"SEEV" Model of Visual Attention Allocation in Action

Wickens, C.D., Goh, J., Hellberg, J., Horrey, W.J. & Talleur, D.A. (2003)

Attentional Models of Multitask Pilot Performance Using Advanced Display Technology. *Human Factors*, 45(3), 360-380.

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 <u>SEEV family of models</u> 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

Flight Simulator Cockpit

Areas of Interest (AOI)

Outside World
OW

Digital ATC
Data Link

Cockpit Display
of Traffic Info
CDTI

Instrument Panel
Cluster
IP

Sample Flight Scenario

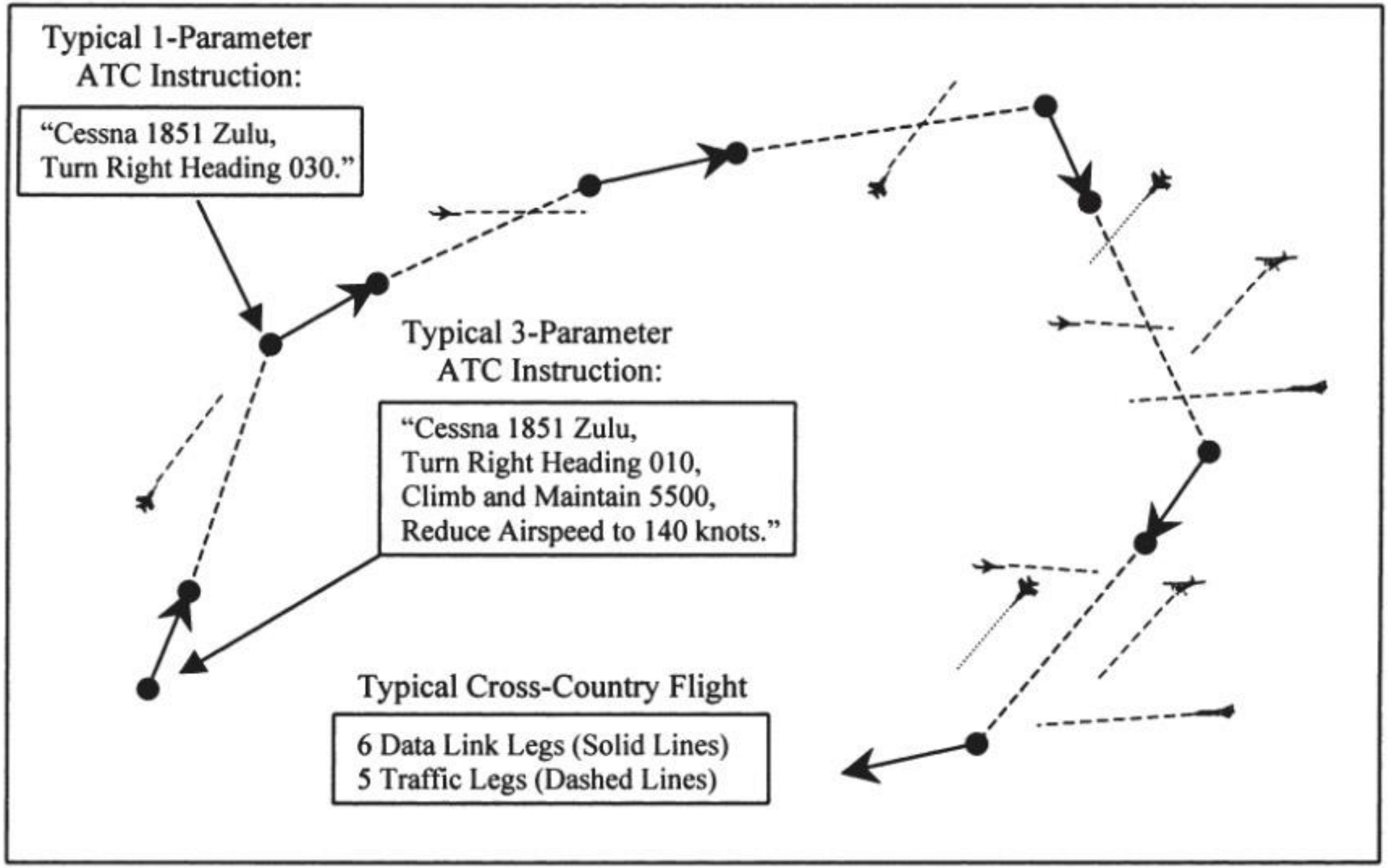
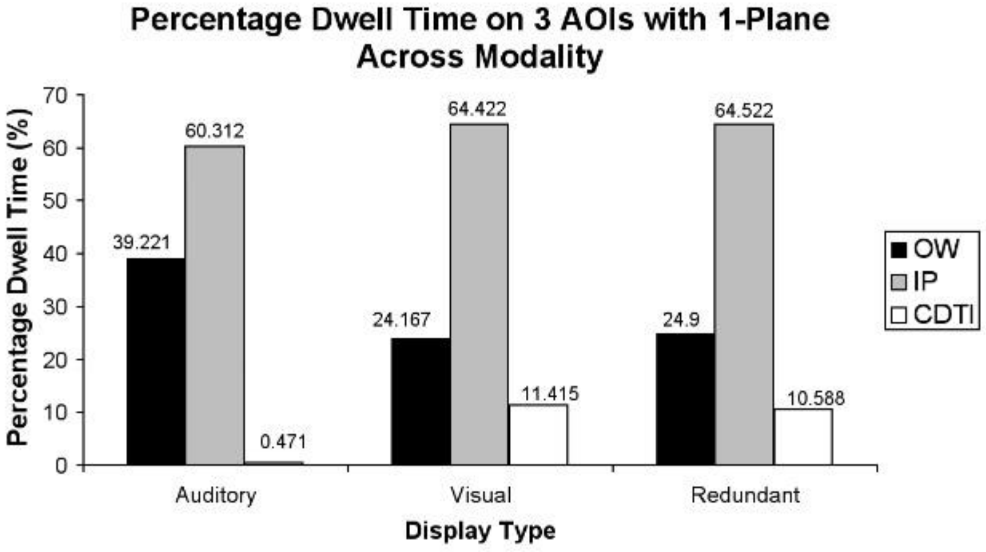


