Cognitive Modeling in Human Factors (Generally) and in Predator UAV Operations (Specifically)

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Outline

- Introduction to Cognitive Modeling
  - Major intellectual influences
  - Benefits as a research approach
  - Cognitive modeling at AFRL-Mesa
- Cognitive Model of Predator AVO
- UAV Synthetic Task Environment
- Model Validation
- Future Research

Major Intellectual Influences

Formal Logic ↓ *Linguistics* ↓ *Digital Computers* ↓

- **Information Processing Psychology** **(1950's – present)**
- **Artificial Intelligence** **(1950's – present)**
- **Physical symbol system hypothesis** **(Newell & Simon, 1976)**
- **Unifying cognitive theories** **(Newell, 1990)**
- **ACT-R** **(Anderson et al, 1998, in press)**

Historical Note: One of Allen Newell's earliest research projects was a *Human Factors* effort at RAND simulating an environment for an Air Defense radar center in order to understand its effectiveness (mid-1950's).

Benefits as a Research Approach

Computational cognitive models …

Require explicit implementation of theory

Allow rigorous testing through precise prediction

Are generative (can learn; can behave in novel situations)

Transition well to applied research areas

(Computer-Generated Forces, Intelligent Training Systems)

"… an explanation of an observed behavior of the organism is provided by a program of primitive information processes that generates this behavior."

- Newell and Simon, 1958, Psychological Review
"Elements of a Theory of Human Problem Solving"

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USAF Need:

Improved representations of human performance and learning

Distributed Mission Operations (DMO) Training will play an increasingly important role in future warfighter training.

Representation of human performance and learning is one of the great challenges to overcome before the full potential of this training approach can be realized.

Applied Technical Objectives

Cognitive models will enable improvements to the effectiveness and flexibility of warfighter training

- **Describe Warfighter Behavior**
  (Computer-Generated Forces)
- **Prescribe Warfighter Behavior**
  (Instructional Agents)
- **Predict Warfighter Behavior**
  (Automated Training Program Assessment)

<u>Domains:</u> Air, C2, Space, IW . . .

Current Research

Basic Research (6.1)

UAV Operator Model

Visuospatial Working Memory

Egocentric and Allocentric Orientation

Applied Research (6.2)

Communicative Synthetic Agents

Modeling Fatigue in Computational Cognitive Architectures

Mathematical Models of Skill Acquisition and Decay

Two Requirements
(for pursuing our research agenda)

- An implementation architecture for developing models of humans
- A simulation system with which those models can interact

Human Representation Systems

Recent reviews (Pew & Mavor, 1998; Ritter et al., 2001) demonstrate there are many systems available for representing human behavior (in alphabetical order):

- 3CAPS/4CAPS
- ACT-R
- APEX
- Clarion
- Cogent
- COGNET/iGEN
- D-COG
- EPAM
- EPIC
- HOS
- Micro Saint
- MIDAS
- D-OMAR
- PDP
- PSI
- SAMPLE
- SmoC and CoCoM
- Soar

ACT-R
(Anderson et al., in press)

