The Canadian Shift in a Montreal Community:

Change and Variation in Perception and Production of the Non-High Short Vowels

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Note on Symbols

Depending on the relevant distinctions within their research, sociolinguists have adopted differing conventions for labeling phonemes, some of which also differ substantially from the universal IPA used by phoneticians. Throughout this paper – except in the case of Figures 8 and 9, plotted with software that does not support IPA characters – I will follow most of the conventions of Boberg (2005), as opposed to those of Labov, Ash, and Boberg (2006) or Wells (1982). The table below includes all symbols used in this paper, *not* every vowel in Montreal English. The sign ≈ indicates that in Montreal English, two historically separate vowel classes have totally merged, while ~ separates two distinct allophones within the phonemic class.

This paper	Boberg (2005)	Labov, Ash, and Boberg (2006)	Wells (1982)	In Figures 8-9
/ɪ/	/ɪ/	/i/	**KIT**	
/ɛ/	/ɛ/	/e/	**DRESS**	e
/æ/	/æ/	/æ/	**TRAP ≈ BATH**	ae
/ɔ/	/ɒ/	/ɑ/ ≈ /ɔ:/	**LOT ≈ THOUGHT**	o
/ʌ/	/ʌ/	/ʌ/	**STRUT**	u
/ʊ/	/ʊ/	/u/	**FOOT**	
/oʊ/	/oʊ/	/ow/	**GOAT**	
/aɪ/ ~ /ʌɪ/	/aɪ/ ~ /ʌɪ/	/aj/	**PRICE**	
/u:/		/uw/	**GOOSE**	
/i:/		/ij/	**FLEECE**	
/eɪ/		/ej/	**FACE**	
/or/		/or/ ≈ /ohr/	**NORTH ≈ FORCE**	
/aʊ/ ~ /ʌʊ/		/aw/	**MOUTH**	

Literature Review

Production: The Canadian Shift

Clarke, Elms, and Youssef (1995), based on impressionistically coded data from the speech of young Ontarians, first noted that /æ/, /ɛ/ and /ɪ/ seemed to be involved in a chain shift that they dubbed the Canadian Shift (CS). They described the CS as a systematic lowering of the front lax vowels in apparent time (Figure 1). In contrast to Labov's (1991) prediction that the merger of /ɑ/ and /ɔː/ would result in a relatively stable "third dialect" of English,[1] the merger had seemed to initiate a pull shift as /æ/ moved into the now vacant low-central region of the vowel space.

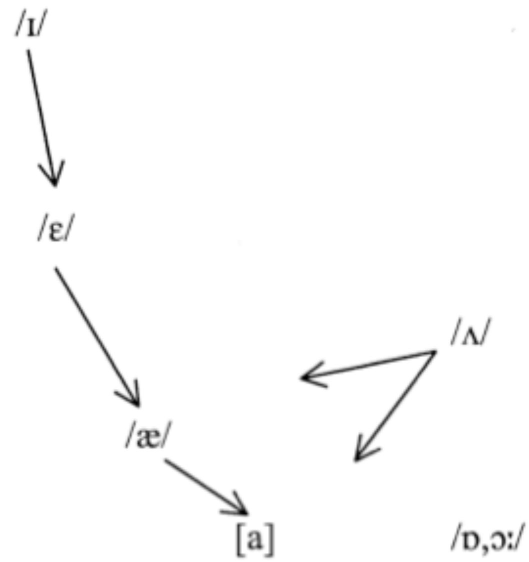

Figure 1: The Canadian Shift, as described by Clarke, Elms, and Youssef (1995)

Methodological issues with the Clarke, Elms, and Youssef (1995) study, including its restriction to Ontario speakers, its lack of a precise system of measurement, and its lack of intergenerational data, have been addressed by several subsequent studies, which confirm the existence of the CS as a pan-Canadian phenomenon but do not agree on its trajectory. Sadler-Brown and Tamminga's (2008) computer-aided vowel analysis found that the CS is currently active in both Halifax and Vancouver; in both cities, /ɪ/ and /ɛ/ are retracting and lowering diagonally, while /æ/ is retracting only along the F2 (back/front) dimension in Vancouver and retracting and lowering diagonally in Halifax. Hoffman (2010) found young women to be leading the retraction of /æ/ in Toronto, while younger Torontonians as a whole were retracting and lowering /ɛ/.

[1] That is, participating neither in the Northern Cities Chain Shift nor the Southern Chain Shift.

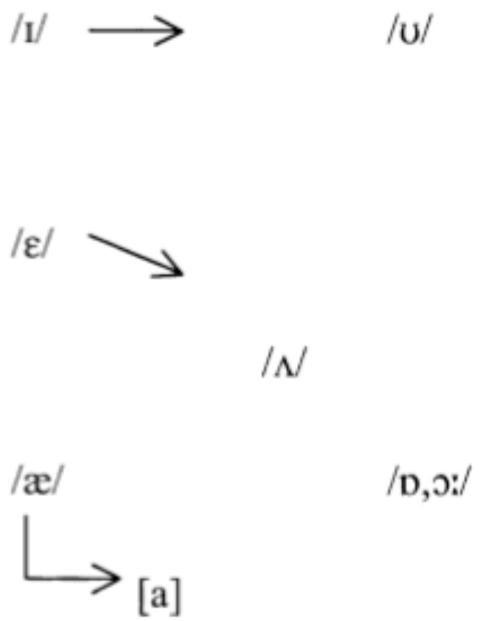

Figure 2: The CS in Montreal, as described by Boberg (2005)

In Montreal, however, Boberg (2005) found that the CS is operating slightly differently, with /ɛ/ retracting toward /ʌ/ without lowering and /ɪ/ retracting toward /ʊ/ in apparent time (Figure 2). Similarly, the results of Hagiwara (2006) indicate that among Winnipeg speakers, /æ/ is lowering and retracting, /ɛ/ and /ɪ/ are retracting without lowering, led by women. These findings are problematic for the definition of the CS as a pull shift in which changing margins of security would theoretically allow vowels' fields of dispersion to progressively move into 'unused' vowel space, as per Martinet's (1955) theory of diachronic phonetic change; instead, the CS may manifest itself as a series of related retractions along the F2 dimension. In this case, its structural basis is less evident, since the *cot*/*caught* merger and movement of /æ/ would not be expected to affect the F2 of the front lax vowels.

Roeder and Jarmasz (2010), however, provide an alternate structural explanation for the Canadian Shift as a systematically related series of retractions. Like Boberg (2005), their study of Toronto English finds strong retraction in /ɛ/ and /æ/, but they also report retraction in /ɔ/, suggesting that,

> …rather than a chain shift, /æ/ and /ɛ/ are simultaneously redistributing within the reconfigured vowel space resulting from the low back vowel merger, and are engaged in a parallel shift that is motivated by the tension between forces of articulation, perception, and contrast. We propose that the vowels are ultimately moving towards equilibrium of a symmetrical vowel system… The Canadian Shift comprises two stages. The first involves concurrent lowering and retraction and the second involves retraction only and includes retraction of /ɔ/. (397-8)

Figure 3 illustrates their proposal for the progression of the CS, as the merger of /ɑ/ and /ɔ/ **(a)** leaves space for /æ/ to move into the low central position **(b)**. Following a stage of backing and retraction **(c)**, /ɛ/ and /æ/ move into the central space **(d)**.

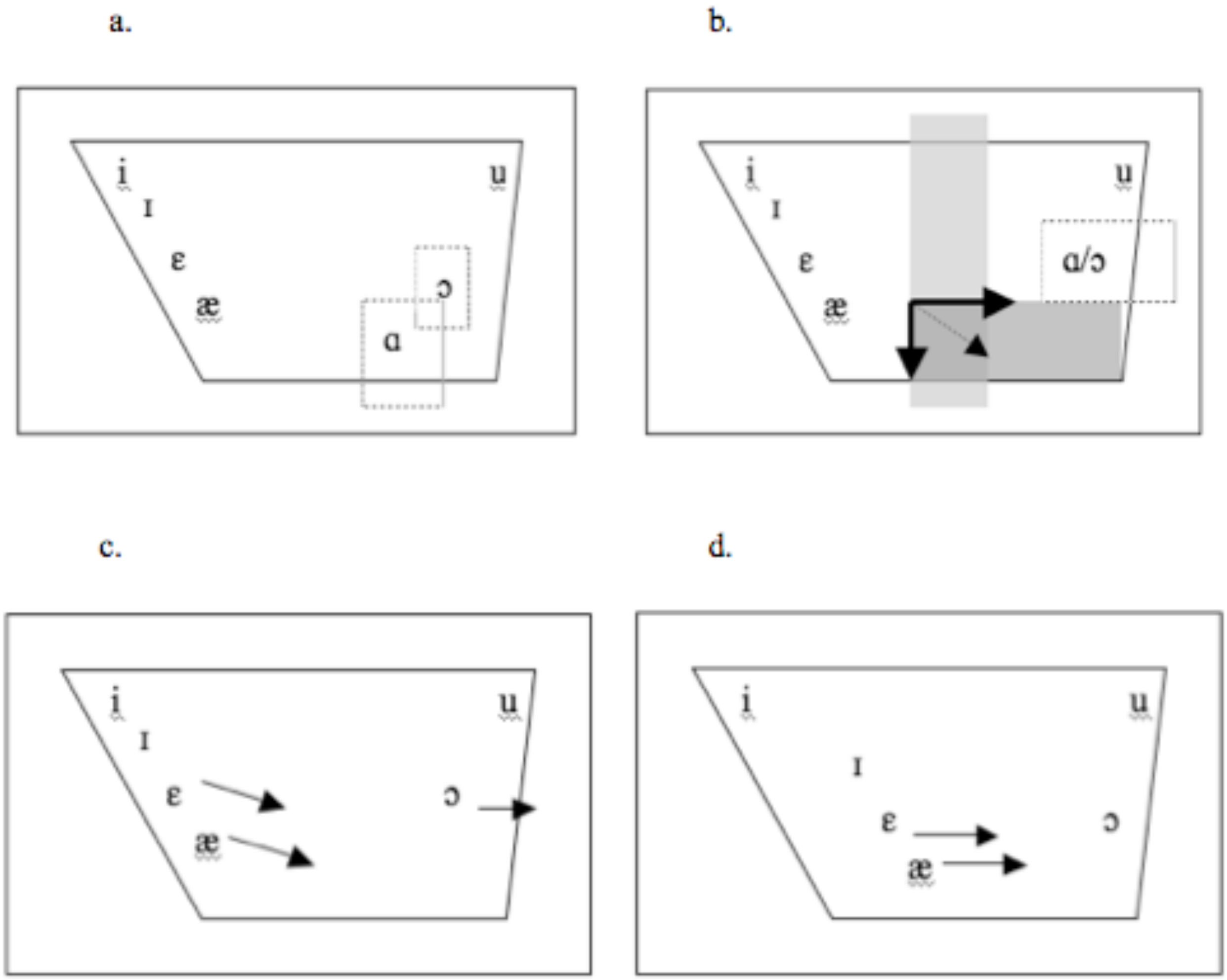

Figure 3: Roeder and Jarmasz's (2010) proposal for the progression of the Canadian Shift.

Perception: Sound Change and Vowel Categorization

To Foulkes, Scobbie and Watt (2010), "the goals of sociophonetics include accounting for how socially-structured variation in the sound system is learned, stored cognitively, subjectively evaluated, and processed in speaking *and listening*" (704, emphasis added). As noted by Kendall and Fridland (2010), it is not enough to think of a 'dialect' as a configuration of productive features of a speaker's or group's language; though speakers' production capabilities are partially based on the speech they perceive, they do not always sound like those they have the most contact with. Indeed, understanding how sounds are stored in memory and how the mental representations of linguistic variables correlate with social information is crucial to interpreting sociolinguistic patterns, and theories of sound variation and change cannot be complete unless the perceptual half of the linguistic equation is accounted for (Janson 1983, Drager 2010). Thomas (2002) notes, however, that "perception has been studied far less by sociolinguists than has speech production" and describes the "huge potential for sociolinguistic perception studies because the area has been neglected for so long" (115).

In an early study of inter-community variation in perception, Willis (1972) analyzed differences in vowel categorization between high school students in Fort Erie, ON, and Buffalo, NY. The accents of the two adjacent communities differ in that Buffalo belongs to the dialect region of Western New York, which preserves the *caught*/*cot* distinction, while the two vowels are fully merged in Canada. Though neither Buffalo's Northern Cities Shift nor Ontario's Canadian Shift had been reported at the time of his investigation, Willis described upstate New Yorkers' "peculiar pronunciation… variously described as fronting, lengthening, and diphthongization of /æ/" (1972, 249). He focused on how each community's /ɛ/–/æ/ (*bet* vs. *bat*) and /æ/–/ɔ/ (*hat* vs.

hot) spoken distinctions were reflected in their perceptual categorizations of vowels.[2] In his methodology, participants were presented with a variety of synthetic vowel stimuli and asked to categorize them as *bet* or *bat* (when testing the /ɛ/–/æ/ distinction), or as *hat* or *hot* (testing the /æ/–/ɔ/ distinction). He found that Canadian subjects showed "well defined phoneme boundaries" between instances of /ɛ/ and /æ/, perceptually dividing the phonemes based on vowel height; those from Buffalo were not as consistent in their responses, but tended to divide /ɛ/ from /æ/ quite differently, based more on the vowel's degree of fronting (see Figure 4). The study also revealed that respondents tended to divide their /æ/ and /ɔ/ vowels differently: the Canadians perceived sounds with lower F2 values as /æ/ compared to Buffalo listeners.

