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TEACHING DARK /l/ WITH ULTRASOUND TECHNOLOGY

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This study examined the efficacy of ultrasound technology for teaching L2 English "dark /l/", [ɫ], to L1 Cantonese students. In a pre-test reading, eight Hong Kong students, aged 15-16 (mean age: 15 years, 9 months), were scanned with ultrasound while reading short token sentences containing word-final [ɫ] tokens in three vowel contexts: /iː/, /ɔ/, and /uː/. Students were then divided into two groups of four, and given a short lesson on the articulation of [ɫ]. The two lessons were identical in every respect except for one: Group 1 received visual feedback from the ultrasound scanner, but Group 2 did not. Finally, in a post-test immediately after the lesson, the students were scanned reading the token sentences a second time. Results from the pre-test indicated that all students except for one in group 2 articulated [ɫ] with a back tongue gesture, but no subsequent front gesture. The resulting sound was vocalized, and more akin to a back vowel than [ɫ]. In the post-test, 3 out of 4 students from Group 1 added a front tongue gesture to [ɫ]; however, in Group 2 there were no major differences between the pre-test and post-test results. The changes in Group 1 occurred across vowel contexts, with somewhat different effects from vowel to vowel.

INTRODUCTION

This study is a preliminary investigation into the efficacy of ultrasound technology in second language (L2) speech instruction. Eight native (L1) Cantonese speakers participated in a pre-test/post-test experiment that was carried out in a Hong Kong secondary school. The target English sound was syllable-final English dark /l/ (henceforth [ɫ]), as in the word "hall". The difficulty of [ɫ] for Cantonese L1 speakers derives from its complex articulation, which involves a back tongue gesture followed rapidly by a front tongue gesture. Additionally, [ɫ] is not a part of the Cantonese phonological inventory (Chan & Li, 2000). For these reasons, Cantonese L1 speakers tend to vocalize [ɫ], and articulate it as a back vowel such as /uː/. In order to test the effectiveness of ultrasound as a method for teaching pronunciation, the eight participants took part in a three-step process: first, they were scanned reading [ɫ] tokens in carrier sentences; then they were given a lesson on the proper articulation of [ɫ]; and, finally, they were scanned reading the carrier sentences a second time.

Previous L2 Instruction using Ultrasound

The use of ultrasound for pronunciation instruction is a relatively new form of articulatory feedback for learners of L2 speech. Technologies employed to provide articulatory feedback have included verbal instructions (Catford & Pisoni, 1970), mirrors (Firth, 1987), and more complex technologies. In the past, however, higher complexity of feedback has often led to intractable difficulties. For example, Truby's (1959) X-rays, which provide a stunningly clear view of the articulators in use, are inappropriate for L2 learning, as prolonged use would endanger the lives of the learners. Overcoming many of these problems, ultrasound scans have emerged as a speech-learning tool that is both technologically complex and feasible for practical use. This technology is harmless, relatively non-invasive, and while expensive, it is becoming much more affordable with the passage of time (Gick, Bernhardt, Bacsfalvi, & Wilson, 2008).

In their most common phonetic application, ultrasound scans provide a mid sagittal view of the tongue that excludes the root and tip. For this reason, some speech sounds are more conducive to successful ultrasound scans than others. In previous ultrasound studies of L2 speech instruction, therefore, the most common phones investigated have been liquids and glides, whose correct articulation corresponds to specific tongue contours in the blade and body of the tongue.

Several previous studies have used ultrasound to teach the articulation of [l] and [ɹ] to Japanese learners of English. First, Gick, Bernhardt, Bacsfalvi, & Wilson (2008) conducted a pilot experiment with three recently arrived Japanese immigrants to Canada. Ultrasound scans were performed on these participants while reading [l] and [ɹ] tokens in word-initial, word-medial, and word-final contexts. After these scans, the pronunciation difficulties of each participant were identified, and the ultrasound images and scanner were used in a variety of ways to demonstrate correct articulation. A post-lesson scan then showed that all three participants were able to produce [l] and [ɹ] more accurately in the three contexts

Using a similar design, Tsui (2012) found that six Japanese adults improved their pronunciation with the help of ultrasound scans. In this case, the lessons were more detailed, and there was up a two-week period between the pre-test and post-test. Tsui (2012) found that the improvement was generally more robust for articulation of [l] although there was improvement for [ɹ] as well.

In another study of 10 newly arrived Japanese immigrants to Canada, Tateishi (2013) had similar results to Tsui (2013): the production of [l] improved more than that of [ɹ] after a training session using ultrasound. However, this study also tested the ability of the subjects to distinguish [l] and [ɹ], and no significant improvement was evident in perception.

Although L2 liquids and glides have been investigated a number of times in ultrasound studies, very little work has examined the English syllable-final variant, [ɫ], which is the focus of the present study. One exception is King & Ferragne (2015), a work in progress that is using ultrasound to examine [ɫ] production among L1 French-English L2 learners. Thus far, ultrasound has been employed solely as a diagnostic tool to establish an articulatory difference between native English speakers and French L1-English L2 speakers in their pronunciation of [ɫ]. Currently, they are designing the next phase of their study, which will include ultrasound training sessions.

The present study adopts an approach similar to those above, but two elements distinguish it from previous work. First, no previous ultrasound speech training studies have focused exclusively on the acquisition of [ɫ] in Cantonese L1 subjects. Second, to the best of our knowledge, ultrasound training has never been used before as an instructional method in Hong Kong.

METHOD

Participants and Lesson

Among the eight participants in the current study, there were four males and four females. These subjects were recruited from the same Form 4 (10^{th} grade) class of a secondary school in Lam Tin, Kowloon. After Form 3, the students at this school are streamed according to their English ability into one of five Form 4 classes. All of the students in the present study were from the second-best class, meaning that their level of spoken English was roughly the same.

