CHANGES IN FUNDAMENTAL FREQUENCY AND F1 ACROSS CHRONOLOGICAL AGE

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ABSTRACT

Chronological age is used widely in academic research and yet it is poorly understood how accurately it measures ageing across the lifespan. The current study considers 17 speakers of English between 22-79 years old (M=51.65, SD=18.09) focusing on whether their f_o and F_1 correlate with chronological age in three different vowels (/ə, iː, ɛ/). I hope to determine whether there is a linear correlation between f_o and chronological age, and F_1 and chronological age, or perhaps the changes we see in speech production are as a consequence of other factors. Results indicate that there is a very weak effect of chronological age on f_o and F_1. Therefore, the evidence suggests more research into other age-grading measures, such as the social and biological should be considered in the future [1, 2], though I argue that chronological age should not be dismissed entirely from research as proven in previous studies [3, 4].

Keywords: chronological age, f_o, speech production, formants, lifespan

1. INTRODUCTION

The present study aims to determine whether f_o and F_1 correlate linearly with chronological age (CA), in hopes of continuing current ageing research in linguistics [3, 4], and consider how we should be evaluating age across the lifespan in future research [2]. When we speak of CA we speak of the numerical value assigned at birth, which is used widely across research areas including linguistics, and yet we know little about how well this measure fully encapsulates all aspects of ageing [5]. Previous research determines that the voice can be impacted by lots of different factors as we age. Social factors known to influence speech production include: class, race, gender, language attitudes, politics and economic experience [6]. In addition, previous research notes how speech production can change depending on our relationship to the individual we are talking to, determining whether we accommodate or not [7] to them, resulting in us subconsciously moving our phonetic targets to align with this other individual [8]. On a more biological level, puberty can cause male speakers to experience vocal fold mass increases, a descending larynx from an increased neck length and width, and a larger nasal cavity [2]. Likewise, hormonal changes such as the menopause have been evidenced to influence voice quality in female speakers, generally causing a 'decrease in lung power, atrophy of laryngeal muscles, stiffening of laryngeal cartilages, vocal fold thickening, and a loss of elastic and collagenous fibres' [9], resulting in a lowering of f_o and F_1 over the lifespan. This lowering of f_o and F_1 is evidenced in previous studies [3, 4] on CA across the lifespan. Reubold et al [4] speculate the reasons for this could be due to: vowel harmonics, with f_o tracking the formants across the lifespan, due to the intrinsic relationship between them [10, 11], vocal tract lengthening over time, or a more perceptual reason to maintain perceived phonetic height over time [3]. Harrington et al [3] conclude that whilst f_o and F_1 both appear to correlate with CA over time, there are still unanswered questions as to why this occurs. As a result, my own study aims to be a precursor to future studies analysing how language may change as a consequence of age by tracking f_o and F_1 across CA. This should help us to understand how speech production may be influenced by increasing age, and how perhaps in future we can incorporate other ageing models into linguistic research. For example, in more recent years, Hejná and Jespersen [2] suggest that perhaps biological and social age are better measures for capturing and understanding linguistic behaviour over CA. As a result, by understanding how much CA can explain variance in f_o and F_1, we can begin to understand why other models of age may be useful to consider alongside CA in future research.

1.1. Summary and predictions

In this study, I compare f_o and F_1 across chronological age (CA), in order to understand the relationship between f_o and CA, and F_1 and CA in speech production. In light of the existing research I suggest the following predictions:

Any correlations seen between CA and f_o could result from hormonal changes such as lower testosterone levels in males and lower oestrogen and progesterone after menopause in females [12]. Additionally, correlations seen between F_1 and CA suggests possible evidence for vowel centralisation as older speakers' vocal tracts centralise with age [12]. If we see correlations between both f_o and CA, and F_1 and CA we would assume that perhaps CA does have an influence on our speech production as we age. Any differences we see between f_o and F_1 may result from differences in voice quality, [13] and the size and strength of the vocal folds causing changes in f_o [9] or changes to the size and shape of the vocal tract causing changes in F_1 [14, 15]. Nonetheless, as mentioned f_o and F_1 are intrinsically linked, so we would expect them to follow a similar trajectory across CA [10, 11]. If correlations between CA and f_o, and CA and F_1 cannot fully be explained or do not occur then future research should consider other biological and social factors in order to observe age-related changes in speech production.

2. METHODS

2.1. Participants

Data from 17 speakers (9 female and 8 male) were collected for the purposes of this study ranging between 22-79 years old (M=51.65, SD=18.09). Male ages ranged from 22-79 years old (M=57, SD=18.21) and females from 22-67 years old (M=46.89, SD=17.61). All speakers within the study were born or raised in Kendal, a small town in the county of Cumbria, UK, bordering Lancashire to the South, Scotland to the North and Yorkshire to the East. Social information revealed that the participants all fell into a lower to upper middle-class socioeconomic status.