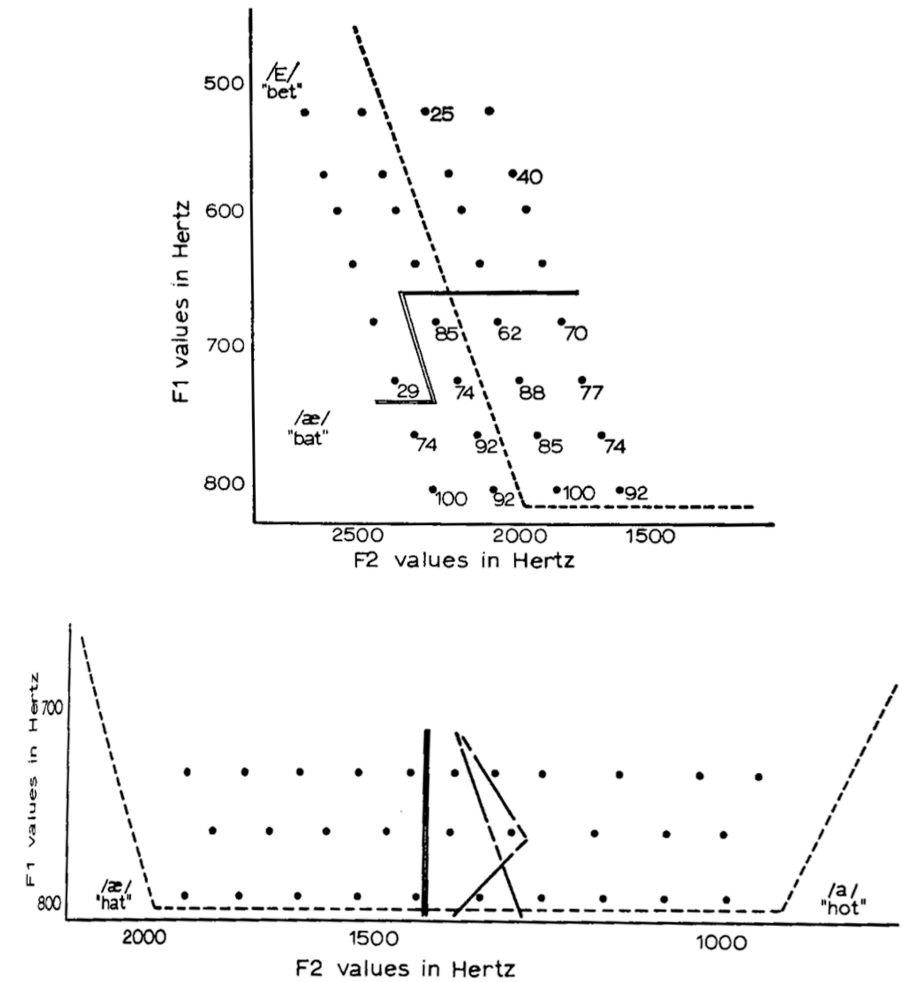

Figure 4: Willis' (1972) results. At top, the division between the perceptual *bet* and *bat* categories is marked for Ontario speakers (bold line) and Buffalo speakers (dotted line). At bottom is the division of *hat* vs. *hot* (though note that ON = dotted line and NY = bold line).

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[2] Willis does not differentiate between the /ɔ/ categories of Canadian English and Buffalo English, which technically do not refer to the same vowel. For instance, in Canada, the /ɔ/ category would include both *hot* and *hawk*, whereas in Buffalo those words contain different phonemes. For the sake of this discussion, both the merged Canadian vowel class and the Buffalo unmerged short vowel in *hot* are labeled /ɔ/.

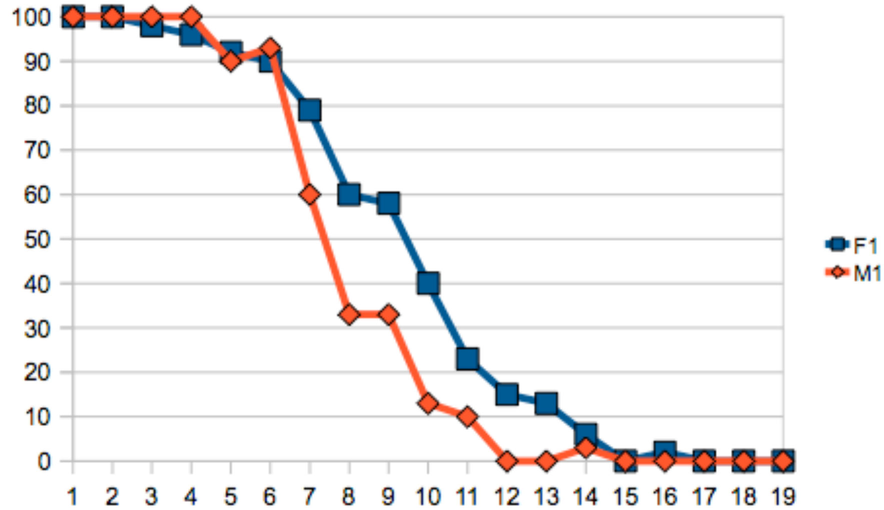


Figure 5: Results of De Decker (2010). Percent /æ/-categorization by gender in the adolescent group. Higher stimuli numbers are closer to *sock*, while lower ones are closer to *sack*.

A later study of Canadian speech was carried out by De Decker (2010), who tested vowel assignments of /æ/ and /ɔ/ among Ontario English speakers of various ages. A speaker was recorded saying the word *sack*, and the vowel was resynthesized and reinserted into the consonant context to create 19 stimuli, with F1 held constant around 1000 Hz and F2 ranging from 2006 Hz to 1259 Hz. The result was a continuum of sounds from *sack* to *sock*, which participants listened to in random order and categorized as *sack*, *sock*, or "could be either". In his middle-aged and adolescent age groups, he found an effect of gender, with women consistently leading in the acceptance of tokens closer to [ɔ] as /æ/ (Figure 5).

In a handful of cases, perceptual investigations have also been paired with analyses of spoken language. Janson (1983, 1986) studied a vowel shift in Stockholm Swedish, eliciting participants' /o:/ and /a:/ vowels and administering a perceptual experiment involving a forced choice between the two vowels along a 20-step continuum. He found that the spoken difference between two generations' vowels was considerably larger than the difference in perceptual categorization, indicating that the shift in perception was lagging behind changes in production. Along the same lines, Kendall and Fridland (2010) investigated the Southern Vowel Shift in Memphis, Tennessee with a production/perception comparison study designed to study how individual variation in the production of /ɛ/ and /eɪ/ affected categorization of the two vowels along a seven-step continuum, given a forced choice. They found that listeners with greater degrees of /eɪ/ centralization in their own speech were more likely to perceptually centralize /eɪ/ – that is, they classified more central stimuli as /eɪ/ compared with non-shifted listeners. A follow up study confirmed these findings, suggesting that shiftedness and dialect region are both significant predictors of perceptual behaviour (Fridland and Kendall 2012).

Research Goals

This investigation into the Canadian Shift is composed of two experiments. Experiment I is a study of the non-high short vowels (/ɛ, æ, ʌ, ɔ/) in the spoken language of Anglophone Jewish Montrealers (n=28); in Experiment II, the same participants categorized a range of synthetically produced isolated vowel tokens ranging across the non-high region of the vowel space as members of the *bet*, *bat*, *but*, or *bought* phonemic classes.

I aim to address several questions in the realms of production and perception. Boberg (2008) concludes from his study of the Canadian English vowel system that "the regional profile of the Canadian Shift is far from clear" (137), and given how few studies have been carried out within each major Canadian city, new sociophonetic data has the potential to clarify the trajectory and operation of the CS. Experiment I will allow for a description of the nature of the CS in Montreal: Are /ɛ/ and /æ/ moving along F1, F2, or both? Who is leading the change? Based on previous studies in Montreal (Boberg 2005, 2008), Experiment I should hypothetically show /æ/ retracting and lowering in the vowel space, with /ɛ/ relatively stable along the F1 dimension but retracting in apparent time. General principles of sociolinguistic variation (Eckert 1989; Labov 1990) as well as previous CS literature (Boberg 2010; De Decker 2010; Hoffman 2010) predict that the group of younger females should be leading this 'change from below'.

If Experiment I finds /ɛ/ to be retracting in the F2 dimension, perception asymmetries are predicted to be found in apparent time such that the younger generation should classify as /ɛ/ a range of stimuli heard by older speakers to be /ʌ/. If /ɛ/ is lowering, there should be asymmetries between classifications of /ɛ/ and /æ/ for stimuli located in the front of the vowel space. In comparing the significance of vowel differences in both the productive and perceptual domains, it is hoped that this study will provide insight into ordered heterogeneity within a single language community and contribute to the literature on the nature of diachronic sound change.

Methodology

Community Selection and Participant Recruitment

Over the course of the 18th and 19th centuries, several Anglophone communities took root in the Montreal as successive waves of immigrants from the British Isles, Italy, and Eastern Europe settled in the city and adopted (or retained) English as a home language. Following Quebec's *Quiet Revolution* in the 1960s, legislation enshrining French as the sole language of government, business, and schooling prompted an 'exodus' of Anglophones from the province; since the 1970s, Montreal has lost over a third of its English-speaking population, mostly to English Canada and the United States (Boberg 2010). Greater Montreal's approximately 377,000 residents who solely speak English at home, along with nearly 450,000 home speakers of English plus another language, are now greatly outnumbered by their monolingual Francophone counterparts (Statistics Canada 2011). Despite – or perhaps thanks to – their small numbers and geographic isolation, Anglophones in Montreal have retained distinctive dialects that differentiate them not only from other Canadians, but from each other. Boberg (2004) has described the three main ethnic varieties of Montreal English as those of British/Irish, Italian, and Jewish-identified speakers and their heavily ethnically homogeneous communities.

To control for the effect of local ethnolect, this study is limited to the city's Jews, who comprise one of the city's well-established English-speaking populations (pop. 80,000; Boberg 2004).[3] In order to qualify, subjects needed to have been born in Montreal to at least one Jewish parent, had to report English as a first or home language, and had to have unimpaired hearing.

[3] This study excluded Hasidic and Ultra-Orthodox Jewish communities, in which Yiddish tends to be the home language.

Participants were recruited through several channels: some were family friends who were contacted personally, while others responded to postings on the McGill University Classifieds website, fliers at the McGill campus Hillel House, or advertisements placed in the weekly bulletin of a Reconstructionist synagogue. Though many older participants had grown up in the historically Jewish neighbourhoods of Outremont and Mile End, located north and east of the city's main topographical landmark, Mount Royal, nearly all had resided for many years in the island's heavily Anglophone Westmount, Hampstead, Notre-Dame-de-Grâce, and Côte-St-Luc areas. All younger participants grew up and/or were currently residing in these and other Anglophone neighbourhoods to the west and south of Mount Royal. Several participants identified themselves as Sephardic Jews (with North African heritage), but Ashkenazi Jews (with Central and Eastern European heritage) made up the majority of the sample.

	Female	**Male**
Younger	1991	1995
	1989	1992
	1988	1992
	1988	1991
	1984	1989
		1988
		1987
Older	1961	1961
	1957	1960
	1952	1957
	1950	1953
	1937	1949
		1949
		1949
		1949
		1949
		1943
		1940

Table 1: Subjects, by year of birth and gender
Younger Females n=5
Older Females n=5
Younger Males n=7
Older Males n=11

Interview

The interview consisted of three main parts. First, subjects were asked to sign a consent form and verify basic demographic information. Next, they were recorded reading a list of 44 sentences containing words with the stressed /ɛ/, /æ/, /ɔ/, and /ʌ/ vowels (Table 2; Appendix). Target words were (mostly) controlled for the voicing, place, and manner of articulation of the consonant following the vowel; these linguistic factors have been shown to variably favour or inhibit shifting, unlike the status of preceding consonants (De Decker and Mackenzie 2000). Finally, participants put on headphones and did the perception task, Experiment II.

Following Consonant	**ʌ**	**ɔ**	**ɛ**	**æ**
voiced stop	hug	knob	beg	lab
voiced stop	mud	nod	bed	bad
voiced fricative	buzz	cause	says	jazz
alvelolar nasal	run	gone	pen	pan
bilabial nasal	gum	mom	gem	ham
open syl + lateral	gully	holly	belly	valley
closed syl + lateral	gull	mall	sell	Sal
voiceless stop	stuck	sock	neck	stack
voiceless stop	mutt	lot	bet	rat
voiceless fricative	rough	soft	Stef	staff
voiceless fricative	fuss	loss	Jess	pass

Table 2: The 44 target words elicited in the sentence list.

Interviews were carried out in several locations in order to minimize inconvenience to and maximize the potential number of participants. The interviews done in the sound-attenuated booths in the McGill Linguistics Building used a combination microphone-headphone set for both the perception and production tasks, with data recorded directly into Praat version 5.3.37 (Boersma and Weenink 2013) at a sampling rate of 44100 Hz; interviews in participants' homes and offices were recorded using a professional high-definition USB recorder, and a set of over-ear Sennheiser headphones were used for the perception task. In the booth setting, a desktop computer and wired mouse were used, while a laptop and wireless mouse were employed in off-campus interviews. When possible, the subject was left alone in the room or booth for both Experiments I and II.

Experiment II: Designing the Task and Preparing Stimuli Tokens

Experiment II was modeled on the perception study carried out by Willis (1972), but modified in several respects. His demonstration of differences in listeners from two neighbouring dialects demonstrated that this appealingly simple type of synthetic vowel perception test could allow for "rapid and objective collection of data relevant to phonetic features of spoken dialects" within a two-dimensional range of F1 and F2 values (Willis 1972, 246; Figure 4). Experiment II experiment aimed to apply such a methodology to a single speech community undergoing a sound change in progress, and instead of testing differences between pairs of vowels (e.g., a forced choice between *hat* and *hot*), the four structurally related vowels /ɛ/, /æ/, /ʌ/, and /ɔ/ were investigated at once, with a forced choice among all four phoneme classes for all vowel stimuli.

Willis' (1972) vowel stimuli were each 300ms long and were played twice to each participant, with one second of silence between the two stimulus iterations. The average duration of stressed short vowels, however, ranges from about 75ms to 250ms in North American English (Escudero and Polka 2003; Wang and Van Heuven 2006). In trials of the Experiment II, isolated stimuli shorter than 250ms were found to be difficult to perceive and categorize, but vowels as long as 300ms seemed unlikely to reflect the natural duration of the non-high short vowels. The stimuli were therefore set at 250ms in duration; any confusion with the long vowels originating in that area of the vowel space (/oʊ/ and /eɪ/) was conceivably avoided because of the stimuli's lack of off-glides, as well as the nature of the forced selection task. In addition, each stimulus was played to each subject only once. The literature on response time in categorical perception indicates that since different people will take different amounts of time to respond to stimuli (and may respond with increasing speed as they become more familiar with the test), playing each stimulus twice could result each response taking advantage of different processing mechanisms;

if the mapping from one token to a phoneme was obvious to the listener just after hearing the first token, this is not necessarily comparable to a response that took the listener two listens to decide upon (Pisoni and Tash 1974; Miller 2001). A 150Hz tone of 250ms duration was used as a mask, since auditory masking between stimuli has been found to wipe working memory and encourage categorical memory trace (Massaro 1972).

