Acoustic phonetic variability and auditory word recognition by dyslexic and non–dyslexic children
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Introduction

- Dyslexics show a phonological awareness deficit, and some are impaired in phoneme categorization.
- Not clear whether impaired in normal auditory word processing.
- Bonte & Blomert (2004) ERP study suggested normal late-stage lexical access, but deviant early acoustic → phonological processing.
Acoustic variability and normal word processing

- Trial-to-trial acoustic phonetic variation due to talker voices, speaking rate, style, and tokens impairs spoken word recognition (Sommers & Barcroft 2006 review; Ryalls & Pisoni 1997 for children)

- Effects of talker and rate variation seen when processing is “slow and effortful” (McLennan & Luce 2005)
Talker and allophone variability

- Words spoken by **multiple talkers** are recognized more slowly and less accurately compared to single talkers (e.g. Mullenix et al. 1989)
- **Different allophones** of a phoneme (e.g. released/unreleased final stop consonants) likewise provide personal/stylistic variation without lexical ambiguity
Research questions: Variability

- Do children demonstrate less accurate/slower recognition of words with greater acoustic variability due to different talkers?
- Do children demonstrate less accurate/slower recognition of words with greater acoustic variability due to different allophones?
Research questions: Dyslexia

- Do dyslexic children demonstrate less accurate/slower word recognition than non-dyslexic children with greater acoustic variability due to talkers?
- Do dyslexic children demonstrate less accurate/slower word recognition than non-dyslexic children with greater acoustic variability due to allophones?
Method: Word recognition task

*Subjects hear:*
- A prompt suggesting the target word
- The *target* word
- A series of 7 test *probes*, which are either the same word as the target, or a different (phonemically overlapping) word

*Subjects respond:*
- For each probe, press a key or button for “same word” or “different word”

*Computer records choice and latency.*
**Method: Talkers**

- All targets: 1 Californian woman
- Test probes in trials with **single talker**: same Californian woman
- Test probes in trials with **multiple talkers**: 2 Californian men, women, boys, girls (the women different from the one above)
- Mixed talker trials vary not only in voice (including age and sex), but in personal speaking rate and to some extent style, especially with children
Method: Wordlist

- All high-frequency words familiar to children
- Target words for Talker trials: cake, big, teach, pool
- Target words for Allophone trials: trade, hit, quit, treat
- Foil words vary in initial consonant, vowel, or final consonant
Single vs. Mixed talker trials

- Target stimuli are same in both sets
- In 4 Single talker trials, target voice also produces the probes
- In 4 Mixed talker trials, target voice does not produce any probes
- Number of match probes in a trial is 3 or 4 (randomized)
- Order of probes in trials randomized
- Order of Single and Mixed trial blocks balanced across subjects
Sample trials: Single vs. Mixed talkers

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Target: TEACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probes:</td>
<td></td>
</tr>
<tr>
<td>1. teach</td>
<td>1. teeth</td>
</tr>
<tr>
<td>2. teach</td>
<td>2. teach</td>
</tr>
<tr>
<td>3. tale</td>
<td>3. teach</td>
</tr>
<tr>
<td>4. peach</td>
<td>4. teach</td>
</tr>
<tr>
<td>5. teeth</td>
<td>5. teach</td>
</tr>
<tr>
<td>6. teach</td>
<td>6. tale</td>
</tr>
<tr>
<td>7. teach</td>
<td>7. peach</td>
</tr>
</tbody>
</table>
Allophone trials

- 4 Allophone trials all use multiple talkers
- Target voice is always among the probe voices
- 2 targets have unreleased final stop, 2 targets have released final stop
- 4 match probes in each trial:
  - SAME voice as target, vs. different
  - SAME allophone as target, vs. different
Sample allophone trial

Prompt

Target: **QUIT** (released /t/)

Probes:

1. pit
2. **quit** (unreleased /t/)
3. **quit** (released /t/)
4. quite
5. **quit** (released /t/)
6. quiz
7. **quit** (unreleased /t/)
Bells and whistles in methods for child listeners

- Practice items before new blocks
- Trials blocked into game-like “levels” with encouraging screen displays
- Spoken prompts to suggest what the target word is (in a voice different from any of the stimulus voices)
- RT countdown bar to encourage responses under 2 sec
Method: Subjects

○ 10 dyslexics, 10 controls
  ● Dyslexics at or below 25th percentile on one or two subtests of Woodcock test of reading ability (words, nonwords)
  ● Controls at or above 40th percentile on both subtests

○ All have normal performance IQ
○ Age ranges in both groups 8–14
○ Groups not yet carefully matched on all variables
Data analysis

