The effects of vowel, consonant and tone competition on Mandarin lexical access: Evidence from monolingual and bilingual learners

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ABSTRACT

Although tone language learners represent the linguistic majority, much less is known about lexical processing in tone language in comparison to non-tone languages such as English. In addition, it remains unclear whether monolinguals and bilinguals differ in how they access spoken words in tone languages. One way of investigating lexical access in language is to investigate the effects of lexical competition on word recognition. This approach can reveal the cohort of related words co-activated upon hearing a particular word. In doing so, this approach can reveal semantic connectivity in the developing lexicon. In the current study, 6-year-old Mandarin learners' spoken word recognition abilities were investigated in a preferential looking task. Mandarin monolinguals (N = 29) and English-Mandarin bilinguals (N = 29) were sampled to investigate the effects of bilingualism on vowel, consonant and tone competition. Children heard labels of target words in the presence of a visual foil. Foils were either distractors that were phonologically unrelated to the targets, or competitors which were minimally different from targets by a vowel, consonant, or tone. Results reveal differential effects of language background on children's abilities and of vowel, consonant and tone competition on word recognition during the kindergarten years.

Keywords: Lexical Access, Lexical Tone, Language Development, Bilingualism, Word Recognition

1. INTRODUCTION

In order to recognise spoken words, the language processing system must select the appropriate candidate within a set of phonologically similar lexical candidates that compete with the target for selection. Existing models of speech recognition differ in their predictions about the nature of the competitor set (e.g. TRACE [1], Cohort [2]). Historically, these models have drawn predominantly from European languages like English and French, which use vowels and consonants to distinguish word meanings. However, the majority of the world's languages use lexical tones in addition to vowels and consonants to distinguish words [3]. With the growing interest in studying language processing in tone languages, there have been some attempts to modify popular models such as TRACE [1] based on empirical evidence derived from tone languages like Cantonese and Mandarin (e.g. modified TRACE [4], TTRACE [5]). However, these models [4, 5] do not make detailed predictions about how factors such as age, type of phonological competition and bilingualism may influence spoken word recognition, which will be explored in the current study.

Previous research with Mandarin learning children has revealed that the relative strength of the mispronunciation effects for vowel, consonant and tone substitutions changes during early childhood. Mandarin learning infants and toddlers demonstrate robust mispronunciation effects for tone [6, 7], likely due to an early attentional bias to pitch variation that may initially boost the phonological salience of tones relative to vowels and consonants [8]. However, smaller mispronunciation effects for tones relative to vowels and consonants are observed for older children [7, 9]. Further up the age spectrum, there is considerable empirical evidence with adult native speakers of Mandarin that tones constrain word recognition less tightly than vowels and consonants [e.g. 4, 10]. However, when word recognition takes place under highly constrained environments, tone and segmental information can exert similar effects [e.g. 4, 11]. For instance, in a visual world paradigm, phonological competitors that differed from targets by a tone or a rime influenced lexical access in a comparable manner [11]. Given the difference in mispronunciation effects for segments and tones in early childhood [e.g. 7, 9], it is unclear whether vowel, consonant and tone competition exert similar effects in child learners, a focus of the current study.

In addition, another critical theoretical question pertains to the effects of bilingualism on spoken word recognition [12]. Lexical access in bilinguals differs from monolinguals as phonologically similar words in both languages are simultaneously activated when bilinguals process speech in one language [12]. Therefore, bilingual learners have to resolve both between- and within-language competition during word recognition, which may influence how easily bilinguals resolve phonological competition relative to monolinguals. This question will be explored in the current study. Furthermore, exposure to the phonological systems of two language systems can modify the ways in which native language sounds are perceived relative to monolinguals [13]. For example, individual differences in English-Mandarin bilingual adults' abilities to categorise native Mandarin tones was related to participants' age of English acquisition and English proficiency [13]. It is an open question whether the mental representations of lexical tones are particularly vulnerable to effects of phonological competition in learners who have acquired English since birth, which will be explored in the current study.

The goals of this experiment were to compare and relative effects of vowel, consonant and tone competition on lexical access, and to determine whether bilingualism influences how learners resolve phonological competition. Based on findings from Mandarin-dominant bilingual adults [11], we predict that for Mandarin monolingual learners, segmental and tone competitors will contend for lexical access in a comparable manner. However, given evidence from adult native speakers demonstrating that only bilinguals who had learned English late in life had monolingual-like neural patterns when categorising lexical tones [13], we predict that for simultaneous English-Mandarin bilingual learners, tone competitors will contend for lexical access to a greater degree relative to vowel or consonant competitors.

2. METHODS

2.1. Participants

Fifty eight native learners of Mandarin were sampled for this study. Half of the sample comprised Mandarin monolinguals (N = 29, M_{age} = 69.48 months, range = 64 to 75 months, 15 boys), and the other half of the sample comprised simultaneous English-Mandarin bilinguals (N = 29, M_{age} = 70.79 months, range = 65 to 78 months, 16 boys). Monolingual children did not have habitual exposure to a second language and attended a monolingual kindergarten program. Bilingual children did not have habitual exposure to a third language and attended bilingual kindergarten programs that conducted lessons in both English and Mandarin. None of the children who participated in the current study had any known disabilities or developmental delays.