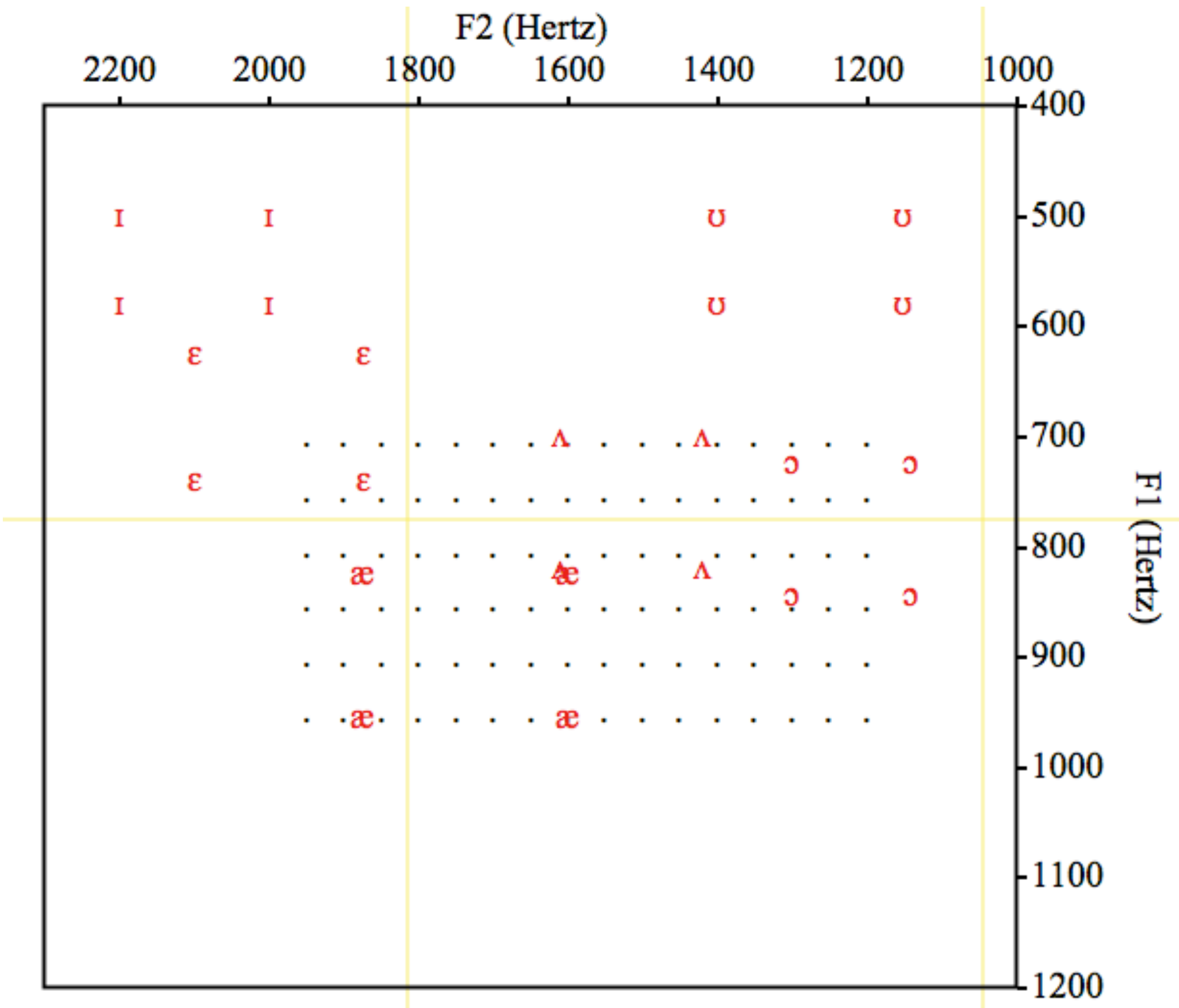


Figure 6: Experiment II Stimuli, arranged in the vowel space according to F1 and F2. Red letters indicate the approximate fields of dispersion ±1std dev from the mean of all Montreal English speakers (Boberg 2005). Black dots indicate the location of each stimulus, placed every 50 Hz from F1=700–950 Hz and F2=1200-1950 Hz.

Human-sounding vowel stimuli with exact F1 and F2 trajectories were synthesized using slightly adjusted version of a Praat script developed by Brasileiro Reis Pereira (2009). Each stimulus had a falling fundamental frequency (F0) contour from 150Hz to 100Hz, making the vowels sound surprisingly natural. In order to test small differences in phoneme classification in the non-high region of the vowel space, 96 stimuli were produced with F1 ranging from 700 Hz to 950 Hz and F2 ranging from 1200 Hz to 1950 Hz. Stimuli were regularly spaced 50 Hz away from each other along both F1 and F2 (Figure 6). A sound chainer script developed by Antoniou (2010) consolidated the mask, stimulus, and two silences into single .wav files (Figure 7).

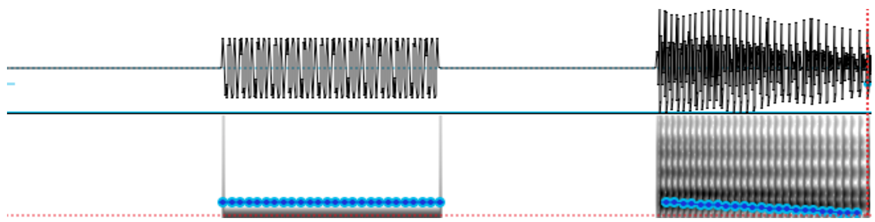


Figure 7: Example audio file. After each click, 250ms silence + 250ms mask tone + 250ms silence + 250ms vowel stimulus.

Subjects were presented with each stimulus once, and stimuli were presented to all subjects in a single random order. The program used for Experiment II was a JavaScript code run on Firefox 3.0. After participants read the on-screen instructions, a mouse click would begin the training exercise, a selection of six stimuli (in addition to the 96 'real' ones) that would not be analyzed. After each click, four large buttons of equal size, with the labels BAT, BET, BUT, and BOUGHT, would appear on the screen (Appendix). Participants matched the sound they heard with the word in which they though it most likely to belong. Between each click to select a vowel category and the onset of the vowel sound 750ms later, the buttons vanished and the screen was blank, providing a visual indication of the separation between each stimulus.

Experiment I: Measurement and Normalization of Production Data

Audio recordings were saved in the .wav format and passed through the Prosodylab-Aligner software to force-align all phonemes and words with corresponding text in Praat interval tiers (Gorman, Howell, and Wagner 2011). In addition to analyzing the 44 tokens of stressed short vowels, F1 and F2 measurements were extracted from 22 anchor vowels in more peripheral regions of the vowel space in order to properly normalize the phonetic data (Appendix); these words were taken the sentences providing surrounding context to the stressed short-vowel target words. As recommended by Harrington and Cassidy (1994), F1 and F2 data were extracted from the midpoint of each short vowel and the 33% and 66% points of each long/diphthongal vowel, using slightly modified versions of a Praat script by Lennes (2003). Adjustments to Praat's formant-identification settings were done on a speaker-by-speaker basis, with each token checked for accuracy. In the whole data set, only a handful of tokens were excluded, most of which were mispronunciations of the target word *holly* as *holy* (for instance, note the missing *holly* in Figure 10).[4]

Normalization of all phonetic measurements is essential to account for the natural physiological differences between human vocal tracts. As part of the perception process, listeners naturally normalize the wide interspeaker variation apparent in phonetic measurements, and measurements of formant values of two speakers producing 'identical' sounds may actually be very different (Johnson, Strand and D'Imperio 1999; Watt, Fabricius, and Kendall 2011). The NORM online software suite was used for all normalization and plotting, and the method described by Lobanov (1971) was selected because it does "an excellent job of factoring out physiologically-caused

[4] I suppose the most common usage of the word *holly* is in conjunction with festive events not applicable to a Jewish sample.

differences in formant values while retaining sociolinguistic differences" (Thomas and Kendall 2007, online; Adank et al. 2004). Plots generated by NORM were rescaled into Hertz in order to orient the vowels in relation to each other in a more familiar way, though these formant values are not directly comparable to those of the synthetic vowels of Experiment II. In fact, even the formants of naturally produced speech are to some degree non-comparable between speakers, let alone compared to synthetic sound (Janson 1983).

Results and Analysis

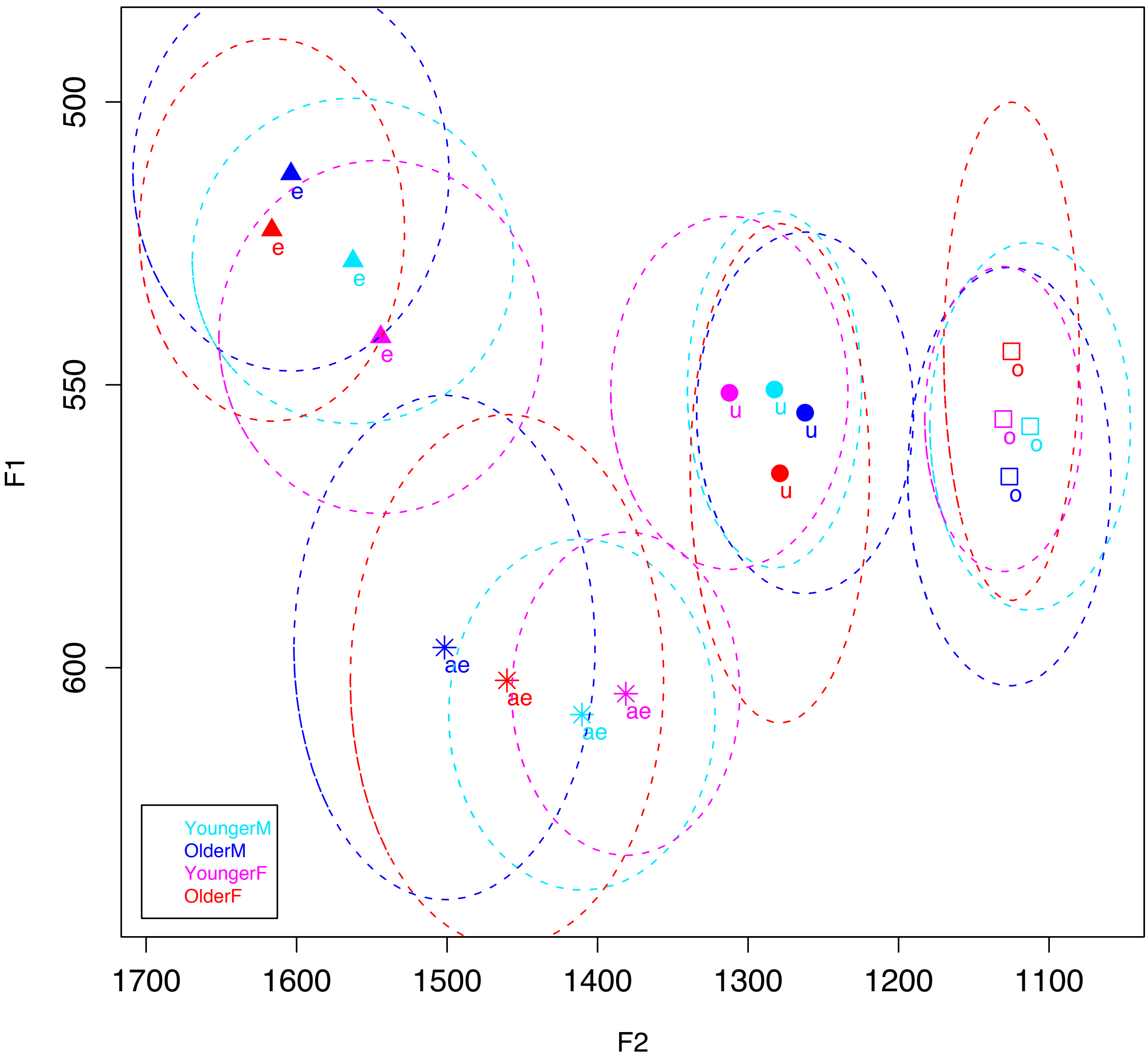
Experiment I: Production

Vowel	Age	Gender	Gender/Age
F1 ʌ	0.0683	0.1401	0.2197
F2 ʌ	0.0005	0.0053	0.4193
F1 ɛ	0.0000	0.0034	0.6545
F2 ɛ	0.0000	0.8990	0.2090
F1 æ	0.0637	0.7649	0.3194
F2 æ	0.0000	0.0017	0.5855
F1 ɔ	0.5602	0.0034	0.0178
F2 ɔ	0.3890	0.3350	0.2000

Table 3: Experiment I, Two-Way ANOVA, interactions of age group and gender (p-values)

Based on the results of Boberg (2005), it was hypothesized that Experiment I would show /æ/ to be retracting and lowering, with /ɛ/ retracting in the vowel space and /ʌ/ and /ɔ/ staying relatively stable. Figures 8 and 9 demonstrate that this prediction is partly borne out, with some important deviations from the expected pattern. As shown in Table 3, age and gender were found to have several significant effects on vowels' F1 and F2 values in a two-way between-subject ANOVA. There was no statistically significant effect on the F1 of /ʌ/, but age ($p<.001$) and gender ($p=.005$) significantly affected its F2. The F1 of /ɛ/ was affected by age ($p<.001$) and gender ($p=.003$), while the F2 of /ɛ/ differed only by age ($p<.001$). The F1 of /æ/ was not significantly affected by age or gender, but its F2 differed by both and age ($p<.001$) and gender ($p=.001$). /ɔ/ was only significantly affected in its F1, by gender ($p=.003$) and an interaction of age and gender ($p=.01$).