An embodied, hybrid cognitive architecture

Declarative Knowledge

Activation $A_i = B_i + \sum_j W_j \cdot S_{ji} + \sigma_A$

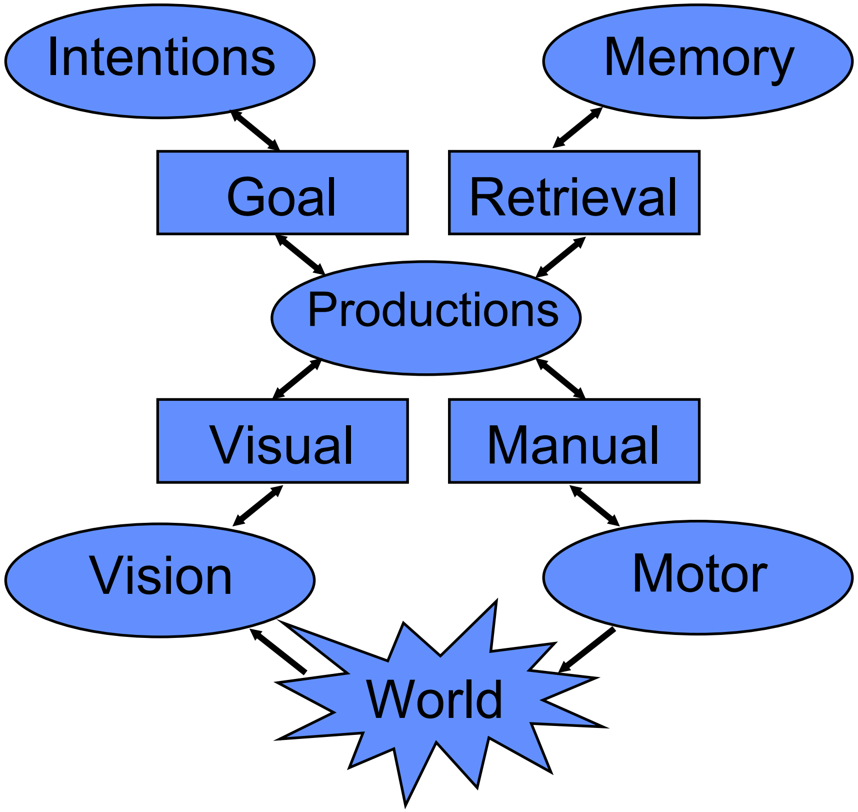
Learning $B_i = \ln \sum_j t_j^{-d}$

Latency $T_i = F \cdot e^{-A_i}$

Procedural Knowledge

Utility $U_i = P_i \cdot G - C_i + \sigma_U$

Learning $P_i = \frac{Succ_i}{Succ_i + Fail_i}$



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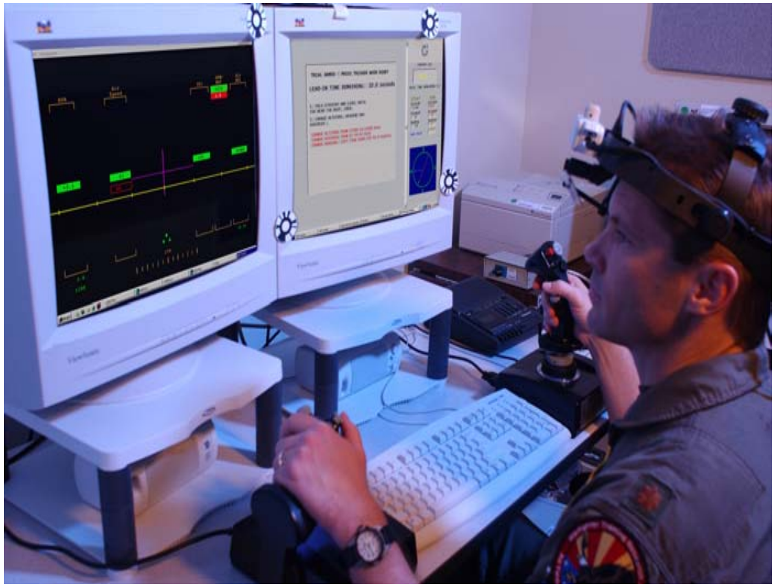
UAV Training Simulation and Synthetic Task Environment

- The UAV Simulator is based on the Predator RQ-1A System 4:
  - The UAV simulator has been used to train Air Force Predator operators at Indian Springs Air Field, Nevada
  - Schreiber, Lyon, Martin, & Confer (2002) found the UAV STE realistic enough to tap UAV-specific pilot skill