2.2. Stimuli

Test stimuli consisted of 36 concrete, imageable words, which belonged to one of five trial types (see Table 1). In the phonological competitor conditions, stimuli pairs were matched such that vowel, consonant and tone competitors differed from targets by one phonemic constituent [11]. In contrast, distractors were phonologically unrelated to targets and consisted either familiar [7, 11], or novel objects [6, 7, 9]. Target and foil pairs were matched on visual salience.

Table 1: Sample Stimuli List.

Trial Type	Target	IPA	Foil	IPA
Vowel Competitor	Horse	[ma(214)]	Rice	[mi(214)]
Consonant Competitor	Rabbit	[tʰu(51)]	Cloth	[pu(51)]
Tone Competitor	Cup	[pei(55)]	Blanket	[pei(51)]
Familiar Distractor	Cow	[niou(35)]	Mountain	[ʂan(55)]
Novel Distractor	Bird	[niɑu(214)]	Accordion	[ʂou(214) fəŋ(55) tɕʰin(35)]

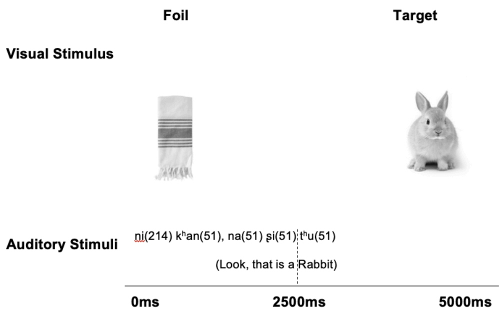
Test stimuli were presented in sentence final position with the carrier phrase [ni(214) kʰan(51), na(51) ʂi(51)] (English translation: look, that is). Given that monolingual and bilingual learners are sensitive to accented speech [14], a monolingual native speaker of Mandarin recorded stimuli for the monolingual sample, and a bilingual native speaker of English and Mandarin recorded stimuli for the bilingual sample. All speech stimuli were recorded in a sound attenuated room and were spoken in a child directed register.

Coloured photographs of targets, competitors and distractors were used to serve as visual stimuli. Target and foil assignment in the first four trial types counterbalanced across participants. For example, 'rabbit' was the target and 'cloth' was the competitor for half of the participants, and this was switched for the other half. Left-right positions of targets and foils were also counterbalanced across participants.

2.3. Procedure

The preferential looking paradigm was used in this task to investigate spoken word recognition. All children were seated at a comfortable viewing distance from an LCD monitor. Auditory stimuli were played via left-right speakers at a conversational level of approximately 70dB. The experimental session comprised 20 pseudo-randomized test trials: vowel competitor trials (N = 4), consonant competitor trials (N = 4), tone competitor trials (N = 4), familiar distractor trials (N = 4) and novel distractor trials (N = 4). Each test trial began with the onset of visual stimuli, which comprised a target and a foil (either a distractor or a phonological competitor). A naming phrase (English translation: look, that is) was used to direct children's attention to the visual stimuli. Following this, the target label, which occurred exactly 2500ms after the onset of the visual stimuli, was played. Each trial lasted 5000ms (see Figure 1).

Figure 1: Sequence of events in each preferential looking test trial.



Participants' eye-movements were either coded offline by a trained coder, or captured automatically by the Tobii 60XL eye-tracking system. Previous investigations have established high reliability between eye-tracking data obtained by offline coding and the Tobii 60XL system [6].

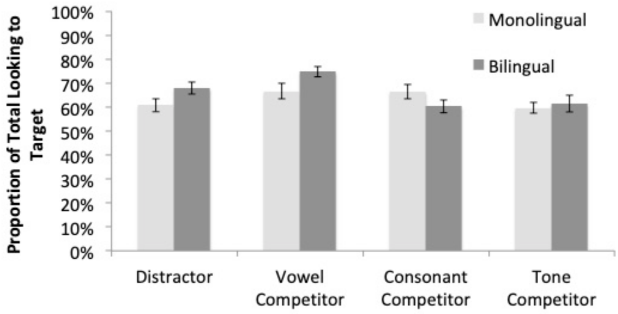
3. RESULTS

In line with conventions established in previous spoken word recognition research [e.g. 15], the dependent variable used in the analysis was fixation to the target after labelling. To allow for time required to initiate an eye-movement in response to labelling, fixation data obtained in the first 200ms was not analysed [15]. Thus, the proportion of total looking to target (PTL) between 200-2500ms after the onset of the target word was aggregated for analysis. PTL was derived from the formula T/(T+D), where 'T' represents total fixation to the target and 'D' represents total fixation to the foil.

