INTERSPEECH 2019
September 15–19, 2019, Graz, Austria

An articulatory-acoustic investigation into GOOSE-fronting in German-English bilinguals residing in London, UK

Scott Lewis[1], *Adib Mehrabi*[1], *Esther de Leeuw*[1]

[1]Department of Linguistics, Queen Mary University of London

scott.lewis@qmul.ac.uk

Abstract

This study explores L2 acquisition of socially conditioned phonetic variation in 13 German-English sequential bilinguals residing in London, UK. The phonetic variable analysed is GOOSE-fronting, i.e. the more front pronunciation of /u/ in words like 'goose', acoustically manifested through an increased $F2$ frequency. In the South of England, GOOSE-fronting is a sound change considered to be led by young females. We investigated whether bilinguals adhered to this pattern, e.g. whether younger female German-English bilinguals exhibited a relatively higher $F2$ frequency in words like 'goose' than other bilinguals. The bilinguals' English /u/ productions were compared against their German /u/ (lower $F2$ as more back) and /y/ (higher $F2$ as more front) to determine the degree of GOOSE-fronting and whether their $F2$ values were closer to /y/ than /u/. Normalised formant values were considered in relation to lingual measurements obtained using ultrasound tongue imaging. The acoustic and articulatory results revealed that female bilinguals indeed produced more front English /u/ vowels than their male counterparts. Within female speakers, age and length of residence in the UK were found to be significant, with younger speakers who had lived in the UK longer than five years displaying the greatest degree of GOOSE-fronting.

Index Terms: GOOSE-fronting, bilingualism, ultrasound, sociophonetics

1. Introduction

Gestural drift, that is 'perceptually-guided changes in speech-production' [1, p. 421], can occur in sequential bilinguals who relocate to areas in which their target second language (L2) is spoken. Various factors have been found to impact upon the extent to which first language (L1) like, pronunciation is achieved by sequential bilinguals in their L2. These factors include age of L2 acquisition [2, 3], length of residence in the L2 speaking environment [4, 5] and amount of L2 usage [2, 6]. Less understood, however, is the extent to which bilinguals perceive and produce fine-grained socially motivated distinctions in the surface realisation of phonemes in their L2, as native speakers are known to do. Standard L2 speech acquisition models, such as the Perceptual Assimilation Model [7] and the Speech Learning Model [8] do not incorporate the acquisition of socially structured variation in speech production. The present paper suggests these models could potentially be enhanced by considering socially motivated variation in L2 speech.

Sociolinguistic competence in an L2 – the use of L2 variants to index social information such as age and gender [9] – would seem to be a key component of L2 acquisition for speakers who acquire their L2 in a naturalistic L2-speaking environment [10]. Previous research has suggested learners are particularly sensitive to gender differences in their target L2, attempting to replicate gender-based variation [11, 12], provided they wish to adhere to L2 community perceptions of gender [13].

The present articulatory-acoustic study investigated gestural drift in 13 German-English sequential bilinguals (Table 1), where the L2 target speech sound – in this case the Standard Southern British English (SSBE) GOOSE vowel, found in words such as 'boot' – was chosen on the basis that it is subject to social variation in its production, outlined shortly.

Traditionally described as a high back rounded vowel, /u/ in SSBE has been moving forward in the vowel space for decades (e.g. [14, 15]). This process, commonly called 'GOOSE-fronting', has been demonstrated not just acoustically, but articulatorily, in electromagnetic articulography [16] and ultrasound [16, 17] studies.

Standard German has not been reported to have undergone this process. Instead, German /u/ is generally reported to be a canonical back vowel [18], phonologically and acoustically distinct from the high front rounded vowel /y/. In contrast, SSBE /u/ represents a single phoneme gradually shifting forward over time in the direction of /y/. This shift, for speakers across the South of England, appears to be linked to the social factors of age and gender, with young female speakers leading the sound change (e.g. [19, 20]). GOOSE-fronting can therefore be inferred to be a relative process, varying in degree as a function of age. Although it has been argued that GOOSE-fronting performs little social-indexical work [21], being phonologically driven, the sound change is more advanced in some speaker groups than others and would appear, importantly, to be perceived as female-led by British English speakers [22]. As such, resulting gestural drift could be inferred to be the product of a speaker's having learned to perceive the social meanings attached to phonetic forms, i.e to be a manifestation of sociolinguistic competence.

