On Taiwanese pupils' ability to differentiate between English /l/ and /r/: A study of L1/L2 cross language effects

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Abstract

Students in South East Asia often struggle with English /l/ and /r/. This study therefore set out to examine how Taiwanese pupils' perception of these sounds is influenced by cross language effects. Most Taiwanese students have Mandarin as L1 and Taiwanese as L2 or vice versa, and English as L3. A same-different discrimination experiment was conducted to measure pupils' ability to discriminate between phonetically close English /r/ and /l/ and Mandarin /ʐ/ and /l/. The results show that L1-Mandarin pupils discriminate both the English consonant contrast and the Mandarin consonant contrast better than L1-Taiwanese pupils. Discrimination difficulty may be higher if two members of a contrast are perceived as belonging to a single L1 category.

Keywords Cross language influence, speech perception, phonetic contrast, l and r, English, Taiwanese, Mandarin

The slang term Engrish is used to characterize how speakers of some East Asian languages confuse /r/ and /l/. The English /r/ is phonetically similar to the Mandarin /ʐ/ in that both are palatoalveolar retroflex. Unlike the Mandarin /ʐ/, the English /r/ exhibits a slight lip-rounding (Duanmu, 2000). According to Hua and Dodd (2000), not all young L1-Mandarin children are able to accurately articulate the Mandarin syllable-initial /ʐ/ and /l/. The Mandarin /ʐ/ was among the three consonants to be acquired the slowest by 90% of 4½ year-old children. Further, 28% of these children replaced the [ʐ] with the glide [j] and 4% of them with the alveolar lateral [l]. The Mandarin /ʐ/ and /l/ were also among the last ten consonants (out of 21) to be acquired, and hence are believed to be difficult to perceive and produce (Locke, 1983).

The Taiwanese phonological system does not contain the English /r/ or the Mandarin /ʐ/, whereas /l/ is a phoneme in all three languages. As /l/ occurs only word-initially in Mandarin and Taiwanese, this study only examined the English /r/-/l/ contrast in word initial position. The English word-initial /l/ is a clear-l, which is acoustically close to the Mandarin /l/ and the Taiwanese /l/, except that English /l/ has a more retracted place of articulation (Ing, 1980). The Taiwanese phoneme /l/ has two allophones [l] and [n] that occur in complementary distribution: [l] only occurs before oral vowels and [n] only before nasalised vowels; conversely, /l/ and /n/ are two phonemes in Mandarin and English.

Phonetic contexts can influence speakers' perception and production. Listeners employ multiple cues to identify consonants. Of these, cues to voicing and manner of articulation mainly lie in the time domain and partially in the spectral domain. The spectral domain also contains cues for place of articulation (e.g., Xu, Thompson, & Pfingst, 2005). Such place cues, compared to other cues, can be affected by formant features of neighbouring vowels and

are thus sensitive to vowel contexts. Transitions between consonants and vowels give changes in vowel formant frequencies. Formant transitions may change in degrees of direction and frequency because of the formant frequencies of the neighbouring vowels. Cues to consonant identity conveyed in formant transitions thus may be strengthened or weakened depending on the vowel context. According to O'Connor, Gerstman, Liberman, Delattre, & Cooper (1957), to distinguish the English /l/ from /r/, the onset frequency of the second formant transition should be moderately higher for /l/ than for /r/ but this is not reliable enough to separate the two. More critically, the third formant onset for /l/ has a similar height as its succeeding vowel, while the third formant onset frequency for /r/ should be lower and slightly higher than the second formant onset. Using synthetic stimuli, O'Connor et al. (1957) confirmed that hearers mostly employed the third formant transitions to distinguish /l/ from /r/.

Bradlow, Pisoni, Akahane-Yamada, and Tohkura (1997) suggested that perceptual learning of English /r/ and /l/ is highly context-dependent. Sheldon and Strange (1982) found that Japanese learners' perception of the contrast between English liquids /r/ and /l/ was affected by within-word position: the contrast was most accurately perceived in word final position but least perceived in prevocalic position in consonant clusters. In addition, Shimizu and Dantsuji (1983) observed that /r/-/l/ contrasts were perceived better in intervocalic positions than in consonant clusters, yet less perceived than in word initial positions. Also, Japanese learners assimilated the English /r/ and /l/ to Japanese /ɾ/ differently due to the succeeding vowels and their within word position (Komaki, Akahane-Yamada, & Choi, 1999). Vowel height (Komaki et al., 1999) and the rounding feature of back vowels (Brown, 1998) were found to also affect the English /r/-/l/ discrimination. Sheldon and Strange (1982) found that the perception rates for /r/ and /l/ were lower when succeeded by non-low vowels than by low

vowels, while Shimizu and Dantsuji (1983) found that word initial /r/-/l/ contrasts achieved a higher perception rate for non-low front vowels than back rounded vowels.

There are discrepancies between these results, as a high front vowel such as /i/ is considered non-facilitating according to its height, while it is considered a more facilitating context compared to back rounded vowels. Also, vowel contexts employed for the English /r/-/l/ contrast are limited: Previous studies used /ɑ/ (Guion, Flege, Akahane-Yamada, & Pruitt, 2000), /i/ (Trehub, 1976), /i, ɑ/ (Komaki & Choi, 1999), /i, u, o, aɪ/ (Sheldon & Strange, 1982), and /i, ɪ, ɛ, ɔ, u/ (Shimizu & Dantsuji, 1983). This study therefore also includes less explored vowels to clarify effects of vowel height and back roundedness.