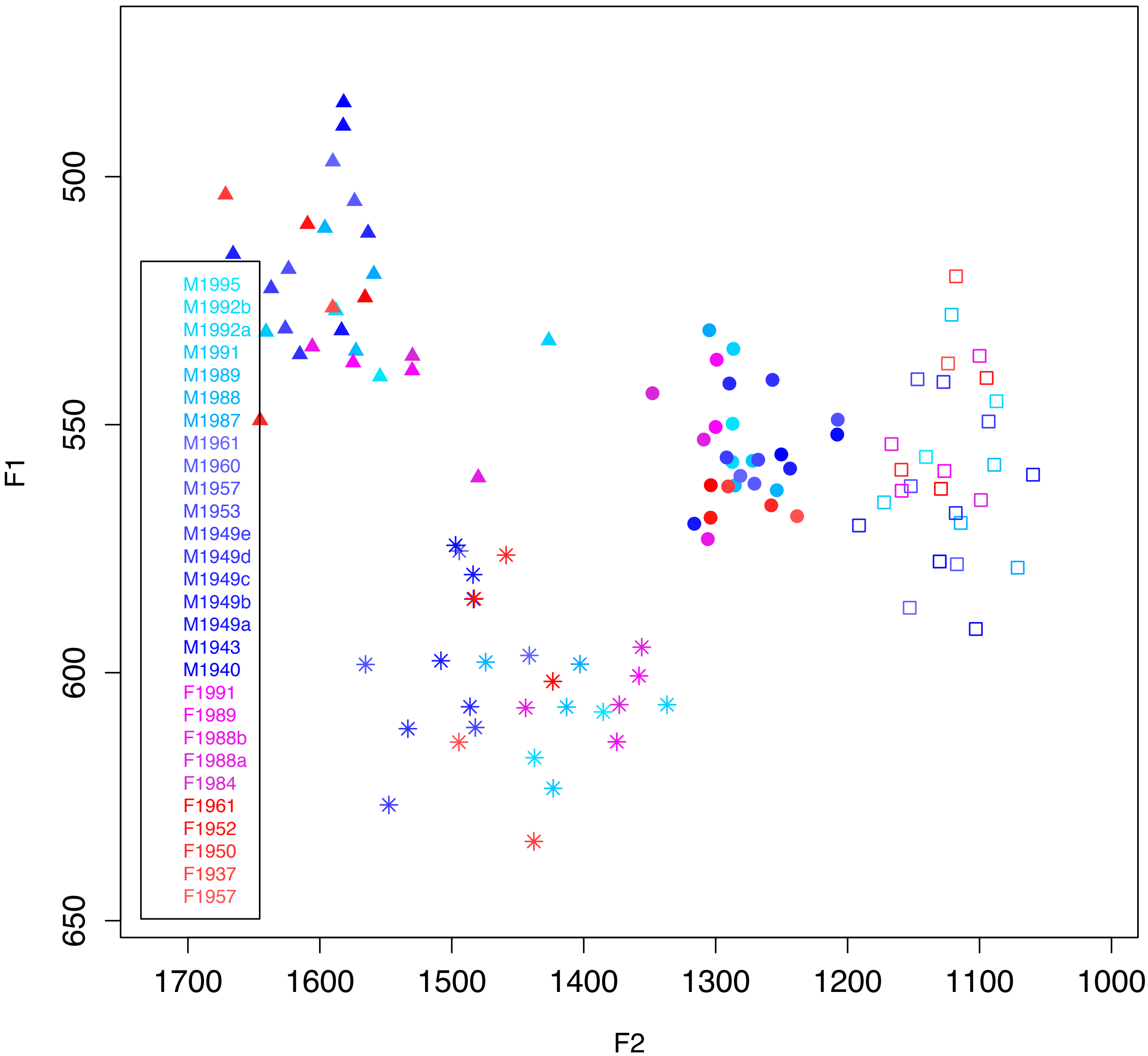
Figure 8: Lobanov-normalized age/gender group means, /æ/, /ɛ/, /ʌ/, and /ɔ/.



Note:
ae = /æ/
e = /ɛ/
o = /ɔ/
u = /ʌ/

Ellipses mark ±1 standard deviation from the group mean.

Figure 9: Lobanov-normalized individual speaker means, /æ/, /ɛ/, /ʌ/, and /ɔ/.



Legend:
Star = /æ/
Triangle = /ɛ/
Circle = /ʌ/
Square = /ɔ/

Though younger speakers as a whole pronounced /ɛ/ with comparatively high F1 values, it seems that subject F1988a (Figure 10) was extreme in this regard. In the normalized data, she is the only participant to produce an /ɛ/ vowel with a mean F1 greater than 550 Hz. She and subject M1992a (Figure 11) were also the only two speakers whose normalized mean /ɛ/ F2 values were below 1500 Hz.

Figure 10: Subject F1988a. Individual non-high short vowels, non-normalized.

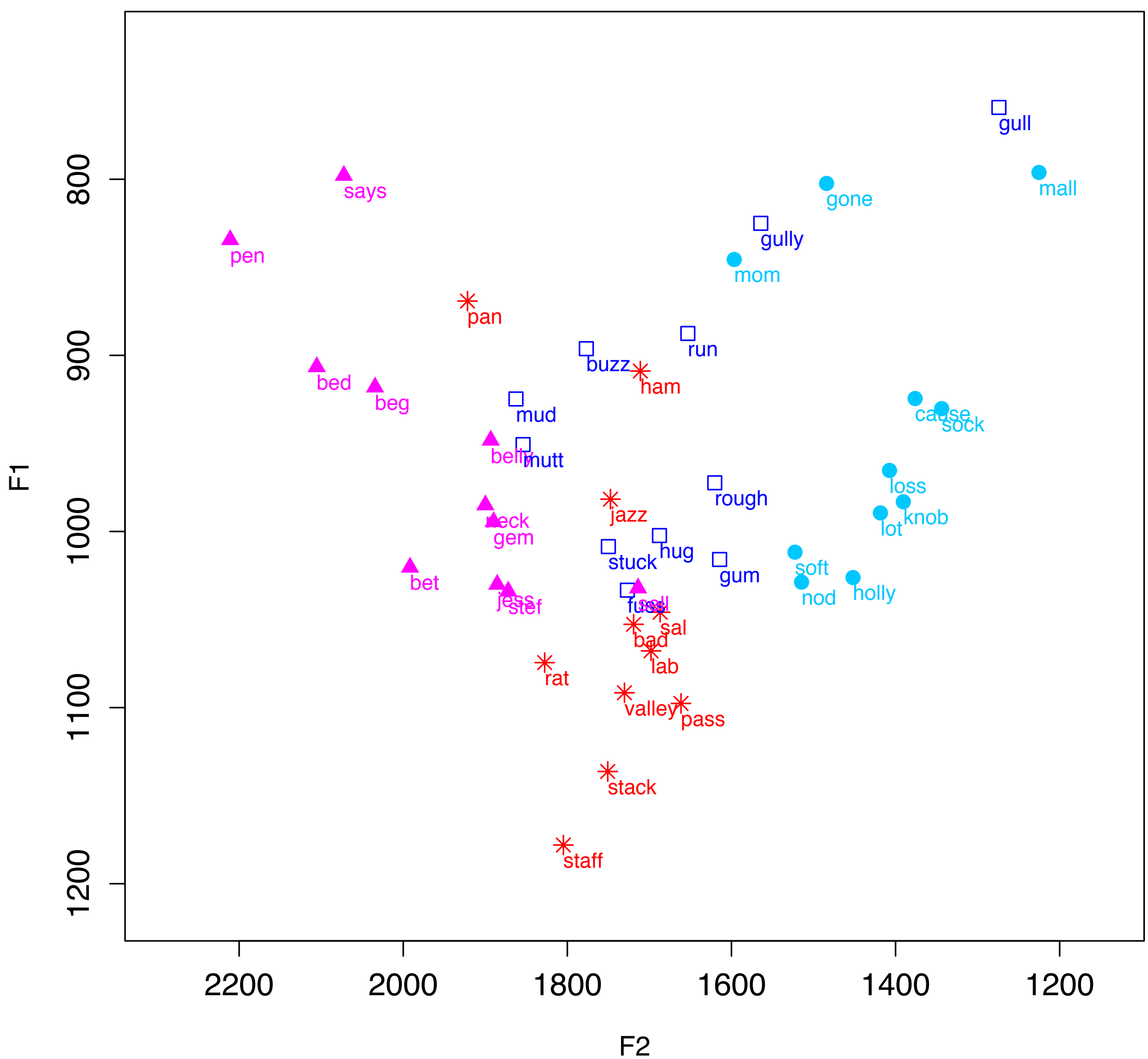
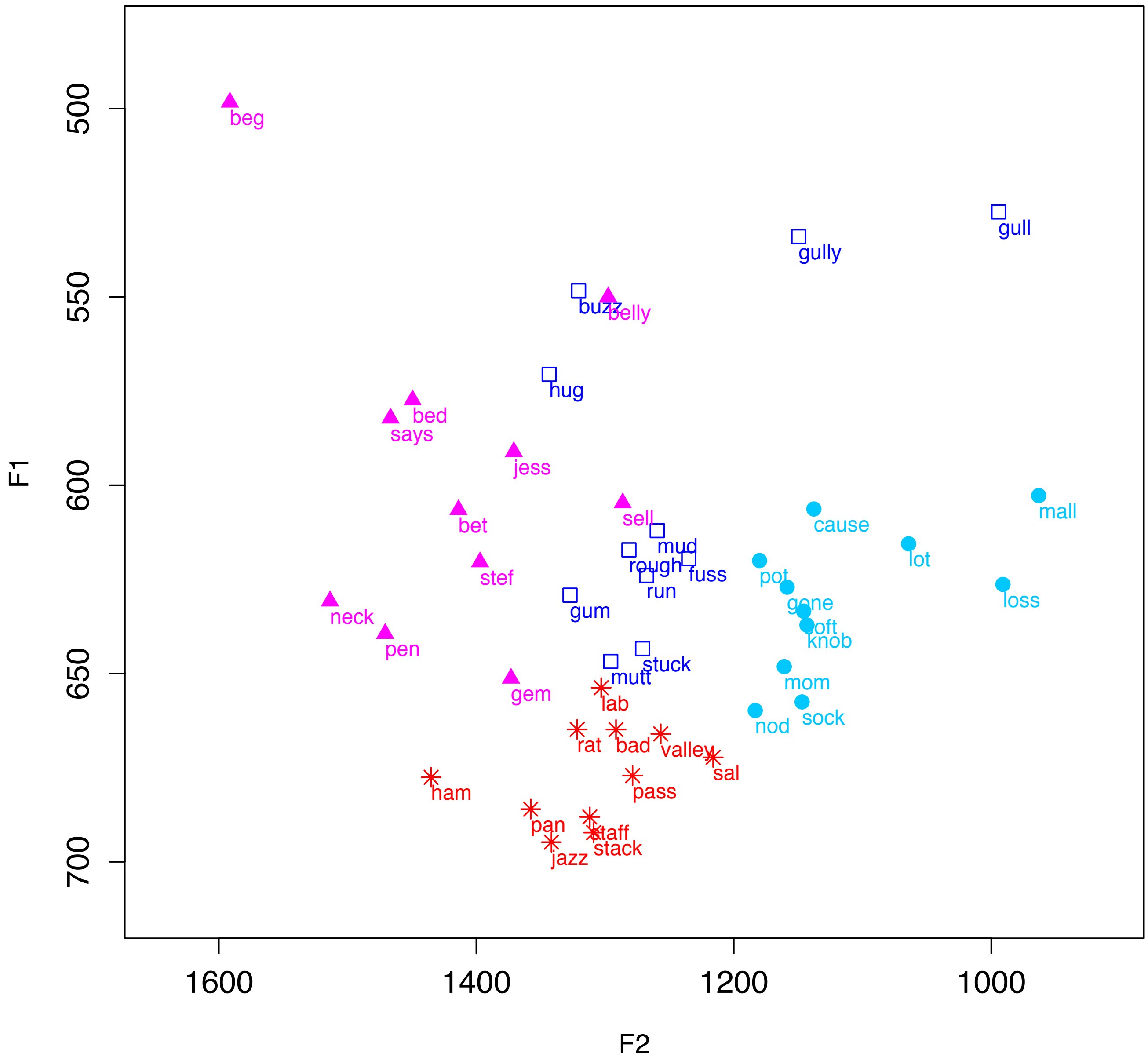


Figure 11: Subject M1992a. Individual non-high short vowels, non-normalized.



Of note here is the difference between the two subjects' fields of dispersion of /æ/ (discussed further in the Discussion section). While M1992a has an /æ/ vowel which stays consistently in the back-central position, F1988a shows a pattern of /æ/-raising before nasals, producing *ham* and *pan* with considerably lower F1 values than the rest of the target words. The intrusion of M1992a's /ɛ/ into his /ʌ/ space is especially striking in the pre-lateral contexts of *sell* and *belly*, but F1988a's /ɛ/ shows far more evidence of movement into the space of her /æ/.

Experiment II – Perception

Vowel	Gender	Age	Gender/Age
F1 ʌ	0.9850	0.3244	0.7669
F2 ʌ	0.6601	0.4654	0.9609
F1 ɛ	0.0230	0.3167	0.2426
F2 ɛ	0.2663	0.2663	0.1878
F1 æ	0.3126	0.8182	0.4907
F2 æ	0.2861	0.8535	0.5861
F1 ɔ	0.0217	0.0034	0.0008
F2 ɔ	0.0200	0.0121	0.0020

Table 4: Experiment II, binomial logistic regression (p-values)

Table 4 lists the results of the binomial regression analysis for the effect of gender, age, and an interaction of the two on the perceptual categorizations of each value, along the F1 and F2 dimensions. /æ/ was categorized very similarly by all groups, and /ʌ/ exhibited too much random variation to for there to be any statistically significant effects on its selection (Appendix). /ɛ/ also lacked a significant age effect, but was significantly affected by gender along both dimensions (F1 p=.02, F2 p<.01). Interestingly, it was /ɔ/, one of the more stable vowels of the sub-system, which demonstrated effects of age (F1 p<.01, F2 p=.01), gender (F1 p=.02, F2 p=.02), and an interaction of the two (F1 p<.001, F2 p=.002).

Since the perception stimuli were spaced along both the F1 and F2 dimensions, response data can be presented in a number of ways to illustrate how these Montrealers' perceptual categorizations of isolated vowels differ by age and gender group. At the most basic level, Figures 12-15 show majority responses for the entire grid tested divided by age and gender group, and the tables in the Appendix show responses visualized by group and vowel (cf. Figure 6). While they do a good job of depicting the slight but statistically significant difference in /ɔ/ classification between groups, the role of /ɛ/ is not as clear. To better visualize where the groups drew their perceptual boundaries between /ɛ/, /ɔ/, and /ʌ/, cross-sections were taken along the F1=700 dimension, or the top row of the perception grid (Figures 16-19).