The present study set out to address two central questions: 1) Do German-English bilinguals demonstrate GOOSE-fronting in English /u/, as determined by the vowel's position in relation to their German /u/-/y/ space? 2) If so, is this influenced by the social factors of age and sex as it is for L1 English speakers? In order to ascertain the extent to which German-English bilinguals patterned like SSBE speakers in the production of the GOOSE vowel, acoustic and ultrasound data were jointly analysed. These methods were used to investigate whether native German speakers produced English /u/ in a fashion that more closely resembled their German language productions of /u/ or /y/; the greater the similarity between speakers' English language productions of /u/ and German /y/, the more fronted their English GOOSE vowel was said to be.

The motivations for combined acoustic and ultrasonic study of GOOSE-fronting were twofold. Although a rise in $F2$ is taken to indicate fronting, the relationship between tongue positioning and formant values cannot be concretely assumed without articulatory evidence [17]: increases in $F2$, for example, can be the result of other articulatory factors, such as lip un-

http://dx.doi.org/10.21437/Interspeech.2019-2637

Table 1: *Background details of the 13 participants. LOR = length-of-residence, M = Male, F = Female.*

	Age	Age of acquisition	LOR
F1	36–40	early-adolescence	>10
F2	31–35	early-adolescence	<5
F3	41–45	early-adolescence	>10
F4	41–45	early-adolescence	>10
F5	41–45	early-adolescence	5–10
F6	26–30	early-adolescence	<5
F7	41–45	late-childhood	>10
F8	26–30	early-adolescence	<5
F9	31–35	late-childhood	>10
M1	36–40	early-adolescence	>10
M2	36–40	mid-adolescence	<5
M3	26–30	early-adolescence	<5
M4	41–45	early-adolescence	>10

rounding. Although lip unrounding has been shown not to be responsible for high $F2$ values in SSBE speakers [16], such a mechanism could be used by L2 users as an alternative to tongue-fronting. As such, direct lingual measurements, as provided by ultrasound, provide a means of confirming the cause of $F2$ changes. Secondly, ultrasound tongue imaging has previously uncovered socially motivated covert contrasts in tongue-positioning that are not readily uncoverable from acoustic or auditory data [23]. Ultrasound and acoustic data jointly considered thus offer a potentially richer, more complete picture of speech and therefore socially conditioned variation.

2. Methods

2.1. Participants

Thirteen native German speaking participants were recruited from personal and professional networks and through an online forum [1]. A summary of their key demographic information is provided in Table 1.

2.2. Stimuli

The stimuli consisted of monosyllabic words following C-V-C, CC-V-C, or C-V-CC patterns. Separate word lists were used for German and English, and were made up of 'target' words, containing the vowels of interest, and distractor words, such as 'reit' (German) and 'ran' (English). The German list contained 78 unique words, with 66 distractors and 12 target words (Blut, Buch, Flut, gut, Hut, Mut, Tuch, süß, süd, tut, übt, Wut). The English list contained 90 unique words with 79 distractors and eleven target words (boost, boot, juice, loop, loose, mood, moose, shoot, spook, Sue, tooth). The words in each list were repeated in three blocks, yielding 9, 27, and 33 examples of German /y/, German /u/, and English /u/ respectively. Unbalanced token numbers for each vowel occurred due to the removal of tokens preceded or followed by rhotics or laterals from analysis. Within and between speaker variation in lateral and rhotic production introduced different coarticulatory effects and made consistent segmentation difficult.

2.3. Procedure

Participants were fitted with a head stabilisation set [24], to ensure probe stability and accuracy of measurements [25]. The probe was placed beneath the speaker's chin and images captured along the midsagittal plane. The participants were presented with single word prompts orthographically on a monitor. The words in each block were randomised, and presented with a one second inter-stimulus interval. Participants were given the opportunity to take breaks between blocks. The experiment lasted approximately 15 minutes per participant. All recordings took place in a sound attenuated booth (IAC acoustics, UK) at Queen Mary University of London. Following the experiment, participants completed an online questionnaire using Google Docs from which background information was extracted.