Several models have been proposed. The native language magnet (NLM) model predicts that early language coding in the brain affects future learning of a new language's phonetic systems (Kuhl, 2000). The model theorises that language experiences distort perception with reduced sensitivity for near categories and sharpened sensitivity between categories (Kuhl, 1991). Phonetic representations that are most frequently used act as perceptual magnets, causing similar sounds to be perceived as members of the same category (Kuhl, 1991). This effect enhances L1 abilities, but hinders non-native phonetic learning.

The perceptual assimilation model (PAM-L2) predicts learners' discrimination patterns based on their L1 phonetic system during non-native discrimination tasks and describes their estimated degree of success (Best & Tyler, 2007). Non-native sounds may be perceived as the following: (a) a good to poor example of one L1 category; (b) falling between two or more L1 categories; and (c) a non-speech element that bears no similarity to any L1 categories. If two non-native sounds are assimilated to two phonetically similar L1 phonemes, it is called *two*

category assimilation. If non-native sounds are assimilated into one L1 category, it is known as *single category assimilation.* If assimilated to one L1 phoneme, where a non-native sound resembles the L1 category more than the other non-native phone, it is termed *category goodness difference.*

The PAM-L2 model defines three additional categories, viz., where one non-native sound is categorized and the other is not, both non-native sounds are uncategorized, and both non-native sounds are highly distinct from the L1 categories. As English word-initial /l/ is phonetically similar to Mandarin word-initial /l/, and English /r/ is phonetically similar to Mandarin /ʐ/, it is likely that L1-Mandarin/L3-English pupils tend to assimilate the L3 phonemes /r/ and /l/ to the L1 phonemes /ʐ/ and /l/ respectively. L1-Taiwanese children may assimilate both non-native English phonemes to the similar L1-Taiwanese phoneme /l/. Hence, this study focused on non-native sounds that are categorised as L1 phonemes, namely, two categories assimilation, single category assimilation, and category goodness difference.

Non-native contrast discriminations can be affected positively, negatively, or minimally by the L1 phonological system, relative to listeners' perceived phonetic relationship between non-native sounds and L1 phonemes (Best & Tyler, 2007). Two categories assimilation can be predicted to exhibit high discrimination rates as the contrasting sounds are on the either side of a L1 phonological space. Single category assimilation and category goodness difference are perceived as one single L1 element and thus discrimination is impeded by L1 phonology. Single category assimilation predicts that two non-native sounds are discriminated poorly as they are phonetically similar, i.e., they are in close phonological positions and have very similar degree of fit. Category goodness difference predicts good discrimination, as both phones are phonetically very different in fit, i.e., good versus poor, though not as good as that

of two categories assimilation since they are assimilated as one L1 category. Uncategorised-uncategorised are said to receive fair to good discrimination relative to how similar non-native phones are perceived in relation to each other and their similarity to L1 categories. They are less affected by similar L1 phonemes.

This study investigated how listeners perceive the English /r/-/l/ contrast and the similar Mandarin /ʐ/-/l/ counterpart, as the L1 phonological system may hinder or facilitate discrimination of non-native contrasts (Best & Tyler, 2007). Further, contrasting non-native with close L1 elements may help clarify whether listeners are merely replacing a non-native phone with a similar L1 sound during discrimination (Brown, 1998). Moreover, listeners' discrimination accuracy is related to the cross-language mapping pattern (Guion et al., 2000). The following research questions were therefore asked:

1. Will children who use Mandarin and Taiwanese as L1/L2 or L2/L1 with different dominance levels, and who are learning English as L3, discriminate the word-initial English /r/-/l/ contrast differently?
2. Will their discrimination of the English /r/-/l/ contrast be conditioned by the succeeding vowels?
3. Will their discrimination of the similar sounding word-initial Mandarin /ʐ/-/l/ contrast be different?

The aim of this study is to test contrastive phonological representations and category formation. The results are discussed in relation to language learning models, in particular, the PAM framework.

Experiment

An AX discrimination task was used to assess the participants' ability to discriminate between the English /r/-/l/ contrast and the Mandarin /ʐ/-/l/ contrast.

Method

Recruitment and screening

Participants were recruited from a primary school in Tainan, Taiwan. Suitable participants were selected from the 320 third graders in the school through screening of language use and Taiwanese language ability. Only those who volunteered were contacted and asked four questions (see Table 1) to determine their group membership: (1) In what language do you talk with your parents? (2) Do you like speaking Taiwanese? (3) Is it easy to speak Taiwanese? (4) What language do you speak better and more often? Children talking with their parents in Taiwanese, enjoying speaking in Taiwanese, finding it easy to speak Taiwanese, and speaking better and more often in Taiwanese were allotted the L1-Taiwanese group. Those who speak with parents in Taiwanese and Mandarin, enjoy speaking in Taiwanese, find it easy to speak Taiwanese, but speak better and more often in Mandarin were assigned to the L1-Mandarin group with high Taiwanese proficiency. Children talking with parents in Mandarin, disliking speaking in Taiwanese, finding Taiwanese difficult, and speaking better and more often in Mandarin were placed in the L1-Mandarin group with low Taiwanese proficiency. Subsequently, potential candidates were invited for an informal chat in Taiwanese with a bilingual Taiwanese and Mandarin teacher. A list of simple questions related to daily life was devised to elicit the children's speech. Only those who expressed themselves naturally and fluently in Taiwanese were included in L1-Taiwanese group or L1-Mandarin with high Taiwanese proficiency. The two groups were further assigned based on their dominant language: L1-Taiwanese L2-Mandarin (Tai-Man), using Taiwanese as

dominant/mother tongue and Mandarin as second language vs. L1-Mandarin L2-Taiwanese (Man-Tai), using Mandarin as dominant/mother tongue and Taiwanese as second language. A few questions in Taiwanese were enough to uncover L1-Mandarin children with low-L2-Taiwanese (Man-[tai]); they comprehended the questions but struggled to articulate complete Taiwanese sentences.