Older Listeners	1950			1800		1700		1600		1500		1400		1300		1200
700	ε	ε	ε	ε		ε	ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ɔ	ɔ
750	ε	ε	ε	ε	ε	ε		ʌ	ʌ	ʌ	ʌ	ʌ	ʌ		ɔ	ɔ
800	ε	ε	ε		ε	æ	ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ɔ	ɔ	ɔ
850	ε	æ	æ	æ	æ		æ	æ	æ	æ				ɔ	ɔ	ɔ
900	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ		ɔ		ɔ
950	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	ɔ		ɔ	ɔ

Figure 12: Older listeners' categorizations

Younger Listeners	1950			1800		1700		1600		1500		1400		1300		1200
700	ε	ε	ε		ε		ε	ε				ʌ	ɔ	ɔ	ɔ	ɔ
750	ε	ε	ε	ε	ε	ε	ε		ʌ			ʌ		ɔ	ɔ	ɔ
800	ε	ε	ε	ε	ε	æ	ε	ʌ	ʌ					ɔ	æ	ɔ
850		æ	æ		æ		æ	æ	æ	æ					ɔ	ɔ
900	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	ɔ	ɔ	ɔ
950	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ			ɔ	

Figure 13: Younger listeners' categorizations

Male Listeners	1950			1800		1700		1600		1500		1400		1300		1200
700	ε	ε	ε	ε			ʌ	ʌ	ʌ	ʌ	ʌ	ʌ	ɔ		ɔ	ɔ
750	ε	ε	ε	ε	ε	ε	ε		ʌ	ʌ	ʌ	ʌ	ʌ	ɔ	ɔ	ɔ
800	ε	ε	ε		ε	æ		ʌ	ʌ	ʌ	ʌ		ʌ	ɔ	ɔ	ɔ
850	ε	æ	æ	æ	æ	æ	æ	æ	æ	æ			ɔ		ɔ	ɔ
900	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	ɔ	ɔ	ɔ
950	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	ɔ		ɔ	ɔ

Figure 14: Male listeners' categorizations

Female Listeners	1950			1800		1700		1600		1500		1400		1300		1200
700	ε	ε	ε	ε		ε			ε		ʌ	ʌ	ʌ	ʌ	ɔ	ɔ
750	ε	ε	ε	ε	ε	ε	ε		ʌ	ʌ	ʌ	ʌ	ʌ			ɔ
800	ε	ε	ε	ε	ε	æ			ʌ			ʌ		ɔ		ɔ
850	æ		æ	ε	æ	ε	æ	æ	æ	æ						ɔ
900	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ		ɔ	ɔ
950	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ	æ		æ	ɔ	

Figure 15: Female listeners' categorizations

Note: where a stimulus did not receive more than 50% of responses, it is left blank.

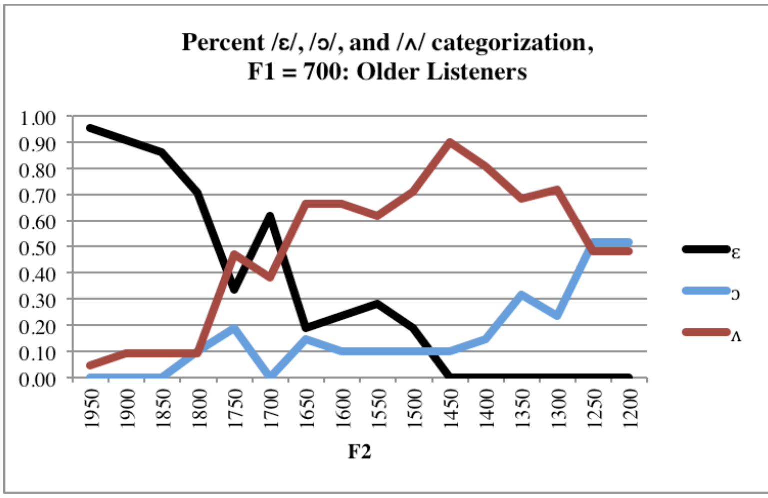


Figure 16

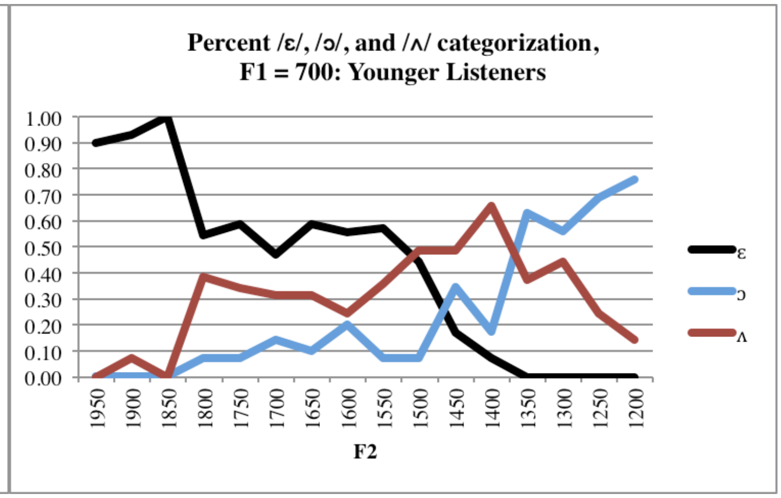


Figure 17

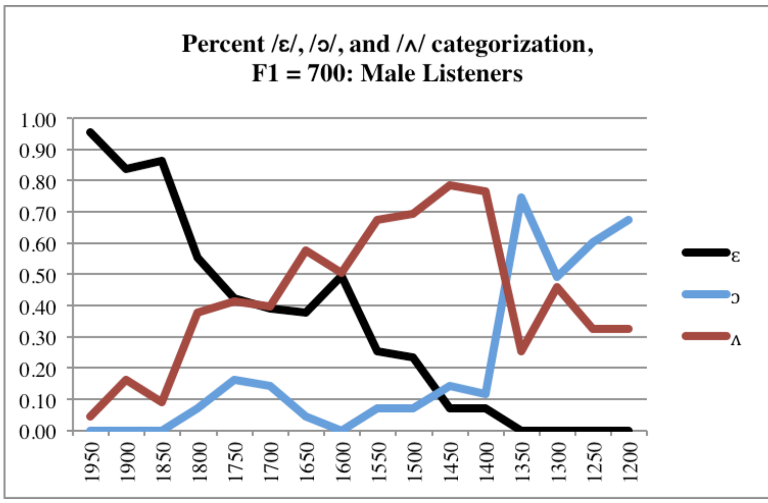


Figure 18

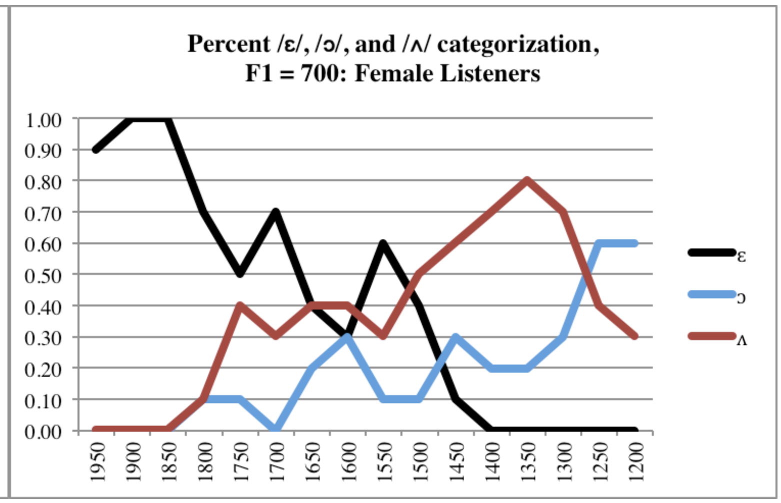


Figure 19

Vowel	Gender	Age	Gender/Age
F2 ʌ	0.0206	0.0814	0.2989
F2 ɛ	0.1980	0.1530	0.3770
F2 ɔ	0.0097	0.0398	0.0328

Table 5: Binomial logistic regression for responses along the F1=700Hz axis (p-values)

Seen along the F1=700 cross-section, some effects of age on /ɛ/ (though for some reason not statistically significant) can be observed. While the older group classified no stimuli with F2<1700 as /ɛ/ more than 30% of the time, while younger listeners take until F2<1500 to drop below that threshold. The lines of /ɛ/ and /ʌ/ cross each other between F2=1800 and F2=1750 and between F2=1700 and F2=1650 for older listeners; the crossover to hearing /ʌ/ for younger speakers is much farther back, at F2=1500.

Looking at the F2=1900 cross-section (Figures 20 and 21), it is also clear that the perceptual divide between /æ/ and /ɛ/ around F1=1900 has remained relatively stable, remaining around F1=850 for both age groups.

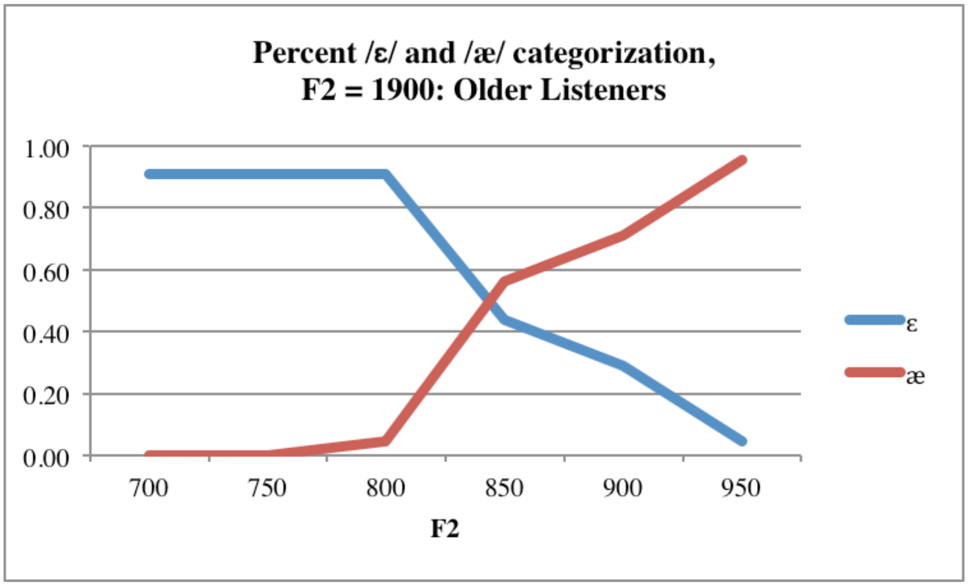


Figure 20

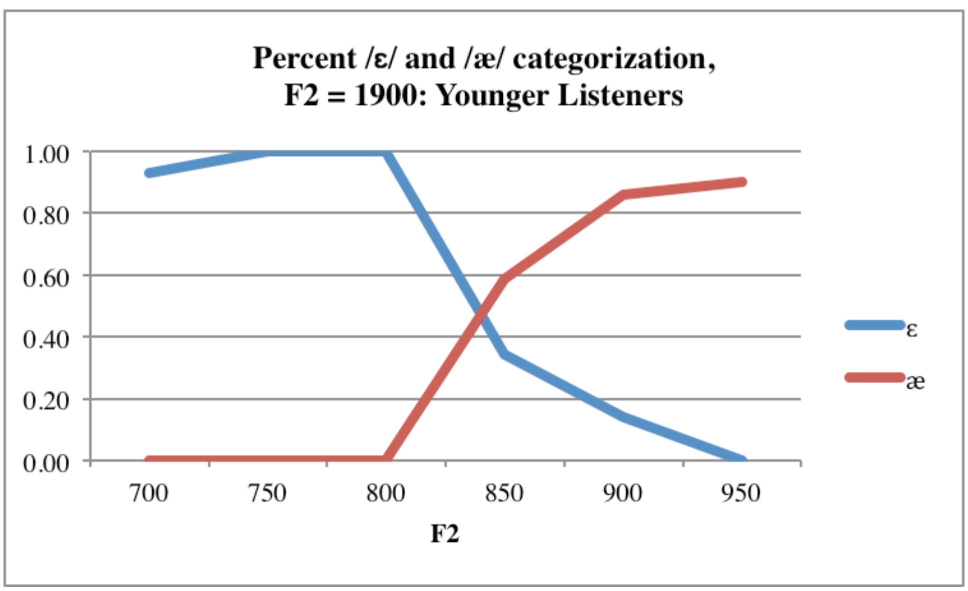


Figure 21

Discussion

Perception and Production on the Move

As predicted, Experiment I demonstrates that /æ/ and /ɛ/ are shifting in apparent time in the vowel spaces of English-speaking Montrealers. An analysis of interspeaker variation shows a significant degree of ordered heterogeneity, with young women leading the change and older males retaining the most conservative pronunciations, the typical progression for a sound change advancing in a community below the level of consciousness (Eckert 1989; Labov 1990). But in contrast to what Boberg (2005) found, it seems as though the operation of the CS in Montreal involves the retraction of /æ/ without any accompanying lowering, while /ɛ/ is simultaneously backing and lowering in the vowel space.

One implication of this finding could be that since Boberg's (2005) study of Montreal, the change has progressed in real time and changed its trajectory. The eldest speakers in his sample was born in 1919, and the youngest in 1981; the birth years of my older group range from 1937 to 1961, while my younger group ranged from 1984 to 1992. Given that there is a gap of three years between his youngest subject and the eldest member of my younger group, the generations are clearly not comparable. It therefore seems likely that over the last decade, /æ/ has 'bottomed out', as it were, having lowered as far in the vowel space as it will go, and is now retracting; though the initial stages of /ɛ/-movement in Montreal may have been only along the F2 dimension, it seems that it is now backing *and* retracting into the space being vacated by /æ/. This provides evidence for Roeder and Jarmasz's (2010) proposal that the Canadian Shift initially operates as a combination of backing and lowering of /æ/ and /ɛ/, before those vowels stop lowering and only continue to retract (Figure 3).

It is unclear, though, why there is a statistically significant difference between how groups produce the F2 of /ʌ/ and the F1 of /ɔ/. Roeder and Jarmasz (2010) do not even consider /ʌ/ in their analysis of the Canadian vowel system, an oversight which ignores the potential for /ʌ/ to move out of the way as /ɛ/ intrudes into its margins of security. For instance, one might expect to find it retracting toward /ɔ/, as in Chicago (McCarthy 2010). /ʌ/ appears, however, to be moving in the opposite direction. This raises the possibility that a merger between /ʌ/ and /ɛ/ could result from this shift; however, given that the means of all groups' /ʌ/ lie within the area where all of their standard-deviation ellipses overlap, the change does not seem to be moving very fast, nor is it very significant at the moment. For this reason, it is also doubtful whether the finding that the F1 of /ɔ/ is higher among females than males is truly significant. Nonetheless, it does suggest that /ɔ/ is *not* retracting in Montreal, in contrast to Roeder and Jarmasz's (2010) evidence from Toronto, though women may be leading an incipient change whereby /ɔ/ moves up the back periphery of the vowel space.

The pattern of /æ/-raising before nasals and an /ɛ/ vowel shifted into the /æ/ space rather than more typical Montreal intrusion on /ʌ/ was noted for subject F1988a (Figure 10; cf. more typical Montreal vowel space, Figure 11). As it happens, F1988a was recorded at her family's home in Montreal, but had been living in Toronto for a year and a half for work. The locations of her vowels therefore seems to reflect a shift in her production norms towards those of Toronto, including its pre-nasal /æ/-raising pattern and lowering of /ɛ/ (Boberg 2008).

