Using crowd-sourced data to analyse the ongoing merger of [ɕ] and [ʃ] in Luxembourgish

Peter Gilles

University of Luxembourg
peter.gilles@uni.lu

ABSTRACT

Similar to neighbouring German varieties, the recent language history of Luxembourgish is subject to an ongoing merger of the alveolopalatal fricative [ɕ] (deriving from the palatal fricative [ç]) and the post-alveolar fricative [ʃ], leading progressively to the collapse, for example, of the minimal pair *frech* [fʀæɕ] 'cheeky, impertinent' and *Fräsch* [fʀæʃ] 'frog'. The present study will draw on a large dataset—which has been recorded using an innovative smartphone application—consisting of fricative realisations of more than 1,300 speakers. In an acoustic analysis, various parameters of the two fricatives will be studied (Centre of Gravity, spectral moments, Euclidian distance, DCT coefficients) and correlated with the speaker's age. The results show that the merger is acoustically manifest for nearly all age groups. Only the oldest speakers keep the two fricatives distinct.

Keywords: sound change, fricative merger, sociophonetics

1. INTRODUCTION

The gradual and ongoing merger of the palatal fricative [ç] with the post-alveolar fricative [ʃ] has been a long-standing issue in Germanic dialectology. For various central German dialects ranging from the west (Cologne) to the east (Berlin), the merger of the two fricatives has created homophones like *fischte/Fichte* '(I) was fishing'/'spruce' [5, 6, 12]. Luxembourgish is also affected by this sound change. Located in the far west of the Germanic-speaking area, the Luxembourgish language is spoken by approximately 260,000 speakers as a first language (total population of 600,000). Due to national independence in the 19th century, its primarily spoken usage and its reduced influence from Standard German, the local language of Luxembourgish developed its own pattern in the phonetic-phonological development of the fricatives in question. From the mid-20th century onward, the palatal fricative [ç] has been moving forward in the articulatory space and today has developed into the alveolopalatal fricative [ɕ] [1, 7]. The extract of the fricative inventory in Table 1 illustrates the systematic embedding of the alveolopalatal fricative. Due to the recent sound change from [ç] to [ɕ], this fricative is already quite close to [ʃ]. The same developments discussed here can also be observed in the voiced counterparts [ʑ] and [ʒ] but will be omitted for spatial reasons.

Table 1: Extract of the fricative inventory of Luxembourgish.

Labial	Alveolar	Post-alveolar	Alveolo-palatal	Uvular
f v	s z	ʃ ʒ	ɕ ʑ	χ ʁ

Note that [ɕ] and [ʑ] are part of a complimentary allophony: they are realised only after a preceding front-vowel, while [χ] and [ʁ] are realised after back-vowels. Thus, a phonetic merger of one of the allophones will also have phonological consequences [9]. A recent study by Conrad [3, 4] focusing on the spectral peak reported the merger of the two fricatives as progressing from older to younger speakers. This research also indicated that the merger is most prominent in the southern region of the country.

While there is no doubt that the merger is an ongoing process, it remains unclear how this change is actually progressing through the speech community in apparent time. The speaker's age will thus be the most decisive factor in the investigation. A broad data basis of fricative realisations that covers all age groups is needed to answer the research question. If a continuously progressing process is expected, will a gradual increase of the merger's usage from older to younger speakers be found? Do parameters like sex and geographical region have an influence on the ongoing merger? Furthermore, the behaviour of the two fricatives in question must be determined: does only [ɕ] move forward toward [ʃ], or is [ʃ] also affected in the change?

A corollary aim of this paper is to explore the possibilities and limitations that arise from the utilisation of crowd-sourced data.

2. DATA AND METHOD

To trace the sound change in the speech community convincingly, the main approach of this analysis is to draw upon as many speakers from all age groups as possible and to gather data under (largely) identical experimental conditions. For data collection, we used our smartphone application *Schnëssen – Är Sprooch fir d'Fuerschung*, designed to document spoken Luxembourgish through crowd-sourcing [18]. This app allows large numbers of participants to be recruited efficiently and quickly. The usual disadvantages of indirect data elicitation (varying sound quality, inconsistent metadata and uneven distribution of groups of participants), however, must also be accepted [17].

Since April 2018, spoken language has been collected by the *Schnëssen* app from approximately 1,500 users who participated in more than 300 recording tasks. The total number of single recordings amounts to more than 190,000.