2.4. Data collection

Ultrasound data was captured using an EchoB system (Articulate Instruments, UK), configured as follows: frame rate = 82fps; scanlines = 64; pixels per scanline = 946; field of vision = 92; pixel offset = 210; depth = 90mm. Audio data was recorded using a Neumann TLM 103 microphone (Neumann, Germany) positioned approximately 12 inches from the speaker, and a Focusrite Scarlett Solo audio interface (Focusrite, UK) with a sampling rate of 22kHz and a bit depth of 16 bits. Both the ultrasound and audio data were recorded into Articulate Assistant Advanced (AAA) [26].

2.5. Segmentation and annotation

Audio data were exported from AAA to Praat [27] for the purposes of segmentation and acoustic analyses. Annotations were conducted manually by the lead author, based on waveform and spectral information. In initial position or following voiceless segments, vowels were deemed to begin with the onset of regular periodic waveforms and clear formant structures. Following voiced segments, abrupt changes in waveform shape/amplitude and increased intensity in the spectrogram were used to denote the vowel's onset. The endpoint of the vowel was marked on the basis of a sudden drop in waveform amplitude and spectral intensity or by the onset of aperiodicity if this preceded such a drop. The calculated vowel duration (μ, σ) are: English /u/ (181ms, 49ms), German /u/ (159ms, 37ms), and German /y/ (159ms, 45ms).

Raw formant ($F1$-$F3$) values for each vowel were automatically extracted using a Praat script at 20%, 50%, and 80% of the vowel's duration. Point tier annotations for each vowel at each of the three time points were also created and imported to AAA. The midpoint of each vowel was selected and splines automatically fitted, with subsequent manual corrections.

2.6. Metrics

For acoustic measurements, we considered two metrics. To establish baseline differences between the three vowels, we used speaker-normalised mean $F2$ values. Normalisation was performed using the Watt and Fabricius method [28], and the mean $F2$ was taken as the average at the 20%, 50%, and 80% points of the vowel. To investigate the position of the English /u/ compared to the German /u/ and /y/, we derived a ratio based on the relative position of the English /u/ in the German /u/–/y/ space, as per Eq. 1.

$$r_{tp} = \frac{\bar{y}_p - e_{tp}}{\bar{y}_p - \bar{u}_p} \tag{1}$$

Where $\bar{y}_p$ and $\bar{u}_p$ represent the mean $F2$ values of German /y/ and /u/ respectively, for a given participant, p, and e_{tp} is the $F2$ value for a given participant's English /u/ token, t. r_{tp} is be-

[1] www.deutsch-in-London.net/forum

tween 0-1 for English /u/ vowels positioned within the German /u/ – /y/ space, with higher values being closer to German /u/, and lower values to German /y/. Values of r_{tp} outside of the 0-1 range indicate an English /u/ with an $F2$ value either more back than the mean German /u/ (if > 1.0) or more fronted than the mean German /y/ (if < 0.0), for a given speaker. This metric implicitly normalises for speaker-specific vowel spaces in terms of the $F2$ dimension and relative to the German /y/ and /u/ vowels. However, it does assume that for all speakers, the German /u/ has a lower $F2$ than German /y/, which is typically the case, and was found in the data presented here.

For the ultrasound data we derived a similar ratio metric, using the Cartesian coordinates of the maximum of the fitted spline for each token. This represents the relative frontedness of the highest point of the tongue, which we expected to follow a similar pattern to the acoustic metric for each vowel. The coordinates of the spline data were exported from AAA, giving 42 (x, y) values per token, corresponding to 42 fan lines. In this representation, the x value corresponds to the front/back position of the tongue, and the y value corresponds to the height. For each token, t, and participant, p, we define e_{tp} as the x coordinate at the maximum value of y. As with the acoustic data, we then calculated a ratio based on the relative position of the English /u/ in the German /u/ – /y/ space, as per Eq. 1, where $\bar{y}_p$ and $\bar{u}_p$ represent the mean x values of the spline maxima for a given participant's German /y/ and /u/ vowels respectively.