Figure 2. Typical cross-country flight.

% Dwell Time Results:
(3) Experimental Conditions x (3) AOI



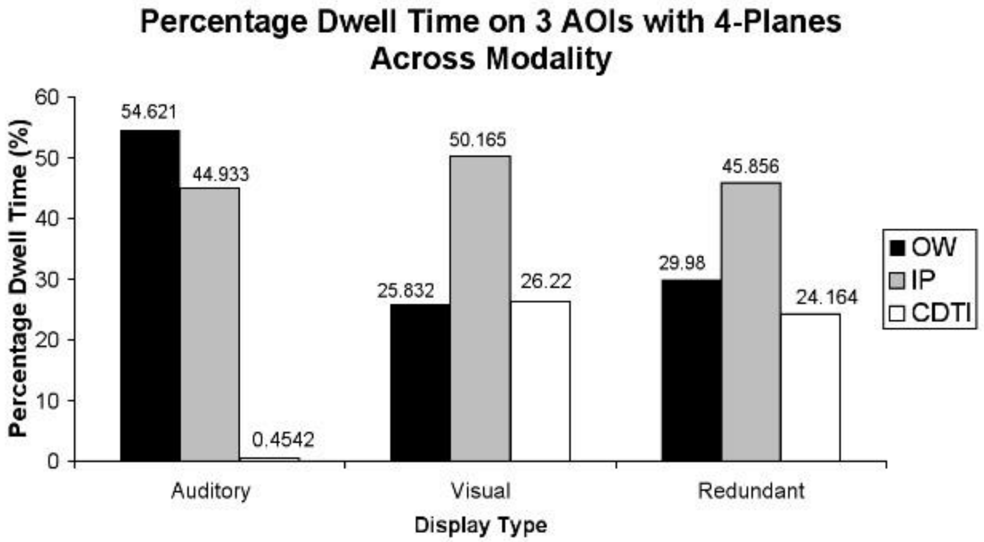
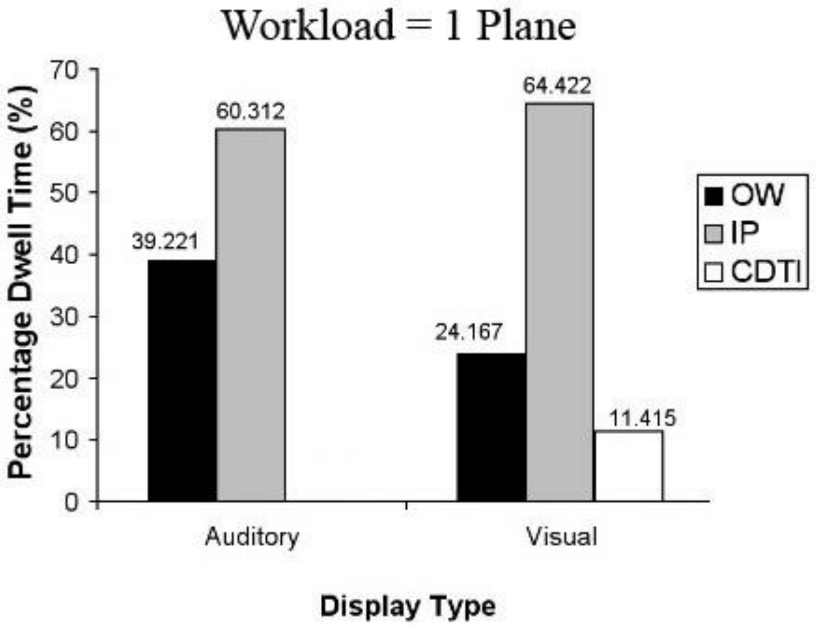
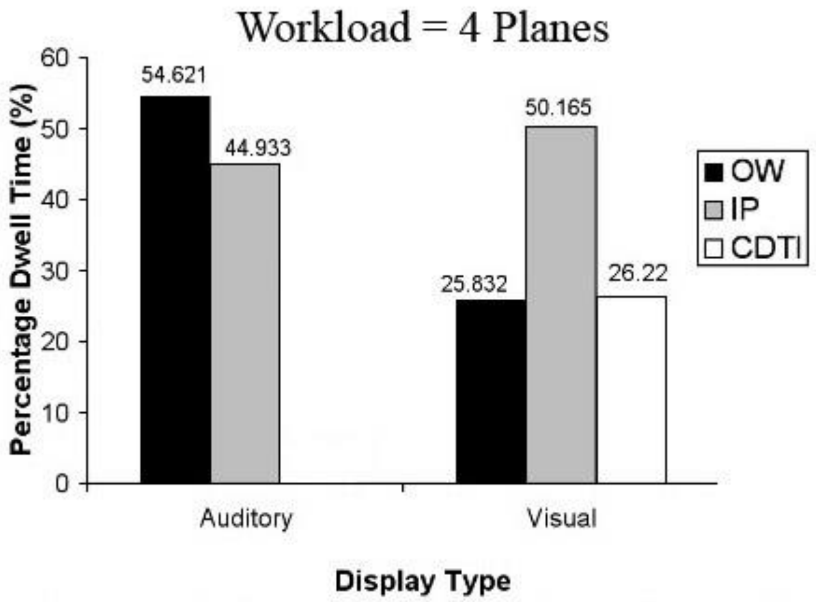


Figure 4. Top: Percentage dwell time on three areas of interest (AOIs) with one plane (low workload) across modality. Bottom: Percentage dwell time on three AOIs with four planes (high workload) across modality. (OW = outside world, IP = instrument panel, CDTI = cockpit display of traffic information.)