The data for this analysis were elicited through translation tasks from German. As all Luxembourgers are highly fluent in Standard German, translating sentences into Luxembourgish works quite well. In addition to the audio data, basic social information such as age, sex, region and language competencies were collected. The various recording tasks in the *Schnëssen* app included numerous instances for the post-alveolar and alveolopalatal fricatives to be used. However, for the present paper, the analysis will be restricted to the minimal pair *frech* [fʀæɕ] 'cheeky, impertinent' and *Fräsch* [fʀæʃ] 'frog', where the two fricatives occur in an identical context. Both items carried sentence stress.

Table 2 gives an overview of the age distribution of 1,320 speakers, which represent roughly 0.5% of all L1 Luxembourgish speakers. Regarding gender distribution, roughly two-thirds of the participants were female and one third were male.

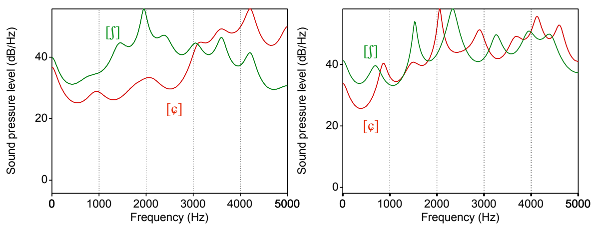
Table 2: Age distribution of the speakers.

Age group	Count	Percentage
≤ 24	238	18%
25 to 34	354	26.8%
35 to 44	241	18.3%
45 to 54	243	18.4%
55 to 64	165	12.5%
65+	79	6%
Total	*1,320*	*100%*

Up until the 45 to 54 age group, the ratio is quite even across age groups. However, the two oldest age groups are less frequently represented in the sample. This can be attributed to the crowd-sourcing method, which reaches more younger than older people.

From these 1,320 speakers, a total of 2,552 fricatives were analysed: 1,299 for [ɕ] and 1,253 for [ʃ]. All recordings were sampled at 44.1 kHz. Figure 1 illustrates the LPC spectra for the two fricatives for an older and a younger speaker, respectively. The distinctness of [ɕ] and [ʃ] is obvious for the older speaker (left), where [ɕ] shows its main spectral peaks above 3,000 Hz, as opposed to [ʃ], with its main spectral peak around 2,000 Hz. For the younger speaker (right), both fricatives exhibit very similar spectral characteristics. More specifically, [ɕ] has developed a lower spectral peak around 2,000 Hz, which increases the similarity to [ʃ].

Figure 1: LPC spectra for [ɕ] and [ʃ] for an older speaker (age group 55 to 64) (left) and a younger speaker (age group 25 to 34) (right).



The sound files containing the two fricatives were automatically segmented using the MAUS-system [15]. All boundaries were checked and corrected manually using the *emuDB-webApp* of the *EMU Speech Database Management System* (EMU-SDMS) [19]. Problematic items, such as noisy signals or wrong wording, were removed. Signal processing was conducted with the *emuR*-library [19]. First, an additional track with the DFT spectrum was inserted into the database. The frequency range was reduced from 500 Hz to 10,000 Hz, which should cover all necessary spectral characteristics for the two fricatives. DFT spectra were extracted at the temporal midpoint of the fricative. All frequency values in Hertz were converted into Bark values to organise the results along a perceptually more adequate frequency resolution. Orienting toward similar studies [8, 12, 13, 14, 16], the following set of spectral parameters were used. Employing spectra moments [11] gives information about the Centre of Gravity (CoG), variance, kurtosis and skewness. Furthermore, the coefficients from a Discrete Cosine Transformation (DCT) provides an additional approach to the quantification of fricative spectra [10, 11]. For both approaches, the Euclidian distances were calculated to determine the amount and progression of the fricative merger.

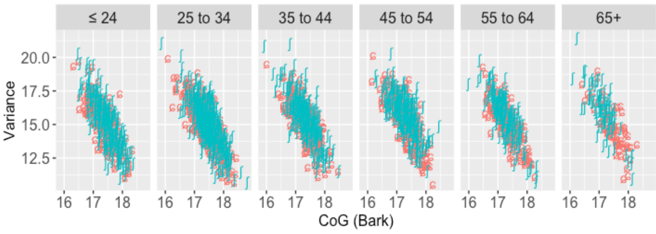
3. RESULTS

3.1 Spectral moments

The spectral moments of the CoG, variance, kurtosis and skewness capture crucial characteristics for the quantification of the acoustical shape of fricatives. For their calculation, the emuR-function *moments* was used.

