Acoustic analysis of speech produced by children with cerebral palsy

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Children with cerebral palsy have motor difficulties that can affect speech. Their speech can be inconsistent which could affect their early reading. Words that they sound out could differ each time they attempt to read the word, making it difficult to develop firm word representations. This project was designed to investigate whether speech inconsistency could be observed in children with different types of cerebral palsy.

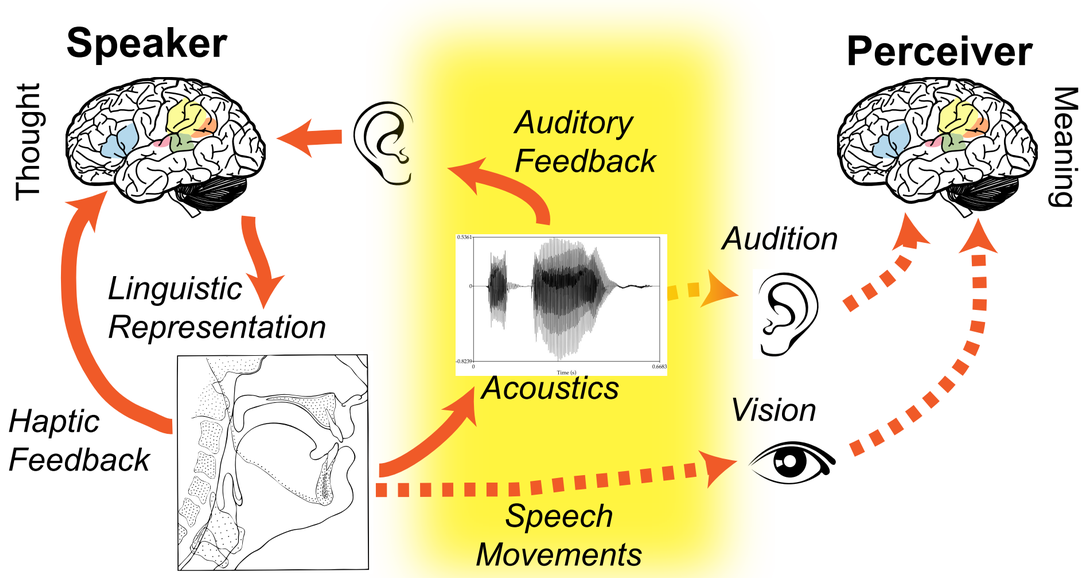


Fig.1 The speech cycle: a theory of how speech is produced and received. Highlighted area shows the link between speech production and auditory perception within the speaker. This area is theorised to be involved in the consistency of speech production.

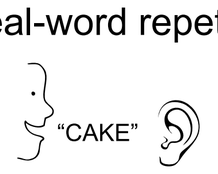
Experimental design

10 × 5 × aged between 6 and 14

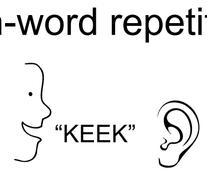
Dr Lindsay Pennington designed the project to emulate the different ways that children produce known and new words. A total of 66 words & non-words were assessed for each child. Three types of word-retrieval tasks were used:

Picture naming

Real-word repetition



Non-word repetition



Each child completed each task three times so that consistency of speech sounds in words produced could be quantified, giving about ~2,970 recordings. Each recording was manually segmented and 4-6 acoustic features were measured for each recording, giving more than 10,000 quantitative measurements (see Fig 2.). During analysis I was blind to the gender, age and type of cerebral palsy for each of the children.

Acoustic measurements

I automatically generated and quantified up to six acoustic features from the manually segmented recordings: **vowel formant frequencies and durations**, **voice onset time**, **hold phase**, **burst release**, **frication** and **pre-voicing durations.** These quantitative measurements enabled statistical comparison between and within word-retrieval tasks. Vowel frequencies (formants) were measured at three points: F1, F2 & F3 to allow comparison between consistency of vowel production.

