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 voice and F1 correlate with chronological age in three different vowels (/a, i/, /ɛ/). I hope to determine whether there is a linear correlation between voice and chronological age, and F1 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 voice and F1. 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, voice, speech production, formants, lifespan

1. INTRODUCTION

The present study aims to determine whether voice and F1 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 voice and F1 over the lifespan. This lowering of voice and F1 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 voice 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 voice and F1 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 voice and F1 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 voice and F1, 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 voice and F1 across chronological age (CA), in order to understand the relationship between voice and CA, and F1 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, \( F_1 \) 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 /a/ vowel, 10 for the /i:/ vowel, and 10 for the /E/ 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 /a/ 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.

<table>
<thead>
<tr>
<th>/a/ Words</th>
<th>/i:/ Words</th>
<th>/E/ Words</th>
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<tbody>
<tr>
<td>liar</td>
<td>dress</td>
<td>fleece</td>
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<tr>
<td>mother</td>
<td>protest</td>
<td>bleed</td>
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<tr>
<td>question</td>
<td>effort</td>
<td>sheep</td>
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<td>vessel</td>
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<td>again</td>
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<td>caution</td>
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<td>evil</td>
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<td>denim</td>
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<td>believe</td>
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<td>melon</td>
<td>regrets</td>
<td>beach</td>
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<td>across</td>
<td>press</td>
<td>breeze</td>
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<td>extra</td>
<td>excess</td>
<td>freed</td>
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</tbody>
</table>

Table 1: Word List used to extract /a/, /i:/ and /E/ vowels from participants.
this paper. This was in order to understand whether or not we could see correlations between CA and \( f_0 \)
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 \( f_0 \) and \( F_1 \) against CA for male and female speakers in the three separate vowels (/a/, /e/, /i/). Results indicate that \( f_0 \) 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.

3.1. /a/ vowel

Overall, there does not appear to be a strong correlation between CA and either \( f_0 \) or \( F_1 \) for the /a/ vowel in both male and female speakers. Using statistical testing, we notice that for male speakers the correlation is \( r=-0.2, p=.02 \) for \( f_0 \) and \( r=0.03, p=.84 \) for \( F_1 \). This shows no significant correlation between CA and \( F_1 \), and CA and \( f_0 \), for male speakers. For female speakers the correlation is \( r=-0.48, p<.001 \) for \( f_0 \) and \( r=-0.08, p=.55 \) for \( F_1 \). This shows no significant correlation between \( f_0 \) and CA, and \( F_1 \) and CA. For female speakers the correlation is \( r=-0.11, p=.26 \) for \( f_0 \), and \( r=0.071, p=.49 \) for \( F_1 \). This shows no significant correlation between \( f_0 \) and CA, and \( F_1 \) and CA. The graphs demonstrate that there is substantial variation within participants, especially for \( F_1 \) in female speakers, but not all these patterns were significant. Results therefore indicate that there is not a decline over CA for either \( f_0 \) or \( F_1 \), going against previous literature in this area [3, 4].

3.2. /e/ vowel

Both male and female speakers produce similar results in their \( f_0 \) and \( F_1 \) for the /e/ vowel across CA. Statistical measures indicate that for male speakers the correlation is \( r=-0.24, p=.02 \) for \( F_1 \), and \( r=-0.071, p=.49 \) for \( F_1 \). This shows no significant correlation between \( f_0 \) and CA, and \( F_1 \) and CA. For female speakers the correlation is \( r=-0.11, p=.26 \) for \( f_0 \), and \( r=-0.24, p=.014 \) for \( F_1 \). Much like the men this shows no significant correlation between \( f_0 \) 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 \( f_0 \) in female speakers, but not all these patterns were significant. Results therefore indicate that there is not a decline over CA for either \( f_0 \) or \( F_1 \), going against previous literature in this area [3, 4].
3.3. /i:/ vowel

There were non-significant negative correlations found for the majority of data for $f_o$ and $F_1$ for the /i:/ 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 /i:/ 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 the study suggesting 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, i; e/1, 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.

6. REFERENCES

factors in convergence of f1 and f2 in spontaneous speech,” 2014, publisher: Unpublished.


