A New Model of Menu Search

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Overview

- Nilsen experiment
- Old models
  - ACT-R with Visual Interface
  - EPIC
- New data
  - Nilsen & Evans (1998)
  - Byrne, Anderson, Douglass, & Matessa (1999)
- Old Models (yes, again)
- New model (ACT-R/PM)
- Other issues

Menu Selection (Nilsen, 91)

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**EPIC Model** (Hornof & Kieras, 97)

- “Parallel Processing Dual Strategy Varying Distance Hybrid Model”
- Assumptions:
  - 50/50 split between systematic top-down search and random search
  - Mix of one item in fovea and three items in fovea
  - Multiple items examined in parallel
  - No mouse movement until target has been detected, one aimed movement made

**EPIC: Systematic Search**

- Look at precue
- Click the GO box and move eyes to top item
- Determine the item one foveal diameter below gaze. Move eyes to that item.
- Quit searching when target item appears in memory.
- Move mouse and gaze to item. Click mouse

- Always starts at item 1
- Never skips items
- Gaze will usually overshoot

**EPIC: Random Search**

- Look at precue. Click the GO box and move eyes to top item.
- As soon as it is determined which items are not in the fovea, randomly choose an item and move gaze to it.
- Quit searching when target item appears in memory.
- Move mouse and gaze to item. Click mouse

- Initial fixation equally likely to be to any menu item
- Up and down saccades equally likely

**ACT-R Model** (Anderson, Matessa, & Lebiere 97)

- Assumptions:
  - Model selects basic feature from target character
  - Attention shifts strictly top-to-bottom
  - Skips characters that do not share feature
  - Mouse moves with attention

- Predictions:
  - Initial fixation on first item with shared feature
  - Some items are skipped
  - Eye never overshoots target
  - Also predicts effects of letter vs digit search with letter vs. digit distractors
New experiment to evaluate EPIC and ACT-R models
- EPIC predicts large effects of menu spacing
- ACT-R predicts large effects of features
- New experiment:
  - Large vs. small spacing
  - Search for (and amongst) single characters vs. words
- Results:
  - Reliable but small effect of spacing
  - Reliable but small effect of character vs. word search

Eye Tracking (byrne, Anderson, Matessa, & Douglass 99)
- 6, 9, and 12 menu lengths
- 11 participants, 108 trials after 36 practice trials
- ISCAN RK726/RK520 Pupil/CR tracker with magnetic head tracking
- Recorded point-of-regard (POR) and mouse position at 120 Hz (every ~8 ms)
- Characters ~0.34° high, ~0.69° apart
- Fixations identified on the basis of velocity

Results: Response Time

<table>
<thead>
<tr>
<th>Target Location</th>
<th>6</th>
<th>9</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Time (ms)</td>
<td>2000</td>
<td>1800</td>
<td>1600</td>
</tr>
</tbody>
</table>

Results: Number of Fixations

<table>
<thead>
<tr>
<th>Target Location</th>
<th>6</th>
<th>9</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fixations</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
**The Models, Revisited**

- Despite good fits to original Nilsen RT data, neither model fares well with respect to the new data.
- What should the “right” model look like?
  - Initial fixation to one of the first three items, usually item 1.
  - Mostly, but not exclusively, top-to-bottom.
  - Some items are skipped.
  - Most bottom-to-top is a result of the target item being skipped.
  - Would still predict number vs. letter effects.

**New ACT-R/PM Model (in progress)**

- Select a feature in the target item.
- Click the menu open.
- Make an initial attention shift.
  - Not sensitive to feature content.
  - Productions that encode the first five locations compete.
  - Conflict resolution preference mirrors initial fixation preferences in the data.
- Further attention shifts again a mix of competing productions.
  - Matching item, up and nearby.
  - Matching item, down and nearby.
  - Matching item, anywhere down.
  - Random item in any direction (more on this later).
**Issue: Visual Features**

- Current ACT-R/PM uses the same Rumelhart & McClelland feature set as the old Visual Interface
- LED-style representation of characters from 16 features:
  - \[ \begin{array}{c}
  \_\_\_ \\
  \_\_\_ \\
  \_\_\_ \\
  \_\_\_ \\
  \end{array} \]
- So, for example, the letter “E”:
- Old Visual Interface could accurately search in peripheral vision for any one of the 16
- Problems:
  - Characters don’t actually look like this (curvature seems important)
  - Discriminations seem too fine

**First fit**

- Represented only part of the features (horizontal vs. vertical vs. diagonal)
- Slightly simpler production set (nearest up vs. nearest down only)

**Why So Bad? Too Many Misses**

- Also wasn’t capturing right distribution of saccades (not enough backtracking)

**New Feature Set (Briggs & Hocevar 75)**

- Also 14 features
  - Horizontal (top, center, bottom)
  - Vertical (single and double)
  - Angle (open top, down, & horizontal)
  - Small curve (convex right, bottom, & left)
  - Large curve
  - Closed curve
  - Continuous curve
- Examples:
  - N: double vertical, angle down, angle top
  - O: large curve, continuous curve, closed curve
  - 5: small curve convex left, horizontal top
**Current Fit**

- Somewhat better
- Still too slow in places, too fast in others
- Not capturing slower initial item

![Current Fit Graph](image1)

**Current Fit (2)**

- Not enough fixations for late positions, long menus
- Too much menu length effect

![Current Fit (2) Graph](image2)

**Other Unresolved Issues**

- Mouse control
  - EPIC model is wait until target is found
  - Old ACT-R model says move mouse with eyes
  - Neither predicts mouse overshoots
  - Data say something in between, but with overshoots
- Are people really sensitive to feature matches?
  - Marginal evidence in eye-tracking data
  - Number vs. letter search effect is robust, however
  - What's the “right” feature set?
- How to best use eye tracking data to improve fits?
  - Are fixation durations necessary?
  - Relationship between fixations and attention shifts?
  - Dario’s HMM parser may be the key

![Other Unresolved Issues](image3)