THE ULTRASOUND STUDY OF /ɹ/ IN NON-NATIVE SPEAKERS

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ABSTRACT

The study examines articulatory properties of the English rhotic when produced by 5 speakers of English as a Second Language born and raised in Poland. Although Polish has a rhotic in its phonemic inventory, auditorily it is different enough for the speakers to try to approximate a non-native retroflex or bunched /ɹ/ when speaking English. The quantitative results from ultrasound imaging show an array of tongue shapes and positions when producing this foreign sound. The general tendency is to produce retroflex-like /ɹ/ regardless of sex, age, time of emigration or the type of formal instruction received in ESL classes.

Keywords: rhotic, ultrasound, non-native articulation

1. INTRODUCTION

The goal of this paper is to examine articulatory properties of /ɹ/ produced by non-native speakers of English. Modern equipment used in the phonetic field, particularly ultrasound, allows for a convenient collection of articulatory data from multiple speakers and describing the results quantitatively. The class of rhotics is very diverse cross-linguistically, which makes its segments interesting to contrast with each other. Specifically, English /ɹ/ and Polish /r/ produced by Polish speakers will be juxtaposed here.

The paper will first look at the relative position and shape for non-native /ɹ/ in respect to /d/ and /g/ (similar in both Polish and English). Then, with the description of English rhotics from Dellatre and Freeman [5], it will serve as a baseline for investigating a range of /ɹ/ articulations utilized by Polish immigrants speaking English. Finally, a contrast of /ɹ/ and /r/ will be shown for each speaker.

2. LITERATURE REVIEW

2.1. English /ɹ/ - auditory and articulatory properties

English rhotic approximant /ɹ/ is said to be produced two-ways: with the tongue bunched or retroflex, or positioned in any way in between the two canonical tongue shapes ([1], [5]). The bunched variant is characterized by drawing the tip of the tongue down and simultaneously pulling up and back of the tongue body. The canonical retroflex is produced by curling the tongue tip up and backwards, close to the alveolar ridge.

In the dialects of English where both productions are found, the two variants are either reported to be auditorily distinct (Scottish English in [8]) or indistinct (American English in [13]). Thus, the preferred dialect may or may not have an effect on ESL speaker's production of /ɹ/.

2.2. Polish /r/ - articulatory properties

An example of a rhotic distinct from the English one may be found in Polish. Polish /r/ is described as an alveolar trill (cf. [6] and [12]). Trills are generally produced by the tip of the tongue rapidly and repetitively hitting the ridge ([7]). The acoustics of a trill may be viewed on a spectrogram with separate vibrations representing each tongue strike ([6]). Since the articulatory, auditory as well as acoustic phonetics of Polish /r/ are very dissimilar to English /ɹ/, it constitutes and interesting case for investigation.

2.3. Applied use of ultrasound in linguistics

Beside the theoretical advantage of a detailed articulatory analysis of English /ɹ/ produced by non-native speakers, an articulatory image and description may be used in applied linguistics as well. Ultrasound has been used for aiding people with cochlear implant in training the adequate articulation of /ɹ/ ([2]). A similar method can be used for the ESL speakers on top of a general description found in accent textbooks (e.g., [11]).

3. METHODOLOGY

3.1. Participants

The total number of participants was 6; however, data from one speaker had to be excluded due to unclear ultrasound image. They were born and raised in Poland, with Polish as their first and only language. The age of emigration was between 13 to 23. Before this time, the participants received only some formal education in English as a Second Language. They started using English on everyday basis only after arriving in Canada.

Participants provided information about their age, age of emigration and familiarity/preference for either British or American accent.

3.2. Equipment

The experiment was conducted in a soundproof booth in the Phonetics Lab at the University of Toronto (www.linguistics.utoronto.ca/research/)
A PI 7.5 MHz SeeMore ultrasound probe by Interson was used to collect ultrasound data of mid-sagittal view of the tongue in mid-utterance. The system has a frame rate of 15 fps and the imaging depth was set to 10 cm during the recording process. The probe was connected to a laptop computer running version 1.3.02 SeeMore software. Visual recordings were done by capturing the image on the computer screen using version 3.5.99 Fraps free software set to a frame rate of 30 fps. Lastly, audio recordings were made with an AT831b lavalier microphone and a Sound Devices USBPre2 pre-amplifier using a sampling rate of 48 kHz. Audio was connected to the laptop computer.

