The Effects of Age on Tongue Motion and Speech Duration

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Motivation

- Models of aging predict, and studies of aging show, a slowing of motor behaviors in older subjects.
- In the oral cavity Hirai et al (1991) showed age related changes in non-speech tongue motor behavior using ultrasound.
  - Subjects touched their tongue tip alternately to the palate and floor at rates of 60, 92, or 120 times/minute.
  - 20 repetitions were recorded and 10 were measured for:
    - Timing of the upper and lower contacts
    - Duration of the up and down movements,
    - velocity of the up and down movements
    - Time lag between cue and contact

Motivation

- Results: For older subjects
  - Contact time was shorter –more so at faster rates
  - Velocities were lower
  - Rhythm was more variable
  - Time lag longer

- Consistent with a model of slowing

Neurological Models of Age Related Slowing

1. Generalized slowing model
   - All cognitive process slow down to a similar extent
   - Supported by meta-analyses of reaction time studies
   - RT of older adults is predicted (fairly linearly) from young adults irrespective of tasks or conditions

2. Domain-Specific Model of Slowing
   - All tasks in domain show similar slowing effects
   - E.g., verbal vs nonverbal effects

3. Process-Specific Model of Slowing
   - Slowing effects vary by cognitive process, not task or domain
   - E.g., memory vs understanding

Reaction Time Results

- Simultaneous matching tasks.
  - Age significantly reduced accuracy and reaction time
  - 60+ group were slower than 20-30s on majority of tasks.
  - Generalized Slowing

- Delayed matching tasks.
  - Accuracy decreased with age, but reaction time did not.
    - Not generalized slowing
  - 60+ group sacrificed accuracy for speed on all tasks irrespective of difficulty
  - Memory component effect explained by process-specific model

Speed/Accuracy Trade-Off

- Age related changes seen in timing and motor control of various behaviors are consistent with neurological changes, such as:
  - Internal noise
  - Decreased attention
  - Increased processing demands
  - Greater trade-off of speed and accuracy

- Muscle tissue alterations also could potentially affect speech by reducing strength.
Expectations

Older speakers may reduce speed and/or accuracy.

Hypothesis:

- H1: Older people will speak more slowly, consistent with a general model of muscular and neurological aging.
- H2: Older speakers will exhibit more variability than younger speakers at non-constriction regions of the vocal tract, which has a low impact on the acoustic signal, but not at phonemic constrictions.
METHODOLOGY
Subjects

- 10 younger female patients aged 20 to 30.
- 10 older female patients aged 64 to 82.
- Women were used instead of men because the ultrasound images were better with women.

Inclusion Criteria

- General Good Health, Normal Oral Motor Exam
- Normal speech
- Normal hearing, normal SRT
- MD/PA accent, no strong dialect
- College education
Speech Tasks

Five (5) repetitions of /əCVp/. 
- 3 Consonants: /s/, /ʃ/ /r/.
- 3 Vowels: /i/, /ɑ/, /u/.

- 20 subjects x 6 CV’s x 5 reps = 600 data sets

- Two subjects had only 3 repetitions of each. Occasionally a subject had only 4 repetitions. One subject had data only for /i/ condition.
Variables and analysis

- Independent variables
  - Age (1=younger, 2=older)
  - Phoneme (a, i, u, r, s, sh)
  - Context (a, i, u, r, s, sh)

- Dependent variables
  - Displacement at Constriction
  - Displacement at Non-constriction
  - SD of each
  - Velocity at Constriction
  - Duration: Phoneme, CV, Total

- SPSS, GLM, 1 way or 3 way ANOVAs
Instrumentation

- Ultrasound Machine: Acoustic Imaging, Phoenix AZ, Model AI5200S.
- 2-4 MHz multifrequency convex-curvilinear array transducer.
- 28 fps, 90 degree sector.
- HATS to stabilize head and transducer.
- Microphone (Audiotek – unidirectional, short range)
- Videotape of subject’s lower face.
Recording Procedures

- Subject seated in HATS with microphone placed 3” from mouth and transducer under chin midsagitally.

