“SEEV” Model of Visual Attention Allocation in Action

Flying a Plane (Main Subtasks)

- **AVIATE**
  Maintain aerodynamic stability (prevent stalling)

- **NAVIGATE**
  Maintain SA regarding hazards (traffic; terrain) and progress toward destination

- **COMMUNICATE**
  Interact with ATC
The modern “glass cockpit” has evolved in such a way as to change the mix between the demands of auditory versus visual information processing.

Digital uplinks and visual display of information to the pilot provides robust and redundant support of SA (Reducing the potential for missed and/or misunderstood comms).
Wickens et al. (2003) examined these issues --- focusing upon how the deployment of new display technology influences pilot mental workload (resource demands) and performance.

Miranda will present details regarding this aspect of the study.

Today, we will examine how Wickens et al. (2003) applied a subset of the SEEV family of models to predict spatial allocation of visual attention across a range of flight scenarios.
Experimental Method

- Flight simulation study
- N=12 experienced pilots
- Primary Task: Fly the plane (Aviate)
- Concurrent Tasks:
  - monitor surrounding air traffic
  - follow flight directives from ATC
- Procedure
  - 6 IFR flights (30 minutes each)
  - Each flight consisted of alternating “communication” and “traffic” segments
Communications Segment

monitor information channel(s) for ATC flight directives
  (via voice; digital data link; or both)

repeat ATC commands aloud

execute required maneuver (heading; altitude; and/or flight speed)

Δ WORKLOAD: 1 vs 3 part ATC directive
Traffic Segment

monitor and “call out” location of other air traffic

ATC “heads up” info provided via:
  auditory (voice) channel
  graphical display of traffic (CDTI)
  or
  both channels (redundant condition)

Δ WORKLOAD: 1 vs. 4 planes encountered
Areas of Interest (AOI)

- Outside World (OW)
- Digital ATC Data Link
- Cockpit Display of Traffic Info (CDTI)
- Instrument Panel Cluster (IP)
Sample Flight Scenario

**Typical 1-Parameter ATC Instruction:**

“Cessna 1851 Zulu, Turn Right Heading 030.”

**Typical 3-Parameter ATC Instruction:**

“Cessna 1851 Zulu, Turn Right Heading 010, Climb and Maintain 5500, Reduce Airspeed to 140 knots.”

**Typical Cross-Country Flight**

6 Data Link Legs (Solid Lines)
5 Traffic Legs (Dashed Lines)

*Figure 2. Typical cross-country flight.*
% Dwell Time Results:
(3) Experimental Conditions x (3) AOI

Figure 4. Top: Percentage dwell time on three areas of interest (AOIs) with one plane (low workload) across modality. Bottom: Percentage dwell time on three AOIs with four planes (high workload) across modality. (OW = outside world, IP = instrument panel, CDTI = cockpit display of traffic information.)
% Dwell Time Results:

10 Conditions x AOI Outcomes to be Modelled

**Workload = 1 Plane**

<table>
<thead>
<tr>
<th>Condition</th>
<th>IP</th>
<th>OW</th>
<th>CDTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual (Load=1)</td>
<td>64.4</td>
<td>24.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Visual (Load=4)</td>
<td>50.2</td>
<td>25.8</td>
<td>26.2</td>
</tr>
</tbody>
</table>

**Workload = 4 Planes**

<table>
<thead>
<tr>
<th>Condition</th>
<th>IP</th>
<th>OW</th>
<th>CDTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory (Load=1)</td>
<td>60.3</td>
<td>39.3</td>
<td>----</td>
</tr>
<tr>
<td>Auditory (Load=4)</td>
<td>44.9</td>
<td>54.6</td>
<td>----</td>
</tr>
</tbody>
</table>
Salience, Effort, Expectancy, Value (SEEV) Model
Subset of SEEV Model tested by Wickens, et al. (2003)

Optimal Expectancy Model in Expert Pilots
## Preliminary Analyses:

**Identify Cognitive Tasks and Visual AOI’s**

<table>
<thead>
<tr>
<th>Areas of Interest</th>
<th>Aviation Subtasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP</td>
<td>Aviate</td>
</tr>
<tr>
<td>OW</td>
<td>Navigate</td>
</tr>
<tr>
<td>CDTI</td>
<td>Communicate</td>
</tr>
</tbody>
</table>

