An Acoustic Study of the Low-Back Merger in South-Central Pennsylvania English: An Apparent-Time Analysis Using Formant Trajectories[1)]

KIMIHIKO KIMURA

1. Introduction

American English has been geographically subdivided into several dialect regions in accordance with pronunciation features resulting from sound changes that occurred during and after settlement from the European continent. Changes in vowels have contributed more to the present classification of American English than have those in consonants.

Of such vowel changes, this research focuses on the loss of contrast between the low-back vowels /ɑ/ and /ɔ/ (referred to as "the low-back merger" below), which is one of the current and most prevalent vowel changes across the United States. This section provides an overview of the low-back merger and clarifies the importance of investigating this research object.

1.1. The low-back merger

The low-back merger in this paper refers to a vowel merger unconditioned by the surrounding phonetic environment. The merger of /ɑ/ and /ɔ/ has often been observed only before nasals, but this partial merger does not show any geographical patterning (Labov et al., 2006) and is not considered in this research.

The low-back merger had already been described by Wetmore (1959) using field data collected in the 1940s for the compilation of linguistic

atlases. Later, this phonological change was reported in broader regions of the United States, and according to Labov, Ash, and Boberg (2006), the merger had spread to the western and northern part of the United States (as well as the southern part of Canada), eastern New England, and western Pennsylvania[2]. The areas where the merger has already spread are shaded in Figure 1.

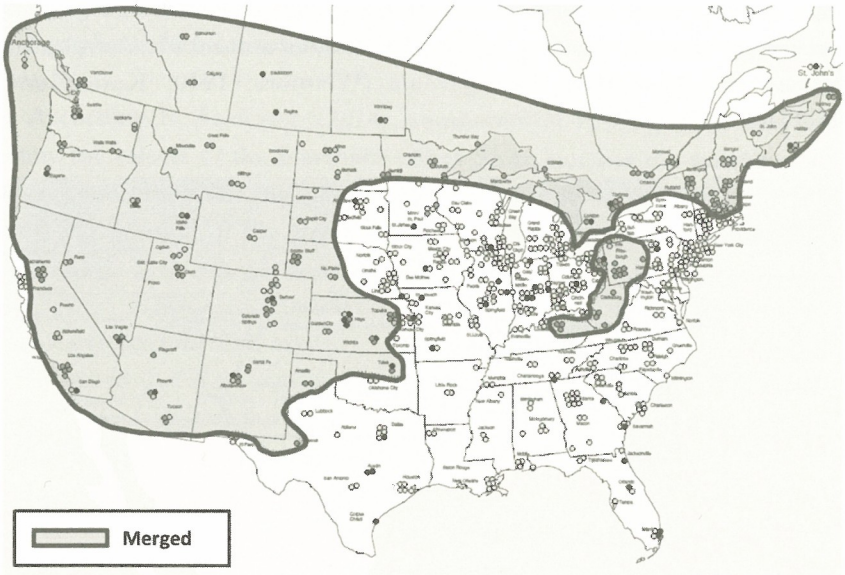


Figure 1 The geographical distribution of the low-back merger in North America (Labov et al., 2006). Shading was added by the present author.

Since the low-back merger is widespread across North America, research on this topic may have connections to other broader sound changes in progress. For example, the low-back merger has been reported as a possible trigger of major vowel shifts throughout North America, namely, the California Shift and the Canadian Shift (Clarke et al., 1995; Eckert, 2008; Hinton et al., 1987; Labov et al., 2006).

1.2. Historical spread of the low-back merger within Pennsylvania

For investigations of the geographical spread of the low-back merger, south-central Pennsylvania constitutes an ideal environment: The boundary of the merger vertically divides the Commonwealth, and it has been spreading eastward since the last century. As shown in Figure 2, the eastern limit of the merger runs across Pennsylvania from north to south (Herold, 1997). This is the result of a geographical spread of the merger originating in the area around Pittsburgh, the largest city in western Pennsylvania (Wetmore, 1940; Kurath and McDavid, 1961).