- Each task repeated 5 times at own pace; task order was randomized.

- Ultrasound images were oriented so that shadows of the hyoid and jaw bones were equidistant from the edges of scan.

- Audio and video were recorded on videotape and digitized with Final Cut Pro onto Mac.
Ultrasound Analysis

- **EdgeTrak**
  - Extract and track the tongue contour (red dots)
  - Store it as a series of xy coordinate points.
CAVITE (Contour Analysis and Visualization Technique)

Palate was drawn in proper position

Vertex was positioned several mm below and halfway between minimum and maximum x

Radii were drawn at constriction for each phoneme
Calculating Displacement and Velocity

- **Constriction Displacement (Velocity):** The displacement occurring at the constriction radius at the second time-frame after the acoustic onset of the phoneme.

- Once this was determined for a phoneme, the following measures were made at the same time.
  - **Non-Constriction Displacement:** The displacement occurring during the constriction displacement of the adjacent sound.
  - **Constriction SD**
  - **Non-Constriction SD**
Acoustic Analysis

PRAAT

- Phoneme duration of /ə/, C, V.
  - /ə/ was occasionally preceded by a glottal stop and silent period; they were not measured.
  - /s/ and /ʃ/ duration was measured at the onset/offset of noise at 4KHz.
  - /r/ duration could not be measured: intervocalic glide.

- Also measured
  - CV duration
  - total duration (from /ə/ onset to /p/ closure)
RESULTS
Aging Effects on Duration

<table>
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<tr>
<th>DV</th>
<th>IV</th>
<th>f</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV dur</td>
<td>Age</td>
<td>4.404</td>
<td>0.037</td>
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<tr>
<td></td>
<td>Phoneme</td>
<td>4.82</td>
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<tr>
<td></td>
<td>Context</td>
<td>4.915</td>
<td>0.003</td>
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<td>Total Dur</td>
<td>Age</td>
<td>11.363</td>
<td>0.001</td>
</tr>
<tr>
<td>Total Dur SD</td>
<td>Age</td>
<td>7.071</td>
<td>0.009</td>
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<tr>
<td>Schwa/TotDur</td>
<td>Age</td>
<td>1.908</td>
<td>NS</td>
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<td></td>
<td>Phoneme</td>
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<td>NS</td>
</tr>
<tr>
<td></td>
<td>Context</td>
<td>.790</td>
<td>NS</td>
</tr>
<tr>
<td>Phone/TotDur</td>
<td>Age</td>
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<td>0.024</td>
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<tr>
<td></td>
<td>Phoneme</td>
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</tr>
<tr>
<td></td>
<td>Context</td>
<td>20.904</td>
<td>0.000</td>
</tr>
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</table>

Results:
Longer durations for older subjects in all measures except schwa.
Acoustic Data Support Models of Slowing

- Duration data were consistent with a General Slowing Model of aging. Older subjects were slower on all tasks except /schwa/.

- Also consistent with a Domain-specific model because we focused on a single domain, namely speech-like tasks.

- Next we turned to aging effects on articulation accuracy, we studied tongue displacement and SD at constriction and non-constriction regions of the vocal tract.
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<tr>
<td>Constriction Displacement</td>
<td>Age</td>
<td>1.487</td>
<td>NS</td>
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<tr>
<td></td>
<td>Phoneme</td>
<td>3.724</td>
<td>0.006</td>
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<tr>
<td></td>
<td>Context</td>
<td>0.305</td>
<td>NS</td>
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<tr>
<td>Non-Constriction Displacement</td>
<td>Age</td>
<td>0.307</td>
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<tr>
<td></td>
<td>Phoneme</td>
<td>2.335</td>
<td>0.056</td>
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<td></td>
<td>Context</td>
<td>4.129</td>
<td>0.003</td>
</tr>
<tr>
<td>Constriction Velocity</td>
<td>Age</td>
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<td>NS</td>
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<tr>
<td></td>
<td>Phoneme</td>
<td>7.329</td>
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</tr>
<tr>
<td></td>
<td>Context</td>
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<td>NS</td>
</tr>
<tr>
<td></td>
<td>Phoneme x Context</td>
<td>2.696</td>
<td>0.007</td>
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Age was NS for all
## Age Effects on Variability