In Experiment II, why are /æ/ and /ɛ/, the most rapidly moving vowels in the system, apparently so stable with regard to age effects (Table 4)? It is surprising that the striking pattern of differential /ɛ/-/ʌ/ crossover in Figures 16 and 17 is not statistically significant for age, since the results seem to clearly indicate that the original prediction – namely, that /ɛ/ retracting along F2 would have the effect of measurably ‘pushing back’ acceptance of /ɛ/ by younger speaker – were borne out. Perhaps one clue lies in the fact that younger speakers “still must classify the older generations’ sounds correctly – something they learned when they were small children. Thus perception cannot shift too radically away from the parents’ pattern” (Janson 1983, 31). But though they must be able to perceive older generations’ sounds correctly, a more important priority – for all humans, regardless of age – is usually the perception of peers’ speech. This raises the possibility that while older and younger groups are accepting a relatively similar spread of stimuli as /ɛ/ and /æ/, younger listeners are far more ambivalent about it: along the F1=700 cross-section, /ɛ/ assignment remains around 50% for the younger group from F2=1800 to F2=1500, while it finally drops below 50% at F2=1650 for older listeners. Boberg (2005) noted that “the retraction of /ɛ/… diminishes the margin of security between /ɛ/ and /ʌ/, potentially causing *deck* and *best* to sound like *duck* and *bust*,” but the results of Experiment II suggest that only the older generation is likely to misperceive /ɛ/ in this way. Younger listeners, given no contextual information to aid their interpretations, are less consistent in their responses to stimuli lying between their mental exemplars of /ɛ/ and /ʌ/; older listeners have no such issue, because it is less relevant for their perception to register more retracted vowels as /ʌ/. De Decker (2010) summed up his findings for /æ/ with regard to F2 (Figure 5):

> There is no evidence to suggest that a *shift* in the overall category range is underway…but the apparent-time data strongly show an *extension* of the right edge among younger listeners… All listeners in this sample would find forms at the onset of the /æ/-range relatively unmarked, though older listeners should consider forms that the most advanced younger speakers produce (i.e. extending beyond the offset) as marked-sounding. These younger speakers, however, should judge them to be equally fine as the forms at the onset.

This is strikingly similar to the pattern found with /ɛ/ in the present study, and may reflect a common progression throughout Canada – or even a more universal mechanism for phonetic change.

Methodological Considerations with Experiment II

The vowel stimuli in Experiment II were in isolation, with no surrounding consonantal context. Other successful perception studies have nested their vowel stimuli between consonants (De Decker 2010, Plichta and Rakerd 2010). Though several studies (Strange et al. 1976; Strange, Edman, and Jenkins 1979; Rakerd 1984; Fox 1989) have indicated that a CVC stimulus improves accuracy in vowel categorization tests, Macchi (1980) "failed to provide evidence that vowels spoken in consonantal context are better identified than naturally produced isolated vowels" (1641). This finding was supported by Diehl, McCusker, and Chapman (1980) and Strange, Jenkins, and Johnson (1983), who found that error rates in phoneme mapping with isolated short vowel stimuli were relatively low.

For simplicity's sake, and to encourage participants to respond quickly instead of spending time searching the screen, the *bet*, *bat*, *but*, and *bought* buttons were presented in the same order each time (Appendix); according to Clopper, Hay, and Plichta (2011), however, this opens the door to participant response bias, as subjects tend "to respond with the leftmost (or topmost) item" (155). Diehl, McCusker, and Chapman (1980), however, note that "anything that enhances the stability of the stimulus representation in short-term memory should also enhance identification performance" (243).

While Experiment II aimed to record individuals' 'default' vowel mapping devoid of social calibration, the sheer variety of significant influences on perception demonstrated by intra- and inter-speaker studies cast doubt on whether completely unbiased categorization is even possible. Knowledge of a speaker's gender has been found by multiple studies to play a part in speech perception (Johnson, Strand, and D'Imperio 1999, Strand 1999), just as listeners calibrate their perception to speaker age (Drager 2010). Niedzielski (1999) found that white residents of Detroit, completely unaware of their own participation in the Canadian Raising of /aw/ (e.g. [hʌʊs] and [ʌʊt] for *house* and *out*), were able to accurately perceive a fellow Detroiter's /aw/ vowel as raised [ʌʊ] *only* when told that the speaker was Canadian; if told that the speaker was from Michigan, they seemed oblivious to the raised vowel and instead matched it with variants of [aʊ] present in Standard American speech, but in neither the listeners' own speech nor the speech of the stimulus-speaker. Hay and Drager (2010) studied a group of New Zealanders in a similar experiment: two groups of participants matched natural vowels in the *fit*/*hit* class produced by a fellow New Zealander to vowels on a synthesized continuum ranging from New Zealand-like [ə] to Australian-like [i]. The group exposed to stuffed toy kangaroos and koalas while doing the experiment consistently perceived the speaker's vowels as closer to the stereotypical Australian [i] pronunciation, while those in a room with stuffed toy kiwi-birds heard the identical stimuli as closer to the New Zealand [ə]. These findings were consistent with an earlier study on exemplar priming by Hay, Nolan, and Drager (2006) which found the same effect in two groups responding to New Zealand *fit*/*hit* vowel stimuli on an answer sheets labeled either 'Australian' or 'New Zealander'. The results of these studies have several implications: listeners use social information to differentially calibrate speakers' phonological spaces; environmental and contextual factors suggesting traits such as gender, age, and nationality, have the power to measurably alter the phonemic categorization; prior knowledge of and stereotypes about these traits can affect perceptual calibration even in the absence of phonetic evidence; and people's self-reported assumptions about their own speech variety can be quite inaccurate.

In order to control for these effects, listeners were specifically denied any information on the identity of the "speaker" of the stimuli they were categorizing. In addition, the stimuli themselves were all produced by a single synthesizer script, so are controlled for any non-F1/F2 phonetic features, such as the values of F0, F3, and breathiness, which have been shown to carry social and linguistic information marking gender and age (Johnson, Strand, and D'Imperio 1999). However, the fact that the accuracy of self-reporting tests may be compromised by so many factors calls into question suggests that even minor experimental shortcuts such as failing to control for participants' environmental surroundings can affect the data.

A final issue to consider is the extensive foreign language exposure of my subject pool. One participant, upon finishing the listening task, complained that I had neglected to give an option for the /œ/ phoneme; though her home and first languages are English, one of the stimuli triggered a mapping to a French phoneme despite the completely English-oriented nature of the on-screen task, instructions, and environment (her home). Though only she specifically addressed this issue in conversation, it would be unsurprising if other subjects faced similar cross-linguistic interference. Ideally, a perception study which does not focus on second-language learners should consist of monolingual speakers in order to control for the possibility of crosslinguistic influence, but this would have been impossible in this particular situation, as bilingualism is an essential skill for English speakers in Quebec's majority-French context (Beddor and Gottfried 1995).

Conclusion

Since its first description by Clarke, Elms and Youssef (1995), the Canadian Shift (CS) has been recognized as one of the most striking systemic vowel shifts currently underway in the English language, and is among the most salient features of contemporary English from Atlantic Canada to British Columbia. In many parts of Canada, the shift can be described as a retraction and/or lowering of /æ/ toward [a], with /ɛ/ lowering and retracting towards [æ] and /ɪ/ lowering and retracting toward [ɛ] (Sadler-Brown and Tamminga 2008; Hoffman 2010; Roeder and Jarmasz 2010). Boberg (2005) described the shift in Montreal as involving a retraction of /ɛ/ and /ɪ/ toward [ʌ] and [ʊ], respectively, but there is no consensus as to the specific phonetic characteristics of the CS, and "with such an array of different research locales, goals, and methodology, the picture of the CS has remained far from complete" (Sadler-Brown and Tamminga 2008, 4).

Results of Experiment I indicate a statistically significant difference in the F1 of /ɔ/ based on gender and in the F2 of /ʌ/ based on both age ($p<.001$) and gender ($p=.005$), while /æ/ is affected by both gender ($p=.001$) and age ($p<.001$) in terms of its F2; /ɛ/ shows age effects in F1 ($p<.001$) and F2 ($p<.001$) and gender effects along F1 ($p<.001$) (Table 3). These findings are consistent with several previous sociolinguistic studies of the CS which indicate that the retraction of /æ/ and the lowering and backing of /ɛ/ are being led by young females in apparent time. While on the whole, the results support Roeder and Jarmasz's (2010) analysis of most recent stages of the CS as a series of retractions, the status of /ʌ/ and /ɔ/ in the shift is still unclear.

Gender was found to significantly affect /ɛ/ perception (F1 $p=.02$, F2 $p<.01$), echoing De Decker's (2010) finding for /æ/ among Ontarians (Figure 5). Given the finding in Experiment I that females are significantly more advanced in this shift, it is unsurprising that they are leading the CS in both production and perception. Cross-sections of the data at F1=700 and F2=1900 show that while younger listeners accept a greater percentage of stimuli lying between /ɛ/ and /ʌ/ as /ɛ/, there is little difference in where the generations draw their perceptual distinction between /æ/ and /ɛ/.

Those carrying out further investigations using a methodology similar to Experiment II would be wise to consider using stimuli in consonantal context in conjunction with other small adjustments in order to increase accuracy and perhaps bolster the statistical significance of perceptual findings. Nevertheless, this data set has proven quite robust, and more analysis could certainly be done on this sample. For instance, from the results of Experiment I, one could 'rank' individual participants based on /æ/ or /ɛ/ advancement to form a shiftedness index that can then be compared with the results of Experiment II to test whether individual participation in a production shift has consequences on perceptual vowel categorization (cf. Kendall and Fridland 2010). It has been shown that the patterns uncovered in Experiment I and II have both confirmed and questioned the findings of previous researchers; utilizing more creative evaluation methods, the data could be explored even further, lending more insight into the progression of the Canadian Shift in apparent time and the nature of vowel shifts, interspeaker variation, and diachronic sound change in general.

References

Adank, P., R. Smits, and R. van Hout (2004) A comparison of vowel normalization procedures for language variation research. *Journal of the Acoustical Society of America* 116:3099-107.

Antoniou, M. (2010) Sound_chainer.praat [Praat script]. Accessed 20 April 2013 at [http://markantoniou.blogspot.ca/2011/09/do-you-have-praat-script-that-can.html].

Beddor, P. and T. Gottfried (1995) Methodological issues in cross-language speech perception research with adults, in W. Strange (ed.) *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues in Cross-Language Speech Research*. Timonium, MD: York Press, pp. 207-232.

Boersma, P. and D. Weenink (2013) *Praat: doing phonetics by computer* [Computer program]. Versions 5.3.37, retrieved from http://www.praat.org/.

Brasileiro Reis Pereira, I. (2009) *The Effects of Bilingualism on Children's Perception of Speech Sounds*. Utrecht: LOT.

Boberg, C. (2004) Ethnic Patterns in the Phonetics of Montreal English. *Journal of Sociolinguistics* 8(4): 538-568.

—— (2005) The Canadian Shift in Montreal. *Language Variation and Change* 17: 133-154.

—— (2008) Regional Phonetic Differentiation in Standard Canadian English. *Journal of English Linguistics* 36: 129.

—— (2010) *The English Language in Canada*. Cambridge: Cambridge University Press.

Clarke, S., F. Elms, and A. Youssef (1995) The third dialect of English: Some Canadian evidence. *Language Variation and Change* 7(2): 209-228.

Clopper, C. G., J. Hay, and B. Plichta (2011) Experimental speech perception and perceptual dialectology, in M. Di Paolo and M. Yaeger-Dror (eds.) *Sociophonetics: A student's guide*. London: Routledge, pp. 149-162.

De Decker, P. (2010) Sounds Shifty: Gender and Age Differences in Perceptual Categorization During a Phonetic Change in Progress. *University of Pennsylvania Working Papers in Linguistics* 15(2).

De Decker, P. and S. Mackenzie (2000) Slept through the ice: A further look at lax vowel lowering in Canadian English. *Toronto Working Papers in Linguistics* 18.

Diehl, R. L., S. B. McCusker, and L. S. Chapman (1980) Perceiving vowels in isolation and in consonantal context. *Journal of the Acoustical Society of America* 69(1): 239-248.

Drager, K. (2010) Sociophonetic Variation in Speech Perception. *Language and Linguistics Compass* 4(7): 473-480.

Eckert, P. (1989) The Whole Woman: Sex and Gender Differences in Variation. *Language Variation and Change* 1: 245-67.

Escudero, P. and L. Polka (2003) *A cross-language study of vowel categorization and vowel acoustics: Canadian English versus Canadian French*. Proceedings of the 15th International Congress of Phonetic Sciences. Barcelona: Futurgraphic.

Foulkes, P., J. M. Scobbie, and D. Watt (2010) Sociophonetics, in J. Hardcastle, J. Laver, and F. E. Gibbon (eds) *The Handbook of Phonetic Sciences: Second Edition*. Wiley-Blackwell, pp. 703-754.

Fox, R. A. (1989) Dynamic Information in the Identification and Discriminiation of Vowels. *Phonetica* 46: 97-116.

Fridland, V. and T. Kendall (2012) Exploring the relationship between production and perception in the mid front vowels of U.S. English. *Lingua* 122: 779-793.

Gorman, K., J. Howell, and M. Wagner (2011) *Prosodylab-Aligner: A tool for forced alignment of laboratory speech*. Proceedings of Acoustics Week in Canada, Quebec City.

Hagiwara, R. E. (2006) Vowel Production in Winnipeg. *The Canadian Journal of Linguistics* 51(2/3): 127-141.

Harrington, J. and S. Cassidy (1994) Dynamic and Target Theories of Vowel Classification: Evidence from Monophthongs and Diphthongs in Australian English. *Language and Speech* 37(4): 357-373.

Hay, J. and K. Drager (2010) Stuffed toys and speech perception. *Linguistics* 48(4): 865-892.

Hay, J., A. Nolan, and K. Drager (2006) From *fush* to *feesh*: Exemplar priming in speech perception. *The Linguistic Review* 23: 351-379.

Hoffman, M. (2010) The Role of Social Factors in the Canadian Vowel Shift: Evidence from Toronto. *American Speech* 85(2): 121-140.

Janson, T. (1983) Sound Change in Perception and Production. *Language* 59(1): 18-34.

—— (1986) Sound Change in Perception: An Experiment, in J. J. Ohala and J. J. Jaeger (eds.) *Experimental Phonology*. Orlando: Academic Press, pp. 253-260.

Johnson, K., E. A. Strand, and M. D'Imperio (1999) Auditory-visual integration of talker gender in vowel perception. *Journal of Phonetics* 27: 359-384.

Kendall, T. and V. Fridland (2010) Mapping Production and Perception in Regional Vowel Shifts. *University of Pennsylvania Working Papers in Linguistics* 16(2): 103-112.