The eight students were then divided into two groups of four. This division was based on two criteria: equity of male to female ratios, and parity of English speaking ability. Each group, therefore, comprised two boys and two girls, and the average L2 speaking proficiency for each group was roughly the same. To determine these levels, the first term speaking examinations results of the participants were compared. The speaking exam is an eight-minute group discussion among four students, which is graded by a single examiner. There are four categories in the marking scheme for this exam: 1. Pronunciation and Delivery; 2. Communication Strategies; 3. Vocabulary and Language Patterns; and 4. Ideas and Organization. Each category is worth 25 percent of the total mark. Table 1 shows the results for each group member as well as the mean result and standard deviation for each group.

Table 1

Term 1 Speaking Exam Results of Participants (Total Marks: 28)

Group 1	**Group 2**
Boy 1 – 11	Boy 2 – 12
Boy 4 – 14	Boy 3 – 13
Girl 3 – 14	Girl 1 – 14
Girl 4 – 13	Girl 2 – 14
Mean (SD) – 13 (1.414)	Mean (SD) – 13.25 (0.957)

For the pre-test and post-test, students were scanned with ultrasound and recorded while reading sentences with embedded [ɫ] tokens in three vowel contexts: [iː], [ɔ], and [uː]. The three sentences were as follows:

1. The meal heater was broken.
2. The hall model was very nice.
3. The pool food cannot be eaten.

These semantically unusual sentences were composed by the authors according to a single criterion: minimal tongue movement in the vicinity of the [ɫ] token. In order to minimize tongue movement, the onset of each token's syllable could be either a labial or a pharyngeal. This restriction also applied to the onset of the syllable following the [ɫ] token. Additionally, the nucleus of the following syllable was the same as the nucleus preceding the [ɫ] token. All of these restrictions ensured that there would be minimal co-articulatory influence on the tongue shape of the relevant tokens. Each sentence was read a total of 10 times by each participant: five times in the pre-test and five in the post-test.

Between the two tests, each group received a 30-minute lesson on how to properly articulate [ɫ]. The lesson for each group was identical except for one key feature: Group 1 received visual feedback from the ultrasound scanner, but Group 2 received no such feedback. The time between the pre-test and the post-test was approximately 1.5 hours. (Please see the Power point slides from the lessons in Appendix 1, which represents the lesson for Group 1; Group 2’s lesson contained the same slides except for the two that refer to ultrasound.)

Ultrasound Scanning

During the pre-test and post-test, a stabilization helmet was employed to stabilize the heads of the participants.

Figure 1: Stabilization helmet (left) and ultrasound apparatus (right)

Helmet stabilization was not employed in the ultrasound lesson in order to facilitate scanning each student in a relatively short amount of time. Stabilization was not required for this part because the data collected during the lesson were not analyzed.

The pre-test and post-test ultrasound data were analyzed using the Articulate Assistant Advanced (AAA) software package (Articulate Instruments Ltd., 2012). The [ɫ] segments were annotated according to their acoustic boundaries, and a single ultrasound frame per token within this boundary was chosen as the representative ultrasound frame for that token. Ideally, articulatory criteria were used to select this representative frame, wherein the frame with the highest rightmost visible edge of the tongue was chosen. In most cases, this would mean the blade, and likely the tip as well, would be raised. In some cases, however, it was difficult to use these criteria to select the representative frame, because the position of the tongue did not change greatly throughout the acoustic boundary of the segment. In these cases, a frame close to the end of the segment was selected.

An SS-ANOVA (Gu, 2002) was conducted on the results to compare the tongue spline shapes of the data from the pre-test and post-test. Ideally, an SS-ANOVA would be conducted to compare the pre-test and post-test tongue splines directly;

however, as the pre/post-test data were taken from separate ultrasound recording sessions, a direct comparison is not permitted because of possible variation in the position and angle of the ultrasound probe. Rather than a direct comparison between the pre-test and post-test splines, therefore, two SS-ANOVA comparisons were conducted: one within the pre-test data, and one within the post-test data. In each data set, the highest point of the front-most, visible part of the tongue during the acoustic duration of the [ɫ] was compared with the lowest point during the first half of the [ɫ] or immediately prior to it. (The demarcations between nuclei and [ɫ] were determined from spectrograms of the data.) In this way, the difference between the highest point and the lowest point in the pre-test can be compared with the difference between the highest point and the lowest point in the post-test. If the highest and lowest points were overlapping or very similar, it would suggest that the [ɫ] is likely to be vocalized, and there would not likely be tongue-tip raising. If the highest and lowest points were separated from each other, it would suggest tongue-tip raising during the highest point, indicating a correct production of [ɫ]. In other words, a stronger distinction between the highest and lowest points in the post-test would indicate improvement in the articulation of [ɫ]. When produced correctly, [ɫ] generally starts off with a back tongue gesture and only near the end is there a tongue tip raising gesture. Cases in which the first half of the [ɫ] has a higher point than the second half did sometimes arise when the preceding vowel is an [iː], and seemed to be due to the influence of coarticulation from the vowel, which is followed by a lowering of the tongue tip for a vocalized coda [ɫ]. Because of this phenomenon, the "lowest point" could come from only the first half of the [ɫ] or before, and the highest point from some point following it anywhere in the [ɫ]. In this way, only if the [ɫ] is produced correctly will the SS-ANOVAs show a sharp difference between the highest point and lowest point, but if coarticulation from a high vowel causes the highest point to precede the lowest point within the duration of the [ɫ], these cases will not be considered to be exemplary productions. To complement these data, the two native English-speaking authors have also judged the acceptability of each of the tokens.

