthetic input. This approach aims to improve the accuracy of speech output through imitation and repeated practice of oral motor exercises (Square et al., 2014). According to the oromotor maturation hypothesis, tongue control plays a crucial role in speech intelligibility as tongue control and phonological development are significantly linked (Ma et al., 2022).

Positive effect of treatment targeting speech motor control and speech intelligibility has been well documented across various clinical populations, including children with autism (Rogers et al., 2006), cerebral palsy (Pennington et al., 2010; Ward et al., 2009), dysarthria (Namasivayam et al., 2015), apraxia of speech (CAS) (Hammarstrom et al., 2019) and SSD children with jaw and orofacial involvement (SSD-MSI) (Square, 2014). However, fewer studies have implemented speech-motor learning in the treatment for SSD children with intact motor mechanisms. Whereas the majority of SSD cases are attributable to be functional or without organic anomaly (Broomfield & Dodd 2004; Shriberg & Kwiatkowski 1994), which highlights the need to extend speech-motor learning beyond motor speech disorders. Furthermore, evidence from the Chinese population is sparse. Wren et al. (Wren et al. 2018) systematically reviewed seven oro-motor-based interventions published between 1996 and 2001 all targeting English-speaking SSD children. From the limited speech motor-based treatment outcome data available for Putonghua-speaking SSD children without co-occurring motor difficulties, Duan & Zhang (Duan & Zhang, 2020) observed that treatment approach targeting “biting the tip of the tongue” and tongue bitmap are conducive to children’s more intuitive understanding of the articulation place based on the data form 40 Chinese children with SSD. Correspondingly, the accuracy of articulation regarding six Putonghua affricates is greatly improved. Nonetheless, the treatment efficacy of the rest of Putonghua consonants in that study was not specified.

Among all the previous studies, findings have been mixed due to high individual heterogeneity in etiology, symptoms, severity, age and pre-treatment linguistic and cognitive abilities (Dodd, 2014; Gierut, 1998). These individual variations all make research in SSDs highly complex. Case studies provide a unique opportunity to address these issues, given the potential variability of SSDs and the differential treatment effect across individuals (Gierut, 1998). Hence, the current treatment aims to investigate the treatment effect of lingual control in a single case with disordered Putonghua phonology.

2. The Current Study

This case study was designed to fill a gap in the literature by examining the effects of lingual control on a monolingual Putonghua-speaking child with moderate SSD irrespective of oro-motor abnormalities. It is intended to illustrate the possible changes in a disordered Putonghua sound system and the treatment approach that may facilitate such change. This goal was addressed through three specific aims:

Does the intervention of tongue control show a significant treatment effect in a child’s disordered Putonghua consonant initials?

Does the treatment effect differ by the articulation place, manner, aspiration, or voicing of the target sounds?

Do the treatment gains at the phoneme and syllable level generalize to the word and the sentence level?

In the preceding literature, speech-motor-skill-learning has shown significant treatment and generalization effects in children with severe profound impairment in speech-motor planning or executing. Therefore, it was hypothesized that if the child’s mandibular opening, lip rounding and retraction are normal, lingual control therapy would be effective in improving Putonghua syllable initials (Aim 1). Secondly, the development of Chinese consonants was closely associated with the place (e.g., blade-alveolar, alveolo-palatal), manner (e.g., lateral, affricate), voicing (with or without voal fold vibration, e.g., /ʐ/ vs. /ɕ/) and aspiration (aspiration vs. non-aspiration, e.g., /tsʰ/ vs. /ts/). And these sounds relationships in English have been reported in the treatment literature, revealing differential treatment effects and generalization (Maas et al., 2008). Hence, it was hypothesized that the treatment effect of the lingual control therapy on disordered Putonghua consonant initials would significantly differ by place, manner, voicing and aspiration (Aim 2). Finally, as treatment of a sound in isolation promoted improvements in sentences and connected speech (Gierut, 1998), it is reasonable to posit that training at the phoneme/syllable level would generalize to words/sentences level (Aim 3).

3. Methods

3.1. Participant

A monolingual Putonghua-speaking girl (H) aged five years and six months participated in the current study. Parents of the participating child provided written consent. H was born at full term after a normal pregnancy and was breast-fed until one year and a half. She was born and raised in Chinese mainland and Putonghua was the only language for H and her primary caregivers. Her history revealed ankyloglossia with lingual frenulum thin at the front and thick below attached to the tongue tip when she was 1;4. Ankylotomy was recommended at the age of 2;5. H made a return visit when she reached two years and five months, but slightly shorter lingual frenulum in absence of abnormal ranges of tongue mobility was reported then, thereby she was not diagnosed with ankyloglossia anymore possibly due to a continuum of developmental changes of her lingual frenulum toward maturity at the early stage. No tongue tie surgery nor other medical procedures were required but semiannual follow-up visits were suggested by pediatric stomatologist to observe the development and maturation of her lingual frenulum. According to clinician's referral and parental reports, the two subsequent visits at the age of 5;1 and 5;5 respectively in two different departments of pediatric stomatology all reported normal length and function of lingual frenulum. No further medical procedures were required since then. Hence, there was no necessary connection between the child's disordered speech and her glossodesmus. When H was five and six months old, her development in all respects was within the normal limit except for sound production. She was diagnosed with functional SSD by an associate chief physician in the Oral and Maxillofacial Surgery Department of Guangzhou Women and Children's Medical Centre. H doesn't have a family history of SSD. Prior to the current treatment, she did not receive any speech-language training.