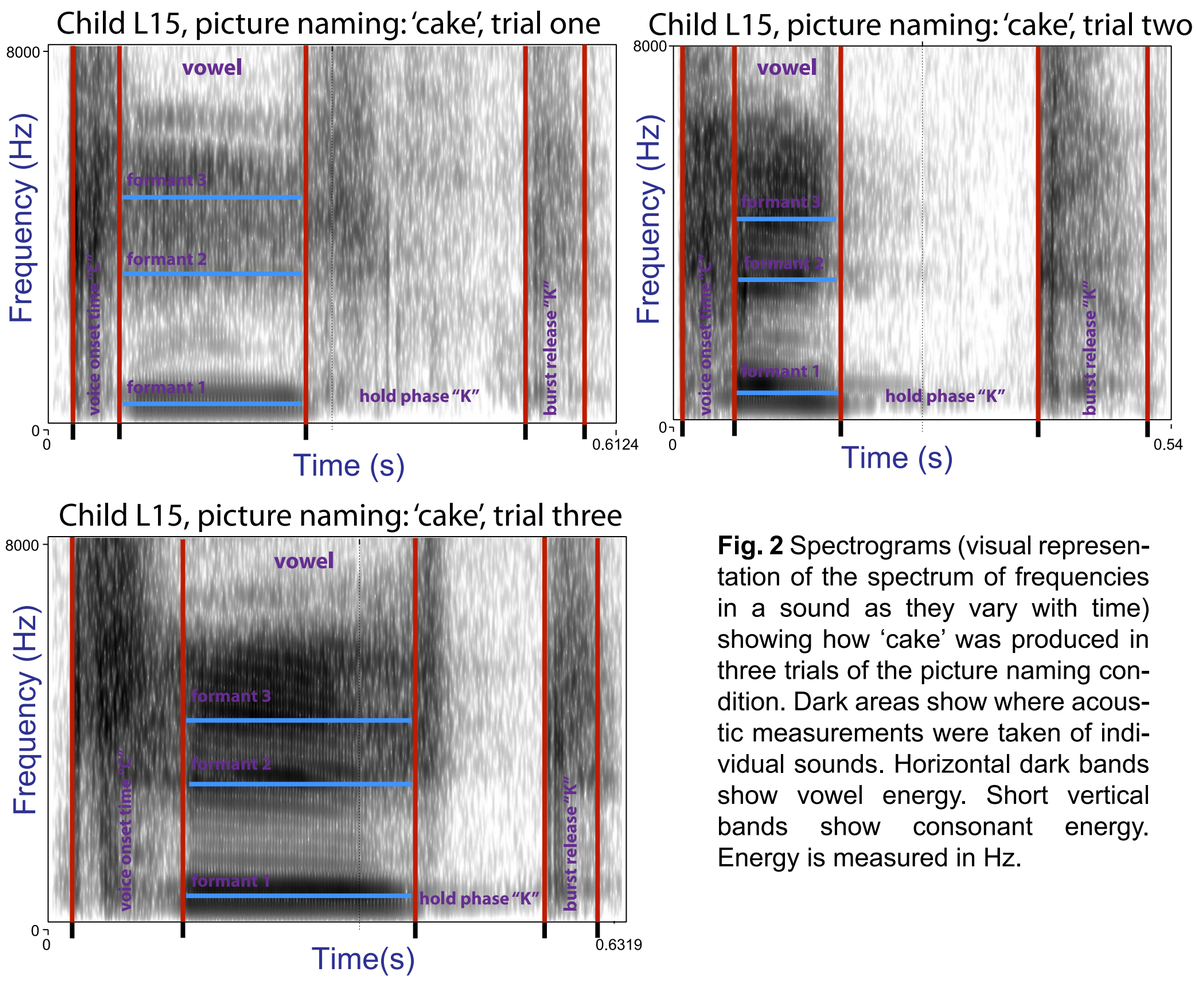


Fig. 2 Spectrograms (visual representation of the spectrum of frequencies in a sound as they vary with time) showing how 'cake' was produced in three trials of the picture naming condition. Dark areas show where acoustic measurements were taken of individual sounds. Horizontal dark bands show vowel energy. Short vertical bands show consonant energy. Energy is measured in Hz.

Measurement tools

After manual segmentation of sound recordings, I used the acoustic analysis software Praat to automatically generate the acoustic measurements. I used the statistical programming software R to combine measurements, to associate quantiative data with qualitative descriptions and IDs, creating a rich database. I also used R to generate plots and to carry out statistical analysis of data from the database (e.g. Figs. 3B, 3C & 4).