Table 1. Participant characteristics

Group	Tai-Man	Man-[tai]	Man-Tai
Family language	Taiwanese	Mandarin	Taiwanese & Mandarin
Attitude to Taiwanese	Enjoy	Dislike	Enjoy
Perceived Taiwanese skill	Easy	Difficult	Easy
Dominant language	Taiwanese	Mandarin	Mandarin

Participants

The 48 children selected for the experiment comprised three groups (Tai-Man, Man-Tai, and Man-[tai]) of 16 pupils with gender balance. The pupils had a mean age of 9 ($\pm$ ½ year) as they were all in the same school year. They were in their second year of formal English training; none were reported having hearing/learning disorders.

Language use and demographics

Mandarin is the official instructional language throughout all education levels in Taiwan. Taiwanese is considered a local language and taught as part of art programs. There is no official policy that encourages "local language" use outside the classroom. Despite this, Taiwanese is widely used on the school grounds, among pupils and staff, although

individuals' proficiency varies. None of the children had been to an English-speaking country. Their formal English instruction started at the second grade and was taught by a L1-Taiwanese/L2-Mandarin teacher. A few children had received English lessons from kindergarten or after-school care-centres.

Stimulus preparations

English stimuli

Six English /r/-/l/ minimal pairs were constructed. The consonant /d/, commonly occurring in CVC syllables, was used as coda to avoid potential coarticulation from preceding vowels (cf. Laver, 1994). The vowels included the high-front /i/, high-back /u/, mid-front /ε/, mid-back /ɔ/, low-front /æ/, and the low-back /ɑ/. Two of the tokens were considered nonwords (*raud* and *lod*) to pair with real words, hence *raud* vs. *laud* and *rod* vs. *lod*.

Mandarin stimuli

Compared to English /r/-/l/, Mandarin /ʐ̩/-/l/ have fewer succeeding vowels. The Mandarin vowels included /ɤ/, /u/, /uo/, /ou/, /aŋ/, and /ao/. Six Mandarin /ʐ̩/-/l/ minimal pairs with falling tone were recorded as singleton words. Although English is not a tone language, all the English stimuli were recorded with falling tones to avoid these being assessed according to tonal cues.

Foils

Two types of foils (distractors) were used to validate the tests and prevent response bias. Type A (change trials) comprised six minimal pairs whose onsets differed from /l/, /r/, or /ʐ/, including /b-s/, /k-w/, /m-h/, /g-p/, /f-s/, and /b-θ/. These pairs served as controls to validate that there were no difficulties associated with a particular consonant type, that participants understood the test procedure, that low discrimination was not caused by task difficulty, as well as releasing tension caused by paying close attention to similar sounding stimuli.

Type B (no-change trials) comprised four sets of three pairs of identical words (12 pairs altogether) to prevent random guessing, i.e., identical English /r/-initial words, identical English /l/-initial words, identical Mandarin /l/-initial words, and identical Mandarin /ʐ/-initial words.

All no-change trials were physically different tokens. Participants decided whether each sound of the pair had the same identity or not.

Trials

For all target test and foil trials, the subsequent pairs had different vowels than the previous pair to avoid bias. Although real English words were used for test trials and foils, these may be considered non-words for most pupils since they are at beginners' level.

Five female L1-Mandarin and five female L1-English speakers produced Mandarin and English tokens respectively, repeating each minimal pair five times. Three L1-Mandarin and L1-English raters assessed the spoken samples. Tokens selected by all three raters were marked as stimuli candidates. Then, the minimal pairs produced by the speaker with the highest scores were used. A list of 30 minimal pairs including both languages was constructed.

Each of the 30 pairs appeared twice in the test totalling 60 trials, and each pair was reversed on the second occurrence to avoid presentation order effects. All the trials and foils were mixed in random order and adjusted such that no two adjacent trials had the same vowel context. The sixty trials were divided into four blocks. The sounds in each pair were separated by a 1 s pause, pairs were separated by 3.5 s pauses and blocks were separated by 20 s pauses.

Listener judgements

The participants were tested two at-a-time in a quiet room. The single session took approximately 15 minutes, including one minute of practice. Instructions were given in Mandarin. For L1-Taiwanese children, extra instructions were provided. The pupils were given a numbered answer sheet and were instructed to draw a circle when they judged a pair to be "the same", to draw a cross when "different", or to tick "not sure" when uncertain. Participants could request a replay of each pair up to four times.

Analysis

ANOVA and correlation analyses were used to interpret the results. Participants' dominance level of languages varies; it is useful to discuss the results with reference to their level of dominance in both languages. Language dominance may be defined as length or distribution of use. A likely Mandarin dominance ordering is Man-[tai] > Man-Tai > Tai-Man, while a likely Taiwanese dominance order is Tai-Man > Man-Tai > Man-[tai]. High, mid, and low are used to differentiate the dominance level for descriptive purposes.