2.2. Data collection

Speech data was collected using a Zoom H1 recording device which produced .wav files at a sample rate of 44,100 Hz. Recordings took no more than 10 minutes. Participants also completed a questionnaire to elicit some social information and their own personal thoughts about ageing.

2.3. Materials

The word list was made up of 40 words. Within this, there were 10 words aiming to elicit a /ə/ vowel, 10 for the /iː/ vowel, and 10 for the /ɛ/ vowel. The vowels were chosen due to their relatively stable nature across the lifespan in the North West of England, being less affected by social change. The /ə/ vowel was also chosen to help replicate findings in previous studies [3, 4], where both f_o and F_1 declined with CA. In addition, there were an extra 10 distractor words. In total this produced 680 tokens, when the distractor words were removed, and the data was analysed and filtered, 469 tokens were eventually used in the final data.

An additional questionnaire was presented to participants, based on existing metrics presented in previous studies [16, 2] which aim to find out how the voice can be affected by speech and how we might measure age, including occupation and social background, how an individual feels about age, and hormonal and biological effects which may impact on an individual's age. In future studies it would be useful to use this data to understand how social factors may be influencing on an individual's age.

/ə/ Words	/ɛ/ Words	/iː/ Words
liar	dress	fleece
mother	protest	bleed
question	effort	sheep
vessel	confess	grief
again	attest	leaf
caution	net	evil
denim	head	believe
melon	regrets	beach
across	press	breeze
extra	excess	freed

Table 1: Word List used to extract /ə/, /ɛ/ and /iː/ vowels from participants.

2.4. Data analysis

Speech data was collated and analysed using Praat [17]. Before analysis, recordings were downsampled to 22,050 Hz, low-pass filtered to 11,025 Hz and high-pass filtered to 50 Hz. From here individual vowels were annotated by word, vowel and speaker in order to extract the formant values. I took the mean of f_o and F_1 across the vowel duration. This was in order to provide a more robust estimate across the vowel, rather than relying on a single timepoint. I present inferential statistics of the results extracting Pearson's r and p values for this paper. This was in order to understand whether or not we could see correlations between CA and f_o, and CA and F_1, and to understand whether there is a relationship between them [18].

3. RESULTS

Figures 1, 2 and 3 present the results of this study showing f_o and F_1 against CA for male and female speakers in the three separate vowels (/ə, ɛ/, iː). Results indicate that f_o and F_1 are both not correlating strongly with CA for all three vowels. In the next few sections I look into each vowel in detail.

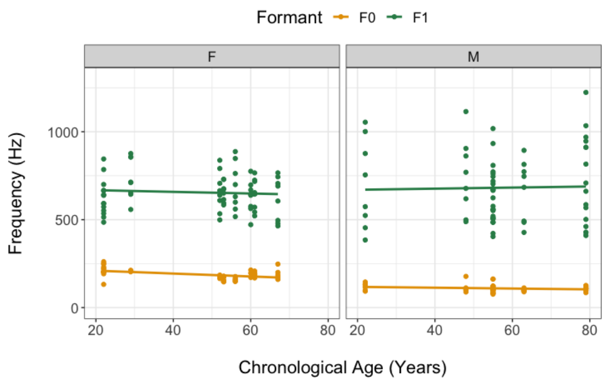

Figure 1: f_o and F_1 against chronological age results for the /ə/ vowel.

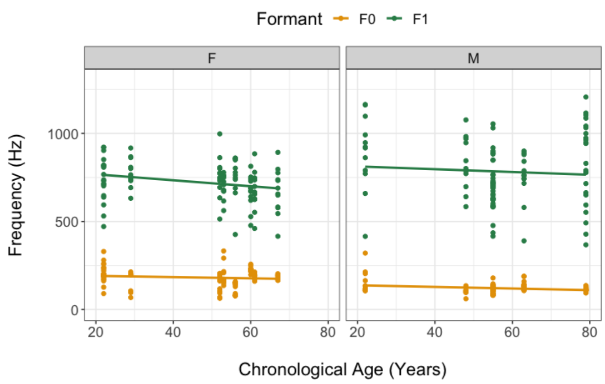

Figure 2: f_o and F_1 against chronological age results for the /ɛ/ vowel.

3.1. /ə/ vowel

Overall, there does not appear to be a strong correlation between CA and either f_o or F_1 for the /ə/ vowel in both male and female speakers. Using statistical testing, we notice that for male speakers the correlation is r=−0.2, p=.2 for f_o and r=0.03, p=.84 for F_1. This shows no significant correlation

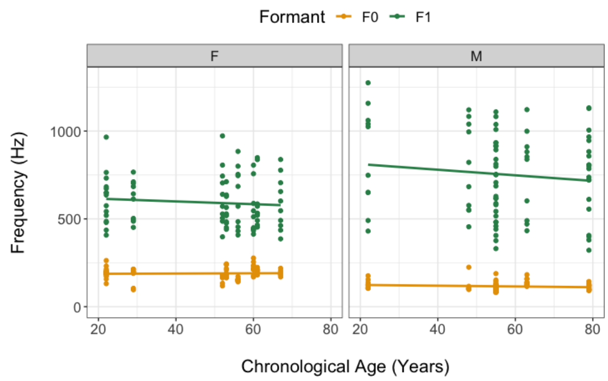

Figure 3: f_o and F_1 against chronological age results for the /iː/ vowel.