*Flight segments only*
Map Visual AOI’s Relevance to Subtasks

- IP
- OW
- CDTI

Arrows indicate relevance:
- Green: IP → Aviate
- Red: OW → Navigate
- Blue: CDTI → Navigate
Visual Attention (Scan) to AOI =

\[ \sum_{\text{TASKS}} [(BW \times \text{relevance(value) of AOI to task} \times \text{task priority}]] \]

*Figure 6. The expected value model of visual scanning or attention allocation. AOI = area of interest, IP = instrument panel, OW = outside world, CDTI = cockpit display of traffic information, BW = bandwidth, Rxy = relevance of AOI to Task Y. The higher the value (V) of a task, the more important that task is.*
Computational Model’s Prediction
of Relative Visual Attention (across AOI’s)

\[
VA_{AOI=i} = \sum_{j=1}^{2} BW_i \times \text{Relevance}_{ij} \times \text{Priority}_j
\]

Subtasks

expectancy

value
Model coefficients are **ORDINAL RANKINGS** based upon expert task analysis
*(0=lowest; N=highest)*

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevance</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Figure 2. Generic matrices used to compute scanning predictions from the model shown in equation (2). Three AOI’s (A, B, C) are depicted. The label “task” includes both separate tasks (such as aviate, navigate) as well as the same task under different conditions (such as aviating while maneuvering, or while flying straight and level). Thus there will be as many data points to predict, as there are cells in the “Relevance” matrix.*
### Optimal Expectancy Model Coefficients
*(Generated via Cognitive Task Analysis)*

**TABLE 1: Parameter Values for Experiment Described in Part 1: Traffic Density and Modality**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AOI</th>
<th>IP</th>
<th>OW</th>
<th>CDTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (B)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual (1)</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Visual (4)</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditory (1)</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditory (4)</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevance (R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviate (V)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Navigate (V)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Aviate (A)</td>
<td>3</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Navigate (A)</td>
<td>2</td>
<td>4</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

**Note.** The values of 1 and 4 in the bandwidth listing correspond to the traffic density.

See next slide for simplified Coefficient Tables
Cognitive Task Analysis Results Expressed as (Quasi-Ordinal) Model Coefficients

<table>
<thead>
<tr>
<th>Bandwidth (BW&lt;sub&gt;i&lt;/sub&gt;) Coefficients by Experimental Condition</th>
<th>Area of Interest</th>
<th>Relevance (R&lt;sub&gt;i&lt;/sub&gt;) Coefficients by Condition/Subtask</th>
<th>Area of Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IP</td>
<td>OW</td>
<td>CDTI</td>
</tr>
<tr>
<td>Visual (1-Plane)</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Visual (4-Planes)</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Auditory (1-Plane)</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Auditory (4-Planes)</td>
<td>2</td>
<td>2</td>
<td>--</td>
</tr>
</tbody>
</table>

Task Priority (P<sub>k</sub>) Coefficients

- Aviate 3
- Navigate 2
- Communicate 1
Sample Computation of Visual Attention Allocation

(Condition = Visual; Workload = 1=plane; AOI = IP)

\[ VA_{AOI} = \sum_{j=1}^{2} BW_i \times \text{Relevance}_{ij} \times \text{Priority}_j \]

\[ = (2 \times 3 \times 3) + (2 \times 1 \times 2) \]

\[ = 18 + 4 \]

\[ VA_{AOI} = 22 \]
Model Predictions vs. Empirical Dwell Times from Traffic Segments of Experiment 1

Figure 8. Model fit of traffic experiment. Squares = CDTI, triangles = OW, circles = IP; small = 1 traffic, large = 4 traffic; solid symbols = visual CDTI, open symbols = auditory.
Homework Assignment

Compute the Visual Attention predictions for the 10 Conditions Represented in SLIDE #6 and Plot their Relationship to the Mean Percent Dwell Times Observed in the Traffic Legs of Experiment 1 (i.e., Replicate Figure 8; plot and $R^2$)
Figure 3. The simulation environment, showing the CDTI to the left and the instrument panel (IP) to the right.