3.2. Pre-Treatment Assessment

The pre-treatment testing demonstrated that H has acquired a complete phone repertoire, with errors confined to apical consonant production (accuracy scored 64.1%), especially in the word-initial position. She exhibited both articulation and phonological disorders. For the articulatory disorder, distortion and substitution are her major error patterns. For instance, her front apical consonants /ts^h, ts, s/, medial apical consonants /l, n/ and linguofacial consonants /ts, ts^h, s / were distorted. In addition, she consistently substituted coronals /t, t^h/ with dorsals /k, k^h/. For the phonological disorder, her major error patterns were manifested in backing and reduced lateral, both involving tongue posture and the utilization of tongue muscles. Condition aggravation was observed in her sentence production (accuracy scored 49.3%), whereas her vowel production and tones are typically developed. All pre-treatment results are illustrated in **Table 1**.

Table 1. Pre-treatment speech sound errors.

Place Features		Apico-dental consonants		Blade-alveolar consonants		Lingua-palatal consonants		Dorso-velar consonants	
Organ Features		Tongue tip	The back of the upper incisors	Tongue tip	Alveolar ridge	Lingual surface	Anterior hard palate	The roof of the tongue	Velar
Error Features		Treated Phonemes							
Articulation Errors	Phoneme distortion	/tsʰ, ts, s/		/n, l/		/tɕ, tɕʰ, ɕ/			
	Phoneme substitution			/t, tʰ/				/k, kʰ/	
Delayed Phonological Process	Backing			/t, tʰ/					
	Reduced Lateral			/l/					

3.3. Stimuli

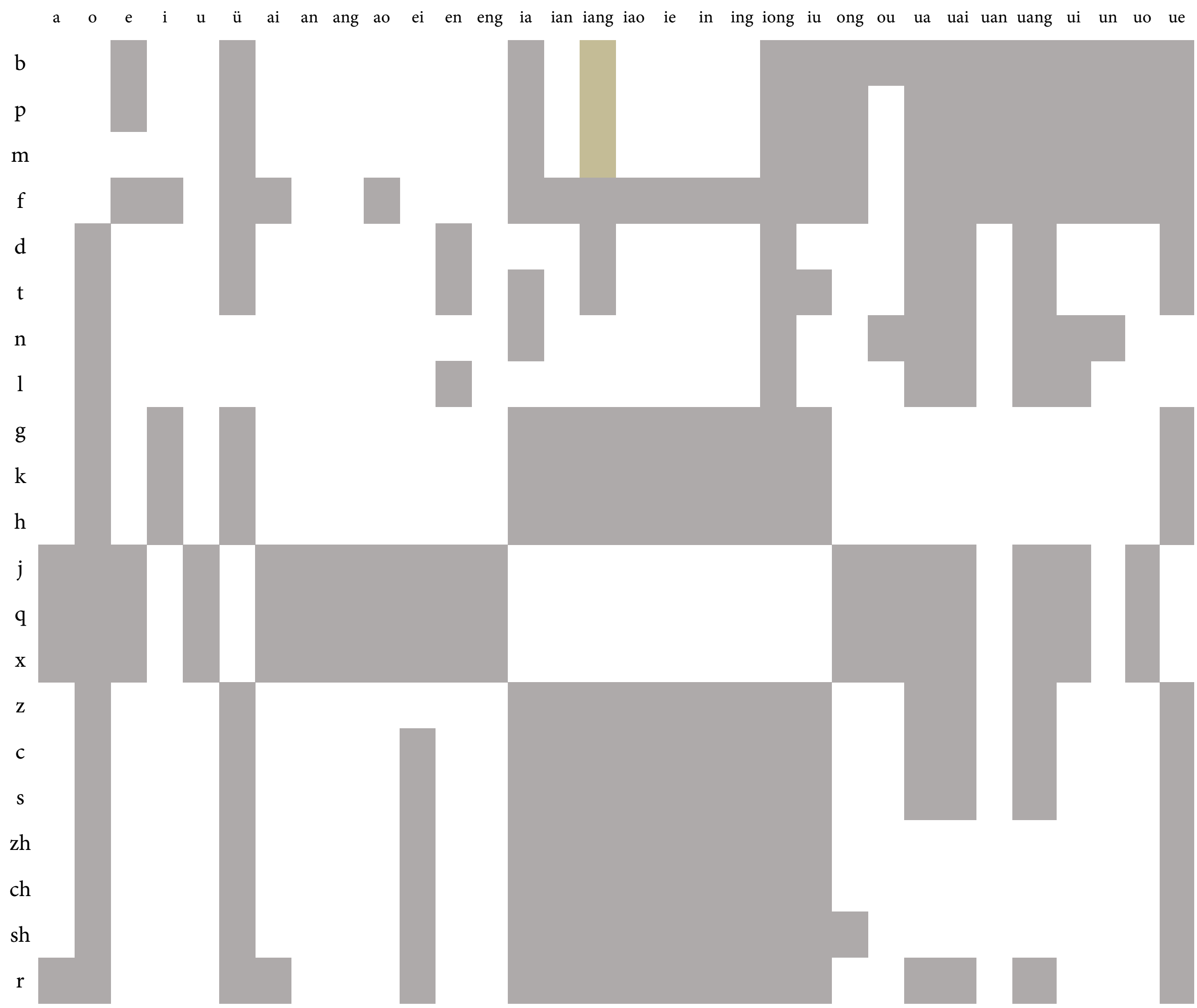
Pre- and post-testing included the full inventory of 21 Putonghua consonants and their total corresponding 371 syllables (see **Table 2**).