RESULTS

Figures 2-7 show the SS-ANOVAs comparing the pre-test and post-test tongue splines of each individual participant (labelled a-d: "a" include the pre- and post-test splines for participant 1, b for participant 2, and so on). The pre-test SS-ANOVAs are on the left and the post-test SS-ANOVAs are on the right. In the SS-ANOVAs, the pink splines represent the lowest point of the front-most visible part of the tongue during the first half of the acoustic duration of the [ɫ] or before (point A), and the cyan splines represent the highest point of the front-most visible part of the tongue during the acoustic duration of the [ɫ] (point B). Individual tracked ultrasound points are reported using dots. The line in the center of each shaded area represents the mean tongue position for the five tokens. The shaded area above and below these lines is the standard error for each mean. Where the pink and cyan bars overlap, there is no statistically significant difference between the pre-test and post-test tongue spline contour. Where the pink and cyan bars do not overlap, there is a statistically significant difference between the pre-test and post-test results.

The results for the [ɔ] vowel are the most clear. In all cases, the pre-test results (on the left) show either a completely overlapping point A & point B, or the difference between point A & point B is small. The post-test results (on the right) show a higher separation between point A & B. The results for the [iː] condition are also very clear.

In Figure 3 a-c, it is clear that the pre-test results (left) all have overlapping point A and point B SS-ANOVAs, but in the post-test results (right) they are no longer overlapping near the tip of the tongue. In the [uː] results, the differences between the pre- and post-test splines are not as great; however, in Figure 4c there is a clear improvement in the post-test. Perhaps because of [uː]'s similarity to the vocalized coda [ɫ], it was harder for the students to learn to raise the tongue in this condition. Another possibility is that because [uː] is a high vowel, even if the tongue tip was raised, point A may still be high due to coarticulation from the [uː]. It is not clear why this effect did not seem to happen for [iː], however.