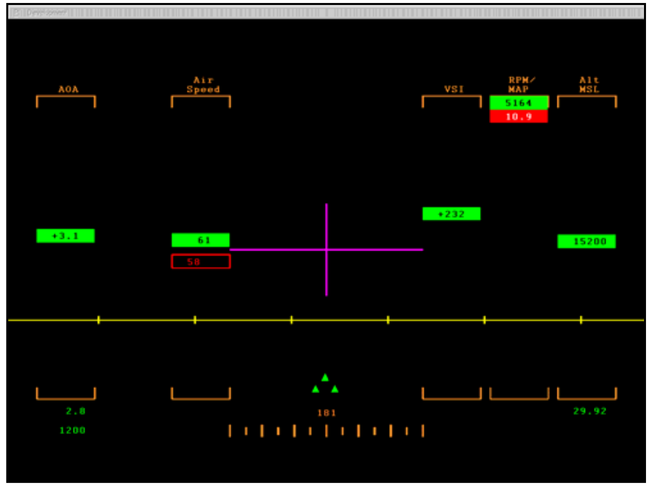


UAV STE Tasks

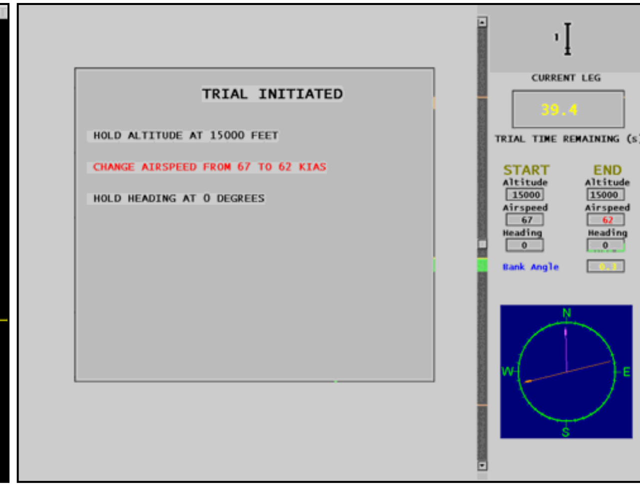
Task 1

Basic Maneuvering

Heads-Up Display



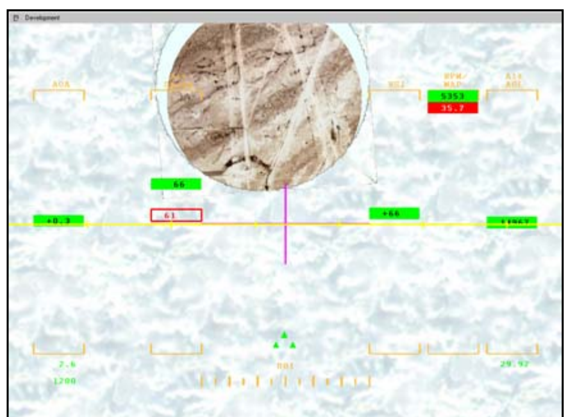
Task Screen



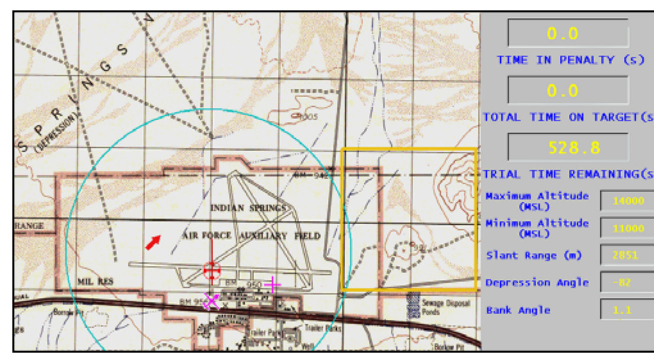
Task 3

Reconnaissance

Ground Camera



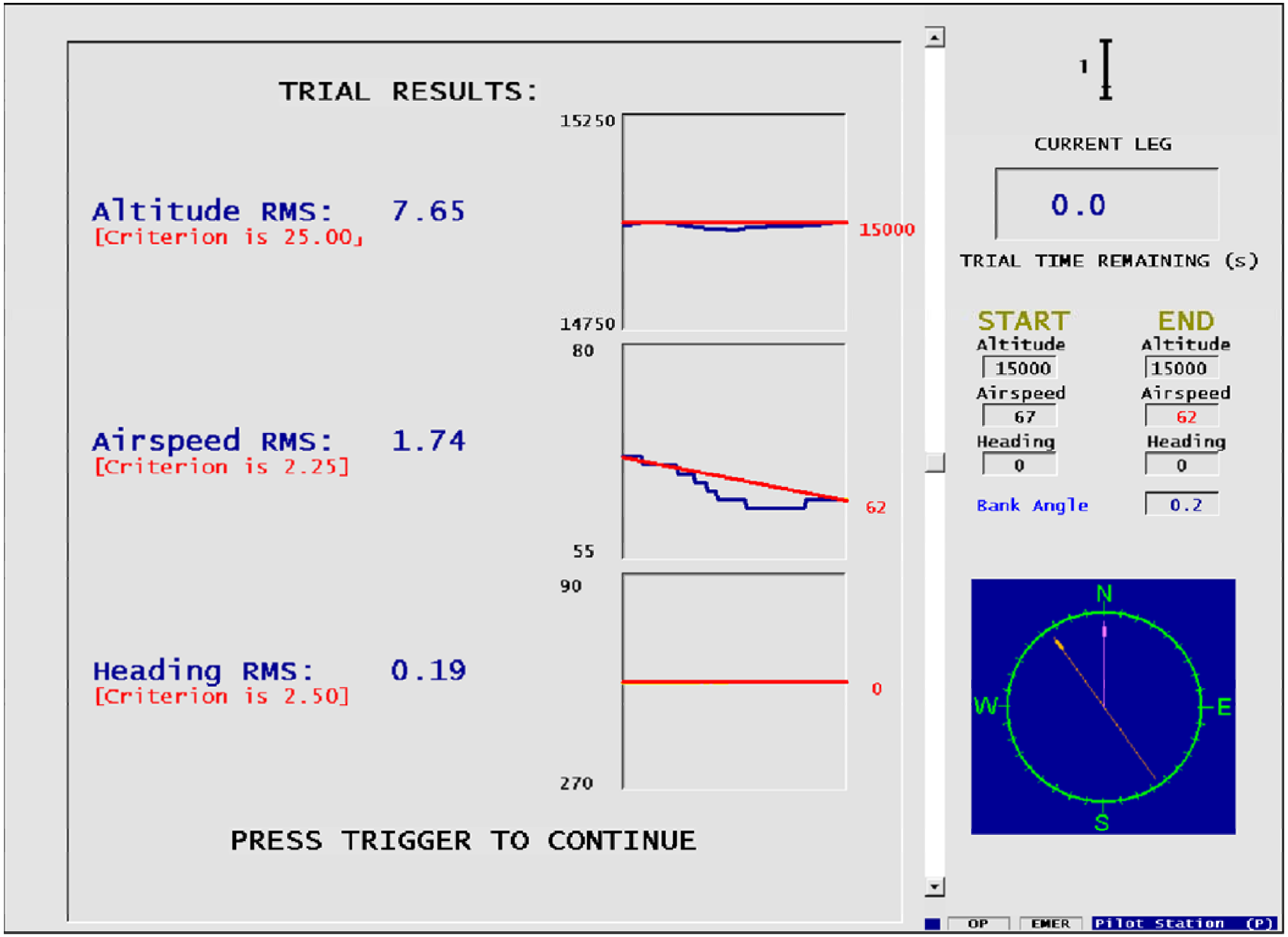
Tracker Map



Performance Goals for Basic Maneuvering

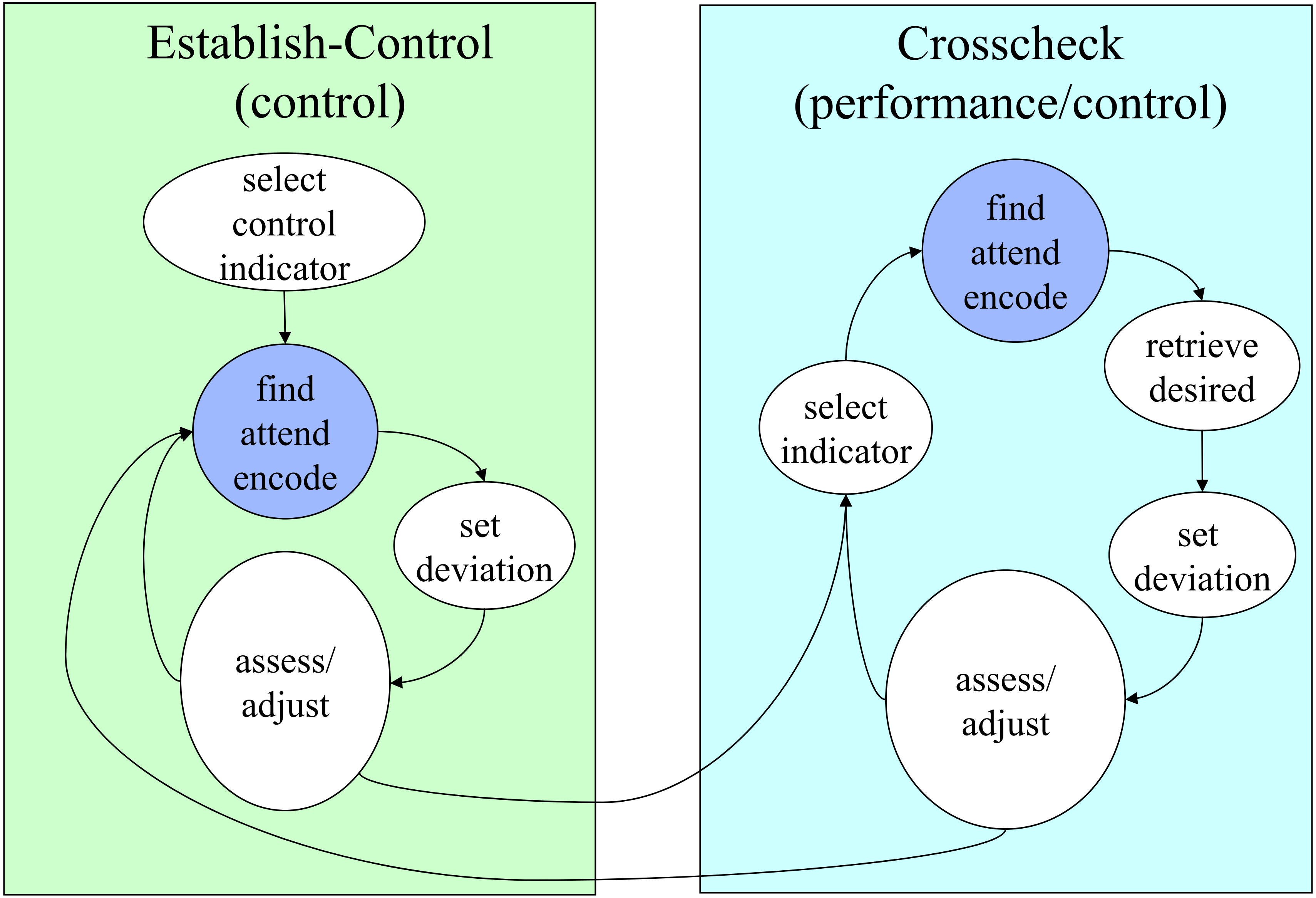
Maneuver 1:	**Airspeed Change**	- Decrease airspeed from 67 to 62 knots - Maintain altitude of 15,000 feet - Maintain heading of 0°
Maneuver 2:	**Heading Change**	- Maintain airspeed of 62 knots - Maintain altitude of 15,000 feet - Change heading right from 0° to 180°
Maneuver 3:	**Altitude Change**	- Maintain airspeed of 62 knots - Increase altitude from 15,000 to 15,200 feet - Maintain heading of 180°
Maneuver 4:	**Airspeed & Heading Change**	- Increase airspeed from 62 to 67 knots - Maintain altitude of 15,200 feet - Change heading left from 180° to 0°
Maneuver 5:	**Airspeed & Altitude Change**	- Decrease airspeed from 67 to 62 knots - Decrease altitude from 15,200 to 15,000 feet - Maintain heading of 0°
Maneuver 6:	**Altitude & Heading Change**	- Maintain airspeed of 62 knots - Increase altitude from 15,000 to 15,300 feet - Change heading right from 0° to 270°
Maneuver 7:	**Altitude, Airspeed, & Heading Change**	- Increase airspeed from 62 to 67 knots - Decrease altitude from 15,300 to 15,000 feet - Change heading left from 270° to 0°

Performance Deviation Data
Feedback Screen



= ideal performance = actual performance RMS = Root Mean Squared Deviation

Model Design based on "Control and Performance Concept"