Results

Overall contrasts

A mixed repeated measures ANOVA was conducted with participant group as between-group factor (Man-Tai, Man-[Tai], and Tai-Man), and contrast as within-group factor (Foil, English /r/-/l/, and Mandarin /ʐ/-/l/). The main effect of group on recognition score was significant $(F(2, 45) = 22.86, p < .001$; see Figure 1), so was the main effect of contrast $(F(2, 90) = 106.42, p < .001)$. A significant interaction was observed $(F(4, 90) = 11.43, p < .001)$. Tukey HSD tests revealed that the scores obtained for the Man-Tai and Man-[Tai] participants did not differ significantly $(p > .05)$, while Tai-Man's scores did from those of Man-Tai and Man-[Tai] $(p < .001)$. The different stimuli (Foil, English, and Mandarin) yielded significantly different scores $(p < .001)$. The interaction of group and contrast was explored through the tests of simple main effects. For the foil contrast, the difference among the three groups was significant $(F(2, 45) = 4.26, p < .05)$. The mean scores of Man-Tai and Man-[Tai] were not significantly different $(p = .584)$, while that of Tai-Man was significantly lower than both L1-Mandarin groups (Man-Tai $p < .01$ and Man-[Tai] $p < .05$). For the English contrast, a significant difference was detected among participant group scores $(F(2, 45) = 25.16, p < .001)$. The mean scores significantly differed between the Tai-Man children and L1-Mandarin groups $(p < .001)$ but not between the two L1-Mandarin groups $(p > .05)$. Mandarin contrast scores were significantly different across the three groups $(F(2, 45) = 15.15, p < .001)$. Man-Tai scored the highest, followed by Man-[Tai] and Tai-Man; the mean difference between groups was all significant (Man-Tai vs. Man-[Tai], $p < .02$; Tai-Man vs. Man-[Tai], $p < .005$; Tai-Man vs. Man-Tai, $p < .001$). It appears as if the more bilingually-balanced Man-Tai children were not affected by L2-Taiwanese in discriminating the Mandarin contrast and that Man-[Tai]'s less L2-Taiwanese dominance did not necessarily help them more accurately discriminate the L1-Mandarin contrast. The simple main effects indicated that the dominant L1-Mandarin children obtained higher discrimination scores than the L1-Taiwanese children

for all contrasts, and that all groups obtained higher scores for the English contrast than the Mandarin contrast.

FIGURE 1

The results (see Figure 1) showed that both L1-Mandarin groups discriminated the English /r/-/l/ better than L1-Taiwanese (Man-Tai mean 81.3%, SD 14%; Man-[tai] mean 81.3%, SD 15.5%; Tai-Man mean 47.4 %, SD 15.8%), suggesting that it is easier for pupils with Mandarin as dominant language to discern the English /r/-/l/ contrast than for pupils with Taiwanese as dominant language. More precisely, pupils with greater portion of Mandarin dominance tended to discern the English /r/-/l/ contrast more accurately. This result may be explained as a possible indication that successful learning of the Mandarin /ʐ/-/l/ contrast may strengthen learners' sensitivity to discern the English /r/-/l/ contrast, as L1-Mandarin children with more Mandarin dominance generally gained better discrimination scores for the English /r/-/l/ contrast than L1-Taiwanese children who use Mandarin less. The L1-Mandarin children exhibited fewer correct responses than Mandarin adults whose rates can exceed 85% (Brown, 2000).

FIGURE 2

English /r/-/l/ contrast

A mixed repeated measures ANOVA with English vowel context (see Figure 2) as within-subjects factor (six levels) and participant group as between-subjects factor (three levels) was conducted. The main effect of group was significant ($F(2, 45) = 25.16$, $p < .001$). The discrimination scores showed no significant difference between Man-Tai and Man-[Tai] groups ($p > .05$) but revealed a significant difference between Tai-Man and the two L1-Mandarin groups ($p < .001$). The main effect of English vowel was also significant ($F(5, 225) = 10.89$, $p < .001$). /ɛ/ was significantly different from /u/ for all groups (Man-Tai $p < .001$, Man-[tai] $< .002$, Tai-Man $< .002$), from /æ/, /i/, and /ɔ/ for Man-Tai ($p < .02$, $< .001$, $< .04$) and Tai-Man ($p < .001$, $< .001$, $< .04$). /ɔ/ was significantly different from /æ/ for Man-Tai and Tai-Man ($p < .04$, $< .001$), from /u/ for Man-[tai] ($p < .02$), and from /i/ and /ɛ/ for Tai-Man ($p < .02$, $< .04$). /æ/ was significantly different from /i/ for Man-Tai ($p < .03$), from /u/ for Man-[tai] ($p < .03$), and from /ɔ/ and /ɑ/ for Tai-Man ($p < .001$, $< .002$). /ɑ/ was significantly different from /i/ for Man-Tai and Tai-Man ($p < .007$, $< .05$), from /u/ for Man-Tai ($p < .005$), and from /æ/ for Tai-Man ($p < .002$). /i/ was significantly different from /ɑ/ for Man-Tai and Tai-Man ($p < .007$, $< .05$), and from /ɔ/ for Tai-Man ($p < .03$).

A significant interaction between the English vowel context and group was observed ($F(10, 225) = 1.92$, $p < .05$). Tests for simple effects were employed. For English vowel context, only /u/ showed insignificant difference among participants' discrimination scores ($F(2, 45) = 1.45$, $p > .05$). The other vowels revealed significant differences: /æ/ $F(2, 45) = 28.72$, $p < .001$; /i/ $F(2, 45) = 7.05$, $p < .003$; /ɔ/ $F(2, 45) = 5.71$, $p < .01$; /ɛ/ $F(2, 45) = 6.29$, $p < .005$; /ɑ/ $F(2, 45) = 7.36$, $p < .003$. Pairwise comparisons showed that the difference among all participant groups' scores in the /u/ context were all insignificant ($p > .05$). Other cases with insignificant differences all involved Tai-Man ($p > .05$).

A mixed repeated measures ANOVA with English vowel position (front and back) and vowel height (high, mid, and low) as within-group factors and group (three levels) as between-groups factor was also employed. For the vowel context, the main effect of group was significant ($F(2, 45) = 25.16$, $p < .001$), as was the main effect of vowel height ($F(2, 45) = 23.4$, $p < .001$). The difference between the discrimination scores of the Man-Tai and Man-[Tai] participants was insignificant ($p > .05$). Contrastively, the difference between Tai-Man and Man-Tai and that between Tai-Man and Man-[Tai] were both significant ($p < .001$). A post-hoc test showed that the high vowel context yielded lower scores compared to the mid and low vowel contexts ($p < .001$). The mid vowel context demonstrated the highest discrimination rate for all groups. For the low vowel context, Man-Tai and Man-[Tai] scored significantly higher than Tai-Man ($p < .001$). The main effect of position (front/back) was not significant ($F(1, 45) = 0.08$, $p > .05$).