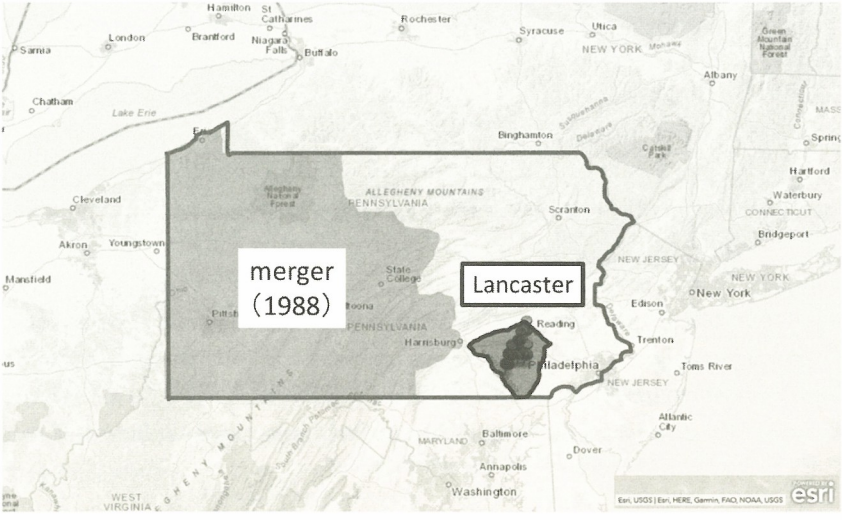


Figure 2 An enlarged map of the Commonwealth of Pennsylvania (the area encompassed in the lightly colored line). The shaded area on the left indicates the region where the merger had reached completion by 1988. The dark-colored region on the right shows the location of Lancaster County.

Labov et al. (2006) reported that the low-back merger had been resisted in eastern Pennsylvania due to the existence of other vowel changes: The fronting of /ɑ/, which is a part of the Northern Cities Shift, is present in northeastern Pennsylvania (Labov et al. 2006), and

in the southeastern region /ɑ/ retains its low-back position, while the tongue position of /ɔ/ has raised to retain the phonemic contrast.

However, this resistant trend is not consistent across south-central Pennsylvania. Even though Labov et al. (2006) interviewed only two south-central Pennsylvanian consultants, the vowel system of south-central Pennsylvania is treated differently from that of western Pennsylvania and Philadelphia. Kimura (2018) also observed an acoustic indication of a shift toward merger in south-central Pennsylvania. The geographical location of south-central Pennsylvania is shaded in Figure 2.

According to Anderson (2014), south-central Pennsylvania does not show the effects of the Northern Cities Shift, nor has the raising of /ɔ/ been reported. This indicates that the blockage of the merger is not simply the result of the trends resisting merger identified by Labov et al. (2006).

1.3. Purpose of this study

As noted in 1.2, this paper aims to investigate the spread of the low-back merger within the Commonwealth of Pennsylvania, which is one of the places where the low-back merger is possibly spreading.

In order to reveal the historical spread of the merger, this research conducts an apparent-time study focusing on the generational differences of consultants' speech.

For the acoustic analysis, this study used a method that is not common but appeared suitable for this case. An examination of the adequacy of the methodology will also be given in Section 3.

In summary, throughout this analysis, attempts were made to address the following two points:

1. Is the low-back merger continuing to spread eastward in Pennsylvania?
2. Is the methodology used in the acoustic analysis adequate?

2. Data and methodology

This research is based on the result of an acoustic analysis of field

recordings made in south-central Pennsylvania. Details of fieldwork and acoustic analysis procedure using first and second formant frequencies (F1 and F2) will be presented in this section.

2.1. Field location and consultants

The sound data used in this analysis were recorded in fieldwork conducted in Lancaster County, PA, in March 2019. As shown in Figure 2, Lancaster County is east of the region where the low-back merger has been completed. The exact places where each field interview was conducted are marked on the map with pushpin icons.

Consultants who were interviewed were all born and raised in south-central Pennsylvania[3]. Detailed information on the consultants is summarized in Table 1. Four of the eight consultants analyzed in this paper are in their 20s, and the other four are in their 70s.

In terms of gender, the samples of this analysis show an uneven distribution. However, as discussed in Section 3, the results show no clear differences by gender.