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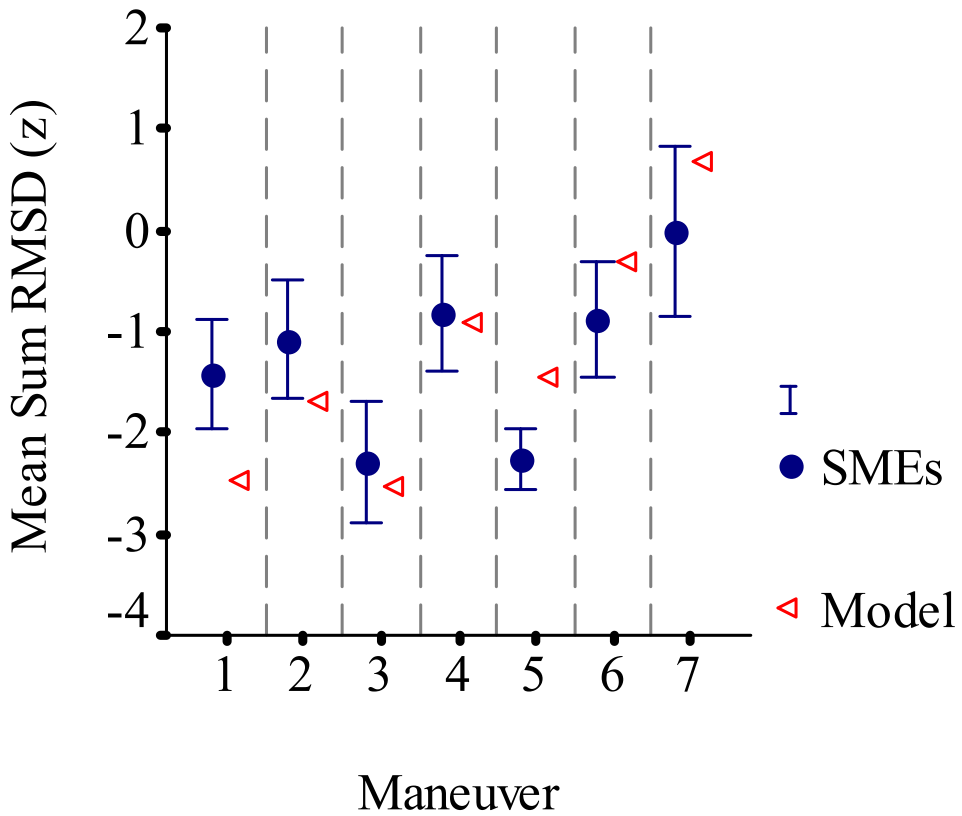
Assessment of Model Validity

- For our purposes, this model is a valid model if:
  - It exhibits a performance level comparable to that of human SME's
  - It uses an aircraft maneuvering process comparable to that used by human SME's
- Data Available for Comparison
  - Performance (RMSD) data from STE
  - Eye Tracking data
  - Verbal Protocols (Concurrent and Retrospective)

