The speaker discriminating power of within-speaker behaviour:

a study based on vowel formants

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Dynamic variability in speech (DyViS): a forensic study of British English

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Hypothesis:

Is diachronic sound change a predictor of where speaker idiosyncrasy lies?

Are sounds which are undergoing change those which are most likely to differ between speakers?
### Analysis: F1 and F2 formants

<table>
<thead>
<tr>
<th>Stable</th>
<th>vs</th>
<th>Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOARD / ɔ /</td>
<td></td>
<td>WHO'D / ʊ /</td>
</tr>
<tr>
<td>HEED / i /</td>
<td></td>
<td>HOOD / ʊ /</td>
</tr>
<tr>
<td>HARD / ɑ /</td>
<td></td>
<td>HAD / æ /</td>
</tr>
</tbody>
</table>

**Measurements:**

Frequencies of F1 and F2 at its steady state and close to the centre of the vowel if possible

**Using Praat**
Materials:

- 50 male SSBE speakers
- Each hVd word preceded by schwa and followed by *today* produced in a sentence with nuclear stress:
  - *It’s a warning we’d better HEED today*
  - *It’s only one loaf, but it’s all Peter HAD today*
  - *We worked rather HARD today*
  - *We built up quite a HOARD today*
  - *He insisted on wearing a HOOD today*
  - *He hates contracting words, but he said a WHO’D today.*

- 6 repetitions
Previous results: n=20

--- Frequency of F2 (Hz)

--- Frequency of F1 (Hz)

/ iː /
/ uː /
/ u /
/ æ /
/ ɑː /

Deterding 1990 n=8
Dyvis 2006 n=20
New results: n=50

--- Frequency of F2 (Hz)

--- Frequency of F1 (Hz)

Deterding 1990 n=8
Dyvis 2006 n=20
Dyvis 2006 n=50
Results: means of 6 tokens per subject x 50
Formant means and ranges:

- **F1**
  - **min:** 236 Hz
  - **max:** 1184 Hz
  - **1 SD:** 315 Hz
  - **2 SD:**
Formant means and ranges:

![Chart showing formant means and ranges for different words.](image)
Results: Formant ranges: F1 vs F2
Results: Formant ranges: F1 vs F2

HZ

ERB
Within-speaker variability:

Comparing standard deviations for F2: stable vs non-stable

Stable: HOARD
Non-stable: HOOD
Non-stable: WHO’D
Very variable WHO’D:
Subject 26

‘He hates contracting words, but he said a WHO’D today’ x 6

F2 in /uː/: 1392 1716 1392 1310 1627 1461 Hz
Very variable WHO’D:

F2 in /u:/:

1392 1716 1392 1310 1627 1461 Hz

--- Frequency of F2 (Hz)

/ i:/

/ æ /

--- Frequency of F1 (Hz)

Deterding 1990 n=8
Dyvis 2006 n=50

Subject 26
Very variable WHO’D:

F2 in /uː/: 1392 1716 1392 1310 1627 1461 Hz

Graph showing the frequency of F2 (Hz) for /iː/ and /æ/ sounds with markers for Deterding 1990 n=8 and Dyvis 2006 n=50.
Very variable WHO’D: subject 26

F2:  1392  1716  1392  1310  1627  1461 Hz
Speaker discrimination power?

Between speaker

Within speaker

Mean Standard Deviation

Mean SD F1
Mean SD F2

Frequency of F2 (Hz)

Frequency of F1 (Hz)
Speaker discrimination power?

LARGE SPREAD F2!

Within speaker
Mean Standard Deviation

LARGE SPREAD F1!
F-RATIO: between-speaker/ within-speaker

![Graph showing F-Ratio for words HEED, HAD*, HARD, HOARD, HOOD*, WHO'D*]
F-RATIO: between-speaker/ within-speaker
Within-speaker patterns:

- If fronted WHO’D, then also fronted HOOD?
Within-speaker patterns:

• Not necessarily!
Within-speaker patterns:

6 most different F2 means: WHO’D very fronted, HOOD not/hardly fronted
Within-speaker patterns:

- If fronted HOOD, then also fronted WHO’D?

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**Diagram Description**

The diagram is a scatter plot with two axes: Frequency of F2 (Hz) on the x-axis and Frequency of F1 (Hz) on the y-axis. The plot includes data points for both HOOD and WHO’D, with a trend line indicating a correlation between the two frequencies. The points are color-coded, with blue dots representing HOOD and red dots representing WHO’D.
Within-speaker patterns:

• No large differences found:
Within-speaker variation (in SD)
Within-speaker variation (in SD)

HOOD

WHO'D*

HOARD

HOOD*

DyViS
Matching speakers:

Within-speaker variation (in SD)

- WHO'D*
- HOOD*

Legend:
- Red: 120-
- Yellow: 80-120
- Light blue: 40-80
- Blue: 0-40
Matching speakers:

Within-speaker variation (in SD)

- **WHO’D***
- **HOOD***

<table>
<thead>
<tr>
<th>Frequency of F1 (Hz)</th>
<th>Frequency of F2 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2300</td>
<td>900</td>
</tr>
<tr>
<td>2100</td>
<td>1100</td>
</tr>
<tr>
<td>1900</td>
<td>1300</td>
</tr>
<tr>
<td>1700</td>
<td>1500</td>
</tr>
<tr>
<td>1500</td>
<td>1700</td>
</tr>
<tr>
<td>1300</td>
<td>1900</td>
</tr>
<tr>
<td>1100</td>
<td>2100</td>
</tr>
<tr>
<td>900</td>
<td>2300</td>
</tr>
</tbody>
</table>

Legend:
- Red: 120-
- Yellow: 80-120
- Blue: 40-80
- Black: 0-40
Matching speakers:

Within-speaker variation (in SD)

WHO’D*

HOOD*

S22
Within-speaker patterns:

Within-speaker variability patterns?

[Graph showing frequency of F2 and F1 with data points for 'WHO'D' and 'HOOD'.]
Within-speaker patterns:

Within-speaker variability patterns?

4:6 HOOD more variable than WHO’D
Within-speaker patterns:

Within-speaker variability patterns?

![Graph showing frequency of F1 and F2 for words 'WHO'D' and 'HOOD'.]
Conclusions:

- This study confirmed:
  - fronting of /u û/ → F2 increased
  - more open /æ/ → F1 increased
  - Resulting in extra large formant ranges for these vowels
- Similar results for n=20 and n=50
- Changing vowels in HOOD, WHO’D and HAD provide better speaker discrimination than historically stable vowels in HOARD and HARD
- WHO’D performs less well than HOOD due to its large within-speaker variability
- Overall, within-speaker variability larger for changing vowels than stable vowels
- Stable HEED F2 performs best due to large between-speaker variability and relatively small within-speaker variability
- When WHO’D is fronting first, fronting of HOOD may be delayed
- When HOOD is fronting, also WHO’D is fronting
RELEVANCE FOR FORENSIC PHONETICS:

• Sounds undergoing change are useful as SPID parameters: they show large between-speaker variability and different usage patterns for speakers

• Concerning the stable vowels, F2 of HEED offers good SPID

• Caution required when measuring changing vowel formants: large range possible for formant frequencies
Acknowledgments

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DyViS research findings can be found at:

http://www.ling.cam.ac.uk/dyvis/