For treatment stimuli, 175 phonological items were selected, including 4 single-syllables (e.g., /tsʰi/, /ɕi/), 127 disyllables (e.g., /ɕy/, /tʰɤ/) and 44 trisyllables (e.g., /ɕwan/, /tɕia/) that covered all target phonemes and their possible combinations within the phonotactic constraints of Putonghua Pinyin (see **Table 3**). All target sounds were embedded in word-initial positions to be more readily identified than medial or final positions (Doubé et al., 2018).

For generalization assessments, a total of 92 word probes were administered, including 3 single-character words, 54 two-character words and 3 three-character words, such as 狗(dog), 蛋糕(cake), 美人鱼(mermaid). These stimuli were concrete nouns from different semantic categories, such as animals (e.g., 蛇 for snake, 猴子 for monkey, 梅花鹿 for sika deer), simple objects (e.g., 锁 for lock, 风筝 for kite, 望远镜 for telescope), fruits (e.g., 苹果 for apple, 菠萝 for pineapple, 西瓜 for watermelon), and action verbs, e.g., 游泳 for swim, 洗澡 for take a shower. All items were commonly used in the child's daily life and had high frequency (Maas et al., 2008; see **Table 4**). Moreover, two sentences that included twenty characters with the target sound were selected for the sentence generalization assessments. Sentence probes were carefully designed to ensure that they both covered the targets and were of a high frequency of occurrence in daily communication for H so that they were not beyond the child's conceptual and lexical ability. For instance, H was very keen on cruising along the Pearl River with her best friends and her favorite foods were milk and candies. So these elements were included in the sentence carrier (e.g., 小伙伴坐船跨珠江 Little friends cruised along the Pearl River) (See **Table 5**). All testing words and sentences for generalization were not targeted in treatment to examine whether treatment effects were generalized to language production beyond the phonemic level (e.g. words and sentences).

Table 2. Pre- and post-treatment measures.

Name	Age	Gender	Language	Testing Date



N: normal; O: omission; D: distortion; S: substitution; ST: stimulability; DA: distortion (apico-dental); DB: distortion (blade-alveolar); DL: distortion (lingua-palatal); B: backing; RL: reduced lateral

Note: Phonemes in left edges are total Putonghua consonant initials. Phonemes in the upper edge are the following vowels. The same horizontal line represents the possible syllable realizations for each given initial on the left edge. Shaded cells are against Putonghua phonics rules and the pronunciation cannot be realized due to the phonotactic constraints of Putonghua Pinyin.

Table 3. Therapy blocks.

Disordered Phoneme	Syllable Level
/tɕ/	/tɕi/, /tɕy/, /tɕjɛ/, /tɕin/, /tɕiŋ/, /tɕyn/, /tɕɥɛ/,/tɕia/, /tɕjæn/, /tjɑŋ/, /tɕjɑʊ/, /tɕjʊŋ/, /ti̯ᵊu/, /tɕwan/
/tɕʰ/	/tɕʰi/, /tɕʰy/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/, /tɕʰ/,/tɕʰ/

Continued

/ɕ/	/ɕi/, /ɕy/, /ɕiŋ/,/ɕɛ/,/ɕin/, /ɕyn/, /ɕɥɛ/, /ɕa/, /ɕæ/, /ɕɑ/, /ɕiʊ/, /ɕi̯ɤʊ̯/, /ɕwan/
/t/	/ta/, /tɤ/, /ti/, /tu/, /taɪ/, /tan/, /tɑŋ/, /tɑʊ/, /teɪ/, /tɤŋ/, /tjɛ/, /tiŋ/, /ti̯ɤʊ̯/, /tʊŋ/, /toʊ/, /tweɪ/, /twən/, /tia/, /tjæn/, /tjɑʊ/, /twan/, /two/
/tʰ/	/tʰa/, /tʰɤ/, /tʰi/, /tʰu/, /tʰan/, /tʰɑŋ/, /tʰan/, /tʰɤŋ/, /tʰjɛ/, /tiŋ/, /tʰan/, /tʰan/, /tʰwo/
/n/	/na/, /nɤ/, /ni/, /nu/, /ny/, /naɪ/, /nan/, /nɑŋ/, /nɑʊ/, /neɪ/, /nən/, /nɤŋ/, /njɛ/, /nin/, /niŋ/, /ni̯ᵊu/, /nʊŋ/, /nɥɛ/, /njæn/, /njɑŋ/, / njɑʊ/, /nwan/, /nwo/
/l/	/la/, /lɤ/, /li/, /lu/, /ly/, /laɪ/, /leɪ/, /leɪ/, /leɪ/, /leɪ/, /lɤŋ/, /ljɛ/, /lin/, /liŋ/, /li̯ᵊu/, /lʊŋ/, /loʊ/, /lyn/, /lɥɛ/, /ljɑŋ/, /leɪ/, /ljɑʊ/, /lwan/, /lwo/
/ts/	/tsi/, /tsa/, /tsɤ/, /tsu/, /tsaɪ/, /tsan/, /tsɑŋ/, /tsɑʊ/, /tseɪ/, /tsən/, /tsʊŋ/, /tsoʊ/, /tsu̯ᵊi/, /tsuᵊn/, /tswan/, /tswo/
/tsʰ/	/tsʰi/, /tsʰa/, /tsʰɤ/, /tsʰu/, /tsʰaɪ/, /tsʰan/, /tsʰɑŋ/, /tsʰɑʊ/, /tsʰən/, /tsʰɤŋ/, /tsʰʊŋ/, /tsʰoʊ/, /tsʰu̯ᵊi/, /tsʰyn/, /tsʰwan/, /tsʰwo/
/s/	/si/, /sa/, /sɤ/, /su/, /saɪ/, /san/, /sɑŋ/, /sɑʊ/, /sən/, /sɤŋ/, /sʊŋ/, /soʊ/, /su̯ᵊi/, /suᵊn/, /swan/, /swo/

Table 4. Items for word generalization assessments.