% Dwell Time Results:
10 Conditions x AOI Outcomes to be Modelled





	% Dwell Time		
Condition	IP	OW	CDTI
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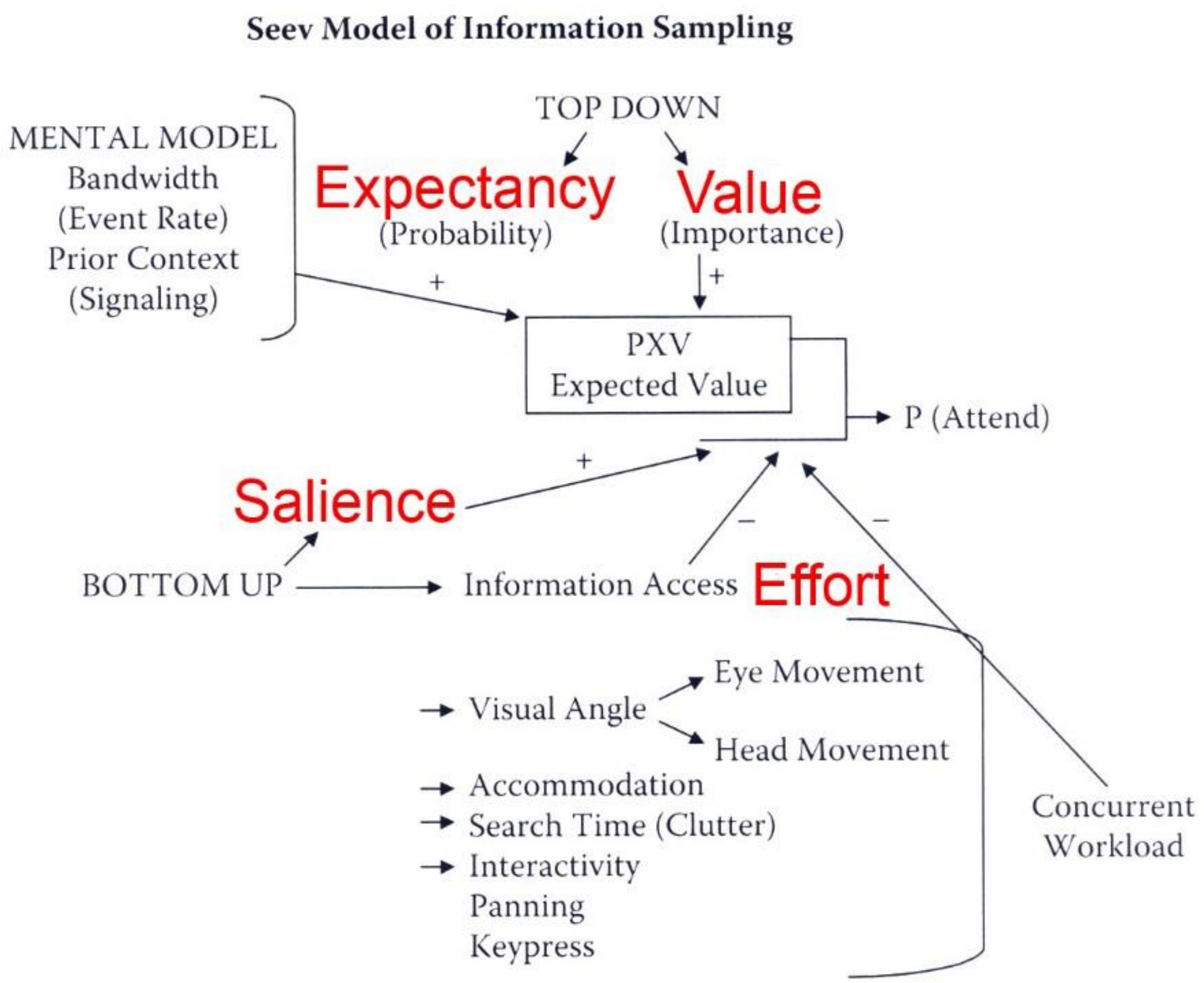
Visual (Load=1)	64.4	24.2	11.4
Visual (Load=4)	50.2	25.8	26.2
Auditory (Load=1)	60.3	39.3	-----
Auditory (Load=4)	44.9	54.6	-----