3.3. Materials and procedure

The experiment focused on the production of a rhotic. Additionally, other consonants needed to be used as controls and distractors. Therefore, all the speakers produced the target ***r****ye* as well as controls ***d****ie* and ***g****uy* in order to compare /ɹ/ against the extreme but natural front (alveolar) and back (velar) positions of the tongue. Each word was produced within the carrier phrase '*I saw*___ '. Each item was repeated 10 times compiling a total of 30 tokens per speaker. Additionally, following the English part of the experiment, the speakers produced Polish words providing a minimal or near minimal pair for a respective English token. Analogous to the English part of the procedure, each Polish token was produced 10 times yielding additional 30 tokens.

Participants were shown a randomized list indicating the required tokens they were required to produce. They were comfortably seated against a wall to ensure maximum stabilization of the head. Preliminary analysis comparing stops in English and in Polish words showed that the obtained splines overlap almost completely, thus there was no accidental head movement.

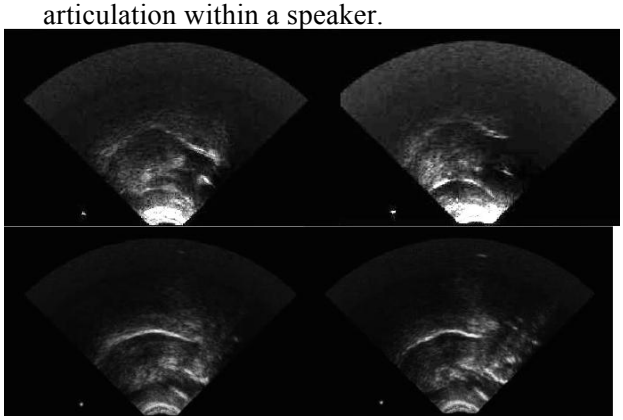
3.4. Data analysis

Obtained video-audio recordings were converted into the separate video and audio, .mp4 and .wav respectively. The files were appropriately annotated in ELAN ([3]). A single frame from each token word in mid-production of the segment was extracted, where the tongue was at the maximum constriction. The frames were exported to EdgeTrak [9], which allowed tracing of the tongue contour. Next, the statistical software R was used to statistically analyze quantitative data [10]. Smoothing Spline-ANOVA with the provided code produced graphs in which two tongue positions can be compared and evaluated within one speaker [4]. Each speaker was analysed for the tongue shapes pairs of /ɹ/ & /d/ and /ɹ/ & /g/. This allowed for establishing the relative position of the tongue in /ɹ/ compared to the most front consonantal articulation in /d/ and high and back for /g/. Finally, Polish part of the recordings was contrasted with English results i.e., /ɹ/ & /r/.

4. RESULTS

This section presents the articulatory results from individual speakers. The tongue shapes vary between speakers and even within a speaker. For example, Figure 1 presents frames from maximal constriction in two separate repetitions of /ɹ/ by Speaker 3 (top) and Speaker 4 (bottom). The ones of the left show the tip of the tongue slightly lower than the body, thus a bunch-like articulation, while the frames on the right display tongue some tip curling.

Figure 1. Two distinct examples of /ɹ/ articulation within a speaker.



4.1. Comparing English rhotic with stops

None of the Polish speakers produced a consistent bunched /ɹ/. Overall, the tongue shapes were closer to the retroflex than bunching.

4.1.1. Speaker 1

S1 is a female Polish participant who came to Canada at the age of 13 – the youngest age of all Polish participants. The results in Figure 2 show that it is not a bunched /ɹ/ but rather a retroflex with the tongue tip going up. When comparing retroflex /ɹ/ of this speaker with her /g/ tongue shape, it is clear that the two maximal heights are quite far from each other.

4.1.2 Speaker 2

Another female Polish S2 arrived in Canada later in her life compared to the previous S1. This may be manifested by a different tongue shape in /ɹ/ production, with the tip of the tongue raised like in retroflex but also some sort of minimal bunching at the back of the tongue (Figure 3). It is therefore different from any typical tongue /ɹ/ shapes from Dellatre and Freeman.

4.1.3. Speaker 3

Similarly to S1, the age of arrival in Canada of S3 was relatively young. The /ɹ/ is also quite retroflex with the tip of the tongue up but not curled back (Figure 4).