A paired-sample *t*-test was conducted to compare PTL in the familiar distractor and novel distractor conditions. Results revealed that differences in distractor familiarity did not influence word recognition, $t(57) = 1.18$, $p = .24$ (Cohen's $d = 0.31$). Thus, the familiar distractor condition and the novel distractor condition were averaged to form the distractor condition.

A 2 x 4 mixed-model analysis of variance (ANOVA) with language group (monolingual/bilingual) as a between-subjects factor and trial type (distractor/vowel competitor/consonant competitor/tone competitor) as a within-subjects factor was conducted with PTL as the dependent variable. The omnibus ANOVA revealed no main effect of language group, $F(1,56) = 0.93$, $p = .34$ (partial eta^2 = .02), a significant main effect of trial type, $F(3,168) = 6.94$, $p < .001$ (partial eta^2 = .11), and a significant interaction between trial type and language type, $F(3,168) = 3.87$, $p = .01$ (partial eta^2 = .07). In light of the interaction with language group, we proceeded to separate analyses for monolingual and bilingual learners (see Figure 2).

Figure 2: Proportion of total looking to target for monolingual and bilingual learners of Mandarin. Error bars reflect SEM.



For each language group (monolinguals/bilinguals), a one-way repeated measures ANOVA with trial type (distractor/vowel competitor/consonant competitor/tone competitor) as a within-subjects factor was conducted with PTL as the dependent variable. There was no main effect of trial type for the monolingual group, $F(3,84) = 2.58$, $p = .06$ (partial eta^2 = .08), which indicates that target fixation for monolingual children did not differ based on the phonological identity of the foil present in their visual world

A corresponding set of analyses with bilingual participants revealed a significant main effect of trial type, $F(3,84) = 7.95$, $p < .001$ (partial eta^2 = .22). This indicates that target fixation for bilinguals differed based on the phonological identity of the foil present in their visual world. Relative to trials with distractors, bilinguals exhibited increased target fixation in trials with vowel competitors (*M*s 67.74% vs. 74.76%) $F(1,28) = 5.38$, $p = .03$ (partial eta^2 = .16). In addition, relative to trials with distractors, bilinguals exhibited reduced target fixation in trials with consonant competitors (*M*s 67.74% vs. 60.24%), $F(1,28) = 7.36$, $p = .01$ (partial eta^2 = .21) and tone competitors (*M*s 67.74% vs. 61.26%), $F(1,28) = 4.26$, $p < .05$ (partial eta^2 = .13).

4. DISCUSSION

In the current study, 6-year-old monolingual and bilingual Mandarin learners heard correct pronunciations of familiar words in the presence of foils. Foils were either phonologically unrelated to targets, or minimally contrastive by a vowel, consonant or tone. Monolingual and bilingual children responded differently to distractors and phonological competitors: only bilingual children were influenced by phonological competition. Consonant and tone competitors hindered bilingual lexical access, while vowel competitors did not.

The finding that monolingual children were unimpaired by phonological competition adds to a growing body of work demonstrating that bilingual lexical access may be less efficient than monolingual lexical access [see 16]. Some models of bilingualism posit that bilinguals have to engage top-down inhibitory mechanisms in order to manage cross-language interference from the non-target language [e.g. 17]. The involvement of these additional mechanisms may thus result in slower lexical selection in bilinguals relative to monolinguals [17]. Alternatively, it may be that lexical representations in bilinguals are more fragile than that of monolinguals [18]. Given that bilinguals necessarily engage less in each language than monolinguals, weaker links between phonology and semantics in each lexicon could ensue [18]. It should be noted that these accounts are not mutually exclusive and could work in concert to make bilingual lexical access less efficient relative to monolinguals.

However, neither the cross-language interference account [17] nor the weaker links [18] account can adequately explain why bilingual lexical access was only compromised when faced with competition from words that minimally differed by consonants or tones. In our study, English-Mandarin bilingual children were not adversely affected by vowel competition. One possibility, given the greater overlap between monophthong vowels in English and Mandarin, relative to onset consonants or tones [19], could be that cross-language correspondences between languages may have benefited words in the vowel competitor condition. Though there is some initial evidence to support the suggestion that phonological overlap benefits bilingual word recognition [20], further research with non-cognate words is necessary.

Instead, another possibility could be that vowel information is privileged relative to consonants and tones in Mandarin. Indeed, a phonological bias towards vowel information over consonant information could arise as a function of both top-down and bottom-up factors. Firstly, vowels are more informative than consonants in Mandarin as the probability of correctly identifying a given word by only knowing its vowel is higher than knowing its consonant [10]. Second, vowels have greater acoustic-phonetic salience than consonants in Mandarin, as they are obligatory components of Mandarin syllables [8] and are processed integrally with tones [5].

The current study provides novel evidence that bilingualism influences how Mandarin learners resolve phonological competition from vowels, consonants and tones. Although Mandarin monolingual children were unaffected by phonological competition, lexical access in English-Mandarin bilinguals was vulnerable to the effects of consonant and tone competition.

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