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Stability of prosodic performance over the lifespan: The (late) Queen's speech

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Abstract

Studies of individual sound change over the lifespan benefit from availability of regular broadcast recordings by individuals whose role keeps them in the public eye over multiple decades. Annual Christmas (and other) broadcasts of the late Queen Elizabeth II have served to disentangle the impact of linguistic sound change on vowel quality from the natural effects of aging. In this paper we show that, in contrast to the well-documented changes in segmental vowel quality, key prosodic features of the late Queen's broadcast speech in the public domain changed little over 70 years.

Five speeches are analyzed, ranging in broadcast date from 1947 to 2017. Each speech was segmented into intonation phrases, based on auditory impression, and each phrase coded for discourse structure. Values of maximum F0 per phrase show expected age-related decline over the lifespan, but linear regression models indicate minimal change across recordings in articulation rate (sylls/sec), number of words and syllables per phrase, and duration of phrase and inter-phrase unfilled pauses; we ascribe the few observed differences to specific contextual factors (e.g., ill health or challenging content). Overall, we interpret this stability as a marker of individual performance style across the lifespan, within a restricted discourse genre.

Index Terms: discourse prosody, lifespan, British English, age-related effects, speech rate

1. Introduction

This study is a first exploration of potential variation across the lifespan of the discourse prosody in speeches given by former UK monarch the late Queen Elizabeth II (henceforth QEII), over a 70-year period between the ages of 21-91 years.

1.1. Segmental variation over the lifespan in QEII's speech

The immediate background to this study is prior work on variation over the lifespan in QEII's speech, which has focused primarily on vowel quality, exploring the extent to which any observed changes in the Queen's speech align with changes in the phonetic realization of the phonological vowel categories of Southern Standard British English over the same period. The influential first paper on this topic [1] showed that a number of QEII's vowel categories had indeed shifted over time (between 1952-2002), for example showing fronting of GOOSE, and lowering and backing of TRAP, in line with ongoing sound changes in the wider community. This shift towards more mainstream phonetic realizations was found to be mirrored in other vowel categories also, including diphthongs [2], overall monophthongal vowel space [3] and HAPPY-tensing [4].

A more recent study has shown that TRAP, GOOSE and HAPPY display 'accent reversion' in QEII's later recordings, shifting roughly halfway back towards their earlier more conservative phonetic properties [5]. F1 values in high and mid vowels were observed to fall gradually across successive annual broadcasts, apparently tracking a parallel fall in average F0 across the lifespan. This correlation was ascribed to greater potential perceptual confusability of F1 with F0 in high vowels [6, 7] (though this account has been called into question [8, 9]). The F1 patterns observed in QEII's speech can be interpreted as an indication that – despite being a frequent public speaker – QEII did not display the reduced F1 variability characteristic of other speakers who had received professional voice training [7].

The only consonantal change studied in QEII's speech to date appears to be r-sandhi [10, 11]. In a corpus of 63 Christmas broadcasts between 1952-2018, Mompean finds a notable lack of intrusive-r at any point and decreasing rate of linking-r over time (in favor of glottalization or vowel hiatus). As for vowel changes, the observed decrease in linking-r also tracks a parallel change over time in a relevant wider population (here, longitudinal data from RP speakers e.g., newsreaders), albeit behind the pace of change in the community (i.e., QEII retains more linking-r). Mompean reports that presence of a tone unit boundary (crucially not marked with a pause) favors linking-r in QEII's speech, in line with general literature on r-sandhi. The study did not examine speech rate effects on r-sandhi but identified speech rate as a fruitful area for future research. To the best of our knowledge, work on prosody in QEII's speech is to date restricted to examination of F0, which we turn to next.

1.2. Prosodic variation over the lifespan

Studies of variation in segmental and/or suprasegmental phonetic features over the lifespan are typically based on either *longitudinal* data collection across real time, either from the same speaker(s) at different timepoints or from different speakers from the same speech community at different timepoints, or on *cross-sectional* data collection across apparent time, from speakers of different ages at one time point. A useful recent overview is provided in [12]. Our focus here is work that has investigated variation across the lifespan in prosodic features, in both spectral (F0) and temporal domains.