Labov, W. (1990) The interaction of sex and social class in the course of linguistic change. *Language Variation and Change* 2: 205-254.

Labov, W. (1991) The three dialects of English, in P. Eckert (ed.) *New ways of analyzing sound change*. New York: Academic Press.

Labov, W., S. Ash, and C. Boberg (2006) *Atlas of North American English: Phonology and Phonetics*. Berlin: Mouton/de Gruyter.

Lennes, M. (2003) Collect_formant_data_from_files.praat [Praat script]. Accessed 20 April 2013 at [http://www.helsinki.fi/~lennes/praat-scripts/public/collect_formant_data_from_files.praat].

Lobanov, B. M. (1971) Classification of Russian vowels spoken by different listeners. *Journal of the Acoustical Society of America* 49: 606-08.

Macchi, M. J. (1980) Identification of vowels spoken in isolation versus vowls spoken in consonantal context. *Journal of the Acoustical Society of America* 68(6): 1636-1642.

Massaro, D. (1972) Preperceptual images, processing time and perceptual units in auditory perception. *Psychological Review* 79: 124-145.

Martinet, A. (1955) *Economie des changements phonétiques – traité de phonologie diachronique*. Berne: Francke.

McCarthy, C. (2010) The Northern Cities Shift in Real Time: Evidence from Chicago. *University of Pennsylvania Working Papers in Linguistics* 15(2).

Miller, J. L. (2001) Mapping from acoustic signal to phonetic category: Internal category structure, context effects and speeded categorization. *Language and Cognitive Processes* 16(5/6): 683-690.

Niedzielski, N. (1999) The Effect of Social Information on the Perception of Sociolinguistic Variables. *Journal of Language and Social Psychology* 18: 62-85.

Pisoni, D. B. and J. Tash (1974) Reaction times to comparisons within and across phonetic categories. *Perception and Psychophysics* 15(2): 285-290.

Plichta, B. and B. Rackerd (2010) Perceptions of /a/-fronting across two Michigan dialects, in D. R. Preston and N. Niedzielski (eds.) *A Reader in Sociophonetics*. New York: De Gruyter Mouton, pp. 223-239.

Rakerd, B. (1984) Vowels in consonantal context are perceived more linguistically than are isolated vowels: Evidence from an individual differences scaling study. *Perception and Psychophysics* 35(2): 123-136.

Roeder, R. and L.-G. Jarmasz (2010) The Canadian Shift in Toronto. *The Canadian Journal of Linguistics* 55(3): 387-404.

Sadlier-Brown, E. and M. Tamminga (2008) The Canadian Shift: Coast to Coast. *Proceedings of the 2008 Annual Conference of the Canadian Linguistic Association*.

Statistics Canada (2011) *Linguistic Characteristics of Canadians: Language, 2011 Census of Population*. Government of Canada, accessed 20 April 2013 at [http://www12.statcan.gc.ca/census-recensement/2011/as-sa/98-314-x/98-314-x2011001-eng.pdf].

Strand, E. A. (1999) Uncovering the Role of Gender Stereotypes in Speech Perception. *Journal of Language and Social Psychology* 18: 86-100.

Strange, W., T. R. Edman, and J. J. Jenkins (1979) Acoustic and Phonological Factors in Vowel Identification. *Journal of Experimental Psychology* 5(4): 643-656.

Strange, W., J. J. Jenkins, and T. L. Johnson (1983) Dynamic specification of coarticulated vowels. *Journal of the Acoustic Society of America* 74(3): 695-705.

Strange, W., R. R. Verbrugge, D. P. Shankweiler, and T. R. Edman (1976) Consonant environment specifies vowel identity. *Journal of the Linguistic Society of America* 60(1): 213-224.

Thomas, E. R. (2002) Sociophonetic Applications of Speech Perception Experiments. *American Speech* 77(2): 115-147.

Thomas, E. R. and T. Kendall (2007) *NORM: The vowel normalization and plotting suite*. Accessed 20 April 2013 at [http://ncslaap.lib.ncsu.edu/tools/norm/].

Wang, H. and V. J. Van Heuven (2006) Acoustical analysis of English vowels produced by Chinese, Dutch and American speakers, in J. M. Van de Weijer and B. Los (eds.) *Linguistics in the Netherlands*. Amsterdam: John Benjamins, pp. 237-248.

Watt, D., A. Fabricius, and T. Kendall (2011) More on vowels: plotting and normalization, in M. Di Paolo and M. Yaeger-Dror (eds) *Sociophonetics: A Student's Guide*. London: Routledge, 105-118.

Wells, J. C. (1982) *Accents of English*. Cambridge: Cambridge University Press.

Willis, C. (1972) Perception of vowel phonemes in Fort Erie, Ontario, Canada, and Buffalo, New York: An application of synthetic vowel categorization tests to dialectology. *Journal of*

Speech, Language and Hearing Research 15(2): 246-255.

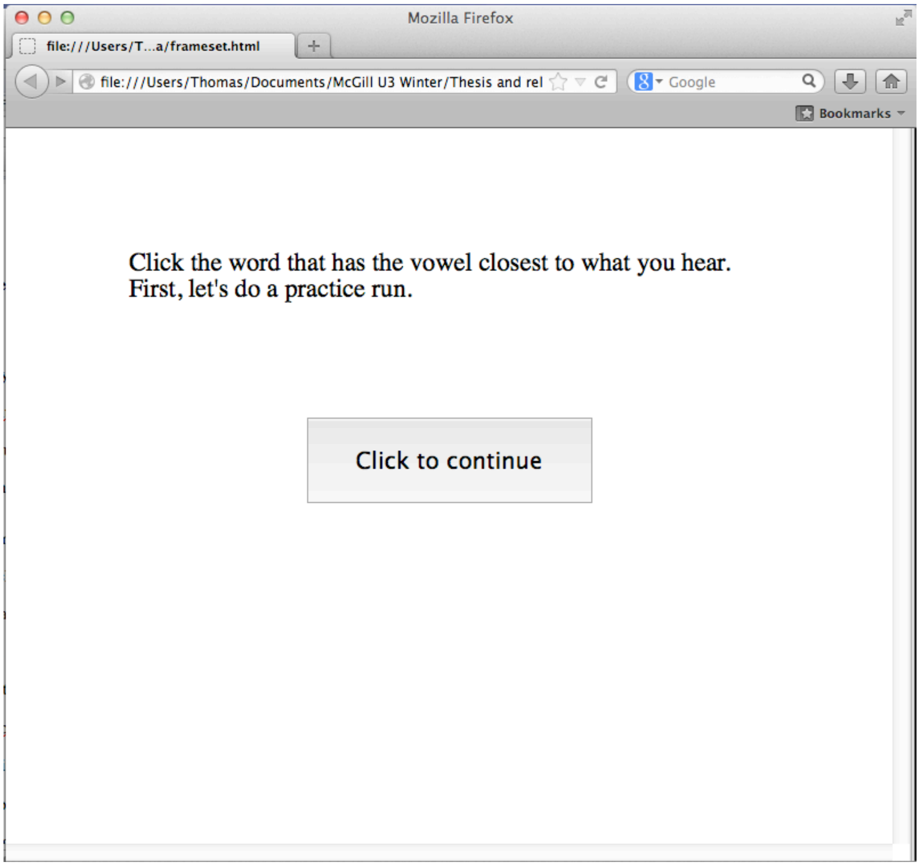
Appendix

List of anchor vowels

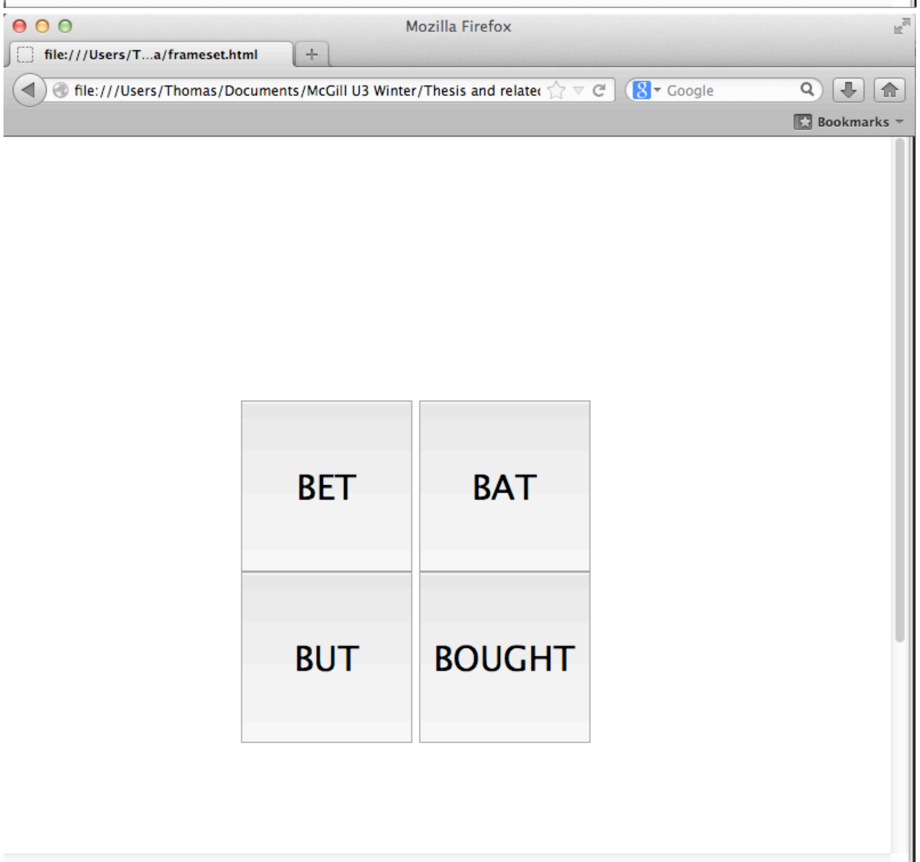
Anchor word	Vowel class
buy	aɪ
mike	ʌɪ
mike	ʌɪ
make	eɪ
make	eɪ
game	eɪ
play	eɪ
bit	ɪ
sleep	i:
believe	i:
easy	i:
keeps	i:
clean	i:
treat	i:
door	or
george	or
poured	or
kosher	oʊ
stone	oʊ
crow	oʊ
supermarket	u:
room	u:
food	u:

Statistical Effects of Experiments I and II, compared

	Prod, Perc	Prod, Perc	Prod, Perc
Vowel	Age	Gender	Gender/Age
F1 ʌ	No, Yes	No, Yes	No, Yes
F2 ʌ	Yes, Yes	Yes, Yes	No, Yes
F1 ɛ	Yes, Yes	Yes, No	No, No
F2 ɛ	Yes, Yes	No, No	No, No
F1 æ	No, No	No, No	No, No
F2 æ	Yes, No	Yes, No	No, No
F1 ɔ	No, Yes	Yes, Yes	Yes, Yes
F2 ɔ	No, Yes	No, Yes	No, Yes



Experiment II screenshot, practice round



Experiment II screenshot, showing placement of buttons

Following pages: Experiment II, percentage responses by group and vowel.

Older Females

1.00	1.00	1.00	0.60	0.40	0.60	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	ɛ
1.00	1.00	1.00	1.00	0.80	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.80	1.00	1.00	0.80	1.00	0.20	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	
0.60	0.60	0.20	0.60	0.20	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.20	0.20	0.00	0.20	0.20	0.20	0.20	0.20	0.20	0.00	0.20	0.40	0.40	ɔ
0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.20	0.60	0.80	
0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.40	0.80	0.60	0.80	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	0.40	0.40	0.80	0.60	0.80	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.60	0.40	0.60	0.80	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.80	0.20	0.80	0.80	
0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	æ
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.20	0.00	0.00	0.20	0.00	0.60	0.20	0.20	0.00	0.20	0.00	0.20	0.00	0.00	0.20	0.00	
0.40	0.40	0.80	0.40	0.80	0.20	1.00	1.00	1.00	0.80	0.00	0.20	0.00	0.00	0.00	0.00	
0.60	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.40	0.00	0.00	0.00	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.60	0.60	0.00	0.60	0.20	0.00	
0.00	0.00	0.00	0.00	0.40	0.40	0.60	0.60	0.60	0.60	0.80	0.80	1.00	0.80	0.60	0.60	ʌ
0.00	0.00	0.00	0.00	0.20	0.40	0.60	0.80	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20	
0.00	0.00	0.00	0.00	0.00	0.20	0.60	0.60	1.00	0.80	0.80	0.80	0.60	0.20	0.20	0.20	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.60	0.20	0.40	0.20	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.40	0.20	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.00	0.20	

Older Males

0.91	0.82	0.73	0.82	0.27	0.64	0.18	0.27	0.36	0.18	0.00	0.00	0.00	0.00	0.00	0.00	ɛ
0.91	0.82	0.91	0.73	0.73	0.64	0.55	0.18	0.09	0.00	0.27	0.18	0.00	0.00	0.00	0.00	
0.64	0.82	0.73	0.36	0.64	0.18	0.18	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	
0.55	0.27	0.09	0.36	0.18	0.36	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.18	0.18	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.27	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.18	0.00	0.09	0.00	0.00	0.00	0.00	0.09	0.64	0.27	0.64	0.64	ɔ
0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.18	0.00	0.27	0.09	0.00	0.18	0.64	0.73	0.82	
0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.09	0.18	0.09	0.27	0.27	0.27	0.73	0.55	0.73	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.09	0.27	0.36	0.55	0.55	0.73	0.64	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.18	0.36	0.73	0.36	0.64	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.27	0.55	0.55	0.73	0.73	
0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09	0.00	0.00	æ
0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.09	0.09	0.09	0.18	0.18	
0.36	0.09	0.09	0.09	0.00	0.64	0.00	0.36	0.00	0.00	0.18	0.18	0.09	0.09	0.36	0.27	
0.45	0.73	0.91	0.64	0.82	0.64	0.91	0.91	0.91	0.82	0.45	0.45	0.36	0.36	0.27	0.27	
0.82	0.82	0.91	0.91	0.91	1.00	1.00	1.00	0.82	0.73	0.91	0.64	0.45	0.18	0.55	0.36	
0.73	0.91	0.91	0.91	1.00	1.00	0.91	1.00	1.00	1.00	0.64	0.64	0.45	0.36	0.27	0.27	
0.09	0.18	0.18	0.18	0.55	0.36	0.73	0.73	0.64	0.82	1.00	0.82	0.36	0.64	0.36	0.36	ʌ
0.09	0.18	0.00	0.27	0.27	0.27	0.45	0.55	0.91	0.73	0.64	0.73	0.73	0.27	0.09	0.00	
0.00	0.09	0.18	0.45	0.36	0.18	0.82	0.55	0.73	0.82	0.55	0.55	0.64	0.18	0.09	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.27	0.18	0.09	0.09	0.00	0.09	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.09	0.18	0.18	0.09	0.09	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.18	0.09	0.00	0.09	0.00	0.00	