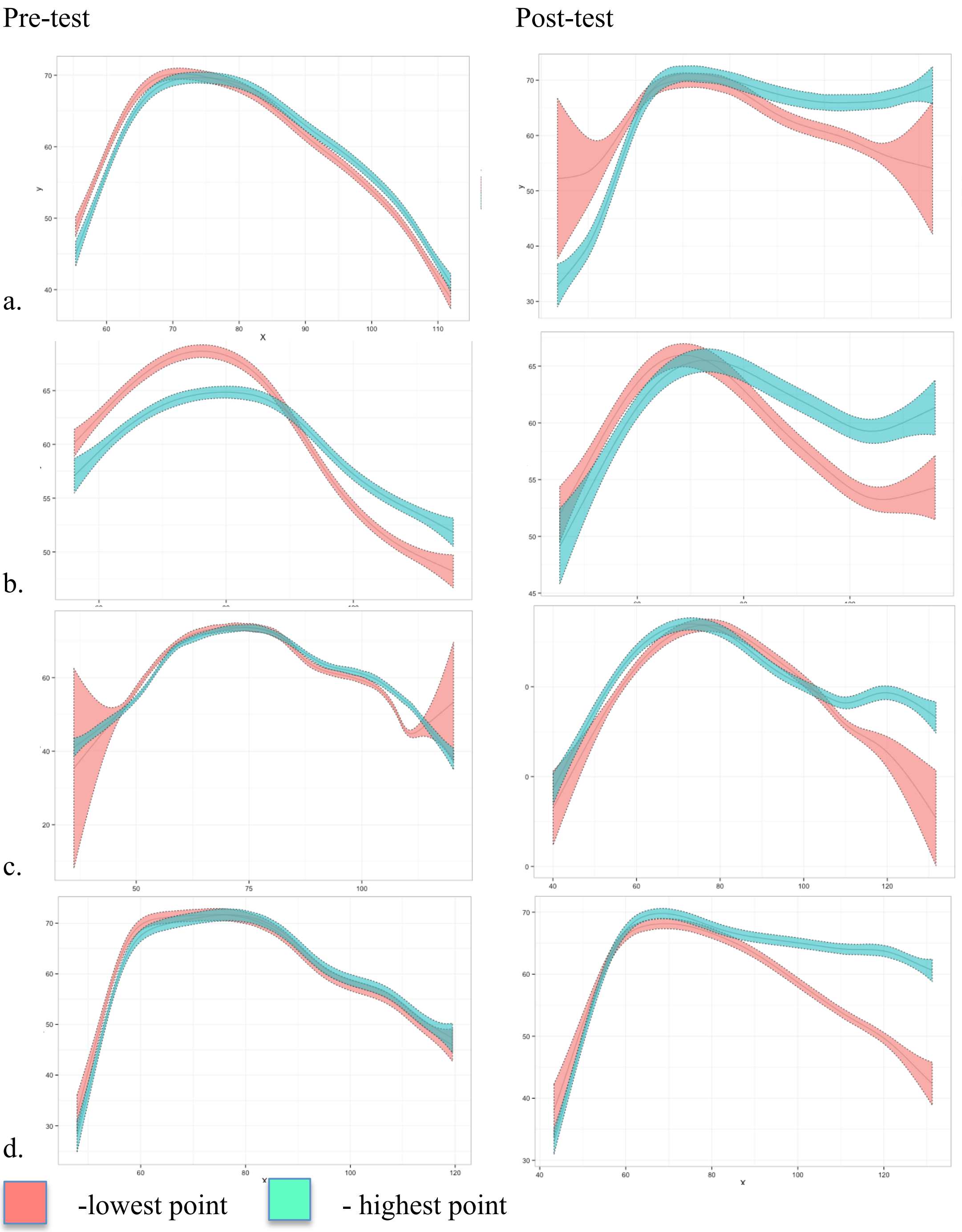

Figure 2. SS-ANOVAS for [ɔ] – ultrasound group

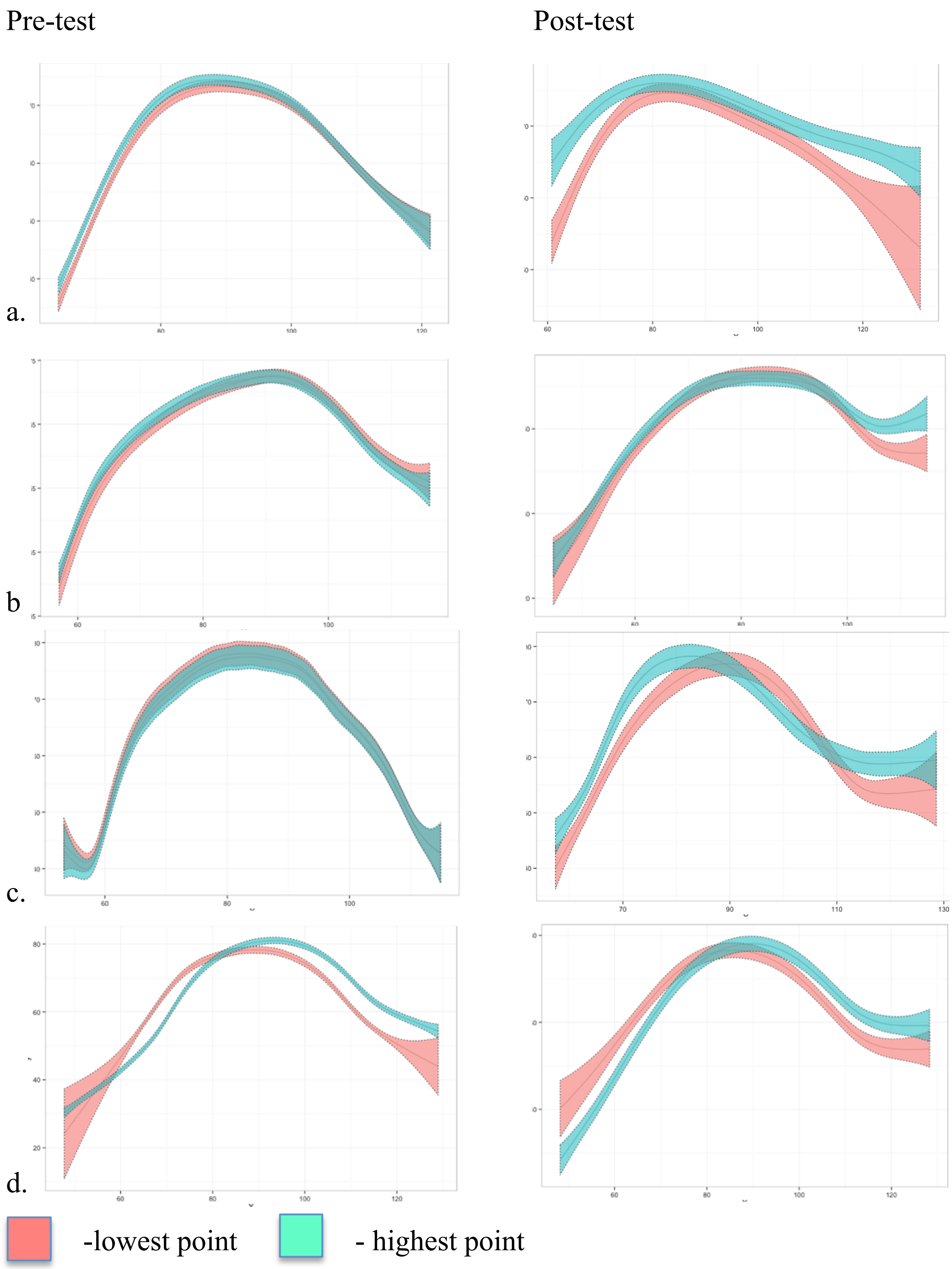

Figure 3. SS-ANOVAs for [iː] - ultrasound group

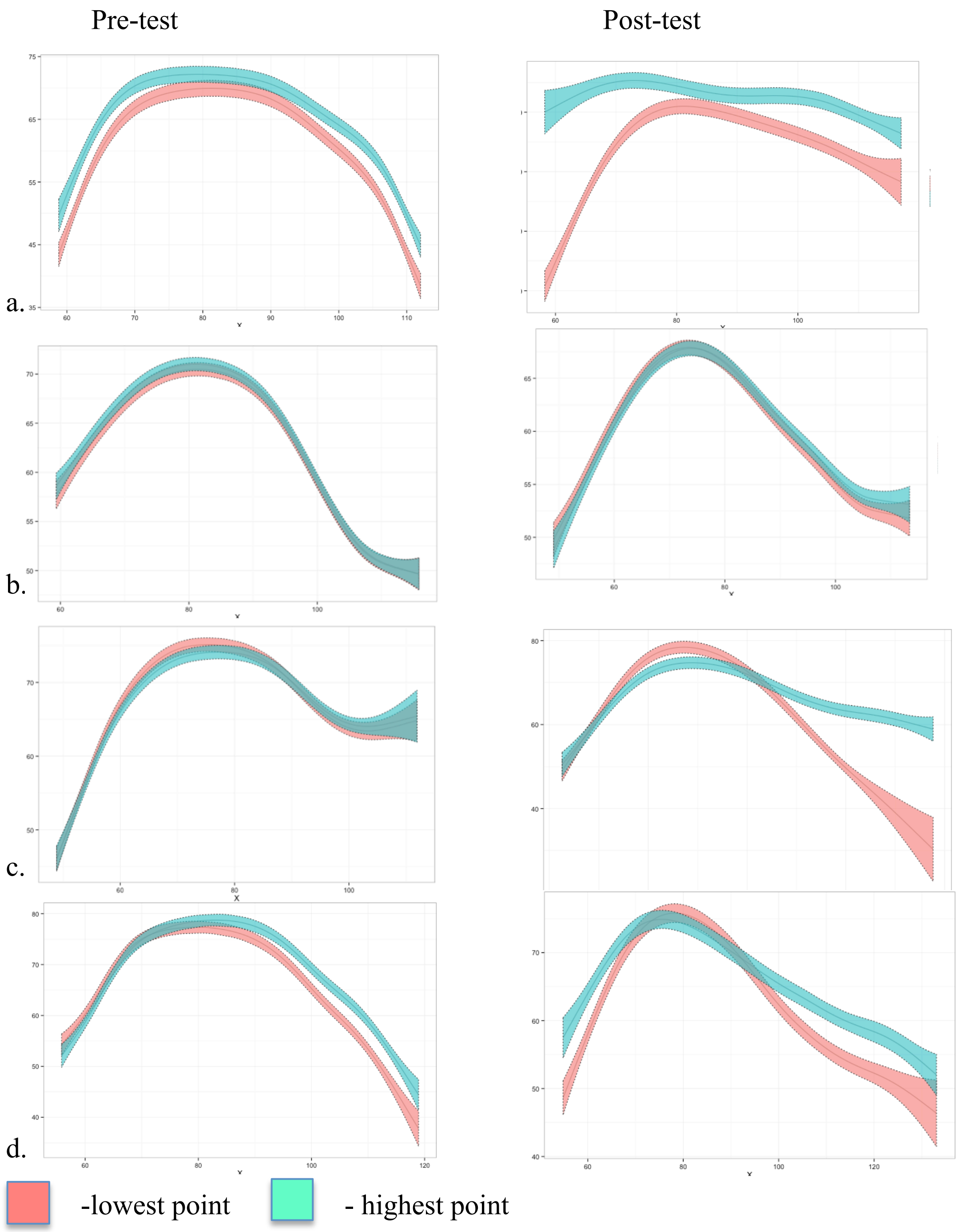

Figure 4. SS-ANOVAs for [uː] - ultrasound group

For the non-ultrasound group, the improvement does not appear to be as strong. Although in Figure 5b there is a large difference between point A and point B, the same difference is also present in the pre-test: the splines indicate that this speaker was already using tongue tip raising in the pre-test, which was corroborated in the judgments (see section 4.2). As for Figure 5a, although there is a difference between point A and point B in the post-test only, the shape of the splines is somewhat different from those in the ultrasound group. In fact, this speaker produced an [ɹ] (as per the judgments in section 4.2) in the post-test. It seems, therefore, that this speaker did raise the tongue tip after the training, but not in the correct configuration for a coda [ɫ].

The [iː] results in the non-ultrasound group strongly suggest lack of improvement after training. Three out of the 4 speakers had an overlapping point A and point B even in the post-test. The one speaker who had a separate point A and point B was b., the same speaker who was already raising the tongue tip for [ɫ] in the pre-test.

In the [uː] splines, two of the students have an overlapping point A and point B. As for the other two students, 7a was the student who produced an [ɹ] instead of an [ɫ], and 7b was the student who could do tongue tip raising in the pre-test. Her pre-tests SS-ANOVAs for [uː] do not seem to suggest tongue tip raising, but this could be due to either of the explanations from the above ultrasound section.

For most of the non-ultrasound group participants, there is no clear difference in tongue tip raising between the pre-test and post-test. Note, again, that subject b. was already able to produce [ɫ] before the training, and while she may have made some exaggerations in her pronunciation after the training, other evident differences may be due to the scanner's field of vision change between the pre-test and post-test.