Only one significant interaction was detected, viz., between height and position ($F(2, 90) = 5.11$, $p < .01$). For the simple main effect of vowel height, the discrimination scores showed no significant difference for high vowels in the front position or back position ($F(1, 45) = 0.07$, $p = .789$). However, significant differences were observed for the mid vowels ($F(1, 45) = 7.75$, $p < .01$) and low vowels ($F(1, 45) = 6.59$, $p < .02$) in front vs. back position. For the simple main effect of position, the discrimination rate for the front and back vowels at different heights was significantly different ($F(2, 44) = 29.92$, $p < .001$; $F(2, 44) = 7.25$, $p < .005$). However, post-hoc tests showed that the high vs. low vowel difference within the front position and the mid vs. low vowel difference within the back position were both non-significant ($p > .05$).

FIGURE 3

Mandarin /ʐ-/l/ contrast

A mixed repeated measures ANOVA with Mandarin vowel as within-group factor (six levels) and group as between-group factor (three levels) was employed. Figure 3 shows that the perception scores of the Mandarin /ʐ-/l/ contrast in the six vowels were significantly different ($F(5, 225) = 17.80$, $p < .001$). The group main effect was also significant ($F(2, 45) = 15.15$, $p < .001$). There was no interaction effects ($F(10, 225) = 0.99$, $p =$ ns). Tukey HSD tests revealed significant differences between Man-Tai and Man-[Tai] scores ($p < .05$), between Tai-Man and Man-Tai ($p < .001$), and between Tai-Man and Man-[Tai] ($p < .02$).

Among the Man-Tai, /ɤ/ and /aŋ/ were the most successfully recognized vowel context (93.7%), followed by /uo/ (84.4%), /ao/ (75.0%), /ou/ (71.9%), and /u/ (46.9%). Post-hoc tests revealed that /u/ was significantly different from /ɤ/ ($p < .001$), /ou/ ($p < .02$), /aŋ/ ($p < .001$), /uo/ ($p < .001$), and /ao/ ($p < .005$). /ɤ/ was also significantly different from /ou/ ($p < .03$).

The Man-[Tai] had a lower recognition rate where the most recognized vowel was /aŋ/ (78.1%), followed by /ɤ/, /ou/ (62.5%), /uo/ (58.3%), /ao/ (53.1%), and /u/ (28.1%). Post hoc tests revealed that /u/ was significantly different from /ɤ/ ($p < .003$), /ou/ ($p < .002$), /aŋ/ ($p < .001$), /uo/ ($p < .02$), and /ao/ ($p < .01$). Moreover, /aŋ/ and /ao/ were significantly different ($p < .03$).

Tai-Man exhibited the lowest recognition rate where the most recognized minimal pair was /ʐaŋ/-/laŋ/ (62.5%), followed by /ʈʂɤ/-/lɤ/ (43.8%), /ʐuo/-/luo/ (40.6%), /lou/-/ʐou/ (18.8%), /ʐuo/-/luo/ (15.6%), and /ʐu/-/lu/ (6.3%). Post hoc tests revealed that /ɤ/ was significantly different from /u/ ($p < .001$), /ou/ ($p < .02$), and /ao/ ($p < .005$), so was /ou/ from /aŋ/ ($p < .001$) and /uo/ ($p < .04$), as well as /aŋ/ from /u/ ($p < .001$) and /ao/ ($p < .001$), and /uo/ from /u/ ($p < .002$) and /ao/ ($p < .02$).

Man-Tai and Man-[tai] were expected to more accurately discriminate the Mandarin /ʐ/-/l/ contrast compared to Tai-Man, since both had L1-Mandarin as well as higher dominance level. It is unclear why Man-[tai] did not score the highest, though the difference between Man-[tai] and Man-Tai is not significant. The participants generally obtained few correct responses with both the Mandarin words involving /u/ and the English /u/ context.

English vs. Mandarin contrast

Pearson correlations were used to examine the relation between the English /r/-/l/ and Mandarin /ʐ/-/l/ contrasts. The correlation coefficients were significant for all groups (Man-Tai $r(14) = .62$, $p < .01$; Man-[tai] $r(14) = .56$, $p < .05$; Tai-Man $r(14) = .71$, $p < .01$). The correlations showed that the participants' abilities to discriminate the Mandarin /ʐ-l/ contrast and the English /r-l/ contrast were strongly correlated. Tai-Man exhibited the strongest correlation, followed by Man-Tai, and finally Man-[tai].

Discussion

The results indicate that the L1-Mandarin participants tend to perceive the difference between the English /r/-/l/ contrast while the L1-Taiwanese does not. It is possible that Mandarin as L1 contributes to higher discrimination rates for the Man-Tai and Man-[tai] since they have a

similar retroflex L1-category /ʐ/ to L3-English /r/ than Taiwanese L1 without a retroflex category.

Further, the high recognition rates of Man-Tai and Man-[tai] who had different L2-Taiwanese proficiencies suggest that Taiwanese as L2 did not hinder perception of the L3-English contrast. Also, having two similar L1 categories (L1-Mandarin /ʐ/ and /l/) did appear to be better than having just one similar L1 category (Taiwanese /l/). Higher levels of Mandarin dominance appeared more beneficial in discriminating the English /r/-/l/ contrast, whereas high Taiwanese dominance seemed less so.