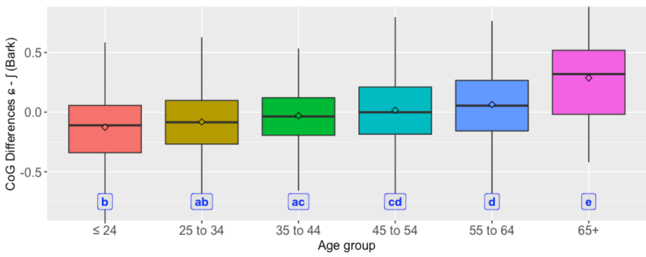
The scatter plot in Figure 2 shows the values for the CoG plotted against the variance for the six age groups. Within the oldest group (65+), a slight distinction between two fricatives was found. The tokens for [ɕ] (red) gather predominantly in the bottom right corner, while the tokens for [ʃ] (blue) are located in the opposite corner, thereby indicating a higher CoG for [ɕ]. However, an overlap between the realisations can also be observed, indicating that in this age group, the fricatives might not be entirely distinct acoustically. For all younger age groups, no group separation is noticeable. Rather, a large overlap of the fricative realisations is characteristic, making it safe to assume that both fricatives have merged into one realisation.

Figure 2: Scatter plots for the distribution of [ʃ] (blue) and [ɕ] (red) according to the spectral moments of CoG and variance for the six age groups.



While the visualisation above illustrates the distribution of realisations within an age group, it is also necessary to investigate the individual distance of realisations within the speakers themselves. This aspect is shown in Figure 3 for the CoG, which has been calculated here as the group mean of the differences between the individual CoG for [ɕ] and [ʃ]. A constant decline in the difference between age groups and thus a gradual sound change in apparent time is clearly visible. The positive value for the age group 65+ (median value of 0.3 Bark) indicates that speakers distinguish the fricatives acoustically. With difference values at around zero for the younger age groups, it becomes evident that a distinction is not being made. Note, however, the slightly negative values for the age groups ≤ 24 and 25 to 34, which could indicate the beginning of a new divergence of the two fricatives.

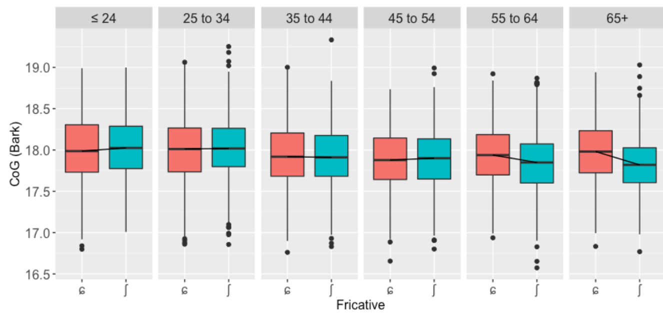
Figure 3: Difference in the CoG between [ɕ] and [ʃ] for the six age groups. The labels indicate the grouping according to the post-hoc tests.



Running an ANOVA for the differences between the individual CoG for [ɕ] and [ʃ] with the factor age returns a significant effect ($F(5, 1226) = 23.007$, $p < 0.001$). Pairwise, multiple Duncan post-hoc tests showed significant effects for nearly all combinations of age groups. The grouping according to the post-hoc tests is indicated below the boxplots by the labels *a* through *e*. As expected, the CoG captures the merger through the age groups quite well. In addition, there are no differences between male and female speakers, and geographical region does not play a role.

However, these differences in CoG do not reveal the acoustic trajectories of the two fricatives in the course of the ongoing merger. To investigate this aspect, the boxplots in Figure 4 depict the CoG for the fricatives side-by-side per age group. The values for [ɕ] are rather stable across the age groups at around 18 Bark, indicating that its place of articulation is hardly changing. However, rather unexpectedly, the CoG for [ʃ] increases from the oldest to the youngest age groups, thus suggesting a move backward toward the alveolopalatal place of articulation. Therefore, it turns out that the change of the post-alveolar fricative seems to be the main active component in the merger.

Figure 4: CoG for [ɕ] and [ʃ] in the six age groups.

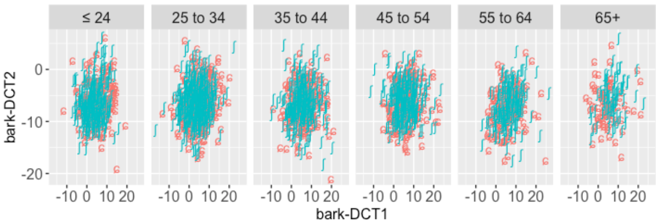


3.2 Discrete Cosine Transformation

The DCT offers an alternative way to quantify spectral characteristics and has proven to capture differences between fricatives more effectively by accounting for the entire spectrum [14]. With the help of DCT, spectral characteristics are represented by a certain number of coefficients, which are derived through a progressive transformation of the spectrum to the corresponding cosine functions. Of particular relevance are three DCTs: DCT1 gives the slope of the fricative; DCT2 represents the curvature of the fricative and is the most efficient parameter, according to [2, 14]; and DCT3 reflects the amplitude of frequency in the higher range. For each DFT spectrum from the centre of each segment, six DCT coefficients have been calculated with the emuR-function *DCT* on the basis of the bark-converted frequency values (bark-DCT1, bark-DCT2, bark-DCT3).