Table 1 Sociolinguistic parameters of the consultants

consultant	gender	age cohort
A	male	70s
B		
C	female	
D		
E	male	20s
F		
G		
H	female	

2.2. Interview

The interview consisted of three parts: A passage reading, a wordlist reading, and a written questionnaire on consultants' language background and their knowledge of phonemic contrasts in their own Eng-

lish variety. This paper focuses on the wordlist reading since use of a wordlist makes it easy to control the number of tokens for each phonetic environment and to ensure at least a minimum number of tokens for each vowel phoneme in question.

2.3. Recording

Interviews were recorded with a voice recorder (SONY ICD-UX560F/B) and a unidirectional monaural microphone (OYMPUS ME52W). All the recorded sounds were encoded with 44.1- kHz/16-bit LPCM, which ensures sufficient quality to avoid aliasing, and were saved in .wav format.

2.4. Selection of tokens

In this analysis, each speaker's vowel space was drawn on a two-dimensional plane to visualize the relative distance between the low-back /ɑ/ and /ɔ/ within his/her phonemic system. Note that only the vowels involved in the California/Canadian Shifts or fronting of the back vowels /ʌ/, /oʊ/, /ʊ/, /u/[4] were plotted.

Vowels in the following contexts were omitted in order to minimize the effects of conditioning by adjacent consonants:

1. Vowels before /l/: post-vocalic /l/ may cause backing of the tongue or off-glide sounds.
2. Vowels before nasals /m/, /n/, /ŋ/: nasal consonants may cause nasalization of proceeding vowels.

After this selection process, the number of tokens of each vowel for each consultant was reduced to:

/i/ (FLEECE): 5 tokens
/ɪ/ (KIT): 4 tokens
/ɛ/ (DRESS): 4 tokens
/æ/ (TRAP, BATH): 5 tokens
/ɑ/ (LOT, PALM): 9 tokens
/ɔ/ (THOUGHT, CLOTH): 12 tokens
/ʌ/ (STRUT): 4 tokens

/oʊ/ (GOAT): 11 tokens
/ʊ/ (FOOT): 8 tokens
/u/ (GOOSE): 30 tokens[5)]

In order to clarify the correspondence of the phonemic representations on this paper to those of other varieties of English, *keywords* for the standard lexical sets introduced in Wells (1982) are given in parenthesis.

The whole list of words used in this analysis is presented in Table 2 in the appendix.

2.5. Acoustic analysis

Acoustic analysis was conducted with Praat acoustic analysis software (Boersma & Weenink, 2019). The method employed in this analysis will be explained in the following subsections.

2.5.1. Formant measurement

In formant measurement, first, the target vowels were annotated to determine their durations. The start and end points of vowel durations were decided by observing the periodic waveforms of vowel sounds.

After annotation, F1 and F2 were measured and recorded throughout the vowel durations. The Gaussian window length for the FFT was set to 25 ms.

2.5.2. Drawing vowel spaces with "formant trajectories"

Measured formant values of each token were plotted in the F1–F2 plane, and in particular formant trajectories of all tokens were drawn in separately F1–F2 planes. An example formant trajectory is shown in Figure 3.

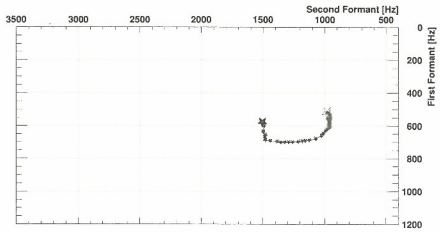


Figure 3 A formant trajectory of /ɔ/ in the word *bought*. The start and end points of the trajectory are indicated as larger blank and filled symbols, respectively.

Information on the raw measured time values is of course lost in this method. However, it is still possible to mark the direction of the formant movement by indicating the starting and ending points of vowel durations. Therefore, drawing the whole formant movement virtually enables three-dimensional information (F1, F2, and the direction of movement) to be represented in a two-dimensional plane. In Figure 3, the starting and ending points of the vowel duration are marked as the larger blank and filled markers, respectively.

This analysis used formant trajectories instead of representative points such as mid-points or averages of vowel formant because such single values are not sufficient to describe the acoustic differences studied in this analysis. Comparison among different methods will be shown in Section 3.

Note that inter-speaker normalization of vowel space was not conducted in this analysis, since the aim of this research is to observe the relationships between the low-back vowels in question within each speaker's vowel space.