The ANOVA analysis confirmed that vowel height had an effect on the English /r/-/l/ contrast. The high vowels /i/ and /u/ are both associated with low discrimination scores for all groups; however, the low vowel /æ/ is not the most successfully perceived by all groups, though it has relatively high correct response rates for Man-Tai (84.4%) and Man-[tai] (87.5%). For Tai-Man, a low vowel-height does not facilitate the English /r/-/l/ contrast since /æ/ exhibited the lowest recognition while /ɑ/ only obtained a moderate recognition (56.3%), compared to the L1-Mandarin groups. Note that /ɑ/, however, has the second highest perception rate for the low-Mandarin-dominant (Tai-Man) and the mid-Mandarin-dominant (Man-Tai) (96.9%). Contrastively, the mid-height /ɛ/ rendered the highest perception rate. In context of back roundedness, the mid-front /ɛ/ was more successfully recognized than the mid-back-round /ɔ/ and the high-back-round /u/, but the high-front /i/ is not necessarily perceived more easily than the back-round /u/. The groups differ in their recognition success: /u/ > /i/ for Tai-Man, /u/ < /i/ for Man-[tai], and /u/ = /i/ for Man-Tai.

One could suspect that Taiwanese as L1 may have a certain language bias or lack of such a bias for successfully perceiving the English /r/-/l/ contrast in the /æ/ environment. It may be challenging for Tai-Man at early stages of language learning to distinguish between the English /r/-/l/ contrast in the /æ/ context since it does not exist in Taiwanese or Mandarin. The low discrimination may be linked to the lips and mouth opening when uttering /æ/, unlike other vowels. However, as /æ/ does not exist in L1-Mandarin either, there is no obvious explanation as to why the Man-Tai and Man-[tai] achieved higher correct response than the Tai-Man. One possibility is that the Tai-Man had simply not retained the L3-English vowel as successfully as the two other groups.

The L1-Mandarin groups discriminate the Mandarin /ʐ/-/l/ contrast better than the Tai-Man. The highest correct response for all groups occurred with the low-vowel /a/ having /ŋ/ coda (Man-Tai 93.7%, Man-[tai] 78.1%, and Tai-Man 62.5%) and the lowest rates with the /u/ context (Man-Tai 46.9%, Man-[tai] 28.1%, and Tai-Man 6.3%). Syllables associated with the tense back vowels tend to be perceptually more challenging than the non-tense back vowels. Four of the six /ʐ/-/l/ minimal pairs have monophthongs or diphthongs with the tense back round vowels (/u/ and /o/), while /ʐaŋ/-/laŋ/ and /ʐɤ/-/lɤ/ do not. All groups exhibited lower correct response for the /ʐu-lu/, /ʐao-lao/, and /ʐou-lou/ contrasts than the other contrasts. Similar to the English /r/-/l/ contrast, the high /u/ context also yields a lower score for the Mandarin /ʐ/-/l/ contrast.

General discussion

L1 effects on English /r/-/l/ contrast

According to PAM, the high discrimination exhibited by the L1-Mandarin groups may be explained by the English /r/-/l/ contrast falling into the L1-Mandarin phonological space and therefore assimilated to the Mandarin /ʐ/-/l/ contrast. This is thus a two-category-assimilation. Most Man-Tai and Man-[tai] participants (10 out of 16 in each group) achieved high (> 83%) correct response as predicted by PAM. A binomial test revealed that this score was significantly above chance level ($p < .01$). The other participants all achieved medium high (> 61.1%) correct responses, also was significantly above chance level ($p < .01$). The only exception was one Man-Tai participant who scored 38.9%.

One may ponder whether English language experience affects perception performance in these pupils. It is possible that although they all had formally received the same amount of English instruction, the Man-Tai and Man-[tai] had privately received additional English training and were hence better prepared for the discrimination task. Extracurricular English training could be related to socio-economical factors, such as L1-Taiwanese pupils from rural areas where parents tend not to send their children to cram schools versus L1-Mandarin children in the cities where resourced families often escort their children to cram schools for fear of future disadvantages[1]. Nevertheless, it is unwise to generalize because of individual differences.

PAM predicted the Tai-Man recognition pattern reasonably well, namely that the English word-initial /r/ is assimilated into the most similar sound, the Taiwanese /l/, since there is no corresponding sound in Taiwanese. The English /r/-/l/ discrimination can therefore be classified as single-category-assimilation and listeners are predicted to exhibit low discrimination accuracy. The correct response of the English /r/-/l/ contrast by the Tai-Man

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[1] Cram schools exist alongside the official education system to strengthen key subjects. Their existence can be explained by parents' fear of children's not succeeding in the official system.

pupils is much lower than that of the Man-Tai and Man-[tai] groups, as PAM predicted. Some Tai-Man pupils may have obtained good L2-Mandarin /ʐ/ ability, although not yet fully acquired. However, it was not possible to assess if any of them had formed a stable Mandarin /ʐ/ category. If so, the perceptual assimilation of the English /r/-/l/ contrast may become a two-categories-assimilation pattern. PAM has traditionally been used to explain phonological acquisition of foreign languages. The bidirectional influences between L1 and L2, inclusive of the dominance level of Mandarin versus Taiwanese, as well as multi-directional influences between L1, L2, and L3 may play a role in learners' L3-English /r/-/l/ contrast, which is beyond the scope of the present study.