The scatter plot in Figure 5 delivers a similar impression compared to Figure 2. While for the age group 65+ one could assume that at least several instances for [ɕ] are distinct from [ʃ] due to a lower DCT1, the picture is less clear than for the spectral moments discussed above. For all younger age groups, most of the values overlap, thus confirming the merger.

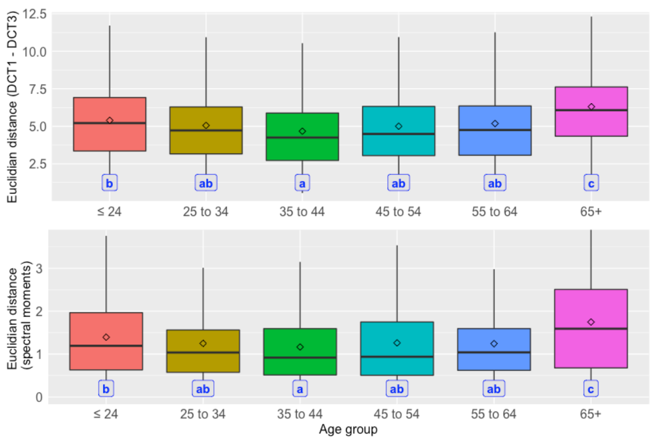
Figure 5: Scatter plots for the distribution of [ʃ] (blue) and [ɕ] (red) according to bark-DCT1 and bark-DCT2 for the six age groups.



3.3 Euclidian distance

The previous discussion centred around the impact of one or two spectral parameters. However, as the fricatives are characterised by either four spectral moments or three DCTs, it is possible to express the differences between the fricatives more appropriately by their distance in a multidimensional space using the Euclidian distances. Figure 6 shows, as expected, the highest distance for the age group 65+, suggesting a more or less clear distinction between [ɕ] and [ʃ]. The subsequent younger age groups are characterised by continuously decreasing distances. Surprisingly, the youngest age groups (≤ 24 and 25 to 34) show slightly increasing distances, which could be seen as a countermovement to the ongoing merger. The pattern across the groups is very similar for both methods. Note, however, that even for the most advanced age groups the distance is never zero (indicating a complete merger). A spectral residuum, therefore, is still present, hinting micro-phonetically at the historically different fricatives.

Figure 6: Euclidian distances based on three DCTs (top) and four spectral moments (bottom) for the six age groups. The labels indicate the grouping according to the post-hoc tests.



As for the statistical evaluation, for both DCTs and spectral moments, age is a highly significant factor in the ANOVA (DCTs: $F(5, 1225) = 4.788$, $p < 0.001$; spectral moments: $F(5, 1225) = 4.969$, $p < 0.001$). Multiple pairwise post-hoc tests single out age group 65+ (*c*) as highly different from the rest. As can be seen from the overlap of groups *a* and *b*, all younger age groups are statistically similar to each other, and the above-mentioned slight increase in the Euclidian distance for the two youngest groups is thus not statistically relevant. Again, the factors 'sex' and 'region' are not relevant to the merger.

4. DISCUSSION

From a sociophonetic perspective, the aim was to trace the progression of the ongoing merger of [ɕ] and [ʃ] in apparent time. It was found that age is the most pertinent factor in the ongoing merger. Only the oldest age group seems to maintain a sufficient acoustical distance to separate the two fricatives. Certain spectral characteristics, most clearly the CoG, confirmed that the merger is progressing gradually from older to younger speakers. Contrary to the findings in [3, 4], the factors 'region' and 'sex' do not play a significant role in the merger. The Euclidian distance turned out to be the most appropriate instrument to estimate the merger. Note that these distances are still greater than zero for the youngest speakers, meaning that the fricatives are acoustically not fully merged.

This study revealed also that the merger is mainly due to the backing of [ʃ], while [ɕ] remains largely stable across the age groups. This important information then helps to clarify the steps of the sound change: In the first phase the former palatal [ç] turned into alveolo-palatal [ɕ] and in a subsequent second phase [ʃ] is moving towards [ɕ].