2.5.3. Drawing "formant movement ranges"

In this analysis, for each consultant, the formant trajectories of each token were displayed in the same vowel space. The resulting vowel space presents the potential variation that the formant values of each vowel may take in an F1–F2 plane. In the following sections, these vowel space areas will be referred to as "formant movement ranges." An example formant movement range is shown in Figure 4.

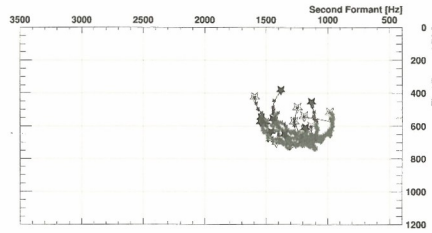


Figure 4 The formant movement range of the phoneme /ɔ/ as pronounced by one of the consultants.

As shown in Figure 4, there was no certain trend in the start and end points of trajectories. Therefore, the start and end points of each token are omitted in order to avoid too much complexity in the resulting vowel space depictions[6)].

This analysis utilizes formant movement ranges because of their advantage over other, frequently used methods when observing the low-back merger in south-central Pennsylvania. Details will be given in 3.1 with some examples of the resulting vowel spaces.

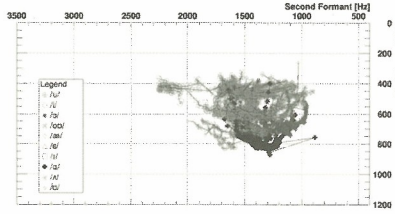
3. Results and Discussion

This section presents and discusses the results of the acoustic analysis and answers the research questions presented in 1.3.

3.1. Observational adequacy of the method

First, the adequacy of the method explained in Section 2 will be examined. Figures 5–12 compare the method used in this research with other frequently used methods, namely those using averages or mid-points of the formant trajectories.

Note that all the figures in this section consist of plots made by three different methods: (1) formant movement range, (2) averages of formants and (3) mid-points of the formant trajectories. Figures 5–8 correspond to speeches of consultants A–D (who are in their 70s), and Figures 9–12 to consultants E–H (who are in their 20s).



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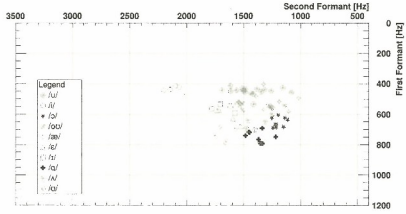

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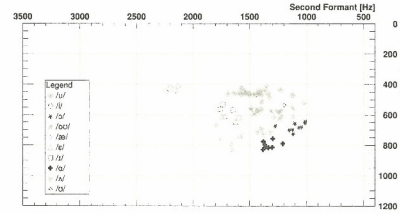

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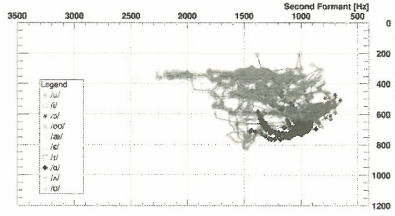
Figure 5 Vowel spaces of consultant A



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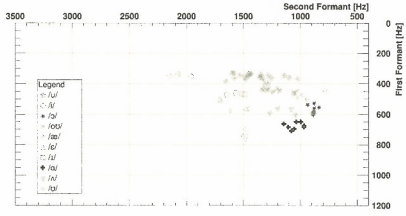

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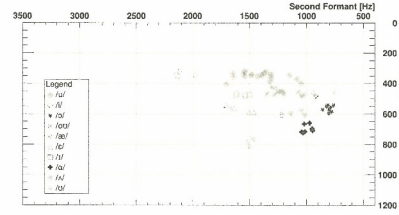

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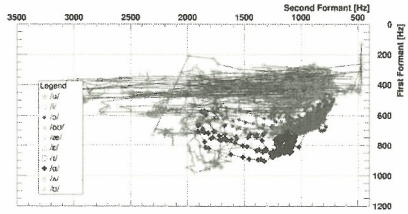
Figure 6 Vowel spaces of consultant B



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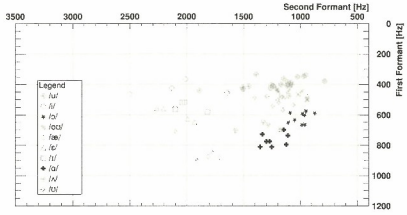