3. Results

3.1. Acoustic data

To test for baseline differences between vowel sounds we fitted a mixed model using the lme4 package for R [29], with normalised `F2` as the dependent variable, fixed effects of `vowel` and `sex`, including an interaction term, and random intercepts for `participant`, stimulus (`word`), a dummy variable indicating whether the consonant preceding the vowel was a coronal (`presegcor`), and the self-reported proportion of time the participants spend speaking English compared to German (`l2prop`). A full factorial ANOVA was conducted on the fitted model, testing for the fixed effects and interaction term. We found a significant effect of `vowel` ($F(2, 53) = 258.9, p < 0.001$) and a significant interaction between `vowel` and `sex` ($F(2, 919) = 17.2, p < 0.001$). A Tukey post-hoc analysis (with Bonferroni correction) showed significant differences between all vowel pairs: German /u/ - /y/ ($z = 20.1, p_{adj} < 0.001$); German /u/ - English /u/ ($z = -13.9, p_{adj} < 0.001$); English /u/ - German /y/ ($z = 10.5, p_{adj} < 0.001$). Given the interaction between main effects, we also conducted an analysis of interaction contrasts. This showed a significant contrast of sex between German and English /u/ ($\chi^2(1) = 28.7, p_{adj} < 0.001$), and German /y/ and English /u/ ($\chi^2(1) = 16.6, p_{adj} < 0.001$). This effect is shown in Figure 1, where the difference between male and female participants was similar for both German vowels, but males appeared to exhibit an English /u/ closer to their German /u/, compared to females.

Due to the limited number of male speakers (n=4), we deemed it unsuitable to consider social factors for this group. However, we further analysed data for female participants to test whether age and length of residence (LOR) in the UK had any effect on the relative $F2$ of English /u/ compared to German /u/–/y/. We fitted a mixed model with $F2$ `ratio` (as defined in Eq.1) as the dependent variable, fixed effects of `age` and `LOR`, and random intercepts for `participant`, `word`,

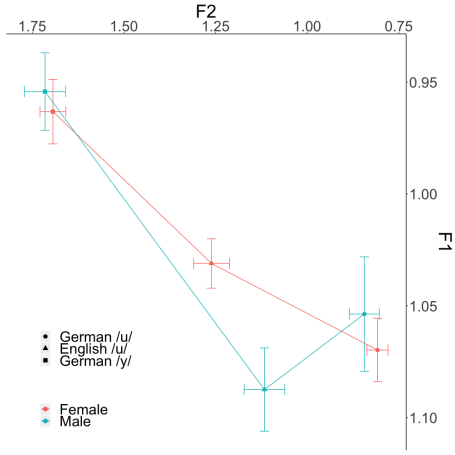

Figure 1: *Normalised F1 and F2 vowel space (mean and multivariate 95% CIs) for the 3 vowel sounds.*

`presegcor`, and `l2prop`. A full factorial ANOVA was conducted on the fitted model, showing significant effects of age ($F(3, 9.3) = 147.2, p < 0.001$) and, to a lesser extent, LOR ($F(1, 7.1) = 16.1, p < 0.01$). These results are shown in Figure 2. For females, fronting of English /u/ appeared to decrease with age, at least within each LOR group. In addition, we observed considerably more fronting in younger female speakers with an LOR of >5 years than speakers in the same age group (31–35) with a lower LOR.

3.2. Ultrasound data

As discussed in Section 2.6, for the ultrasound data we only considered a single metric - the ratio of the x coordinate of the tongue splines for English /u/ relative to the German /u/–/y/ space. This gave a measure that was relative to each speaker's German /u/–/y/ space, and allowed us to compare across speakers. As with the acoustic analysis, we only considered social factors for the female group, fitting a mixed model with `ratio` as the dependent variable, fixed effects of `age` and `duration`, and random intercepts for `participant`, `word`, and `l2prop`. A full factorial ANOVA on the fitted model resulted in significant effects of age ($F(3, 2.1) = 30.2, p < 0.05$) and LOR ($F(1, 7.5) = 8.8, p < 0.05$). Overall, these results concur with the acoustic analysis, as can be seen by comparing Figures 2 and 3. However, females aged 31–35 who had lived in the UK more than 5 years displayed more GOOSE-fronting in the acoustic than ultrasound data.