4.1.4. Speaker 4

S4's background is similar to S2 since both of them arrived in their early twenties and have been living in Canada for only a few years. The results for S4 in Figure 5 also show that /ɹ/ may be described as retroflex when looking at the tongue tip but there is some bunching at the back of the tongue. The tongue position highly overlaps of /ɹ/ with /d/.

4.1.5. Speaker 5

The only male speaker in the Polish group produced a clear retroflex /ɹ/. On one hand his background is similar to S2 and S4 as he arrived in Canada in his twenties and has been residing there for a very short period of time. On the other hand, he has been intensively exposed to the North American /ɹ/ earlier by participating in a youth exchange and attending an American high school for a year.

Figure 2. Average tongue shape by S1.

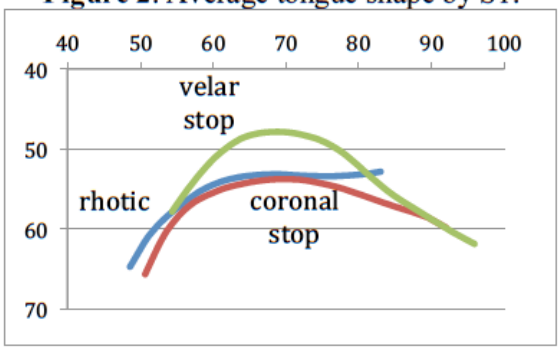


Figure 3. Average tongue shape by S2.

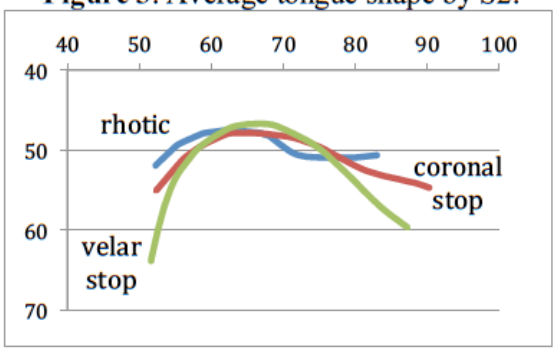


Figure 4. Average tongue shape by S3.

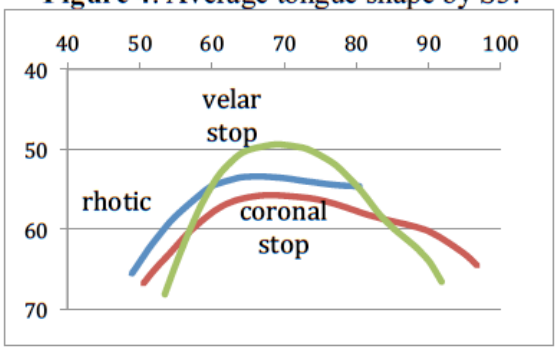


Figure 5. Average tongue shape by S4.

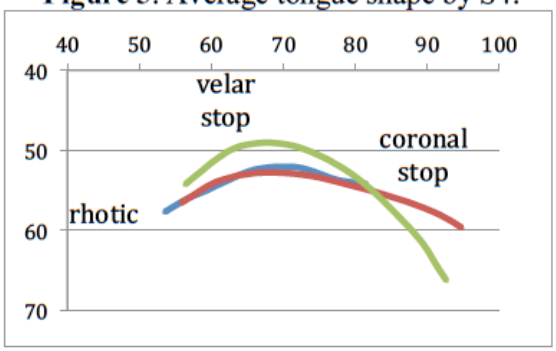
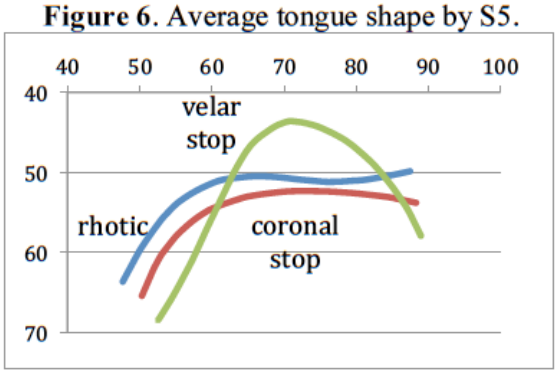


Figure 6. Average tongue shape by S5.