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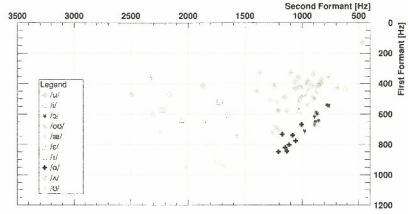

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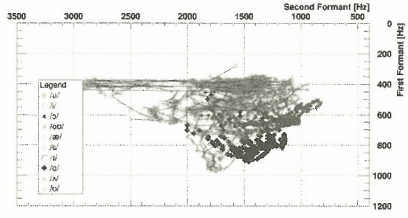
Figure 7 Vowel spaces of consultant C



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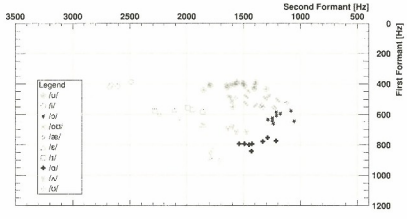

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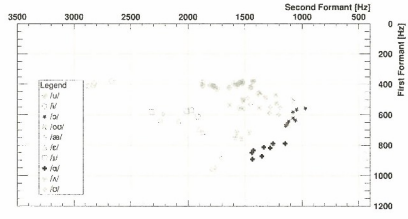

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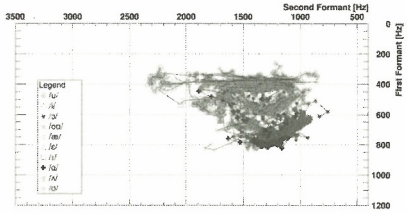
Figure 8 Vowel spaces of consultant D



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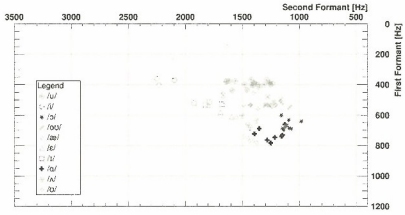

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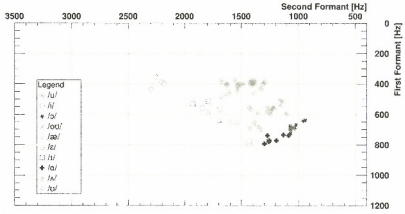

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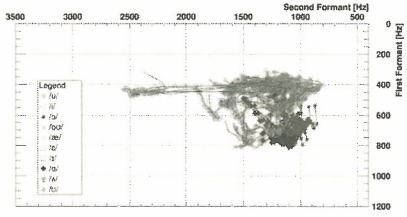
Figure 9 Vowel spaces of consultant E



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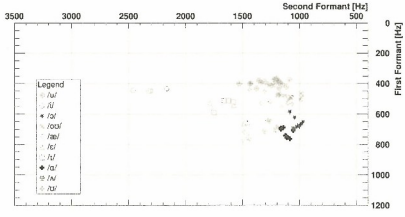

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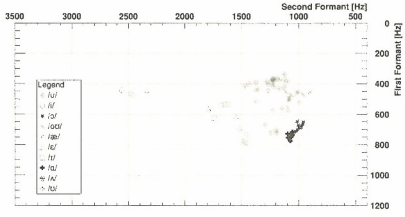

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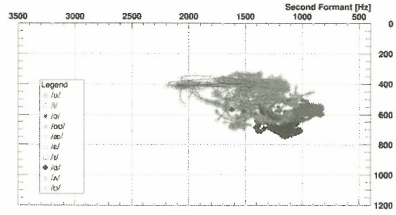
Figure 10 Vowel spaces of consultant F



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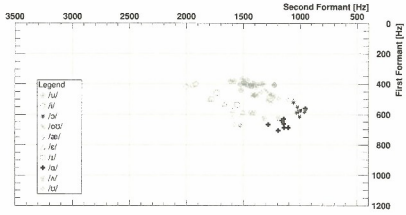

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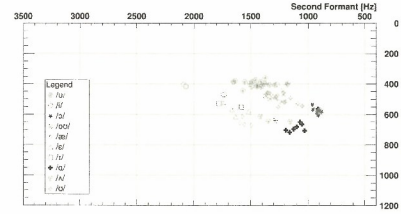