4. Discussion

Using articulatory and acoustic methods, this study compared German-English sequential bilinguals' productions of English /u/ against their German /u/ and /y/ to determine degree of GOOSE-fronting. The acoustic results revealed that, overall, both male and female bilinguals made a three way distinction between English /u/, and German /u/ and /y/, with $F2$ values for the first vowel falling between those of the latter two. However, sex was found to be significant in determining the extent to which bilinguals contrasted English language productions of /u/ with German /u/ and /y. $F2$ values were higher in English than German /u/ for males and females, but this difference was greater in females. Since higher $F2$ frequencies are

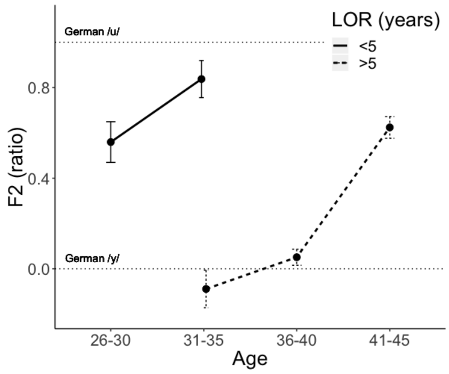

Figure 2: *Female F2 ratio values (mean and 95% CIs) of English /u/ relative to German /u/-/y/ space (as per Eq. 1).*

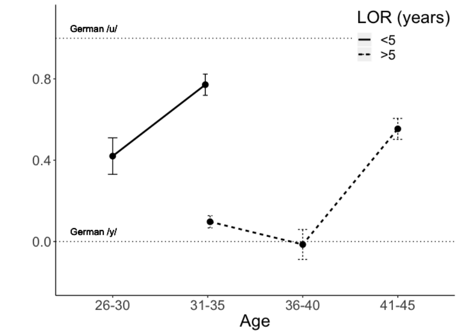

Figure 3: *Tongue spline x coordinate ratio (mean and 95% CIs) of English /u/ relative to German /u/-/y/ space (as per Eq. 1), for female speakers.*

correlated with fronter productions, the female bilinguals appeared to demonstrate greater GOOSE-fronting than the males. This accords with literature on speakers from Southern England [19] and suggests the bilinguals perceived GOOSE-fronting in a manner similar to the English native speakers reported in [22].

Due to low male speaker numbers, further analyses were not presented for men. Age and LOR were, however, considered for females. Both factors were significant. On average, females who had lived in the UK less than five years produced English /u/ with an $F2$ value closer to their German /u/ than /y/ compared to their counterparts with an LOR greater than 5 years. This finding was not unexpected and corresponds with results reported elsewhere (e.g. [4, 5]).

Moreover, for females, the ratio difference between $F2$ values for English /u/ and German /u/ appeared to decrease as a function of age. That is, the older the speaker, the more backed were their English /u/ productions. For the oldest group of speakers (41–45), $F2$ values for English /u/ were closer to German /u/ than /y/. The relatively younger speakers with LOR greater than 5 years, in contrast, showed very little ratio difference between English /u/ and German /y/. As German /y/ is a front vowel, the acoustic similarity between it and English /u/ in $F2$ terms for the younger female bilinguals is a clear indication of GOOSE-fronting in these speakers. That younger female speakers demonstrated more GOOSE-fronting than older ones again accords with GOOSE-fronting being a sound change led by young females [20]. It appears, consequently, that the bilinguals tested were attuned to age-related distinctions in the use of GOOSE-fronting by SSBE speakers. The resulting gestural drift demonstrated could, therefore, be considered to have been socially conditioned.

The ultrasound results largely supported the acoustic findings. Ratio values, accounting for the difference between highest point values for English /u/ and German /u/, as well as English /u/ and German /y/, revealed the same effects as described above: younger females with a LOR greater than five years displayed the least amount of difference between their productions of English /u/ and German /y/. Given that German /y/ is a front vowel, the similarity between English /u/ and German /y/ in ratio terms suggests GOOSE-fronting was most advanced in the younger female bilinguals with a LOR greater than 5 years. This again suggests the bilinguals were able to perceive socially motivated variation and produce subtle vowel differences paralleling those found in socially similar SSBE speakers.

The ratio distances were largely similar in the ultrasound and acoustic data. However, an exception occurred for the 31–35 age group with LOR greater than 5 years. The acoustic results suggest their English /u/ was further forward in the vowel space than their German /y/, whereas this was not the case in the ultrasound data. This difference seems to have been led by one speaker: F9. It is possible the discrepancy for this speaker is evidence of the non-linear relationship between constriction location and formant values [17]. It could be that lip unrounding occurred during F9's productions of English /u/, increasing its $F2$ beyond that found for /y/. Across the board, however, it appears that, like the SSBE speakers presented in [16], the bilinguals examined here produced a lingual distinction between English and German /u/ vowels.