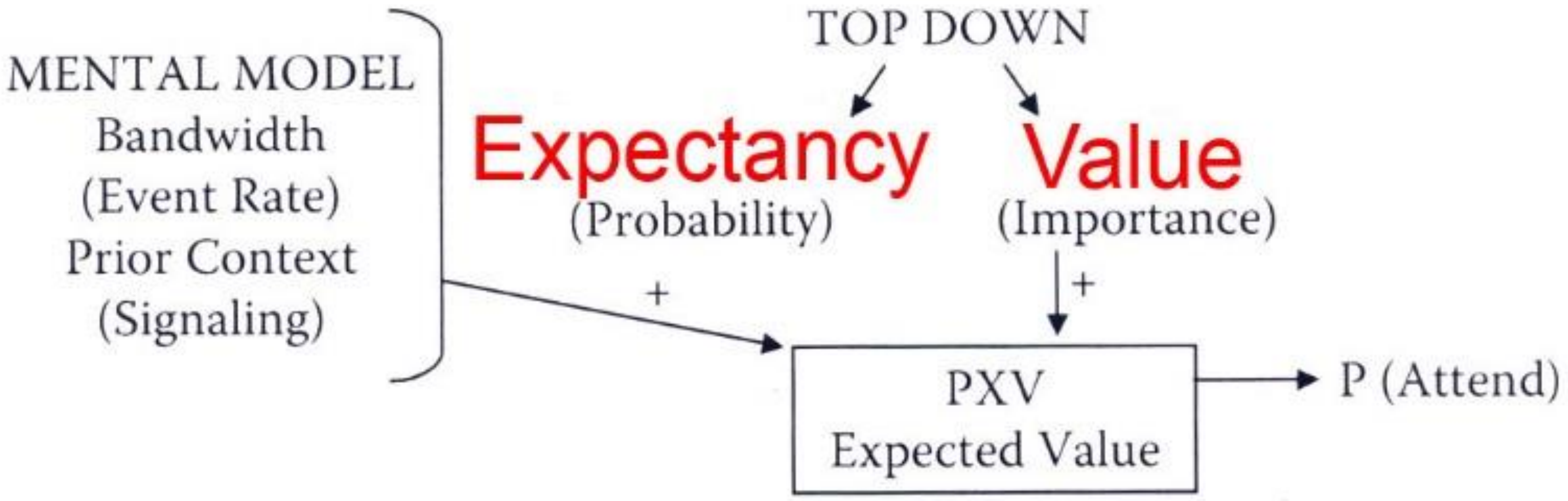
Slide 6

Salience, Effort, Expectancy, Value (SEEV) Model



Subset of SEEV Model tested by Wickens, et al. (2003)