4.3. SS-ANOVA results

The results from SS-ANOVA confirm the statistical difference in tongue position. Table 1 below shows the patterns of /ɹ/ articulation contrasted with each stop. The dominant pattern, as marked with shaded cells, is that the tip of the tongue if always higher and more retracted compared to both stops. On the other hand, the front of the tongue in /ɹ/ is usually higher than in /d/ but lower than in /g/, however the tendency is not as strong as with the tongue tip. Both back and front of the tongue overlap significantly in the backness of /ɹ/ and /d/, while when contrasted with /g/, rhotic is more retracted.

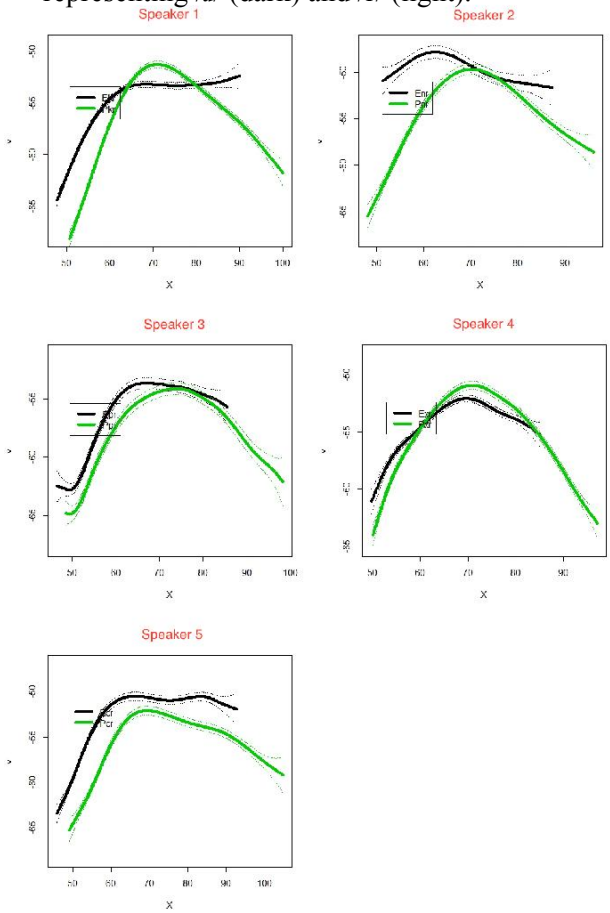
Table 1. SS-ANOVA results in the tongue position broken down into tongue parts. Each cell represents the number of participants for whom given segment was higher or more retracted within a one-way comparison. Some cells do not add up to 5 if some speakers exhibited no statistical difference.

		back	front	tip
R - D	higher	2 ɹ	3 ɹ	5 ɹ
	more retracted	-	-	4 ɹ
R - G	higher	3 ɹ 2 g	4 g	5 ɹ
	more retracted	2 ɹ	3 ɹ	4 ɹ

4.2. Comparing English and Polish rhotics.

The rhotics in Polish and English are very distinct both articulatorily and auditorily. Therefore, it was hypothesized that each Polish speaker will not choose to produce their native trill /r/ when reading English material. If such is the case, the juxtaposition of the two rhotics in SS-ANOVA graphs for each speaker will prove a great difference in the tongue shape and position. It is indeed the case for each and every speaker. The tongue, particularly its tip, is significantly lower in the production of Polish /r/ compared to English /ɹ/, while for the latter it is also more retracted. Interestingly, for S3 and S4, the shape is and position of back and front of the tongue are very similar in /ɹ/ and /r/. It does not seem to correlate with any of the predicted social factors such as sex, age at the time of the experiment, age of immigration or the number of years spent in Canada.

Figure 7. SS-ANOVA splines for all speakers representing /ɹ/ (dark) and /r/ (light).



5. SUMMARY

The articulatory results from Polish ESL speakers varied vastly both across and within speakers. However, none of the participants produced a clear and consistent bunched /ɹ/ similar to their American peers. The sample of Polish speakers was diverse regarding their age of arrival, length of the stay in Canada or preferred dialect of English. Nevertheless, the tongue contour was very retroflex-like, in some cases a clearly retroflex type like indicated by Delattre and Freeman [5]. While, none of the social factors correlate with the degree of retroflexion at this point, the strong preference for this manner of articulation suggests that retroflex may be less marked for the L2 learners than bunching.

6. REFERENCES

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