The answer to the first research question is that the L1-Mandarin pupils with low L2-Taiwanese tend to discriminate the L3-English /r/-/l/ contrast better than the L1-Mandarin pupils with high L2-Taiwanese. Man-Tai has a lower Mandarin dominance than Man-[tai], having also more use of L2-Taiwanese, and hence more L1-Mandarin dominance may help discriminate the English /r/-/l/ contrast because of similar L1-Mandarin sounds. Knowledge of an L2 (or bilingualism) may potentially hinder perceptual sensitivity in an L3. The perception results thus point to an unfavourable L2 influence which is in agreement with Wrembel (2010) who found that L2 speech sounds may impact speakers' L3 production during early L3 phonological acquisition. Both L1-Mandarin groups achieved higher perception rates than the L1-Taiwanese pupils with L2-Mandarin and low Mandarin dominance. The L1-Mandarin groups' perception patterns can, according to PAM, be interpreted as a two-category-assimilation and the L1-Taiwanese group's perception as a single-category-assimilation.

Vowel context effects

This study shows that the participant group had a significant main effect on English /r/-/l/ contrast discrimination, with discrimination in various vowels having generally two patterns based on the levels of L1 dominance. The mid and high L1-Mandarin dominance scored higher than the low L2-Mandarin dominance that had high L1-Taiwanese dominance. In half of all vowel contexts, the mid L1-Mandarin dominance discriminated better than the high L1-Mandarin dominance. The high /i, u/ received lower scores than that of the mid-front /ɛ/, and that of the mid-back /ɔ/ achieved a score in between. The low-back /ɑ/, however, exhibited a high score for all participants. Although vowel height has a significant main effect on participants' performance, only the difference between the high vowels and the mid vowels was statistically significant. The front/back position had no significant effect. The mid-back -round /ɔ/ generally obtained higher scores than the high-back-round /u/ for all groups and the /u/ exhibited the lowest scores; hence, the roundedness feature alone cannot seem to explain the discrimination difference between /ɔ/ and /u/. Contrastively, Shimizu and Dantsuji (1983) found that the non-low front /i/ and /ɛ/ yielded more correct responses (94.8%) than the back-round /u, ɔ/ (87%), thus the back-rounding feature was thought to affect listeners' discrimination. One explanation is that their participants were university students with extensive English training whereas the participants herein only had one year of English training. Further, their tasks were possibly easier since they employed identification tests with English minimal pairs while this study employed the same-different tests comprising randomized stimuli with distracters.

There may be a phonetic basis for the observations. With two formant patterns (the first and second formant), when the second formant transition moves from the /r/-/l/ region to the frequency level of the following front vowels, it is heard as /r/ but when the transition falls to the frequency level of the back vowels, it is heard as /l/. Further, as the succeeding front to

back vowels, the third formant transition needed to distinguish /r/ from /l/ also changes (O'Connor et al., 1957).

As mentioned, the third formant onset for /l/ should be nearly as high as its preceding vowel's third formant onset, while for /r/ the third formant onset should be lower than that for /l/ but slightly above that of /r/'s following vowel. Even so, according to O'Connor et al. (1957), the change from /l/ to /r/ may be possible simply by gradually lowering the third formant onset. Consequently, the discrimination of /l-r/ could be possible based on the third formant onset.

Therefore, if the onset frequency of the third formant of /l/ is gradually lowered, one may hear the sound pass from /l/ to /r/. Hence, vowels having a lower onset third formant frequency would more closely match the phonetic characteristics of /r/. Thus, the possibility of hearing the consonant as /r/ simply based on a low third formant onset frequency would be $- u > ɔ = ɑ > æ = ɛ > i$, where ambiguity occurs due to the same low onset frequency of the third formant, it would be necessary to make use of the first and second formants. The second formant transition raising from the /r/-/l/ region to the following front vowels would be heard as /r/, thus it is more likely that a higher second formant transition for /ɛ/ should be more easily perceived as /r/ than for /æ/, hence it is more likely that /ɛ/ > /æ/. As the second formant of /ɑ/ has a higher frequency than that of /ɔ/, it is likely that /ɑ/ would be perceived as /r/ rather than /ɔ/, thus /ɑ/ > /ɔ/. The overall possible order would thus be $u > ɑ > ɔ > ɛ > æ > i$.

If /l/ is perceived based on a low onset third formant frequency, the likely order would be reversed, hence $- u < ɔ = ɑ < æ = ɛ < i$. The first and second formant could help resolve clarity if uncertainty happens because of the same low onset frequency of the third formant. Hence, a fall in the second formant from the /r/-/l/ region to the following back vowels would

be heard as /l/, therefore lower second formant transition for /ɔ/ may be more likely perceived as /l/ than /ɑ/, hence /ɔ/ > /ɑ/. As the second formant of /æ/ is lower in frequency than that of /ɛ/, it is more likely that /l/ is perceived in /æ/ context than in /ɛ/ context, hence /æ/ > /ɛ/. The likely perception order would then be u < ɑ < ɔ < ɛ < æ < i.

As seen, /r/ would be easier to perceive with its succeeding front vowels and /l/ with its succeeding back vowels. Thus, given both discrimination tasks, it may be challenging for listeners to discern between /r/ and /l/ when followed by front /i/ and back /u/, since these two vowels are the most fitting for perceiving /r/ or /l/ (e.g., [rid] vs. [lid] or [rud] vs. [lud]). The results reported herein reflect this trend. The high-front and high-back /i, u/ are most challenging. The vowels further away from the /i/ and /u/ space would be easier to discern /r/ from /l/. This may explain why /ɛ, ɑ, ɔ/ are among the contexts with the highest scores for all groups. The three vowel contexts that received the highest percentage of correct response are ɛ > ɑ > æ (Man-Tai), ɛ > ɔ > æ (Man-[tai]), and ɛ > ɑ > ɔ (Tai-Man).