Optimal Expectancy Model in Expert Pilots



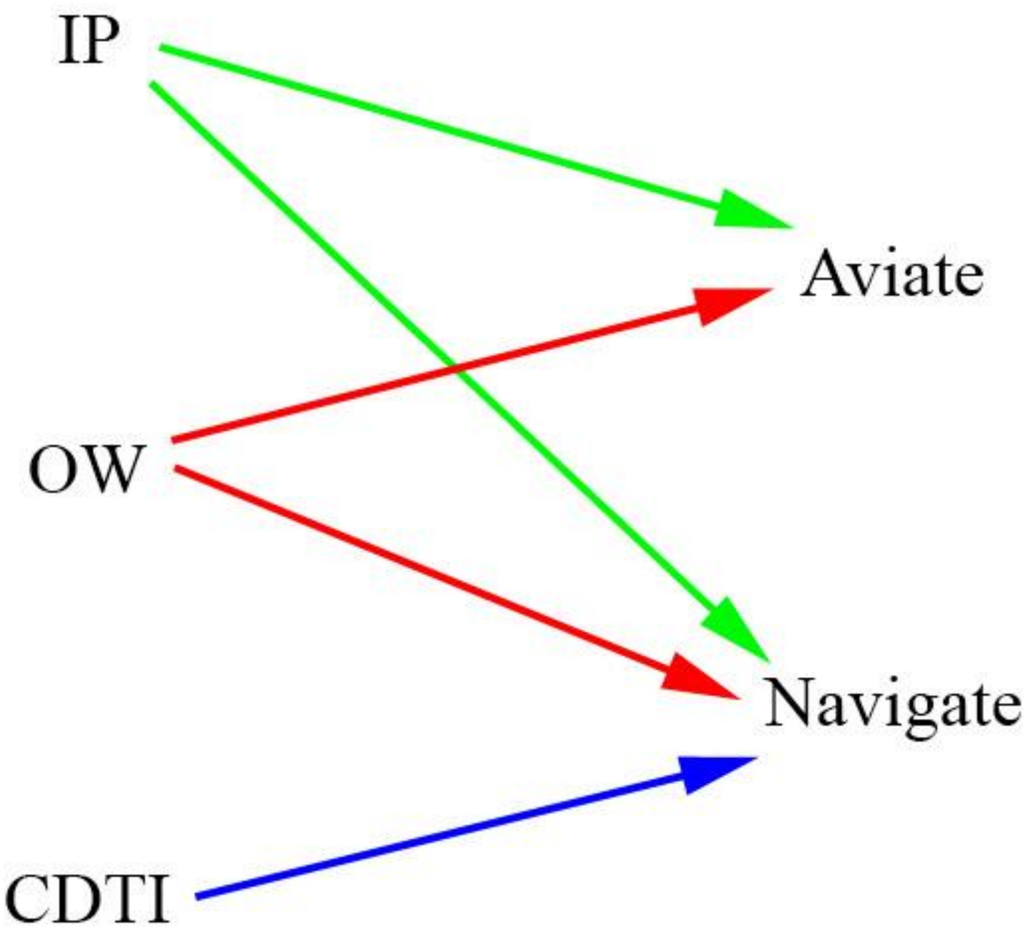
Preliminary Analyses:

Identify Cognitive Tasks and Visual AOI’s

Areas of Interest	Aviation Subtasks
IP	Aviate
OW	Navigate
CDTI	~~Communicate~~

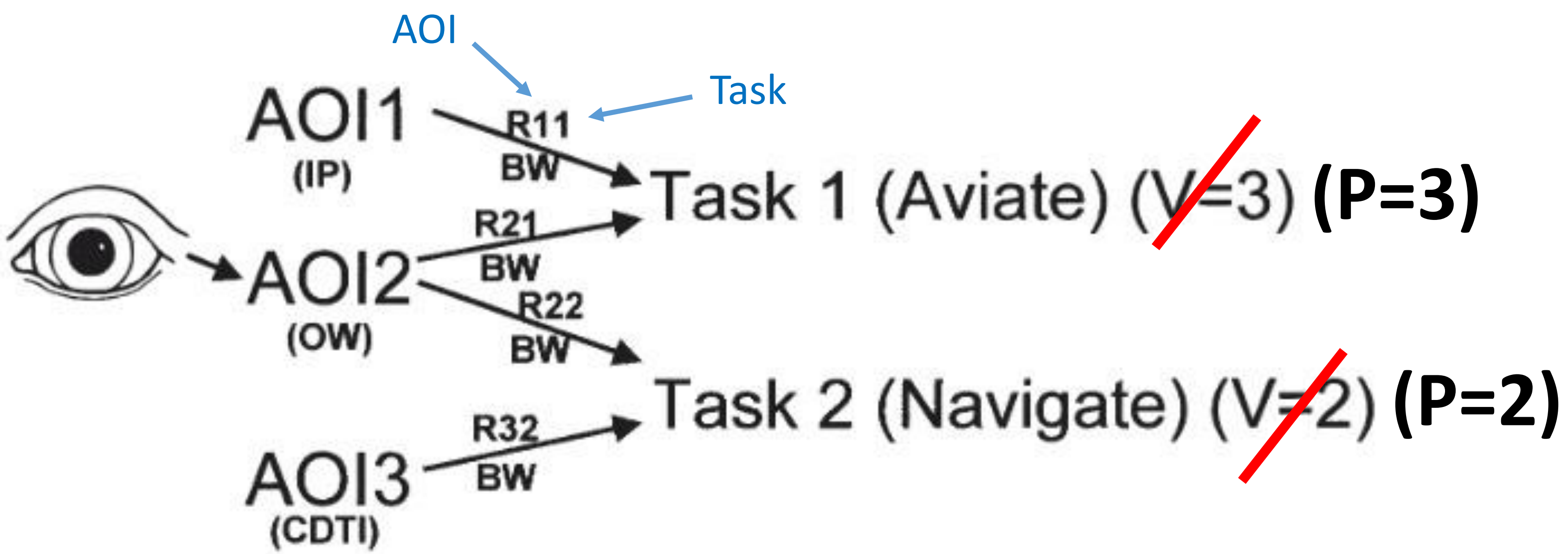
Flight segments only

Map Visual AOI's Relevance to Subtasks



Wickens, et al. 2003

Optimal Expectancy Model (SEEV submodel)



Visual Attention (Scan) to AOI =

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

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)

$$VA_{AOI=i} = \sum_{\substack{j=1\\ \text{Subtasks}}}^{2} \underbrace{BW_{i}}_{\text{expectancy}} \times \underbrace{\text{Relevance}_{ij} \times \text{Priority}_{j}}_{\text{value}}$$

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

Bandwidth

AOI: A	B	C

Relevance

Task	A	B	C
X			
Y			
Z			

	Priority
X	
Y	
Z	

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

	AOI			
Parameter	IP	OW	CDTI	
Bandwidth (B)				
Visual (1)	2	1	0.5	
Visual (4)	2	2	2	
Auditory (1)	2	1	—	
Auditory (4)	2	2	—	
Relevance (R)				Priority (V)
Aviate (V)	3	1	0	3
Navigate (V)	1	2	2	2
Aviate (A)	3	1	—	3
Navigate (A)	2	4	—	2

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

See next slide for simplified Coefficient Tables

Wickens, et al., 2003

Cognitive Task Analysis Results Expressed as (Quasi-Ordinal) Model Coefficients

Bandwidth (BW_i) Coefficients by Experimental Condition

	Area of Interest		
	IP	OW	CDTI
Visual (1-Plane)	2	1	0.5
Visual (4-Planes)	2	2	2
Auditory (1-Plane)	2	1	--
Auditory (4-Planes)	2	2	--

Relevance (R_j) Coefficients by Condition/Subtask

	Area of Interest		
	IP	OW	CDTI
Visual/Aviate	3	1	0
Visual/Navigate	1	2	2
Auditory/Aviate	3	1	--
Auditory/Navigate	2	4	--

Task Priority (P_k) Coefficients

Aviate	3
Navigate	2
Communicate	1

Sample Computation of Visual Attention Allocation

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

$$VA_{AOI} = \sum_{\substack{j=1 \\ \text{Subtasks}}}^{2} BW_i \times Relevance_{ij} \times Priority_j$$

$$= \underbrace{(2 * 3 * 3)}_{\text{aviate}} + \underbrace{(2 * 1 * 2)}_{\text{navigate}}$$

$$= 18 + 4$$

$$VA_{AOI} = 22$$

Model Predictions vs. Empirical Dwell Times from Traffic Segments of Experiment 1