Elicited Words	Target pronunciation			Target pronunciation	
	Initials	Syllables		Initials	Syllables
1) 白菜(cabbage)	/p/	/paɪ/	47) 九(nine)	/j/	/ji̯ᵊu/
2) 杯子(cup)	/p/	/peɪ/	48) 气球(ballon)	/tɕʰ/	/tɕʰi/
3) 手表(watch)	/p/	/pjɑʊ/	49) 气球(ballon)	/tɕʰ/	/tɕʰi̯ᵊu/
4) 菠萝(pineapple)	/p/	/po/	50) 裙子(skirt)	/tɕʰ/	/tɕʰuᵊn/
5) 书包(school bag)	/p/	/pɑʊ/	51) 青蛙(frog)	/tɕʰ/	/tɕʰiŋ/
6) 斑马(zebra)	/p/	/pan/	52) 西瓜(watermelon)	/ɕ/	/ɕɿ/
7) 尾巴(tail)	/p/	/pa/	53) 鞋子(shoes)	/ɕ/	/ɕɛ/
8) 苹果(apple)	/pʰ/	/pʰiŋ/	54) 小鸟(bird)	/ɕ/	/ɕjɑʊ/
9) 葡萄(grape)	/pʰ/	/pʰu/	55) 星星(star)	/ɕ/	/ɕiŋ/
10) 盾牌(shield)	/pʰ/	/pʰaɪ/	56) 大象(elephant)	/ɕ/	/ɕjɑŋ/
11) 眉毛(eyebrow)	/m/	/meɪ/	57) 粽子(rice dumpling)	/ts/	/tsʊŋ/
12) 眉毛(eyebrow)	/m/	/mɑʊ/	58) 洗澡(take a shower)	/ts/	/tsɑʊ/
13) 斑马(zebra)	/m/	/ma/	59) 嘴巴(mouth)	/ts/	/tsu̯ᵊi/
14) 飞机(plane)	/f/	/feɪ/	60) 粽子(rice dumpling)	/ts/	/tsɿ/

Continued

15) 风筝(kite)	/f/	/fɤŋ/	61) 白菜(cabbage)	/tsʰ/	/tsaɪ/
16) 灯泡(bulb)	/t/	/tɤŋ/	62) 雨伞(umbrella)	/s/	/san/
17) 剪刀(scissor)	/t/	/tɑʊ/	63) 锁(lock)	/s/	/swo/
18) 钉子(nail)	/t/	/tiŋ/	64) 松鼠(squirrel)	/s/	/sʊŋ/
19) 蛋糕(cake)	/t/	/tan/	65) 蜘蛛(spider)	/ʈʂ/	/ʈʂʅ/
20) 大象(elephant)	/t/	/ta/	66) 蜘蛛(spider)	/ʈʂ/	/ʈʂu/
21) 坦克(tank)	/tʰ/	/tʰan/	67) 桌子(desk)	/ʈʂ/	/ʈʂwo/
22) 葡萄(grape)	/tʰ/	/tʰɑʊ/	68) 风筝(kite)	/ʈʂ/	/ʈʂɤŋ/
23) 牛奶(milk)	/n/	/ni̯ᵊu/	69) 叉子(fork)	/ʈʂʰ/	/ʈʂʰa/
24) 牛奶(milk)	/n/	/naɪ/	70) 牙齿(tooth)	/ʈʂʰ/	/ʈʂʰ/
25) 小鸟(bird)	/n/	/njɑʊ/	71) 虫子(worm)	/ʈʂʰ/	/ʈʂʰ/
26) 菠萝(pineapple)	/l/	/lwo/	72) 窗子(window)	/ʈʂʰ/	/ʈʂʰwɑŋ/
27) 辣椒(pepper)	/l/	/la/	73) 蛇(snake)	/ʂ/	/ʂɤ/
28) 梅花鹿(sika deer)	/l/	/lu/	74) 松鼠(squirrel)	/ʂ/	/ʂʊŋ/
29) 轮子(wheel)	/l/	/luᵊn/	75) 石头(stone)	/ʂ/	/ʂʅ/
30) 恐龙(dinosaur)	/l/	/lʊŋ/	76) 手表(watch)	/ʂ/	/ʂoʊ/
31) 月亮(moon)	/l/	/ljaŋ/	77) 勺子(spoon)	/ʂ/	/ʂɑʊ/
32) 西瓜(watermelon)	/k/	/kuɑ/	78) 扇子(fan)	/ʂ/	/ʂan/
33) 狗(dog)	/k/	/koʊ/	79) 猪肉(pork)	/ʐ/	/ʐoʊ/
34) 乌龟(turtle)	/k/	/ki̯ᵊu/	80) 美人鱼(mermaid)	/ʐ/	/ʐən/
35) 苹果(apple)	/k/	/kwo/	81) 青蛙(frog)	/w/	/wa/
36) 蛋糕(cake)	/k/	/kaʊ/	82) 乌龟(turtle)	/w/	/wu/
37) 裤子(trousers)	/kʰ/	/kʰu/	83) 尾巴(tail)	/w/	/weɪ/
38) 坦克(tank)	/kʰ/	/kʰɤ/	84) 蚊子(mosquito)	/w/	/wən/
39) 恐龙(dinosaur)	/kʰ/	/kʰʊŋ/	85) 望远镜(telescope)	/w/	/wɑŋ/
40) 猴子(monkey)	/x/	/xoʊ/	86) 美人鱼(mermaid)	/j/	/jy/
41) 梅花鹿(sika deer)	/x/	/xuɑ/	87) 牙齿(tooth)	/j/	/ja/
42) 辣椒(pepper)	/j/	/jjaʊ/	88) 眼睛(eyes)	/j/	/jiŋ/
43) 橘子(orange)	/j/	/jy/	89) 白云(white cloud)	/j/	/juᵊn/
44) 眼睛(eyes)	/j/	/jiŋ/	90) 游泳(swim)	/j/	/jʊŋ/
45) 毛巾(towel)	/j/	/jin/	91) 月亮(moon)	/j/	/jɥɛ/
46) 夹手(pinch hand)	/j/	/jia/	92) 望远镜(telescope)	/j/	/jiŋ/