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<tr>
<td>Constriction SD</td>
<td>Age</td>
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<td>NS</td>
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<tr>
<td></td>
<td>Phoneme</td>
<td>1.756</td>
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<tr>
<td></td>
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<tr>
<td>Non-Constriction SD</td>
<td>Age</td>
<td>0.021</td>
<td>NS</td>
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<td></td>
<td>Phoneme</td>
<td>7.988</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Context</td>
<td>1.548</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Phoneme X</td>
<td>3.013</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Context</td>
<td>1.548</td>
<td>NS</td>
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Age was NS
Do the Models of Aging fit this data?

- Acoustic data supported age related slowing.
- Tongue data did not.
  - Displacement showed no age related effect at constriction or non-constriction radius.
  - SD also showed no age related effect at constriction or non-constriction radius.
  - Velocity at constriction – no age effect.
- However, these two data sets suggest a difference between the speed/accuracy tradeoff in older vs. younger subjects.
  - Lower speed, and unchanged accuracy in older subjects.
Effects of Context on Displacement

- Changes at the constriction are more acoustically salient than at the non-constriction site.
- Looked at Non-constriction vs Constriction Displacement and SD.
- Age differences may be seen as an age x context interaction, with a greater context effect in older subjects at the non-constriction site.
## Context Effects on Displacement

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<tr>
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<td>0.021</td>
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<tr>
<td><strong>More coarticulation</strong></td>
<td>Phoneme</td>
<td>7.988</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Not more variability</strong></td>
<td>Context</td>
<td>1.548</td>
<td>NS</td>
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This study found.

- Tongue Displacement was a very stable parameter.
- Durations were longer with age.
- These are consistent with trade-offs of speed to maintain accuracy, and a General Slowing Model.
- These subjects were all healthy, which may have reduced aging effects.
Other theories of Aging

(1) Reduced Processing Resources

- Aging leads to a reduction in the quantity of processing resources (attention, memory, speed)
  - Space: memory
  - Energy: attentional capacity
  - Time: tradeoffs between rate and decay of processing

- Processing resources are not restricted by tasks or domains but allocated across a broad range of cognitive processes.

- To enhance cognitive tasks greater amounts of these resources need to be allocated to them.

Other theories of Aging

(2) Selective Optimization with Compensation.

- Manage the dynamics between gains and losses of aging.
  - Selection: Restrict ones life to fewer domains
  - Optimization enrich and augment reserves maximize chosen life courses
  - Compensation: when specific capacities are lost.
- Artur Rubinstein: Reduced his repertoire, practiced them more often, slowed his speed prior to fast movements to heighten the impression of speed.

These models predict

- Reduced function in aging is overcome by
  - (1) focusing resources or
  - (2) restricting domains of activity.

- Behavior is slowed with age but task is not compromised because slowing
  - (1) allows selective resource allocation or
  - (2) is a means of compensation

Our data are more consistent with the first model.

- Older speakers slowed speech and maintained tongue displacement and precision.
Because speech is overlearned, it is very well practiced. An important domain that doesn’t get neglected – at least not in these subjects.

Slowing down speed allows processing resources to be better allocated to the tasks.

These subjects were normal-to-optimal aging candidates – they may not need much compensation, such as non-constriction effects.

Future study needs to include less successful agers.
The authors would like to thank Keith Mays and Katie Dietrich-Burns for comments.
THE END