Most studies have found that average F0 falls as a speaker transitions from younger to older adulthood into middle age, in both men and women, but results are more diverse for F0 trajectory over the lifespan into later old age [13-16]. A cross-sectional study of 84 US English speakers found that mean F0 decreases steadily over the lifespan in women, but showed an upturn in their oldest age group (70-92 years) for men [13], matching the literature survey results in [17]. A 'U-shaped' F0 trajectory over the lifespan in men is also shown in a longitudinal study of three male US English speakers, with the 'upturn' starting around age 70 on average, but later into the 70s for some individuals [14]. Male/female F0 trajectory differences may to some extent mirror differing physiological causes: [17] attributes the large F0 decrease in women at/after menopause to hormonal changes, and the later life F0 upturn in men to muscle atrophy or increased vocal cord stiffness, but

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both older men and women were found to have larger overall vocal tract volume compared to younger speakers in [18].

Studies of QEII's average F0 values show a steady fall across successive Christmas broadcasts up to 2002 (age 76), tracking a parallel fall in F1 in high and mid vowels, as noted above [6, 7]. Recent work [5] addressed F1 changes in data up to 2017 (age 91) but does not report F0 in the extended dataset. The conclusion of [12, 14] is that the detail of how F0 trajectory varies over the lifespan is likely both speaker- and task-specific.

Few studies of age-related prosodic variation investigate F0 beyond average F0 or F0 range. An exception is the exploratory study in [16] which reports a wide range of automatically extracted F0 and other measures in broadcast interview speech samples at ages 51, 74 and 82, from a single male speaker of European Portuguese. They report increasing median F0 values (cf. the 'upturn' noted in other studies for males in this age range) but also greater F0 variability and wider F0 range.

Studies on temporal variation over the lifespan have mostly investigated measures of speech rhythm and/or speech rate. Two separate cross-sectional studies of speech rhythm in read speech samples from younger versus older speakers of Italian [19] and German [20] found increased %V in older speakers. The %V rhythm metric reflects the relative proportion of vocalic material in the speech signal. A longitudinal study of a single male speaker of US English, in five public lectures given in the age range 40-89 years, found no %V differences but did report slower speech rate across the lifespan [21] (whether measured as segments, vowels or consonants per second). In contrast, the previously mentioned study of three male US speakers sampled across a similar age range [14] found a U-shaped curve, with speech rate increasing on average between ages 50-70 years then slowing again (with speech rate measured as vowels per second); the turning point at which speech rate started to slow differed by individual (all between 70-80 years). A longitudinal study of articulation rate (automatically detected syllables per second, excluding pauses), in nine scripted formal speeches given in Dutch by Queen Beatrix of the Netherlands between the ages of 42-74 years, showed an initial decrease the first few years but then a steady increase in articulation rate overall, with increased acceleration in later portions of each speech, in later years [22]. Age-related slowing of tempo was expected, so observed increased tempo with age is attributed to a putative increase in tempo in the wider speech community.

Few studies of age-related temporal variation investigate durational measures beyond speech rate or speech rhythm. A study of inter-pause unit (IPU) durations, pause durations and articulation rate (AR), in samples of spontaneous interview speech produced by French and German speakers in their 70s versus 80s, found a mixed picture [23]. Older German speakers had slower AR, but older French speakers had faster AR and also longer IPU durations; in contrast, older speakers of both French and German produced fewer syllables per IPU.

1.3. Prosodic variation across genres and speakers

Prior work on prosodic and other phonetic variation across the lifespan draws on studies of speech across a range of spoken discourse genres, as seen in the above review, ranging from spontaneous speech obtained using interviews to read laboratory or broadcast speech. Longitudinal studies of individual speakers often take advantage of archived broadcast recordings of various kinds by public figures, but potential for interaction of speech genre effects on prosody with age-related effects has typically not been a primary focus of the research.

Wichmann [24] classifies speech genres in terms of mode (scripted versus unscripted) and type of speech event. In Wichman's typology QEII's speeches are all scripted monologues, given in public (whether live or for later broadcast), and are all goal-oriented rather than unconstrained.

A key prosodic feature marking discourse structure is *topic reset* [24], that is, higher F0 at the start of a new discourse topic. This feature arises due to a distinction between local and global pitch range, with F0 falling steadily both within and across the intonation phrases (IPs) within each discourse topic. Non-initial phrases within a discourse topic thus show a smaller initial pitch reset than that seen at the start of a new discourse topic. Zellers [25] used discourse prosodic features such as pitch reset to show that British English speakers display consistent (though not identical) patterns in mapping prosodic structure to discourse topic structure when presented with a script to read. Nevertheless, work in forensic speech science has identified minimal but non-trivial individual differences between speakers in markers of fluency and disfluency, such as use of filled and unfilled pauses. QEII's speeches are scripted, so filled pauses (*uhm*, *er*) are rare, but the incidence of unfilled pauses has also been shown to be both speaker- and task-specific [26].