Table 5. Sentence probes.

/l-joʊ/	/k-ɤ/	/ɕ-jɑʊ/	/x-wo/	/b-an/		/ts-wo/	/ʈʂʰ-wan/	/kʰ-uɑ/	/ʈʂ-u/	/tɕ-jɑŋ/	
六	个	小	伙	伴	，	坐	船	跨	珠	江	。
N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D	N/D	N/D	
Sentence 1 translation: Six little friends cruised along the Pearl River.											
/t-oʊ/	/tɕʰ-y/	/pʰ-ɑʊ/	/n-aɪ/	/f-ən/		/tsʰ-aɪ/	/ʂ-eɪ/	/s-ʊŋ/	/m-i/	/tʰ-ɑŋ/	
都	去	泡	奶	粉	，	猜	谁	送	蜜	糖	。
N/D	N/D	N/D	N/D	N/D		N/D	N/D	N/D	N/D	N/D	
Sentence 2 translation: All (kids) go for milk powder. Guess who will deliver the honey?											

Note: N: normal D: distorted.

3.4. Treatment

A total of 12 individual treatment sessions were administered once a week over 6 months, with 40 minutes per session. Lingual control therapy was employed by focusing on two key elements of motor learning, e.g., the prepractice considerations and feedback conditions. More specifically, the effectiveness of phonological therapy derives from clinical feedback and child's motivation to rectify the phonatory error (Doubé et al., 2018). Hence, the focus of treatment instructions was no more than the articulatory placement of the tongue to avoid over-instruction and optimize the prepractice (Schmidt, 1991). Two types of immediate feedback were provided, e.g., knowledge of performance (KP; e.g. "please bite your tongue tip gently") and knowledge of results (KR; e.g. "excellent! The position of your tongue tip is correct"), while delayed KP and KR were offered to assist home practice via WeChat communication between SLP and the child's parents. Feedback frequency was high (e.g. feedback after every attempt) at the beginning of treatment, and gradually faded away towards the end of treatment (e.g. augmented feedback is withdrawn and feedback limited to incorrect production only). This approach aimed to improve the self-awareness of speech sound errors (Maas et al., 2008). Each treatment session began with a review of home practice activities to determine whether the new skill development or the same target of the last treatment session is applicable. The core of each treatment session was the instruction-feedback supported massed practice for sound production acquisition through repeated probes.

The intervention targeted both non-speech and speech. The Non-speech training focused on the child's tongue muscle movements to establish independent tongue movements such as tongue stretching out, tongue retraction and tongue elevation. Table 6 specifies the treatment steps. The speech lingual control component targeted speech production in increasing linguistic complexity (e.g., words and sentences) by emphasizing the anterior tongue use. Specifically, at the onset, the training centered on the auditory bombardment of target phoneme

Table 6. Lingual control therapy plan.

Speech Organs	Lingual Movement	Motor Activity	Motor Target	Target Sound Description
Tongue body	anterior-posterior dimension	Tongue protruding from and retracting into the oral cavity	Establish mobility, stability and equilibrium for independent tongue movement	Basal carriage for all target sounds
Coronal	inferior-superior dimension	Bending the anterior part of the tongue upward	Encourage control of the tip and blade of the tongue	Lingua-palatal Distortion: /tɕ, tɕ^h, ɕ/ The anterior part of the tongue rises, approaching the palate
	Static state	Biting the tongue tip gently	Enhance tongue tip tension	Blade-alveolar Distortion: /t, t^h,n, l/ The tip of the tongue touches the alveolar ridge.
		Clamping the teeth together and holding the tongue behind the the back of the upper teeth to create an obstruction to airflow	Increase tongue tip stability	Apico-dental Distortion: /ts^h, ts, s/ The tip of the tongue approaches the back of the upper incisor to create an obstruction to airflow
Dorsal	inferior-superior dimension	Elevation of the dorsal surface of the tongue	Facilitate posterior tongue use	Velar Substitution: /k, k^h/ Discrimination

or phoneme combinations as well as guidance on the phonetic placement of the tongue with the aim of improving speech sound awareness and speech self-monitoring (Gierut, 1998). When the perception of speech sounds was established, the intervention followed with sound production tasks which began in isolated phonemes and advanced to syllables (See **Table 3**). All utterances were required to start with the tongue tip bite gently between the child's teeth to enhance tongue tip use in articulation. Words and sentences were untrained to monitor whether the treatment gain would generalize to other linguistic contexts.