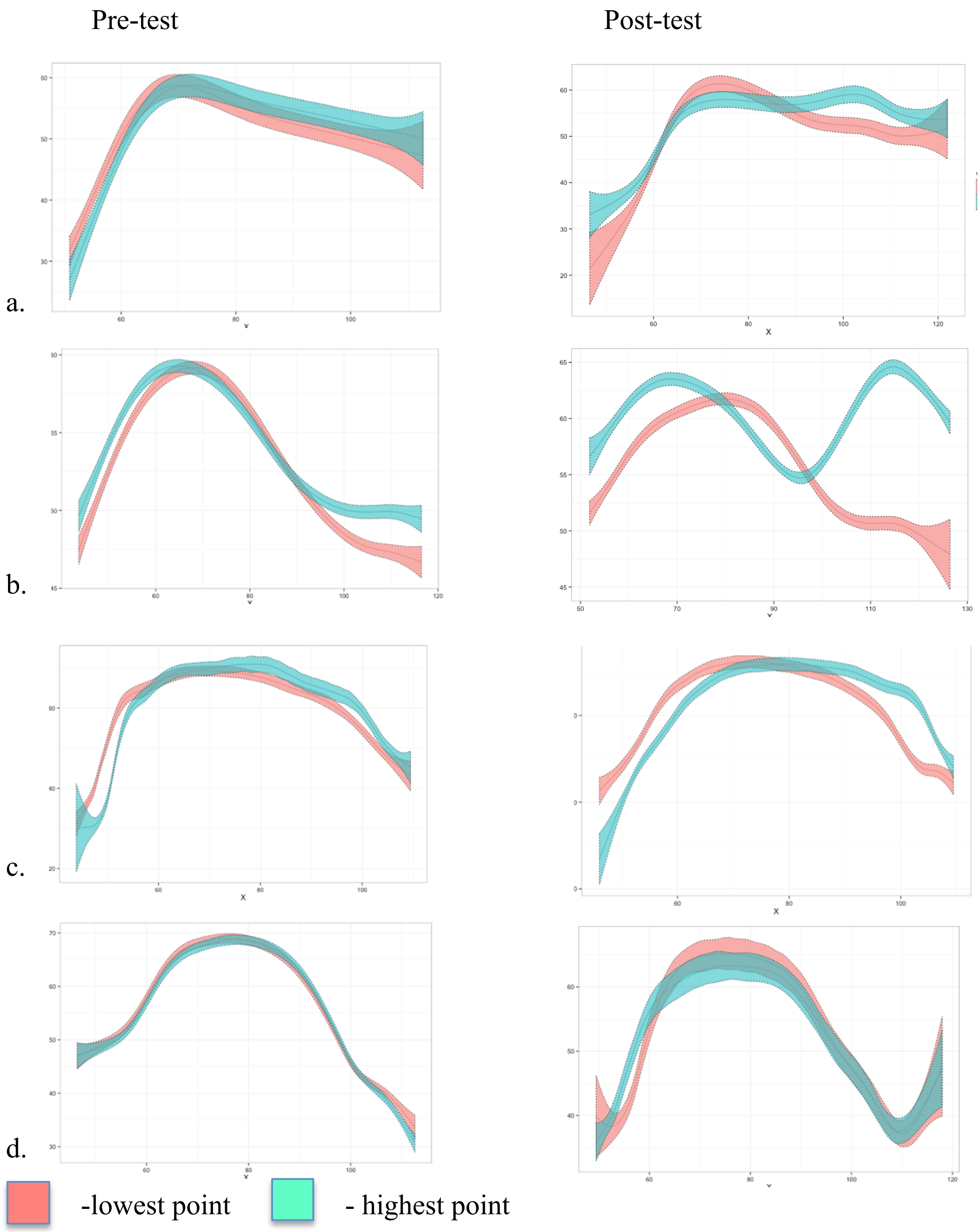

Figure 5. SS-ANOVAS for [ɔ] – non-ultrasound group

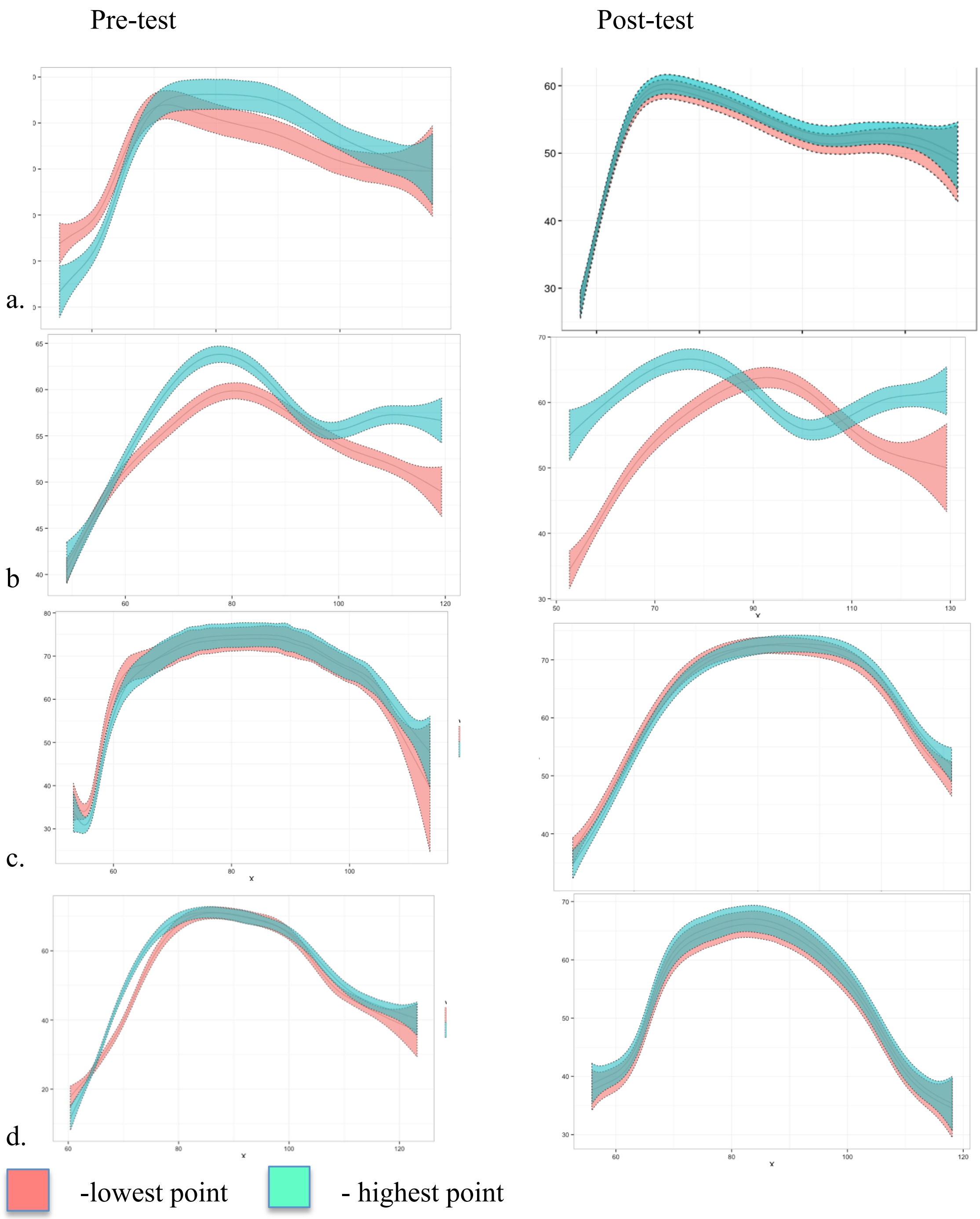

Figure 6. SS-ANOVAS for [i:] – non-ultrasound group

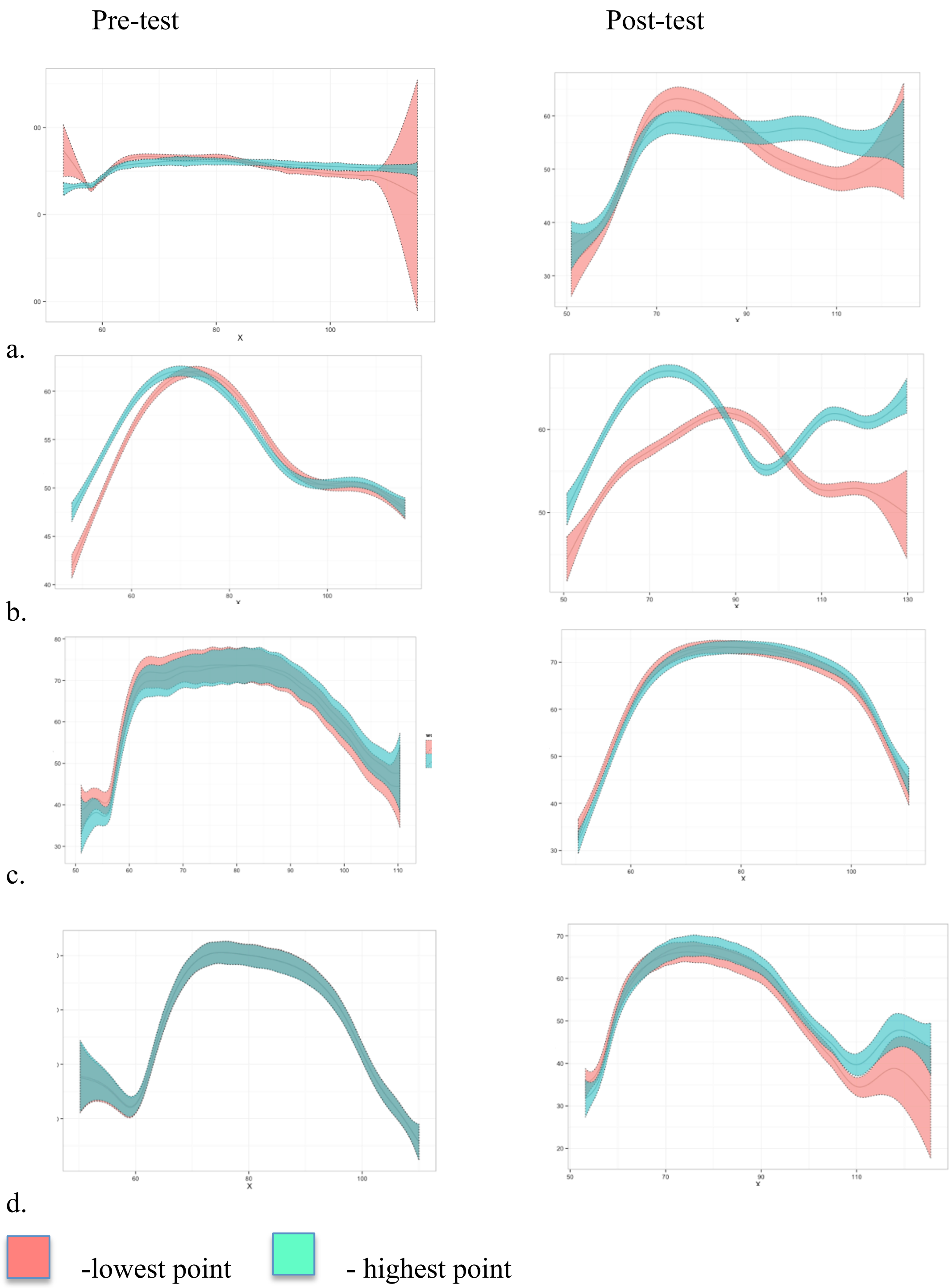

Figure 7. SS-ANOVAs for [uː] - non-ultrasound group

Judgments

To corroborate the ultrasound results, acceptability judgments were conducted by the first two authors, who gauged whether they perceived the productions to be an accurate English [ɫ]. (The judges were aware of the group identity for each of the speakers.) Each token was categorized as *[ɫ]*, *vocalized [ɫ]*, */r/*, or *not sure*. Out of 240 tokens, there were 32 disagreements between the judges (That is, one judge saying *[ɫ]* and the other saying *a vocalized [ɫ]*. There were no disagreements where one judge said *[ɫ]* and the other said */r/*.) For these 32 disagreements, a third native English-speaking judge was selected to re-judge the tokens, and her judgments were used for those tokens. For all other tokens, the judgments of the original two judges were used.

In order to conduct statistical analysis, the data were transformed into a binomial "acceptable"/"not acceptable" form, where *[ɫ]* is considered "acceptable" and *a vocalized [ɫ]*, or *an /r/* are considered "not acceptable". If one judge said *not sure*, this was ignored, and the judgment of the other judge alone was used. There were no cases where both judges said "not sure" for the same token. The data are presented below. Two one-tailed Fisher's tests (Fisher, 1954) that tested whether the improvements between the pre-test and post-test were significant were conducted separately for the ultrasound and non-ultrasound group, respectively. From the p-values, it is clear that the ultrasound group's improvement was significant, and the non-ultrasound group's improvement is not significant. These results support the ultrasound group's training being more successful than the non-ultrasound group's training.