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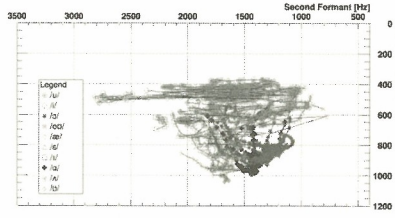
Figure 11 Vowel spaces of consultant G



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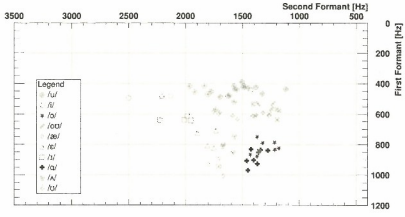

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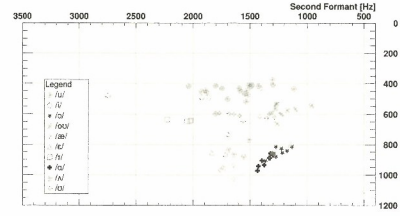

(3)

Figure 12 Vowel spaces of consultant H

In Figures 5–12, the low-back vowels /ɑ/ and /ɔ/ are plotted as filled symbols, /ɑ/ in black and /ɔ/ in dark gray. The other vowels are plotted uniformly in light gray.

Acoustically, the low-back merger is manifested as the overlap of the plots of /ɑ/ and /ɔ/ tokens in the vowel space[7]. In Figures 5–11, while the respective plots (2) and (3) show the same degree of overlap in each figure, the plots in (1) show different tendencies from those in (2) and (3). While (2) and (3) present complete separation (B, D, G) or partial overlap (A, C, E, F) (Figure 12 is an exception, since it presents consistent results using all the three methods: Greater overlap is observed than for the other consultants), tendencies correlated with consultants' ages are displayed in (1): The formant movement ranges of the consultants in their 70s show only partial overlaps that are smaller than those of the consultants in their 20s.

Thus, the formant movement range is observationally adequate. Using representative formant values (i.e., averages or mid-points) is not sufficient, in this case in south-central Pennsylvania, to describe the generational change in low-back vowels.

3.2. Inter-generational comparisons

Figures 13 and 14 present the formant movement ranges of /ɑ/ and /ɔ/ extracted from Figures 5–12 to make the generational difference visually clearer.