Home practice is included to strengthen the in-clinic training (Jesus et al., 2019). H's parents were highly supportive and had eager anticipation for a successful intervention in time before her entry to primary school. They reviewed treatment targets under the guidance of the SLP and executed homework, which required the child to repeat the target sounds from each therapy block on a daily basis (three times a day, 15 minutes each time). Home practice videos were sent via WeChat to the SLP for feedback.

3.5. Procedure

Pre- and post-treatment assessments and treatment sessions were all administered individually by an SLP in a speech clinic. All speech samples were audio-recorded in pre- and post-treatment assessments, while the treatment sessions were video-recorded to document both the auditory prompt and the visual instruction. The SLP's instruction and the child's response were transmitted from a microphone in the treatment room to a studio monitor capable of connecting to headsets via Bluetooth in the observing room. Both the researcher and parents wore headphones and observed assessments and the therapy through a window fitted with a one-way glass in the observing room. Due to the lack of standardized tests of Putonghua phonology (Wu et al., 2019), direct imitation was used to elicit speech production. The child was asked to imitate the articulation verbatim and the correct pronounced words were coded as "1", whereas the incorrect word elicitation was coded as "0".

3.6. Data Analysis

Statistical analyses for all obtained data were performed in R Studio version 4.1.1 (RStudio Team, 2021). To address research question one, Fisher's exact test was conducted to examine the differences in response accuracy between pre-treatment and post-treatment time points. Next, the linear regression model was fitted to investigate the effect of time on the treatment responses. Specifically, the time point (e.g., pre-treatment, post-treatment) was the independent variable and the response accuracy was the dependent variable. With respect to the second research question, the author has approached the linear interaction effect model investigating whether the treatment shows a differential effect by distinct places, manners, voicing and aspiration characteristics. Regarding the third research question, the linear regression model was adopted to test if treatment of a sound focus on production at the phoneme and the syllable level promotes increased sound accuracy in connected speech at the word level and the sentence level based on the differences in accuracy of word and sentence probe responses respectively between time points.

4. Results

Results from Fisher's exact test showed a significant association between pre-treatment and post-treatment (two-tailed p-value < $2.2*10^{-16}$), suggesting that treatment might have a strong effect on response accuracy. The regression results revealed a significant effect of time (beta = 0.46701, SE = 0.02517, $p < 2*10^{-16}$), indicating that the patient demonstrated significant improvement on the trained sounds over the course of treatment.

The linear regression with interaction results did not reveal significance among various manners, aspirations and voicing ($p > 0.05$). Nevertheless, significant interaction effects were found in the place of articulation. Specifically, apico-dental*treatment (beta = 1, SE = $2.172*10^{-2}$, t = 46.043, $p < 2*10^{-16}$), blade-alveolar*treatment (beta = 0.9892, SE = $2.005*10^{-2}$, t = 48.149, $p < 2*10^{-16}$), lingua-palatal*treatment (beta = 1, SE = $2.212*10^{-2}$, t = 45.213, $p < 2*10^{-16}$), indicating that differential therapeutic effect of the patient can be found among these places of articulation.

Results of the linear regression model revealed significant differences in accuracy by time points for both word and sentence level data (beta = 0.3587, SE = 0.341, t = 7.134, $p = 2.23*10^{-11}$), (beta = 0.57895, SE = 0.11637, t = 4.975, $p = 1.62*10^{-05}$), suggesting that the child has achieved substantial generalization at both the word level and the sentence level. Figure 1 and Figure 2 display the response accuracy in words and sentences.

5. Discussion

The current treatment case study presented three key findings. First, the accuracy of the child's apical initials has changed positively following the lingual control therapy. Her overall intelligibility improved considerably through intensive treatment within half a year before starting elementary school. No subsequent phonological treatment was needed according to the post-treatment report from the SLP. As a consequence, H opened up for more verbal interaction with peers. Secondly, various sound locations may interact with each other and differentially affect the treatment outcomes. Thirdly, the treatment outcome was generalized from the trained individual phonemes and syllables to the untrained continuous phonetic units of words and sentences.

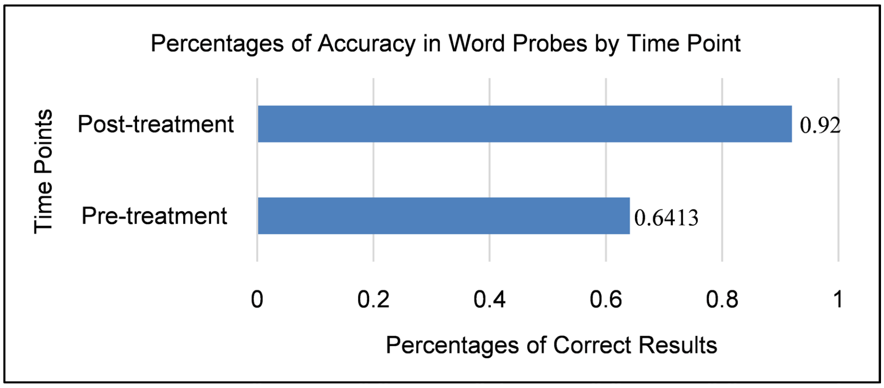


Figure 1. Correct percentage of assessed words by time point.