between CA and F_o, and CA and F_1, for male speakers. For female speakers the correlation is r=−0.48, p=<.001 for f_o and r=−0.08, p=.55 for F_1. This shows no significant correlation between CA and F_1 and a weak significant correlation between CA and f_o. Looking at the graphs, we can note that for female speakers there is a slight decline in f_o and F_1 overtime, but not to a great extent and with considerable participant variation across CA. Similar results can be observed for male speakers, however this time with a slight rise in f_o and decline in F_o, but with variation and 'troughs' forming at around 55 years old with a steep decline, and then rise again in F_1 across CA. Nonetheless, these correlations are non-significant, suggesting the /ə/ vowel does not appear to vary much across CA in terms of f_o and F_1.

3.2. /ɛ/ vowel

Both male and female speakers produce similar results in their f_o and F_1 for the /ɛ/ vowel across CA. Statistical measures indicate that for male speakers the correlation is r=−0.24, p=.02 for F_o, and r=−0.071, p=.49 for F_1. This shows no significant correlation between f_o and CA, and F_1 and CA. For female speakers the correlation is r=−0.11, p=.26 for f_o, and r=−0.24, p=.014 for F_1. Much like the men this shows no significant correlation between f_o and CA, and a weak-significant correlation between F_1 and CA. The graphs demonstrate that there is substantial variation within participants, especially for F_1, but also f_o in female speakers, but not all these patterns were significant. Results therefore indicate that there is not a decline over CA for either f_o or F_1, going against previous literature in this area [3, 4].

3.3. /iː/ vowel

There were non-significant negative correlations found for the majority of data for f_o and F_1 for the /iː/ vowel across CA. Male speaker correlation shows that r=−0.15, p=.2 for f_o and r=−0.11, p=.32 for F_1. This shows no significant correlation between f_o and CA, and F_1 and CA. Female results follow a similar pattern with the correlation as r=0.039, p=.72 for f_o and r=−0.089, p=.42 for F_1. This shows no significant correlation between f_o and CA, and F_1 and CA. As a consequence, the /iː/ vowel demonstrates little correlation between F_1 and CA, and f_o and CA. The results indicate that instead, f_o and F_1 remain relatively stable across CA, especially for f_o, suggesting that perhaps there is little change in f_o and F_1 across CA.

4. DISCUSSION

The results of this study indicate that there is very weak non-significant correlations between f_o and CA, and F_1 and CA. There appears to be little difference between the vowels presented in this study suggesting the weak relationship between CA and f_o, and CA and F_1 is consistent across the vowels. The slight linear decrease we do see could stem from changes in f_o and F_1 over CA due to the centralising of the vowel space due to ease of articulation as we get older. Though previous results on this are mixed and vary between the genders [19, 20, 21]. In addition, particularly for the female participants, slight declines after around 50 years old could stem from hormonal influences such as the menopause [22]. Nevertheless, changes in F_1 are not linear, instead we see some fluctuation. These troughs, most notably seen in male speakers, have been acknowledged in previous work [23, 24] and occur around the age of 55 years as reflected in the results of this study, though some studies argue for much later, around 80 years old [4]. The conclusion presented in the past has been that these troughs are speaker dependent [4]. Perhaps these individual speaker discrepancies are actually what is being observed in this study. Despite this, male speakers' F_1 is far more variable than female F_1, perhaps because of anatomical differences such as men having a longer pharynx [25] or perhaps a more social reasoning such as Smyth and Roger's [26] suggestion that women have more careful speech articulations than men. Nonetheless, the evident similarity in trajectory between f_o and F_1 across CA could stem from the intrinsic relationship between f_o and F_1 [10, 11], with F_1 simply following f_o across CA in order to maintain perceptual distance [4]. Overall, however there is little change across CA in f_o, and in F_1, suggesting that there is a weak relationship between f_o and CA, and F_1 and CA. These results could also have been influenced by low token numbers, using an apparent-time methodological approach and significant gaps in age groups such as between 30-40 years for both sexes. Future research should explore further the implications of social and biological ageing, and explore a wider range of ages in order to fully understand how speech production changes across the lifespan.

5. CONCLUSIONS

The aim of this initial study was to determine whether chronological age correlates with f_o and F_1, in order to understand whether there is a linear relationship between them, or whether we need to consider other forms of ageing, such as social and biological, in order to accurately measure ageing as a whole. In light of this research there is a very weak effect of chronological age on f_o and F_1 in the vowels /ə, iː, ɛ/, suggesting that other factors may better explain variation in the data, such as biological or social age. Future research should hope to determine how much of an effect these different forms of ageing are having and influencing each other across the lifespan.

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