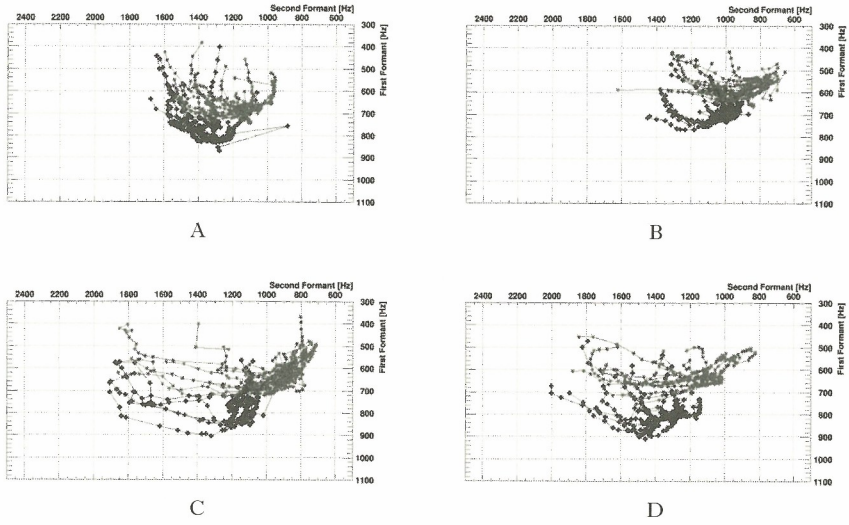

Figure 13 Formant movement ranges of consultants A, B, C, D

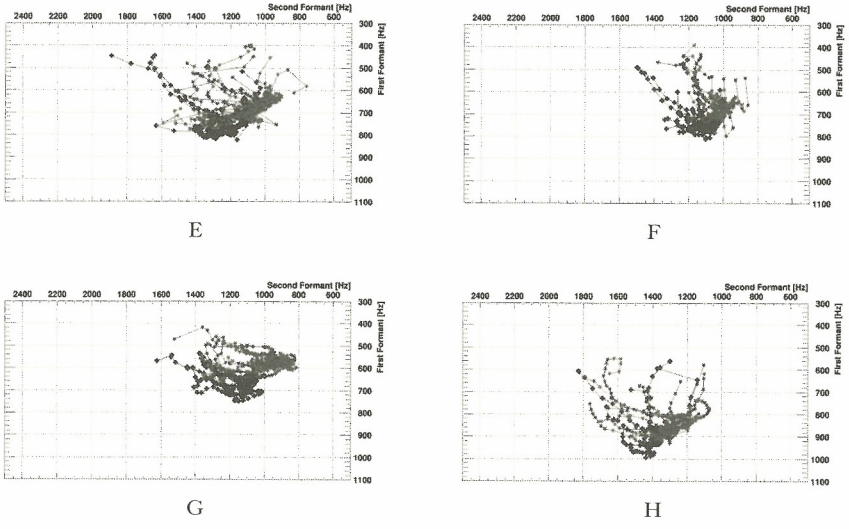

Figure 14 Formant movement ranges of consultants E, F, G, H

As discussed in 3.1, younger consultants E, F, G, H presented greater formant movement range overlaps than the older generation. This indicates that, at least in terms of F1 and F2, the contrast of the low-back vowels /ɑ/ and /ɔ/ has weakened between the two age groups.

Note that whether the vowels are really moving toward a merger or other phonetic feature(s) have instead come to distinguish these vowels in the 50-year generational gap is not clear from this acoustic analysis. Further investigation is necessary to answer this question.

4. Conclusion

By adopting the formant movement ranges, this analysis succeeded in extracting the characteristic feature of older and younger age groups, which are difficult to observe with methods using average or mid-point formant frequencies. This result supports the observational adequacy of the formant movement range.

In addition, the younger generation presented a greater degree of overlap between the low-back vowels /ɑ/ and /ɔ/ than the older generation. This indicates that the role of F1 and F2 values as distinctive characteristics of these vowels has weakened in south-central Pennsylvania. Whether this result indicates an eastward spread of the low-back merger remains for future research.

Appendix The wordlist

Table 2 The list of words used in this research

/i/	/ɪ/	/ɛ/	/æ/	/ɑ/	/ɔ/	/ʌ/
peace	miss	beg	cap	cog	bought	bus
peak	pick	best	pack	cot	caught	cup
seat	sit	dead	pass	dock	cause	cut
steep	tip	step	sat	got	dog	duck
tea			tap	hot	law	
				lock	loss	
				pot	paw	
				spa	sauce	
				top	saw	
					talk	
					taught	
					toss	

/oʊ/	/ʊ/	/u/				
		Labial_	Coronal_	Dorsal_	/l/_	/r/_
bluecoat	book	boost	dew	coop	blew	brew
coat	cook	boot	do	cuckoo	bluecoat	crew
coke	could	mood	dude	goose	clue	cruse
cope	foot	spooky	duke	scoot	flute	fruit
dose	good		snoop		loop	group
go	look		soup		loose	rude
goes	put		sue		lute	
sew	took		suit			
soak			two			
soap						
tote						

Acknowledgements

The author would like to thank Prof. H. Saito from the Tokyo University of Foreign Studies for her valuable comments and advice. A part of this research was supported by JSPS KAKENHI Grant Number JP 18H00661.

NOTES

1) This paper is based on an oral presentation at the 340th regular meeting of the Phonetic Society of Japan.

2) This region extends to West Virginia and eastern Kentucky as well as the western

half of Pennsylvania.

3) One of the consultants (consultant G) spent two and a half years of his adolescence from the age of 14 in Kenya.

4) This is a realizational difference distributed widely across the United States.

5) The quality of /u/ is reported to be influenced by the place of proceeding consonants (Labov et al., 2006). In order to confirm the dependency on the phonetic environment, more tokens containing the GOOSE vowel were collected. This will be examined in future studies.

6) As noted in 2.5.2, the direction of the formant movement can be added as needed.

7) Note that factors other than the backness and height of the tongue can influence the formant frequencies (e.g., the roundedness of the lips). Such factors change the shapes of the resonant cavities, such as oral cavity, nasal cavity, and pharynx.

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