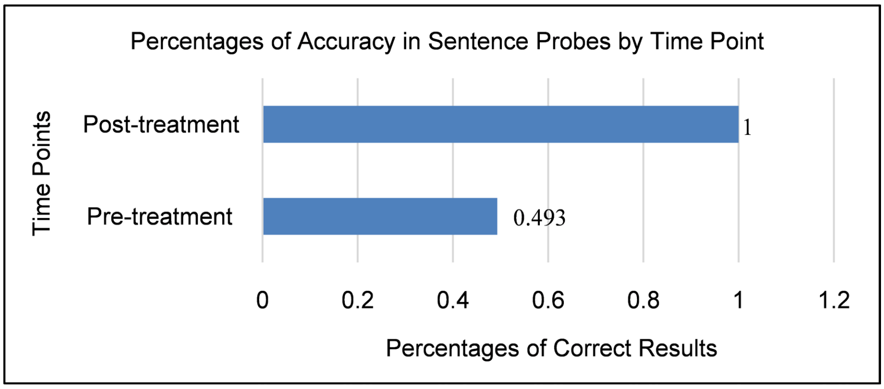


Figure 2. Correct percentage of assessed sentences by time point.

The treatment effect of this research is consistent with an array of previous part-whole approaches in speech remediation targeting the single component in the articulatory system, implying that simple task treatment (e.g. tongue control) not only avoids unnecessary practice on task aspects already mastered but also minimizes the cognitive load in treatment for children by means of avoiding too lengthy task instructions (Maas et al., 2008; Park et al., 2004). Nevertheless, with evidence to the contrary, complex task treatment targeting the extensive coordination among multiple components across speech subsystems (e.g. multi-sensory treatment) was proven to facilitate greater learning relative to simple task treatment, suggesting that the part-whole approach is less efficient than the whole-whole approach (Gierut, 2001, 2007; Morrisette & Gierut, 2003). Possible reasons for the discrepancy regarding the part-whole relationship in task modeling lie in the different atypical nature and severity of the disorder. For this case treatment, backing was the major deviant phonological process identified for the patient, which reflects the child's preference of post-positioning of the tongue in the articulatory process. That is why she consistently realized coronals as velars, such as 葡萄/pʰu tʰɑʊ/ realized as [pʰu kɑʊ], 盾牌/tuᵊn pʰaɪ/ realized as [kuᵊn pʰaɪ], 坦克/tʰan kʰɤ/ realized as [kʰan kʰɤ], 洗澡/ɕi tsɑʊ/ realized as [ɕi kɑʊ], indicating changes in articulating locations backward. A possible underlying deficit for backing is related to the abnormality of the tongue balance in the process of tongue movements (Jeng, 2011). To address this issue, the training of anterior-posterior and tongue-tip biting exercises included in the current lingual control therapy was efficacious in restraining the postposition of the tip and blade of the tongue during articulation and establishing the stability and equilibrium for the tongue in movements. Similar findings were reported by Duan & Zhang (Duan & Zhang, 2020) concluding that the scientific teaching of "biting the tip of the tongue" is helpful in emphasizing the obstruction position is not on the roof of the tongue, but rather the tip or blade of the tongue. Kent (Kent, 2021) also supported this view of point from the biological perspective that the superior longitudinal muscle as one bulk of the tongue has motor units arranged in an anteroposterior dimension so that the neural control of tongue shape and tongue movements was permitted by the regional activation. This conclusion is in line with the present lingual control therapy that activated the anterior tongue control through the training of nonspeech tongue movements in the anterior-posterior dimension. In addition, regarding the disordered error patterns, Zhu concluded that velar stops /k/ and /kʰ/ were often absent from disordered Putonghua-speaking children's phonemic inventories. The fact that the child in this study consistently realized /k, kʰ/ as substitutes for /t, tʰ/ does not support this standpoint, highlighting that the acoustic variability of the deviant system for phonologically disordered children should be taken into account before universal conclusions are drawn and investigating variables plays a crucial role in children's phonological treatment. Moreover, Mohring (Mohring, 1931) suggested that phonemes with which disordered children had the least difficulty were acquired earlier than phonemes they found difficult in normally developing children. Zhu argued that Putonghua-speaking children with SSD make errors with early acquired phonemes in normative data does not support this suggestion. The findings of this case study echoed Zhu's argument and diverged from the suggestion from Mohring (Mohring, 1931). Specifically, the child's disordered phonemes /t, t^h, n/ are acquired at age of 1;6, 2;0 and 2;6 respectively by normally developing children, while her accurately produced phonemes /k, k^h/ are acquired at age of 3;00 by normally developing children. As such, it shows that there exists no necessary correspondence between the developmental trajectories and the aberrant degree of disorders. Phonological disorder is diagnosed with reference to normal development, but not vice versa.

Different underlying deficits may lead to different deviant processes or error patterns, suggesting differential diagnosis and treatment. For speech production disorders that mainly involve lingual motions, tongue control comes into play in concert with places of articulation because of unshared properties. To illustrate, for the participant of this case study there are three disordered apical dental consonants (/ts/, /ts^h/, /s/), four disordered balde-alveolar consonants (/t/, /t^h/, /n/, /l/) and three disordered blade-palatal consonants (/ts/, /ts^h/, /s/), all of which involve raising and lowering the tip of the tongue in production, with the major difference being that articulatory contacts of the tongue tip are either approaching or pressing against distinct parts of the oral cavity, namely the back of the upper incisor, alveolar ridge and anterior hard palate respectively, to create an obstruction to airflow. Corresponding to the tip of the tongue, coronal raising included in the lingual control therapy involves the training of the upward bending of the anterior part of the tongue to establish the stability of the tongue tip for apical consonant initials. In addition, three disordered lingua-palatal consonants /tɕ/, /tɕʰ/, /ɕ/ were identified too. These sounds involve the lifting of the lingual surface approaching the anterior hard palate. Accordingly, tongue elevation in the inferior-superior dimension was adopted to encourage control of the blade of the tongue in the course of pulling up and retracting the blade of the tongue. Moreover, the child exhibited substitution with two dorso-velar consonants /k/, /k^h/ which are produced with movements of the roof of the tongue. The elevation of the dorsal surface of the tongue was exercised to discriminate between posterior tongue use and anterior tongue use. In general, even the speech motor control centers on no more than the tongue, intervention of different portions of the tongue shows different treatment outcomes specific to sound locations. Implicational relationships among sound categories suggest that therapeutic effect differs with distinct places of articulation. Tongue maturation hypothesis may account for the differentiation of treatment effect by place of articulation. It is proposed that the production of apical sounds utilizes the peripheral and relatively smaller muscles responsible for the motion of the tongue tip, whereas the production of both lingua-palatal and dorso-velar sounds involves central and large muscles that control the tongue blade and tongue dorsum (Ma et al., 2022). The rationale is that muscle movements are not shared with in terms of place of articulation.

