A Research Platform for measuring vowel spaces using acoustic reflectometry

In earlier studies (Watson, Palethorpe and Harrington, 2004, Harrington, Palethorpe and Watson, 2000), we showed that people's vowel spaces do change over time. We measured the changes on speech for 4 different people, from samples of their speech recorded over a 30 years period. Changes in the vowel space were observed, and were in the direction of the general community. Whilst the changes may be phonetically motivated, many of the changes could also be a consequence of the aging process. As we age significant changes to the supraglottic vocal tract occur, such as pharyngeal and tongue muscle atrophy, loss of lower jaw movement, lowering of the larynx and tooth loss (see for example Xue et al 1999, and Linville and Rens , 2001 for discussions on this). These changes to the physiology of the vocal tract may have an impact on the vocal tract as an acoustic chamber.

To investigate any possible effects that aging may have on vowel production we have developed a research platform which enables use to directly measure vocal tract shapes, using a non-invasive technique called acoustic reflectometry. The acoustic reflectometer sends a sound impulse into the vocal tract, and measures the reflections near the lips, and from these reflection coefficients the cross-sectional area of the vocal tract can be calculated. Using the Levinson-Durban recursion algorithm we are able to convert the reflection coefficients into filter coefficients of an all-pole digital filter, which we use to model the vocal tract. From these filter coefficients we are then able to derive a frequency spectrum and find the first and second vocal tract formants. We are restricting ourselves initially to the first two formants, for these two are the traditional dimensions on to which the vowel space is plotted. In this study we compare the formants from the measured vocal tract shapes, with those derived from formant analysis on recorded speech, to make sure our approach is valid.

In a preliminary study of two speakers we studied the four tense vowels which are on the periphery of the vowel space, namely /i:, a:, o:, and u:/. For each speaker we obtained 10 vocal tract measurements from the acoustic reflectometer for each vowel, and 10 speech recordings of each vowel in a HVD frame. However for all vowels we found there was considerable mismatch between the 1st two formants obtained through the two different approaches. We hypothesize that this is due to the effect of the glottal source on the formant calculation in the speech recording. Epps et al (1997) suggest that the formants in whispered speech correlate to the formants of the vocal tract. In order to test this we recorded whispered versions of the 4 vowels in a HVD frame for each speaker. For each vowel we obtained 5 recordings, and we then calculated the average first and second formants. These formant values of the whispered vowels compared favourably with those values obtained via the acoustic reflectometer measurements.

Unfortunately we also found, in the study, that the mouth piece required for the acoustic reflectometer, compromised the vowel production. It was not possible to get the open jaw movement required for the /a:/ vowel, and its formant values were similar to /o:/. This means that to get a picture of the entire vowel space we would need to redesign the mouth piece, so it retains its acoustic sealing function, but allows for greater jaw mobility. Nonetheless the results demonstrate that with our research platform we will be

able to at least focus on the high vowels, and through measurements of speakers in different age groups, obtain some understand of the effect of the aging process on vowel production.

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