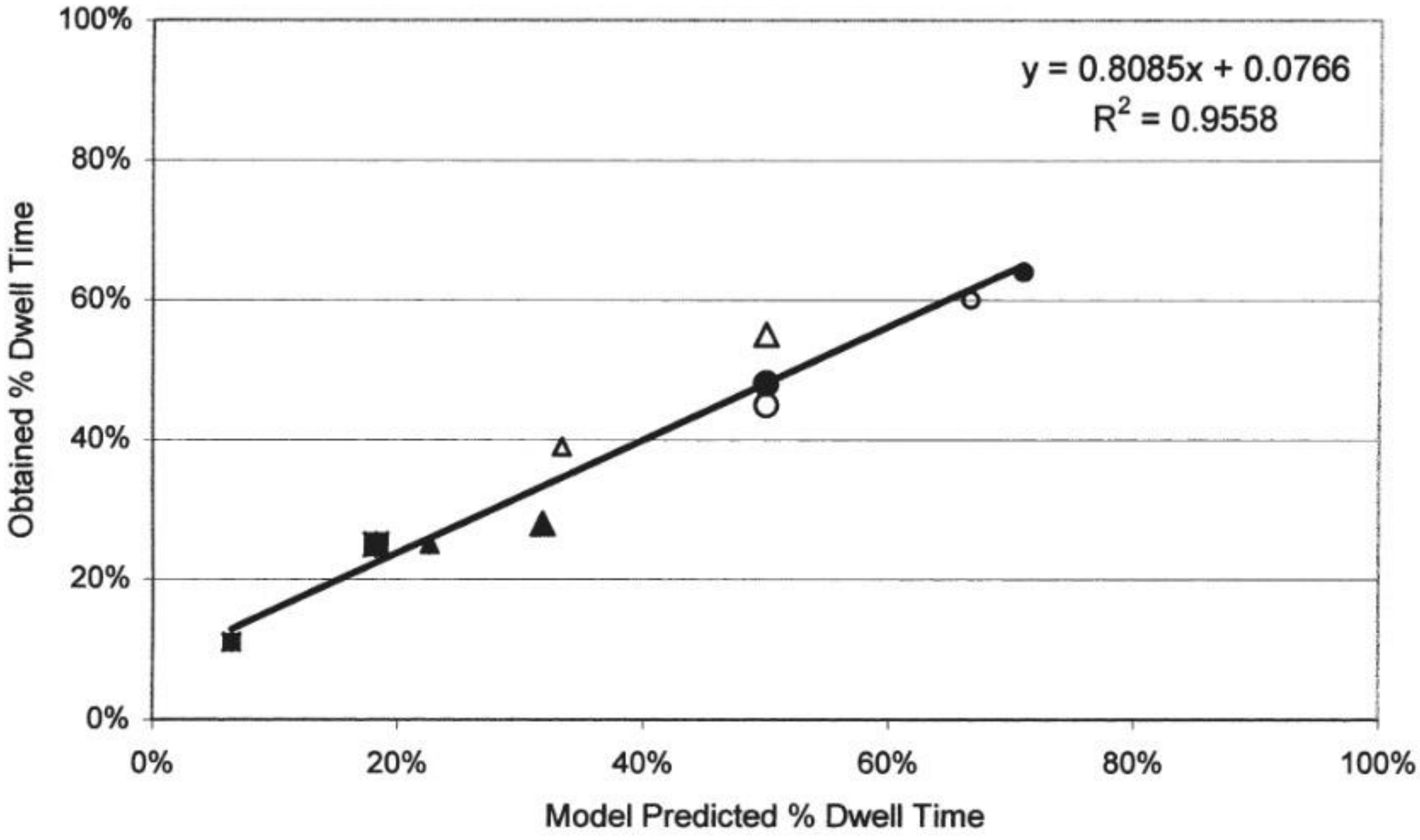


Figure 8. Model fit of traffic experiment. Squares = CDTI, triangles = OW, circles = IP; small = 1 traffic, large = 4 traffic; solid symbols = visual CDTI, open symbols = auditory.

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.