1.4. The present study

The present study explores whether there is variation across the lifespan in discourse prosodic features of QEII's speech. The starting hypothesis is that prosodic properties of the late Queen's performance in public speaking will not display major changes over the 70-year period examined, in part due to the restricted discourse genre (scripted speeches) but also as a marker of individual performance style. The annual Christmas broadcasts have been described as "less likely to be affected by […] changes in speaking style" [27 p.3]. To increase potential for variation, this study includes samples of QEII's speech from public speeches given to a live audience as well as traditional straight-to-air or pre-recorded radio and TV broadcasts.

2. Methods

2.1. Materials

Data samples from public speeches given by Queen Elizabeth II at five timepoints between 1947-2017 were analyzed (listed in Table 1). The recordings were originally selected and shared with the author by the BBC, but most are in the public domain. The first two recordings are from live broadcasts: on radio from Cape Town in 1947 and the first live TV broadcast of the annual Christmas message in 1957. The 1990s recordings were both delivered to an audience, in Westminster Abbey in 1990 and in the Guildhall in 1992; in the 1992 recording QEII's voice is audibly hoarse due to flu [28]. The 2017 broadcast was pre-recorded for TV. All speeches are in British English.

Table 1: *Public speeches and broadcast data analyzed with duration of analyzed portions (in seconds).*

Year	Occasion	Age	Duration
1947	21st Birthday Broadcast	21	101.5
1957	Christmas Broadcast	31	129.2
1990	Commonwealth Day	63	131.6
1992	40th Anniversary of Accession	66	119.8
2017	Christmas Broadcast	91	370.36

2.2. Analysis

The audio was converted to .wav format for analysis. Each speech was manually annotated by the author with reference to the waveform and spectrogram in Praat [29]. First, the speech was segmented into intonational phrases (IP), defined primarily by presence of a following pause. A Praat script was used to identify and measure maximum F0 in each labelled phrase, and to extract duration in seconds of each phrase and following pause. The number of words and syllables per phrase (as produced, rather than based on canonical syllables) was counted and Articulation Rate (syllables/second excluding pauses) calculated. Outlier values were checked; one value in 1992 was manually corrected for a tracking error due to creak. Each phrase was then labelled for position in discourse structure, using the categories proposed by [25] (cf. [24]), as in Table 2.

Table 2: *Discourse structure categories from [25].*

Code	Type	Description
T	Topic	The beginning of a new topic
A	Addition	New information on same topic
E	Elaboration	More detail or clarification of a previous utterance
C	Continuation	Completing an idea begun in the previous utterance

3. Results

3.1. Overview

Linear regression models (lm) were run in base R [30], without random effects as there are no repeated measures, to predict untransformed values of: max F0 (in Hz), Articulation Rate (per phrase), Word Count (per phrase), Syllable Count (per phrase), Phrase Duration (in seconds) and Pause Durations (in seconds). A likelihood ratio test between models with and without an interaction between *year* and *category* showed model fit was not improved by inclusion of the interaction for any dependent variables, as shown in Table 3. The model predictions reported below are thus all from model structure: DV ~ *year* + *category*.

Table 3: *Model comparison likelihood ratio results [DV ~ year + category] vs. [DV ~ year * category].*

DV	df	SS	F	p
maxF0 (Hz)	12	15538	0.953	.495
AR (sylls/sec)	12	6.171	0.899	.549
Word Count	12	81.76	0.790	.661
Syllable Count	12	217.3	1.035	.418
Phrase Durations (s)	12	9.090	1.032	.421
Pause Durations (s)	12	4.146	0.857	.592

The model comparison results in Table 3 suggest that, in this initial sample of data at least, there was no change over time in how the measured prosodic characteristics were deployed in QEII's speeches to mark the discourse categories labelled here.

Model predictions are visualized in Figure 1, based on pairwise comparisons extracted using emmeans [31]. All models are treatment coded with 1947 as reference level for *year* and T (beginning of a new topic) as reference for *category*. Model summaries are reported in Table 4. Values of t greater or less than 2 were interpreted as indicating a significant effect.