For a further assessment of the merger, it is necessary to use more diverse speech material, especially with varying preceding vowels. Nevertheless, the large number of speakers makes it possible to draw a reliable path of the sound change in the speech community.

Finally, the aspect of perception has been completely excluded from this acoustic study. Further experiments will reveal how the acoustic impression of the merger is matched by the listener's perception.

5. REFERENCES

[1] Bruch, R.. 1954. *Das Luxemburgische im Westfränkischen Kreis*. Luxemburg.

[2] Bukmaier, V., Harrington, J. 2016. The articulatory and acoustic characteristics of Polish sibilants and their consequences for diachronic change. *Journal of the International Phonetic Association* 46/3. 311-329.

[3] Conrad, F. 2018. Der Zusammenfall von /ʃ/ > /ɕ/ < /ç/ im Luxemburgischen. In: Belz, M., Mooshammer, C., Fuchs, S., Jannedy, S., Rasskazova, O., Żygis, M. (eds.) *Proceedings of P&P 13*. 29-32.

[4] Conrad, F. *submitted*. The merger of /ʃ/ and /ç/ in Luxembourgish.

[5] Dogil, G. 1992. Phonologische Nachbarschaft trotz akustischer Ferne. Untersuchungen zur /ç/ - /ʃ/-Neutralisation im Saarland. In: Bronner, M., Braun, E., Fix H. (eds.). *Nachbarschaften. Festschrift für Max Mangold*. Saarbrücken. 57-66.

[6] Féry, C. 2017. *Die* allophonischen Frikative in der Standardsprache und in den hessischen Dialekten. In: Konopka, M., Wöllstein A. (eds.). *Grammatische Variation: Empirische Zugänge und theoretische Modellierung*. Berlin, Boston. 181–202.

[7] Gilles, P., Trouvain, J. 2013. [Illustrations of the IPA] Luxembourgish. *Journal of the International Phonetic Association* 43/1. 67–74.

[8] Gordon, M., Barthmaier, P., Sands, K. 2002. A cross-linguistic acoustic study of voiceless fricatives. *Journal of the International Phonetic Association* 32/2. 141-174.

[9] Hall, T. A. 2013. Alveolopalatalization in central Germany as markedness reduction. *Transactions of the Philological Society* 112/2. 143-166.

[10] Harrington, J. 2010. Acoustic Phonetics. In: Hardcastle, W. J., Laver, J., Gibbon, F. E. (eds.). *A Handbook of Phonetics.* Second edition. Oxford. 81-129.

[11] Harrington, J. 2010. *The Phonetic Analysis of Speech Corpora*. Wiley-Blackwell.

[12] Jannedy, S., Weirich M. 2014. Sound Change in an Urban Setting: Category Instability of the Palatal Fricative in Berlin. *Journal of Laboratory Phonology* 5(1). 91-122.

[13] Jannedy, S., Weirich, M. 2016. The acoustics of fricative contrasts in two German dialects. In: Draxler, C., Kleber, F. (eds.). *Proceedings of P&P 12*, Munich. 1-4.

[14] Jannedy, S., Weirich, M. 2017. Spectral moments vs discrete cosine transformation coefficients: Evaluation of acoustic measures distinguishing two merging German fricatives. *The Journal of the Acoustical Society of America* 142, 395-405.

[15] Kinsler, T., Reichel, U. D., Schiel, F. 2017. Multilingual processing of speech via web services. *Computer Speech & Language* 45. 326–347.

[16] Kleber, F., Lowery, M., Stegmaier, R. 2018. The production and perception of the German /s, ç, ʃ/ contrast. Berlin. In: Belz, M., Mooshammer, C., Fuchs, S., Jannedy, S., Rasskazova, O., Żygis, M. (eds.) *Proceedings of P&P 13*. 101-104.

[17] Leemann, A., Kolly M.-J., Purves, R., Britain, D. Glaser, E. 2016. Crowdsourcing language change with smartphone applications. *PLoS ONE 11(1).* https://doi.org/10.1371/journal.pone.0143060

[18] *Schnëssen – Är Sprooch fir d'Fuerschung*. Smartphone application for Android and iOS to collect and document the present-day language variation, developed at the Institute for Luxembourgish linguistics and literatures, University of Luxembourg https://infolux.uni.lu/schnessen/

[19] Winkelmann, R., Harrington, J., Jänsch, K. 2017. EMU-SDMS: Advanced speech database management and analysis in R. *Computer Speech & Language* 45. 392-410.