The results concur with previous research. The German-English bilinguals tested appeared to perceive subtle differences in social meaning attached to phonetic features and replicate them (as per [9, 11, 12]). In Southern England GOOSE-fronting is more advanced in younger, female speakers [19, 20, 22], and we found that it was the younger, female bilingual speakers who demonstrated the greatest degree of GOOSE-fronting here. The extent to which speakers demonstrated gestural drift in the production of the GOOSE vowel seems, therefore, to have been a manifestation of sociolinguistic competence in L2 speech.

Standard L2 speech acquisition models, such as the Perceptual Assimilation Model [7] and the Speech Learning Model [8] do not incorporate the acquisition of socially structured variation in L2 speech production. However, the present findings suggest that groups of bilingual speakers differed in the extent to which they displayed gestural drift, paralleling the fine-grained socially motivated distinctions evident in L1 speakers of SSBE. Key to determining the degree of gestural drift exhibited was the concept of sociolinguistic competence. Therefore, standard models could perhaps be enhanced by considering socially motivated variation in L2 speech.

5. Conclusion

This study explored L2 acquisition of socially conditioned phonetic variation in 13 German-English sequential bilinguals living in London, UK. Bilinguals were found to differ acoustically and articulatorily in the degree of GOOSE-fronting displayed. This was influenced by the social factors of age and sex, suggesting that the bilingual speakers were sensitive to fine-grained social variation present in SSBE speakers' productions. These findings suggest that standard models of L2 acquisition ought to consider socially motivated variation in L2 speech production.

6. References

[1] M. L. Sancier and C. A. Fowler, "Gestural drift in a bilingual speaker of Brazilian Portuguese and English," *Journal of Phonetics*, vol. 25, no. 4, pp. 421–436, 1997.

[2] J. E. Flege, M. J. Munro, and I. R. A. MacKay, "Factors affecting strength of perceived foreign accent in a second language," *The Journal of the Acoustical Society of America*, vol. 97, no. 5, pp. 3125–3134, 1995.

[3] N. Abrahamsson and K. Hyltenstam, "Age of onset and nativelikeness in a second language: Listener perception versus linguistic scrutiny," *Language learning*, vol. 59, no. 2, pp. 249–306, 2009.

[4] J. E. Flege, O. Bohn, and S. Jang, "Effects of experience on non-native speakers' production and perception of English vowels," *Journal of Phonetics*, vol. 25, no. 4, pp. 437–470, 1997.

[5] P. Trofimovich and W. Baker, "Learning second language suprasegmentals: Effect of L2 experience on prosody and fluency characteristics of L2 speech," *Studies in Second Language Acquisition*, vol. 28, no. 1, pp. 1–30, 2006.

[6] G. Jia, D. Aaronson, and Y. Wu, "Long-term language attainment of bilingual immigrants: Predictive variables and language group differences," *Applied Psycholinguistics*, vol. 23, no. 4, pp. 599–621, 2002.

[7] C. Best, "A direct realist perspective on cross-language speech perception," in *Speech perception and linguistic experience: Issues in cross-language research*, W. Strange, Ed. Timonium, MD: York Press, 1995, pp. 171–204.

[8] J. E. Flege, "Second language speech learning: Theory, findings, and problems," in *Speech perception and linguistic experience: Issues in cross-language research*, W. Strange, Ed. Timonium, MD: York Press, 1995, pp. 233–277.

[9] E. Schleef, "Migrant teenagers acquisition of sociolinguistic variation: The variables (ing) and (t)," in *Language Variation-European Perspectives IV: Selected papers from the Sixth International Conference on Language Variation in Europe (ICLaVE 6), Freiburg, June 2011*, P. Auer, J. Reina, and G. Kaufmann, Eds. Amsterdam: John Benjamins Publishing, 2013, pp. 201–213.

[10] M. Howard, I. Lemée, and V. Regan, "The L2 acquisition of a phonological variable: the case of /l/ deletion in French," *Journal of French Language Studies*, vol. 16, no. 1, pp. 1–24, 2006.