3.2. Pitch

Values of maximum F0 per phrase show the expected age-related decline in F0 over the lifespan, with a slight fall from age 21 to age 31 (1947 to 1957), stepping down to a lower level at ages 63 and 66 (1990 and 1992). At the much older age of 91 (in 2017) F0 values were lower again, matching the findings of research on older female US English speakers in [13]. Max F0 values differ significantly between each successive pair of recordings across the lifespan except between the two recordings made in the 1990s. Pitch variation by position in the discourse structure matches that found by [25], with highest F0 in topic-initial phrases (T), and lowest F0 in continuations (C), and this pattern is consistent across all five speeches examined.

3.3. Tempo

Articulation Rate shows no effect of *year*, indicating no change in speech rate across the lifespan in these recordings. It is clear in Figure 1 that AR is slower in 1992, but additional pairwise comparisons confirm that differences with the years with fastest AR are not significant (e.g., 1992~1990: β=0.3391, t=1.654; 1992~1957: β=0.3320, t=1.786). In contrast, the size of phrases in terms of Word Count varies by *year*, though not by *category*. For Syllable Counts, only 1992 stands out. There is an effect of *year* for Phrase Duration, but of *category* for Pause Duration. Phrase durations decrease slightly over time such that phrases in 2017 are significantly shorter than in 1947, but phrases in 1992 are shorter than in all other years (confirmed by relevelling the model with reference to 1992: 1992~1947: β=0.873, t=4.11; 1992~1957: β=0.643, t=3.01; 1992~1990: β=0.559, t=2.38; 1992~2017: β=0.525, t=3.15). Shorter phrase durations combined with lower word/syllable counts result in an AR in 1992 which, though slower, does not differ from other years. The main predictor of Pause Duration is discourse structure, with longer pauses after a Continuation relative to all other categories, but no other significant pairwise comparisons.

4. Discussion and Conclusion

This first exploration of prosodic variation across the lifespan in a small sample of speeches produced by QEII between the ages of 21-91 shows falling F0 over time, in line with expectations in the literature [13, 17]. The age-related F0 decline over time operates alongside 'regular' F0 variation by discourse topic structure, but crucially without any significant interactions between *year* and *category*, demonstrating a highly stable prosodic performance style over a 70-year period. Stable F0 cues to discourse structure are matched by consistent speech tempo, with no significant differences in AR over time. There is a tendency towards shorter phrases over time (cf. [23]), in both word count and duration, but only the 1992 speech stands out – perhaps due to ill health or the challenging content – and even in this context AR is stable, in contrast to [14, 21, 22]. Temporal stability thus also operates alongside 'regular' durational cues to discourse structure (e.g. longer post-C pauses), independent of year.

The remarkable stability of prosodic performance observed in QEII's speeches, aged 21-91 years, appears to be rooted in maintenance of consistent cues to discourse structure, which the restricted discourse genre (scripted speeches) may also foster. Future research will seek to corroborate these findings across more time points and using additional acoustic measures previously found relevant in the literature on prosodic variation across the lifespan, such as rhythm metrics and F0 variability.