Table 2

Results for ultrasound group's judgments

	Pre-test	Post-test
Acceptable ([ɫ])	1	49
Not Acceptable (V or r)	58	10
Total Tokens	59	59
p-value (Fisher's Test)	p< .0001 (significant)	

Table 3

Results for non-ultrasound group's judgments

	Pre-test	Post-test
Acceptable ([ɫ])	23	30
Not Acceptable (V or r)	36	29
Total Tokens	59	59
p-value (Fisher's Test)	p< .1333731 (not significant)	

DISCUSSION

Both the ultrasound spline SS-ANOVA results and the judgment results suggest that the training received by the ultrasound group may have been more effective than the training received by the non-ultrasound group. Although both groups seemed to show some improvement, the SS-ANOVAs for the ultrasound group show much clearer significant differences between the pre-test and post-test, while the non-ultrasound group's SS-ANOVA pre-test and post-test results for the most part are mostly not significantly different. The same can be said about the judgment results: the judgments of the ultrasound group indicated significant improvement, but the same judgment of the non-ultrasound group did not.

At the outset of this experiment, a high degree of [ɫ] vocalization was evident among the eight participants. This finding is noteworthy because these participants joined the study on a voluntary basis; there was no selection process that precluded students who did not vocalize [ɫ]. In other words, although this sample is extremely small, it does seem to suggest that [ɫ] vocalization is common in the L2 English of L1 Cantonese speakers. The results of the present study indicate that ultrasound may be an effective means of addressing this pronunciation difficulty.

Although the overall findings suggest improvement for the ultrasound group, there was a discrepancy between the SS-ANOVA results and the listener judgments. In the SS-ANOVA results, the improvement was most evident in the [ɔ] tokens, and, to a lesser extent, the [iː] and [uː] tokens. According to the judgments, however, the improvements were more general across the three vowel contexts. Perhaps this is because [iː] and [uː] vowels are high vowels that involve greater elevation of the tongue. Because the overall shape of the tongue is more raised, it more difficult to see raising of the tongue tip clearly on the ultrasound scans. This is partly because the ultrasound scanner cannot see the exact tip, and its position can only be extrapolated from the position of the blade. In other words, the differences in tongue shape would not be as extreme between [ɫ] and its vocalized version for [iː] and [uː]. If this is the case, then differences in these two vowel contexts may not be as evident in SS-ANOVA.

A second crucial aspect of vocalization that SS-ANOVA cannot capture is lip rounding. Regardless of tongue shape, [ɫ] will tend to sound more vocalized when the lips are rounded as in an English back vowel. This information was part of the verbal instructions to all of the students (see Appendix 1), and so neither group should have had an advantage in this regard. As for the data analysis, because the listener judgments focused on the total sound and not just the tongue shape, they were more likely to take the sound of lip rounding into account. This seems to strengthen the case for improvement of the ultrasound group across the three vowel contexts.

This investigation was a pilot study, so the amount of instruction was not ideal (approximately 30 minutes in total, but time spent with the actual ultrasound machine was even less). It seems, then, that even a small amount of ultrasound training may have affected the students' pronunciation, which bodes well for future work in this area. It must be acknowledged, however, that no subsequent tests were conducted to see whether this lesson had a lasting effect on the pronunciation of the students. The possible success of this method notwithstanding, it is unlikely that a short 30-minute lesson would have any kind of lasting effect. With this in mind, the authors are currently carrying out an expanded study that drastically increases the lessons and the amount of time that students use the ultrasound machine. A longer course of study, with multiple training sessions, would give students a better chance of retaining any articulatory adjustments they have made during the ultrasound training sessions. Additionally, the expanded study instructs students on several different segments, instead of focusing on [ɫ] solely.

By focusing on a more comprehensive range of L2 phones, this broader study will address a wider range of intelligibility issues in Hong Kong English. Foremost among these are three pairs of vowels that present difficulties to many Hong Kong students: [iː] – [ɪ]; [æ] –[ɛ]; and [uː] – [ʊ]. Many Hong Kong students find these pairs quite challenging to differentiate, which leads to decreased intelligibility. It is hoped that the use of ultrasound will allow students to better visualize distinct tongue positions for these vowels, and thereby improve their intelligibility in the process. The present, preliminary study suggests that ultrasound has the potential for success when used to address these kinds of problems.

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Appendix One – Lesson Powerpoint

Listening practice

Two gestures: first back, then forward

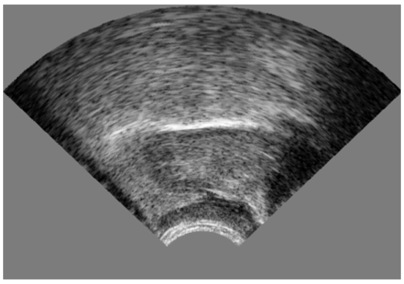
No lip rounding

Listen and watch carefully

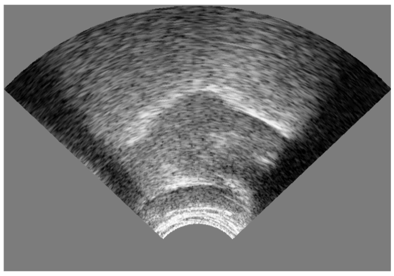
real	mall	rule
feel	fall	school
deal	hall	pool

Tongue shape differences at

Correct



Incorrect



Visualization

Let's look at our own tongue shapes on the ultrasound.

Practice - Pairs

i	a	u
feel – few	hall - how	cool - coo
meal – mew	ball - bow	tool - two
seal – 燒	mall – 貓	fool – 膚

Practice

A – How do you feel today?
B – I'm a real mess.

A – How do the students feel after the meal?
B – A few feel sick.

A – How many students are in the hall?
B – All in all there are two hundred.

More practice

A – Where did you fall down?
B – I fell down in the hall.

A – Is the weather cool today?
B – It's too cool to go in the pool.

A – What does it say in the school rule book?
B – It says you should not act like a fool.

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