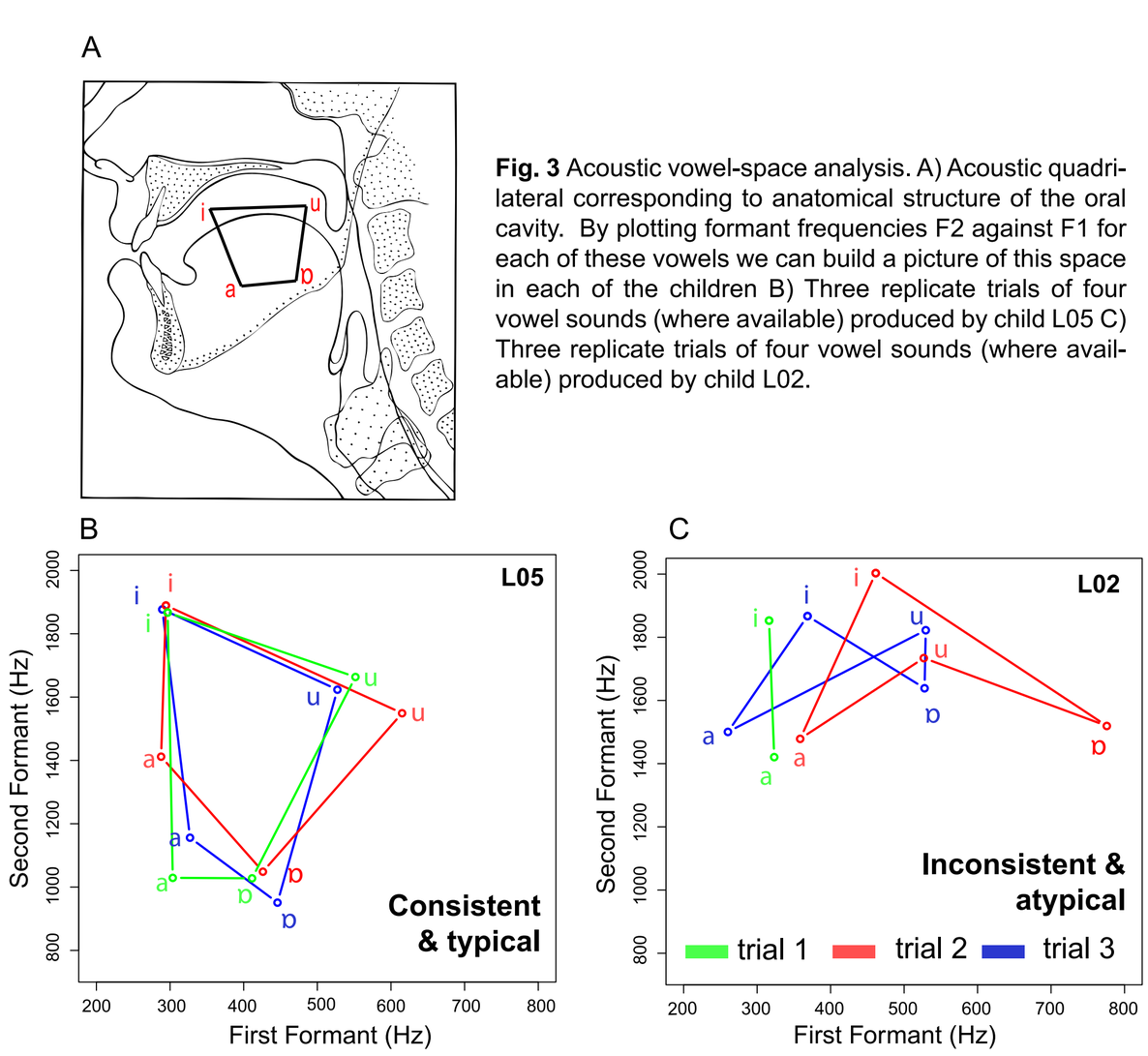


Fig. 3 Acoustic vowel-space analysis. A) Acoustic quadrilateral corresponding to anatomical structure of the oral cavity. By plotting formant frequencies F2 against F1 for each of these vowels we can build a picture of this space in each of the children B) Three replicate trials of four vowel sounds (where available) produced by child L05 C) Three replicate trials of four vowel sounds (where available) produced by child L02.

Results

I observed differences in the acoustic vowel space available for children to produce vowel sounds (see Fig. 3) and these quantitative observations are consistent with perceptual observations. These children have the same type of cerebral palsy but vastly different acoustic profiles. Such variability between individuals means that demonstrating the statistical significance of differences between groups could be difficult.

Initial, statistical tests identified very few significant differences between word-repetition and picture naming tasks within the children. Due to techical recording difficulties (poor quality or missing recordings) or severity of the speech disorder causing acoustic interference with other word parts (e.g. kangaroo_v2), all three trials were not captured for all items (see Fig. 4).

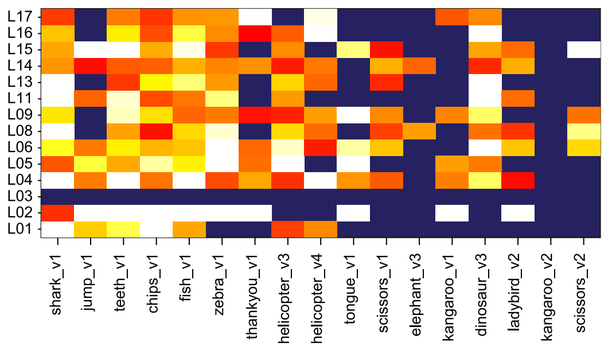


Fig 4. Heatmap showing range of durations across all available trials of vowel features during the picture-naming task. Red indicates more consistent durations, yellow indicates less consistent durations white means inconsistent durations and missing data is purple (insufficient observations to calculate range) are indicated in white.

Discussion

Although inital statistical analysis does not show significant differences between features measured in different tasks within each child, the data does show that individual difference between children within groups may be large. This suggests that variability between individuals (as well as missing replicates in source data) may make identification of real differences challenging. We have learned from this pilot study that an experimental design focussing on greater number of replicates rather than number of words may be more likely to uncover true differences. Analysis is ongoing as the scope of the project extended past the time limits of the research scholarship period.

Future research

This project is part of a larger investigation into inconsistencies of speech in children with cerebral palsy. The results will be compared with data from a perceptual project where student speech therapists listen to the same recordings and record what sounds they perceive. I am currently carrying out this project as part of the 100 hours initiative under the supervision of Dr. Lindsay Pennington in the Institute of Health and Society.