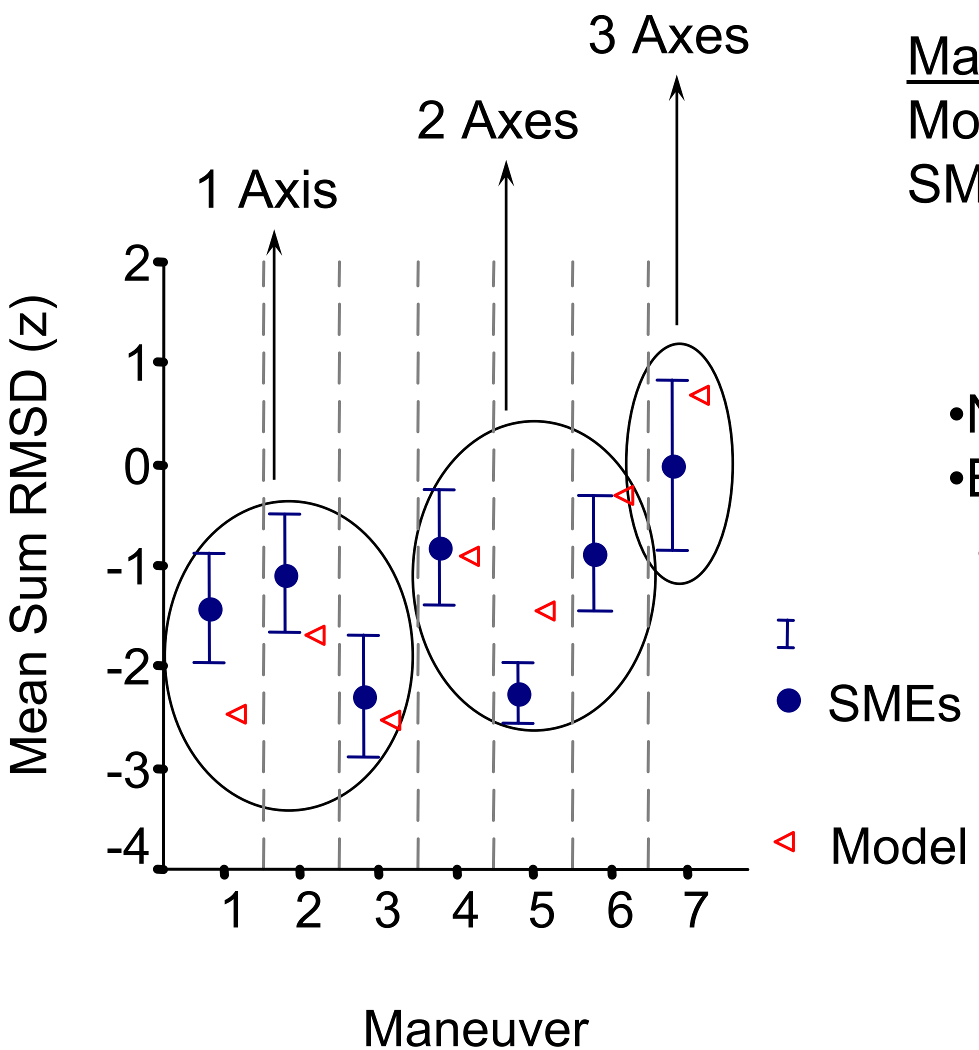
Comparison of Performance by Maneuver



$r^2 = .64$

RMSSD = 3.45

Model Predicts Effect of Maneuver Complexity on Performance



<u>Main Effect of Maneuver Complexity</u>

Model: $F(2,137) = 59.02$, $p < .001$

SMEs: $F(2,449) = 37.05$, $p < .001$

- Not intentionally "engineered" in
- Emerges from design of model and constraints in the architecture

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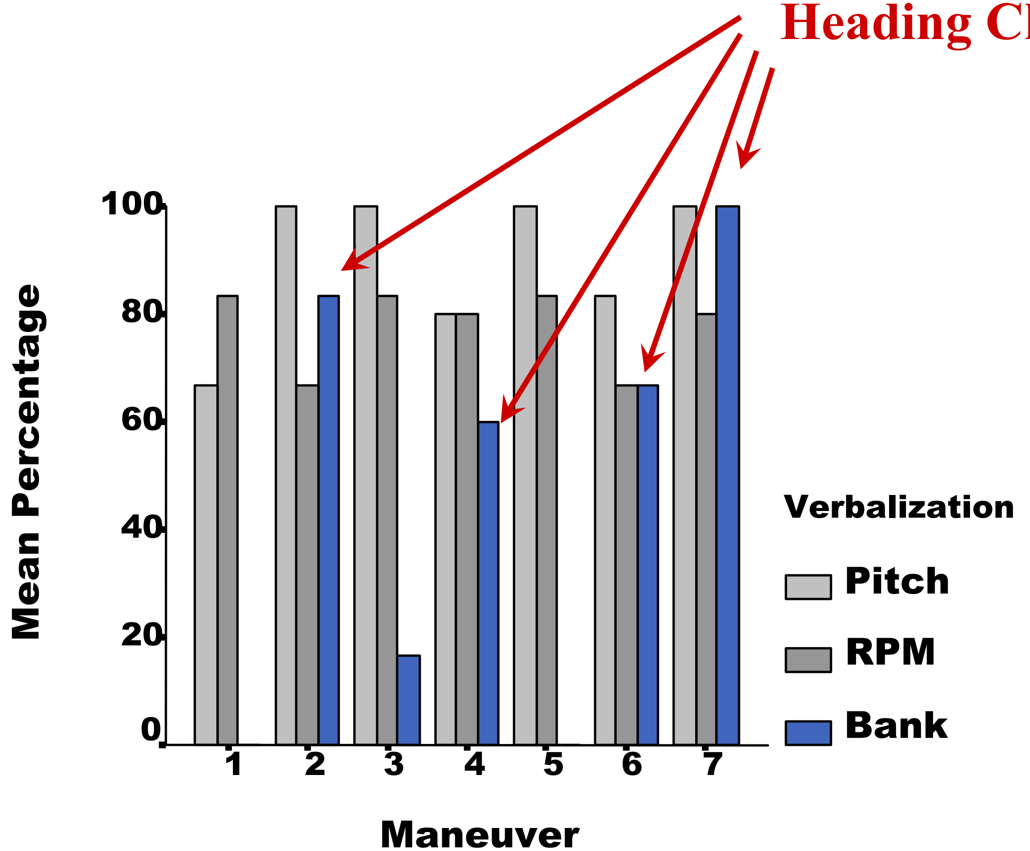
Retrospective Protocols

1) **ALL of the SME's reported using a flight control process that involved establishing control settings (pitch, power, and/or bank) and then crosschecking and adjusting from there.**

2)