[11] H. D. Adamson and V. Regan, "The acquisition of community norms by Asian immigrants learning English as a second language: A preliminary study," *Studies in Second Language Acquisition*, vol. 13, no. 1, pp. 1–22, 1991.

[12] R. C. Major, "Gender and stylistic variation in second language phonology," *Language Variation and Change*, vol. 16, no. 3, pp. 169–188, 2004.

[13] Y. Ohara, "Finding ones voice in Japanese: A study of the pitch levels of L2 users," in *Multilingualism, second language learning, and gender*, A. Pavlenko, A. Blackledge, I. Piller, and M. Teutsch-Dwyer, Eds. Berlin: Mouton de Gruyter, 2001, pp. 231–256.

[14] D. Deterding, "The formants of monophthong vowels in Standard Southern British English pronunciation," *Journal of the International Phonetic Association*, vol. 27, no. 1-2, pp. 47–55, 1997.

[15] S. Hawkins and J. Midgley, "Formant frequencies of RP monophthongs in four age groups of speakers," *Journal of the International Phonetic Association*, vol. 35, no. 2, pp. 183–199, 2005.

[16] J. Harrington, F. Kleber, and U. Reubold, "The contributions of the lips and the tongue to the diachronic fronting of high back vowels in Standard Southern British English," *Journal of the International Phonetic Association*, vol. 41, no. 2, pp. 137–156, 2011.

[17] P. Strycharczuk and J. M. Scobbie, "Fronting of Southern British English high-back vowels in articulation and acoustics," *The Journal of the Acoustical Society of America*, vol. 142, no. 1, pp. 322–331, 2017.

[18] M. Pätzold and A. P. Simpson, "Acoustic analysis of German vowels in the Kiel corpus of read speech," *Arbeitsberichte des Instituts für Phonetik und Digitale Sprachverarbeitung Universität Kiel*, vol. 32, pp. 215–247, 1997.

[19] A. Williams and P. Kerswill, "Dialect levelling: Change and continuity in Milton Keynes, Reading and Hull," in *Urban Voices*, P. Foulkes and G. Docherty, Eds., 1999, pp. 141–162.

[20] J. Harrington, F. Kleber, and U. Reubold, "Compensation for coarticulation, /u/-fronting, and sound change in Standard Southern British: an acoustic and perceptual study," *Journal of the Acoustical Society of America*, vol. 123, no. 5, pp. 2825–2835, 2008.

[21] V. Fridland, "Patterns of /uw/, /ʊ/, and /ow/ fronting in Reno, Nevada," *American Speech*, vol. 83, no. 4, pp. 432–454, 2008.

[22] R. Alderton. (2018) Speaker gender and salience in sociolinguistic speech perception: GOOSE-fronting in British English. [Online]. Available: doi: 10.31234/osf.io/4tj8z

[23] E. Lawson, J. Stuart-Smith, and J. Scobbie, "Articulatory insights into language variation and change: Preliminary findings from an ultrasound study of derhoticization in Scottish English," *University of Pennsylvania Working Papers in Linguistics*, vol. 14, p. 13, 2008.

[24] Articulate Instruments Ltd, "Ultrasound stabilisation headset users manual: Revision 1.13," *Edinburgh, UK: Articulate Instruments Ltd*, 2008.

[25] J. M. Scobbie, A. A. Wrench, and M. van der Linden, "Head-probe stabilisation in ultrasound tongue imaging using a headset to permit natural head movement." in *Proceedings of the 8th International Seminar on Speech Production*, 2008.

[26] Articulate Instruments Ltd, "Articulate Assistant Advanced user guide: version 2.17," *Edinburgh, UK: Articulate Instruments Ltd*, 2017.

[27] P. Boersma and D. Weenink, "Praat: doing phonetics by computer [Computer program]. Version 6.0.48," *http://www.praat.org/*, 2019.

[28] D. Watt and A. Fabricius, "Evaluation of a technique for improving the mapping of multiple speakers vowel spaces in the f_1 - f_2 plane," *Leeds Working Papers in Linguistics and Phonetics*, vol. 9, no. 9, pp. 159–173, 2002.

[29] D. Bates, M. Mächler, B. M. Bolker, and S. C. Walker, "Fitting linear mixed-effects models using lme4," *Journal of Statistical Software*, vol. 67, no. 1, 2015.