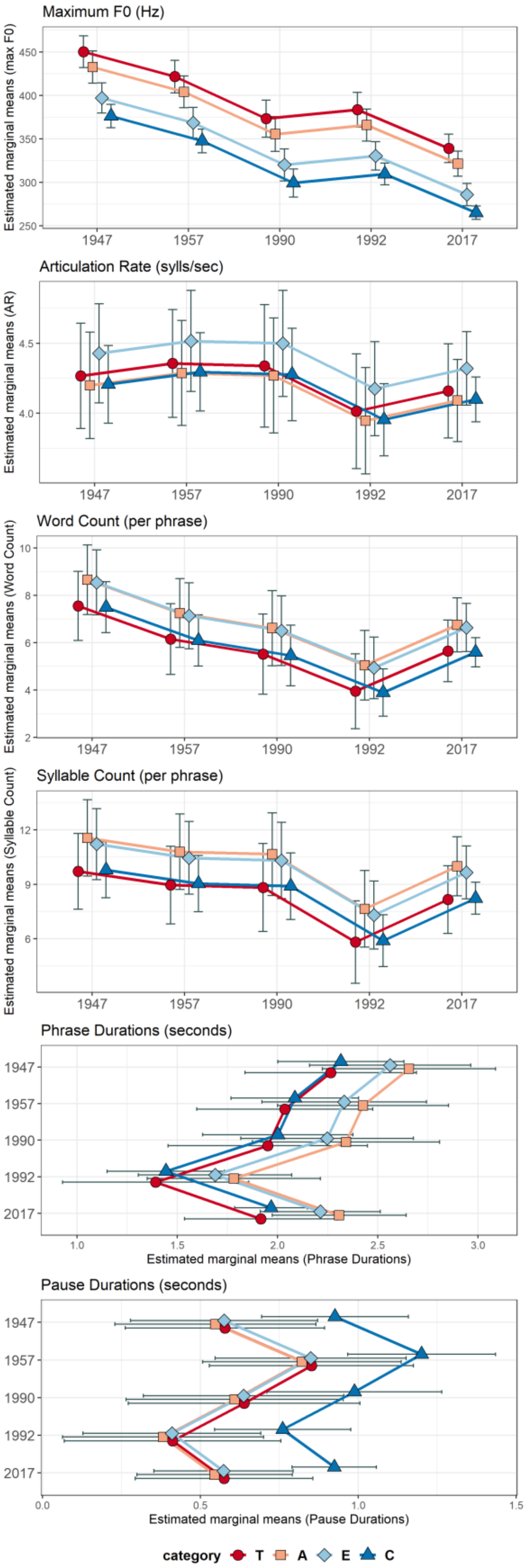

Figure 1: *Model predictions by year + category for: MaxF0 (Hz), Articulation Rate, Word Count, Syllable Count, Phrase durations (s) and Pause durations (s).*

Table 5: *Model summaries (DV ~ year + category), treatment coded with reference to 1947 and T(opic).*

DV		β	SE	t	p
maxF0 (Hz)	(int)	450.48	9.3		
(per phrase)	1957	-28.65	9.3	-3.1	.002
	1990	-77.16	10.2	-7.5	<.001
	1992	-66.86	9.1	-7.3	<.001
	2017	-111.3	7.4	-15.0	<.001
	A	-17.68	10.4	-1.7	.092
	E	-53.22	9.9	-5.4	<.001
	C	-74.08	8.4	-8.8	<.001
Articulation	(int)	4.27	0.19		
Rate	1957	0.09	0.19	0.46	.643
(sylls/sec)	1990	0.07	0.21	0.34	.736
(per phrase)	1992	-0.25	0.19	-1.36	.177
	2017	-0.11	0.15	-0.71	.480
	A	-0.07	0.21	-0.32	.750
	E	0.16	0.20	0.79	.430
	C	-0.06	0.17	-0.35	.724
Word	(int)	7.56	0.74		
Count	1957	-1.40	0.74	-1.91	.058
(per phrase)	1990	-2.04	0.81	-2.51	.013
	1992	-3.60	0.72	-4.99	<.001
	2017	-1.90	0.59	-3.23	.001
	A	1.10	0.83	1.33	.186
	E	0.99	0.79	1.26	.211
	C	-0.06	0.66	-0.09	.931
Syllable	(int)	9.72	1.06		
Count	1957	-0.76	1.06	-0.72	.471
(per phrase)	1990	-0.90	1.17	-0.77	.442
	1992	-3.91	1.04	-3.78	<.001
	2017	-1.56	0.84	-1.85	.065
	A	1.84	1.19	1.55	.124
	E	1.49	1.13	1.33	.187
	C	0.08	0.95	0.08	.937
Phrase	(int)	2.265	0.217		
Durations	1957	-0.229	0.216	-1.06	.290
(seconds)	1990	-0.314	0.239	-1.32	.190
	1992	-0.873	0.212	-4.11	<.001
	2017	-0.348	0.173	-2.01	.045
	A	0.390	0.243	1.60	.110
	E	0.296	0.231	1.28	.201
	C	0.050	0.195	0.26	.797
Following	(int)	0.578	0.160		
Pause	1957	0.274	0.160	1.72	.087
Durations	1990	0.061	0.176	0.35	.728
(seconds)	1992	-0.166	0.157	-1.06	.291
	2017	-0.002	0.128	-0.02	.985
	A	-0.030	0.179	-0.17	.866
	E	-0.002	0.170	-0.01	.989
	C	0.349	0.144	2.42	.016

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