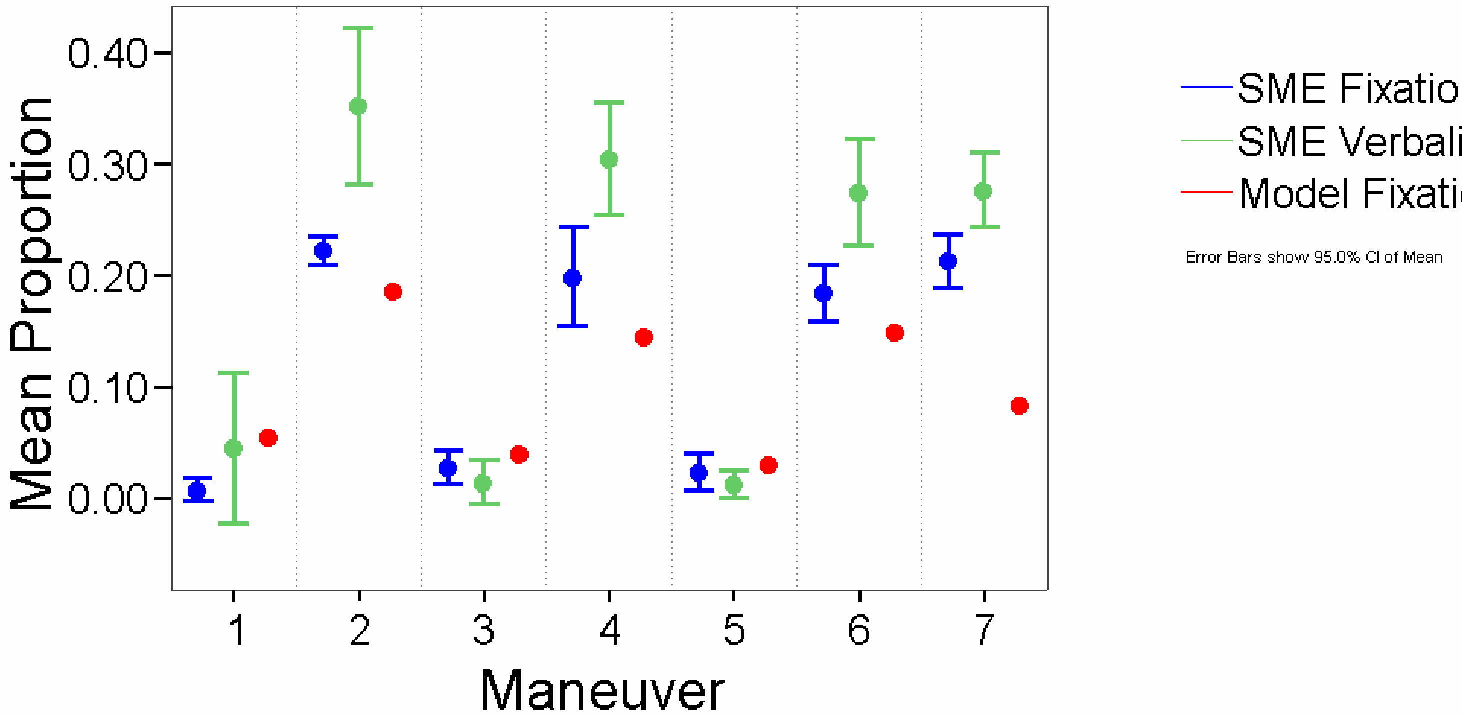
Heading Change on 2, 4, 6, 7



SMEs reported setting bank angle more for heading change maneuvers

Comparison of Human and Model Attention to Lateral Axis

Attention to Lateral Axis = Attention to Heading, Bank Angle, and Compass



What SME's fixate and what they verbalize concurrently are both influenced by the information processing demands of the maneuver.

Conclusion

- Analysis of Verbal Protocols and Eye Movements suggests:
  - Pilots are using the Control and Performance Concept, which is consistent with the model implementation
  - The distribution of operator attention across instruments is influenced by the goals and requirements of the maneuver, which is consistent with the model implementation
- Given that the model's performance level is a good approximation to SME performance,
- And given that the information processing of the model is similar to the information processing seen in SME's,

- We conclude that the model is worth taking seriously as a valid representation of expert pilot performance on the basic maneuvering task.

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The End Becomes the Means

Now we're in a position to use the model as a research tool for exploring related research questions of interest.

- **Individual differences in knowledge/strategy**
- **Effects of sleep restriction on performance**
- **Extension of model to flying recon missions**

Questions?