- Scoring: eliminate errors, too-short RTs; replace RTs longer than 3 SDs with 3 SDs
- RTs corrected for word duration
- Foils not analyzed, only matches
- Separate analyses of Talker variability trials vs. Allophone variability trials
- Due to missing values, some averaging, but some cells empty
Analysis of Talker trials

- 1 datapoint per trial: average RT of correct matches
- RM ANOVA
  - Between-subject factors:
    - Group (dyslexic, control)
    - Wordlist (order1, order2)
  - Within-subject factors:
    - Talkers (target voice, mixed voices)
    - Word (big, cake, pool, teach)
Results: Talker variability

- In the Talker variability trials, is a mixed set of voices harder (slower)? (Talkers factor)
  - No effect of Talkers (no main effects at all)

- Does the order of conditions matter? (Wordlist interactions)
  - Talkers x Wordlist interaction
  - Mixed talker trials are slower when they are heard first, and those subjects are faster when they then hear the Single talker trials
Talker x Wordlist interaction

![Graph showing Talker x Wordlist interaction](image-url)

- **RT** on the y-axis
- **Wordlist** on the x-axis
- Lines for SingleFirst and MixedFirst conditions
- Asterisks indicating significance

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Analysis of allophone trials

- 1 datapoint per match probe
- Averaged 2 trials with released stop targets and 2 with unreleased targets
- 2 RM ANOVAs
  - Between-subject factors:
    - **Group** (dyslexic, control)
    - **Wordlist** (order1, order2)
  - Within-subject factors:
    - **Talker** (target voice, other voice)
    - **Allophone** (released, unreleased)
Results: Talker variability

- In the Allophone variability trials, is a probe harder (slower) when the voice is different from the target voice? (Talker factor)
  - Main effect of Talker in trials with released stops in targets
  - Probes with voices different from target voice are slower than probes with the target voice
Effect of Talker on RT

![Bar chart showing the comparison of response time (RT) between a target voice and different voices. The x-axis represents the target voice vs. different voices, with two categories labeled 1 and 2. The y-axis represents RT in seconds, ranging from 0 to 0.45. The chart indicates a higher RT for the second category compared to the first.](image-url)
Results: Allophonic variability

In the Allophone variability trials, is a probe with a different allophone harder (slower)? (Allophone factor)

- Main effect of Allophone in both analyses:
- Probes with unreleased allophone are slower than probes with released allophone, whether it matches the target allophone or not
Allophones in targets & probes
Results: Allophonic variability

Is it even harder (slower) when the talker also varies? (Talker interactions)

- **Allophone x Talker** interaction in trials where target has a released allophone:
  - Unreleased allophone probes are especially slow in a different voice
  - Talker effect only with unreleased allophone probes
Talker x Allophone interaction with released allophone targets

![Bar chart showing reaction times (RT) for released and unreleased allophones for same and different talkers.](chart)

- **Y-axis:** Reaction time (RT)
- **X-axis:** Talker condition (Same talker vs. Different talker)
- **Legend:**
  - Released allophones
  - Unreleased allophones

The chart illustrates the reaction times for released and unreleased allophones across different talker conditions.
Summary: Talkers

- In the Talker variability trials, there was no overall effect of Single talker vs. Mixed talkers; listeners were slowest on Mixed talker trials when heard first (same result as Ryalls & Pisoni 1997)

- In the Allophone variability trials with released stop targets, listeners were slowest on unreleased allophones in a different voice from the target
Summary: Allophones

- In the Allophone variability trials, unreleased allophones are slower regardless of the target allophone.
- Only when the target stop is released, do other effects of interest arise: Talker, Group.
Why are released stops special?

- Released final stops are a form of clear speech; they are presumably better exemplars of the stops.
- Perhaps activation of released target also facilitates comparison with probes.
Results: Dyslexia

Main effect of **Group** in trials where target has a released allophone:

- **Controls are faster than dyslexics**
- No significant interactions of any factors with Group (e.g. the groups share the Talker x Allophone effect of slower unreleased stops in a different voice)
Group difference by target

![Bar chart showing group differences for rel and unrel targets between Dyslexics and Controls.](image-url)
Summary: Dyslexia

- Dyslexics are slower than controls in a subset of trials: Allophone trials with released allophone targets.
- Specifically, dyslexics are not any faster with released allophone targets than with unreleased allophone targets.
Overall summary

- Children re Talker variability: Effects in some conditions, but not all
- Children re Allophone variability: Unreleased allophones are slower; whether it matches target doesn’t matter
- Dyslexic children re Talker variability: Perform like controls
- Dyslexic children re Allophone variability: Slower than controls on some targets; perform like controls re probes
References

Streeter & Nigro (1979) The role of medial consonant transitions in word perception, *JASA* 65: 1533–1541