Younger Females

0.80	1.00	1.00	0.80	0.60	0.80	0.60	0.40	1.00	0.60	0.20	0.00	0.00	0.00	0.00	0.00	ε
0.80	1.00	1.00	1.00	1.00	0.80	0.80	0.40	0.60	0.20	0.40	0.40	0.00	0.00	0.00	0.00	
0.80	1.00	1.00	1.00	0.80	0.20	0.60	0.20	0.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.40	0.40	0.60	0.00	0.40	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	
0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.00	0.00	0.40	0.20	0.40	0.40	0.80	0.80	ɔ
0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.20	0.40	0.40	0.80	0.40	0.60	
0.20	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.40	0.20	0.40	0.20	0.60	0.60	0.20	0.80	
0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.40	0.40	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.60	0.60	1.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.40	0.20	
0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20	æ
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.20	0.00	0.00	0.00	0.40	0.20	
0.00	0.00	0.00	0.00	0.20	0.80	0.00	0.40	0.00	0.40	0.40	0.40	0.20	0.40	0.80	0.20	
0.80	0.60	0.40	0.20	1.00	0.20	1.00	1.00	1.00	1.00	0.60	0.60	0.80	0.80	0.60	0.60	
0.80	1.00	0.80	1.00	1.00	1.00	1.00	1.00	0.60	0.60	1.00	0.80	1.00	0.20	0.00	0.00	
1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.40	0.80	0.40	0.40	
0.00	0.00	0.00	0.20	0.40	0.20	0.20	0.20	0.00	0.40	0.40	0.60	0.60	0.60	0.20	0.00	ʌ
0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.40	0.20	0.20	0.60	0.20	0.20	0.20	
0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.20	0.20	0.20	0.40	0.20	0.00	0.00	0.00	
0.20	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.00	0.00	0.00	0.20	0.40	0.00	
0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.60	0.00	0.20	0.40	

Younger Males

1.00	0.86	1.00	0.29	0.57	0.14	0.57	0.71	0.14	0.29	0.14	0.14	0.00	0.00	0.00	0.00	ε
1.00	1.00	1.00	0.86	1.00	0.71	0.71	0.43	0.14	0.43	0.14	0.00	0.00	0.00	0.00	0.00	
0.57	1.00	0.71	0.57	0.57	0.29	0.71	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	
0.57	0.29	0.29	0.43	0.14	0.29	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	
0.14	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.14	0.14	0.29	0.00	0.00	0.14	0.14	0.29	0.14	0.86	0.71	0.57	0.71	ɔ
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.14	0.00	0.57	0.71	0.71	0.86	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.29	0.43	0.43	0.43	0.71	0.57	0.86	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.57	0.29	0.86	0.86	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.29	0.57	0.71	1.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.57	0.29	0.71	0.71	
0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	æ
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.00	
0.29	0.00	0.29	0.00	0.43	0.57	0.14	0.29	0.00	0.00	0.00	0.14	0.14	0.14	0.43	0.00	
0.29	0.57	0.71	0.57	0.86	0.57	0.57	0.86	0.86	0.86	0.14	0.29	0.29	0.29	0.14	0.14	
0.86	0.71	0.86	1.00	1.00	1.00	1.00	0.86	0.86	0.71	0.86	0.57	0.57	0.14	0.00	0.00	
0.86	1.00	1.00	0.86	1.00	0.86	0.86	1.00	0.86	0.86	0.71	0.57	0.14	0.29	0.14	0.00	
0.00	0.14	0.00	0.57	0.29	0.43	0.43	0.29	0.71	0.57	0.57	0.71	0.14	0.29	0.29	0.29	ʌ
0.00	0.00	0.00	0.14	0.00	0.29	0.29	0.43	0.86	0.43	0.57	1.00	0.43	0.29	0.14	0.14	
0.14	0.00	0.00	0.43	0.00	0.14	0.14	0.71	0.86	0.57	0.57	0.43	0.43	0.14	0.00	0.14	
0.14	0.14	0.00	0.00	0.00	0.14	0.29	0.14	0.14	0.14	0.57	0.71	0.14	0.43	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.29	0.14	0.29	0.29	0.00	
0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.14	0.29	0.29	0.29	0.43	0.14	0.29	

All older (averaged)

0.95	0.91	0.86	0.71	0.34	0.62	0.19	0.24	0.28	0.19	0.00	0.00	0.00	0.00	0.00	0.00	**ɛ**
0.95	0.91	0.95	0.86	0.76	0.52	0.47	0.09	0.05	0.00	0.14	0.09	0.00	0.00	0.00	0.00	
0.72	0.91	0.86	0.58	0.82	0.19	0.09	0.10	0.05	0.05	0.10	0.00	0.00	0.00	0.00	0.00	
0.57	0.44	0.15	0.48	0.19	0.58	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.29	0.29	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.14	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.10	0.19	0.00	0.15	0.10	0.10	0.10	0.10	0.15	0.32	0.24	0.52	0.52	**ɔ**
0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.19	0.00	0.14	0.05	0.00	0.09	0.42	0.66	0.81	
0.00	0.00	0.00	0.05	0.00	0.00	0.10	0.05	0.09	0.05	0.14	0.14	0.34	0.76	0.57	0.76	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.15	0.44	0.38	0.47	0.67	0.66	0.72	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.10	0.29	0.48	0.56	0.48	0.72	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.24	0.67	0.37	0.76	0.76	
0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.00	**æ**
0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.05	0.05	0.09	0.09	
0.28	0.05	0.05	0.15	0.00	0.62	0.10	0.28	0.00	0.10	0.09	0.19	0.05	0.05	0.28	0.14	
0.43	0.56	0.85	0.52	0.81	0.42	0.95	0.95	0.95	0.81	0.23	0.33	0.18	0.18	0.14	0.14	
0.71	0.71	0.95	0.95	0.95	1.00	1.00	1.00	0.91	0.86	0.85	0.62	0.43	0.09	0.27	0.18	
0.86	0.95	0.95	0.95	1.00	1.00	0.95	1.00	1.00	1.00	0.62	0.62	0.23	0.48	0.24	0.14	
0.05	0.09	0.09	0.09	0.47	0.38	0.66	0.66	0.62	0.71	0.90	0.81	0.68	0.72	0.48	0.48	**ʌ**
0.05	0.09	0.00	0.14	0.24	0.34	0.53	0.67	0.95	0.86	0.82	0.86	0.86	0.54	0.25	0.10	
0.00	0.05	0.09	0.23	0.18	0.19	0.71	0.57	0.86	0.81	0.67	0.67	0.62	0.19	0.15	0.10	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.34	0.29	0.35	0.15	0.20	0.15	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.05	0.09	0.09	0.35	0.25	0.10	
0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.19	0.15	0.10	0.15	0.00	0.10	

All younger (averaged)

0.90	0.93	1.00	0.54	0.59	0.47	0.59	0.56	0.57	0.44	0.17	0.07	0.00	0.00	0.00	0.00	**ɛ**
0.90	1.00	1.00	0.93	1.00	0.76	0.76	0.41	0.37	0.31	0.27	0.20	0.00	0.00	0.00	0.00	
0.69	1.00	0.86	0.79	0.69	0.24	0.66	0.10	0.20	0.17	0.00	0.00	0.00	0.00	0.00	0.00	
0.29	0.34	0.34	0.51	0.07	0.34	0.07	0.00	0.00	0.00	0.17	0.00	0.10	0.00	0.00	0.00	
0.17	0.14	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.07	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.07	0.07	0.14	0.10	0.20	0.07	0.07	0.34	0.17	0.63	0.56	0.69	0.76	**ɔ**
0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10	0.27	0.17	0.20	0.49	0.76	0.56	0.73	
0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.27	0.24	0.41	0.31	0.51	0.66	0.39	0.83	
0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10	0.29	0.24	0.63	0.63	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.14	0.59	0.66	1.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.29	0.24	0.56	0.46	
0.10	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.07	0.10	**æ**
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.17	0.00	0.00	0.00	0.27	0.10	
0.14	0.00	0.14	0.00	0.31	0.69	0.07	0.34	0.00	0.20	0.20	0.27	0.17	0.27	0.61	0.10	
0.54	0.59	0.56	0.39	0.93	0.39	0.79	0.93	0.93	0.93	0.37	0.44	0.54	0.54	0.37	0.37	
0.83	0.86	0.83	1.00	1.00	1.00	1.00	0.93	0.73	0.66	0.93	0.69	0.79	0.17	0.00	0.00	
0.93	0.90	1.00	0.93	1.00	0.93	0.93	1.00	0.93	0.93	0.76	0.69	0.27	0.54	0.27	0.20	
0.00	0.07	0.00	0.39	0.34	0.31	0.31	0.24	0.36	0.49	0.49	0.66	0.37	0.44	0.24	0.14	**ʌ**
0.00	0.00	0.00	0.07	0.00	0.24	0.24	0.31	0.53	0.41	0.39	0.60	0.51	0.24	0.17	0.17	
0.07	0.00	0.00	0.21	0.00	0.07	0.17	0.56	0.53	0.39	0.39	0.41	0.31	0.07	0.00	0.07	
0.17	0.07	0.00	0.00	0.00	0.27	0.14	0.07	0.07	0.07	0.39	0.46	0.07	0.21	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.27	0.17	0.07	0.14	0.07	0.24	0.34	0.00	
0.00	0.10	0.00	0.00	0.00	0.07	0.07	0.00	0.07	0.07	0.14	0.24	0.44	0.21	0.17	0.34	

All Males (Averaged)

0.95	0.84	0.86	0.55	0.42	0.39	0.38	0.49	0.25	0.23	0.07	0.07	0.00	0.00	0.00	0.00	**ɛ**
0.95	0.91	0.95	0.79	0.86	0.68	0.63	0.31	0.12	0.21	0.21	0.09	0.00	0.00	0.00	0.00	
0.60	0.91	0.72	0.47	0.60	0.23	0.45	0.00	0.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00	
0.56	0.28	0.19	0.40	0.16	0.32	0.12	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	
0.16	0.23	0.12	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.21	0.05	0.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.07	0.16	0.14	0.05	0.00	0.07	0.07	0.14	0.12	0.75	0.49	0.60	0.68	**ɔ**
0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.16	0.00	0.21	0.12	0.00	0.38	0.68	0.72	0.84	
0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.16	0.19	0.35	0.35	0.35	0.72	0.56	0.79	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.21	0.18	0.56	0.42	0.79	0.75	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.16	0.32	0.65	0.54	0.82	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.21	0.56	0.42	0.72	0.72	
0.00	0.00	0.05	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.07	0.00	**æ**
0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.07	0.05	0.05	0.05	0.16	0.09	
0.32	0.05	0.19	0.05	0.21	0.60	0.07	0.32	0.00	0.00	0.09	0.16	0.12	0.12	0.40	0.14	
0.37	0.65	0.81	0.60	0.84	0.60	0.74	0.88	0.88	0.84	0.30	0.37	0.32	0.32	0.21	0.21	
0.84	0.77	0.88	0.95	0.95	1.00	1.00	0.93	0.84	0.72	0.88	0.60	0.51	0.16	0.27	0.18	
0.79	0.95	0.95	0.88	1.00	0.93	0.88	1.00	0.93	0.93	0.68	0.60	0.30	0.32	0.21	0.14	
0.05	0.16	0.09	0.38	0.42	0.40	0.58	0.51	0.68	0.69	0.79	0.77	0.25	0.46	0.32	0.32	**ʌ**
0.05	0.09	0.00	0.21	0.14	0.28	0.37	0.49	0.88	0.58	0.60	0.86	0.58	0.28	0.12	0.07	
0.07	0.05	0.09	0.44	0.18	0.16	0.48	0.63	0.79	0.69	0.56	0.49	0.53	0.16	0.05	0.07	
0.07	0.07	0.00	0.00	0.00	0.07	0.14	0.07	0.07	0.12	0.42	0.45	0.12	0.26	0.00	0.05	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.16	0.07	0.12	0.23	0.16	0.19	0.19	0.00	
0.00	0.00	0.00	0.00	0.00	0.07	0.12	0.00	0.07	0.07	0.23	0.19	0.14	0.26	0.07	0.14	

All Females (averaged)

0.90	1.00	1.00	0.70	0.50	0.70	0.40	0.30	0.60	0.40	0.10	0.00	0.00	0.00	0.00	0.00	**ɛ**
0.90	1.00	1.00	1.00	0.90	0.60	0.60	0.20	0.30	0.10	0.20	0.20	0.00	0.00	0.00	0.00	
0.80	1.00	1.00	0.90	0.90	0.20	0.30	0.20	0.20	0.10	0.10	0.00	0.00	0.00	0.00	0.00	
0.30	0.50	0.30	0.60	0.10	0.60	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.00	
0.30	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.00	0.00	0.00	0.10	0.10	0.00	0.20	0.30	0.10	0.10	0.30	0.20	0.20	0.30	0.60	0.60	**ɔ**
0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.10	0.20	0.10	0.20	0.20	0.50	0.50	0.70	
0.10	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.10	0.20	0.10	0.50	0.70	0.40	0.80	
0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.30	0.20	0.50	0.50	0.60	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.30	0.30	0.50	0.60	0.90	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.40	0.20	0.60	0.50	
0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10	**æ**
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.10	0.00	0.00	0.00	0.20	0.10	
0.10	0.00	0.00	0.10	0.10	0.70	0.10	0.30	0.00	0.30	0.20	0.30	0.10	0.20	0.50	0.10	
0.60	0.50	0.60	0.30	0.90	0.20	1.00	1.00	1.00	0.90	0.30	0.40	0.40	0.40	0.30	0.30	
0.70	0.80	0.90	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.90	0.70	0.70	0.10	0.00	0.00	
1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.20	0.70	0.30	0.20	
0.00	0.00	0.00	0.10	0.40	0.30	0.40	0.40	0.30	0.50	0.60	0.70	0.80	0.70	0.40	0.30	**ʌ**
0.00	0.00	0.00	0.00	0.10	0.30	0.40	0.50	0.60	0.70	0.60	0.60	0.80	0.50	0.30	0.20	
0.00	0.00	0.00	0.00	0.00	0.10	0.40	0.50	0.60	0.50	0.50	0.60	0.40	0.10	0.10	0.10	
0.10	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.10	0.20	0.10	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10	0.00	0.00	0.00	0.40	0.40	0.10	
0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.40	0.10	0.10	0.30	