With respect to efficacy, changes in both treated and untreated targets are crucial indicators. In this research, it has been tested that treatment gains went beyond the treated phonemes and syllables to the nonintervention words and sentences, suggesting that the treatment in the control of oral movements in isolation is likely to transfer to systematic speech sound production and the hierarchy of linguistic units might be related to the optimization of the generalization effect. In other words, with the emphasis on the treatment of the target sound in given smaller linguistic units as exemplars, the production of the target sound in units of increasing linguistic complexity may need not be intervened directly so that using a limited number of stimuli is possible to achieve widespread gains across the entire phonetic contexts. The theory of phonological acquisition provides an alternative account for this finding stating that children's phonological awareness is a gradual progress and phonological acquisition is a developmental continuum progressing from an initial stage of the articulation of a certain sound or phoneme to the final stage of articulating phonemes systematically accurately (Stanovich & Jordan, 2000; Zhu, 2002). Other intervention studies similarly have shown the extension of the treated syllable level to the untreated word level (McReynolds, 1972; Powell & McReynolds, 1969).

In brief, the aforementioned key treatment findings from this study have three important clinical implications. First, the diagnosis of the presence of concomitant impairments and the analyse of the uniformity across error patterns can be attributed to deciding clients' priority for treatment, which reveals the complexity of correlations between causal factors and associated deficits and treatment strategies. In this case, the child's speech disorder has no known organic cause indicating that her speech sound disorder was functional without occurring impairments. Moreover, her error patterns were especially relevant to the motoric ability of the tongue, thereby establishing tongue control would seem to be a prioritized therapeutic goal. The clinical implication of these analyses is that notwithstanding the lack of clarity in SSD diagnostic guidelines, in therapeutic procedures those aspects of the articulatory system that are developing atypically should be given priority before multiple vocal behaviors are involved in the training. The findings also have implications for the choice of treatment targets. To meet varying functional demands, the target selection modeling by the clinician should be monitored carefully. The results found in the current study imply that nonspeech oral-motor exercises including repeated tongue elevations, tongue biting as well and tongue-strengthening combined with articulation training of phonemes or syllables starting with the tongue tip bit might result in positive changes for backing and apical consonants disorders. The analysis of the surface error patterns might suggest a supportive treatment target if there exist some commonalities across error patterns. Thirdly, the understanding with respect to movement places and sequences of lingual muscles for Putonghua phonology are particularly essential for Putonghua-speaking patient with SSD. Both clinical and linguistic knowledge are important for SSD treatment.

While the findings of the current study are encouraging, they only included one single case, which makes definitive conclusions premature. The positive outcome of the treatment argues for research on larger numbers of children of homogenous age and causal factors. Second, it remains unclear whether other non-motor-based approaches have similar treatment effects as this study only used an oral-motor approach without the control group. Thirdly, the maintenance of therapy gains was not measured so whether changes continue beyond the treatment phase awaits investigation. Lastly, spontaneous production of the patient which might better reflect their actual sound production ability was not examined because imitation was the only elicited speech mode adopted in this work. Though children might have learned speech production from the examiner through imitation at the testing time (Peng & Chen, 2020), it was hard to collect spontaneous speech data especially the child was highly introverted and timid. With this background, if the subject was challenged too much, the risk of communication breakdown would be increased and the patient might be less motivated to engage fully in treatment tasks wherein the learning may be hampered ultimately (Mass et al., 2008). Future research should be directed towards larger sample sizes with comparative designs incorporating spontaneous speech data prior to making further conclusions in this direction.

6. Conclusions

This study sought to investigate the application of the lingual control treatment approach to a monolingual Putonghua-speaking preschooler with functional speech-sound disorder. The participant demonstrated robust improvements in the accuracy of Putonghua consonant initials over the course of treatment. Additionally, the treatment gains of phonemes and syllables were generalizable to untreated words and sentences. Overall, findings from this case study are in line with motor learning theory and indicated that for Putonghua backing and apical consonant initial disorders where both the planning and the production of spatiotemporal parameters and movement sequences of lingual muscles are disrupted, the dynamic lingual training integrating auditory and visual information would endow the tongue musculature with the potential to meet specific demands of lingual motions and effect changes in the location of the tongue body.

Importantly, interfering factors to the misleading of an articulatory gesture which consequently leads to the failure in articulatory realization of certain sounds, particularly early acquired sounds in the normative sample, remains unknown, which points to future studies to examine the reasons contributing to the breakdown in the speech-processing chains of children with SSD. Moreover, the relationship between treatment instructions and feedback and treatment outcomes is another area that warrants continued research so that our understanding of the Putonghua perception-production interface and how these two domains may be linked during SSD treatment can be deepened.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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