The answer to the second research question is that children's discrimination of the English /r/-/l/ contrast tends to be conditioned by the succeeding vowel. The high-front /i/ and high-back-round /u/ were among the contexts that young listeners found hard to discriminate, while the mid-front /ɛ/ provided the most auditory-phonetic clear environment for perceiving the English /r/-/l/ contrast. The low-front /æ/ context did not facilitate the English /r/-/l/ contrast for the L1-Taiwanese children. This tendency was not found in the L1-Mandarin children. Vowel height and participant group had significant effects. The effect of the front/back feature was insignificant. The acoustic characteristics of the formant transitions from /r/ to /l/ help explain the observations.

L1-L2 effects on Mandarin /ʐ/-/l/ contrast

A strong ability in a related L2 (Taiwanese) seems to have little impact on the L1 consonant contrast, as the Man-Tai discriminated more accurately than the Man-[tai] who have the highest level of Mandarin dominance. Thus, more exposure to more than one language at a young age could potentially benefit language acquisition. On the other hand, one could also argue that it may be because the L1-Mandarin children did not need to access their L2 to accurately complete the task. Still, this explanation does not answer why the high-Mandarin dominant (Man-[tai]) did not discriminate better than the mid-Mandarin dominant (Man-Tai). The Tai-Man's low correct response rate could partially reflect their challenge of learning Mandarin /ʐ/. The observation suggests that the influence of L1-Taiwanese on L2-Mandarin acquisition may be present. This is also in agreement with the prediction of the L2LP model (Escudero, 2005) where learners' L2 initial state tends to display individual variations in their target L2 perception. The overall phonological system (including L1, L2, and L3) of the Tai-Man group probably has not yet included the Mandarin /ʐ/, despite that these pupils are extensively exposed to Mandarin in school. It is likely that their Mandarin /ʐ/ will be successfully acquired over time, although individual learner differences are also probable.

Pearson correlations show that the relation between children's discrimination of the Mandarin /ʐ/-/l/ contrast and the English /r/-/l/ contrast is significant for all groups. The Tai-Man achieved a higher mean score for the English /r/-/l/ contrast than the Mandarin /ʐ/-/l/ contrast, suggesting that the English /r/ is perceptually more distinct to the Taiwanese /l/ than the Mandarin /ʐ/. As non-Taiwanese phonemes, both /r/ and /ʐ/ may be assimilated to the closest L1-Taiwanese phoneme /l/. Although both contrasts yield low scores, the Speech Learning Model (Flege, 1995) predicts that the English /r/ may be more efficiently developed into a new phonetic category in the learners' phonological system if given proper guidance. The

Tai-Man pupils received formal training in the Mandarin and English phonemes at different time spans. L3-English learning is introduced later with a less intensive regime compared to L2-Mandarin learning.

PAM also predicts the Tai-Man's English /r/-/l/ and the Mandarin /ʐ/-/l/ contrasts as single-category-assimilation with low discrimination, which was confirmed by the low recognition rates compared to the L1-Mandarin participants. The L1-Mandarin children succeeded in discriminating the English /r/-/l/ contrast, which is as predicted by PAM's two-category-assimilation to the Mandarin /ʐ/-/l/ contrast. However, the lower discrimination of the Mandarin /ʐ/-/l/ contrast compared to that of the English /r/-/l/ contrast, even among the L1-Mandarin groups, remains unexplained.

Furthermore, sound merging may have occurred in the social environment. A fully retroflex Mandarin /ʐ/ is said to be merging into /l/ in contemporary Taiwan, especially in informal occasions (K. S. Chung, 2006). However, all L1-Mandarin informants produced retroflexed sounds successfully. Although teachers may administer pronunciation drills for the Mandarin /ʐ/ and other retroflex sounds in class, pupils' articulations could still vary in different socio-linguistic situations and with different interlocutors. The pupils may be exposed to speakers with varying Mandarin /ʐ/ pronunciation accuracy, where /l/ is increasingly replacing /ʐ/ (R. F. Chung, 2006). This may explain why even higher Mandarin dominant pupils obtained lower discrimination scores for the Mandarin /ʐ/-/l/ contrast than for the English /r/-/l/ contrast. It appears as if the /ʐ/ and /l/ consonants have become allophones among young learners, but production data is needed to verify this.

The answer to the third research question is that the L1-Mandarin pupils with high L2-Taiwanese discriminate the Mandarin /ʐ/-/l/ contrast better than the L1-Mandarin pupils with low L2-Taiwanese. Thus, L2-Taiwanese influence on the Mandarin /ʐ/-/l/ contrast is not obvious. In terms of dominance level, the comparatively high-Mandarin dominant does not discriminate the Mandarin contrast as well as the mid-Mandarin dominant that happens to have higher level of L2-Taiwanese dominance. However, both groups achieve higher discrimination than the Tai-Man. It would then appear that near-balanced levels of L1 and L2 dominance (or most balanced bilinguals) would overall benefit the most in discriminating the Mandarin /ʐ/-/l/ contrast. The L1-Taiwanese perception patterns correspond to PAM single-category-assimilation.

Conclusion

This study examined the English /l/-/r/ contrast by pupils using both Mandarin and Taiwanese, where one is L1 or L2 and with different levels of dominance, compared with the close Mandarin /ʐ/-/l/ contrast. All of these were observed within a set of succeeding vowels to verify their effect on discrimination. Discrimination patterns were described primarily using the PAM framework. The results show that discrimination accuracy tends to be related to whether two members of a contrast are perceived as exemplars of a single L1 category. Implications for teaching may include designing teaching materials that more strongly emphasise these critical contrasts. Pupils should be exposed to these contrasts systematically over time and their perception and production developed and trained for both L2 and L3, concurrently with their L1.

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Figure captions

FIGURE 1 Perception of English /r/-/l/ vs. Mandarin /ʐ/-/l/ contrast

FIGURE 2 Correct response percentage for English /r/-/l/ at specific vowel contexts

FIGURE 3 Correct response percentage for Mandarin /ʐ/-/l/ at specific vowel contexts