Training Simulation for Complex Cognitive Tasks: Visual Scan Patterns in Helicopter Navigation

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Training Simulation for Complex Cognitive Tasks: Visual Scan Patterns in Helicopter Navigation

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Approved for public release; distribution unlimited

10th Annual MOVES Research and Education Summit 2010, 13-15 July.
The Team

• Joseph Sullivan, CDR (PI, PhD candidate)
  – The Committee: Rudy Darken, PhD; Tony Ciavallelli, PhD; Michael McCauley, PhD; Joseph Cohn, PhD; Ted Lewis, PhD; Gurminder Singh, PhD.
• Quinn Kennedy, PhD (Co-PI, psychologist)
• Ji Hyun Yang, PhD (Co-PI, research fellow)
• Michael Day (engineer/programmer, MS student)
• Interns
  – Noah Lloyd-Edelman, Chris Edgar, and Edgar Rizo

• NMSO and ONR sponsored work
• Cognitively complex and demanding task
  — Continuous monitoring of system and environment parameters

• Challenges of training novice helicopter pilots
  — Timely advice
  — Safety
Research idea

• Currently, instructors have very few salient cues to rely on to assess trainee’s navigation performance during flight.
  – Specifically, trainees’ cognitive states, e.g, when trainees are lost, do the trainees realize it?
• What could be an useful cue to indicate trainees’ cognitive states?
Background

• IFR flight: Experts looked at instruments more often than novices, and novices dwelled longer than experts (Bellenkes et al., 1997).
• VFR flight: More fixations and shorter dwell times also were associated with good landings, providing indirect evidence that these visual strategies cause expertise differences in landing performance (Karsarkis et al., 2001).
• VFR flight: Novice pilots were more likely to fly OTW (Ottati et al., 1999).

• Eye tracking measures can be used to determine level of visual processing load (Van Orden et al., 2001).
• Modeled cognitive states – engaged vs. relaxed, normal vs. distracted, fatigued vs. alert – from eye movement and pupil size (Marshall, 2007).
• More experienced users focused on content-oriented concepts, whereas less experienced users spent too much on concepts of which they were uncertain. Also shorter attention spans and more scattered gazes (Yan Liu et al., 2008).
• People tend to trade the cost of frequent ocular movements with the cost of maintaining information in working memory when dealing with complex visuomotor tasks (McCarley & Kramer, 2007).

• Mean dwell is not a good measure for distinguishing between flight tasks (Katoh, 1997).
• Fixation durations are log-normally distributed (Velichkovsky et al., 2000).
Research objectives

• Investigate potential improvements to training simulation by analyzing the influence of flight expertise on visual scan patterns in helicopter overland navigation

• Understand cognitive processes associated with helicopter overland navigation
METHODS
Design of experiment

• Hypotheses
  – 1. Experts and novices have little difference in flight RMS error.
  – 2. Expert pilots have clearly defined visual scan strategies (more fixations, shorter dwells, more view changes, etc.) than novices.

• Independent variables
  – Expertise of pilots are defined with;
    • Total flight hours
    • Instructing experience

• Dependent variables
  – Flight performance
  – Eye tracking parameters
    • Scan time, dwell duration, number of fixations per view, OTW-MAP view changes

• Navigation task design
  – Twenty nine Palms, 11 legs with various route difficulties
Elevation map & satellite image
Experiment procedure

• IRB approval
• Participant recruiting
  – Military personnel who at least took overland navigation classes
• Interview, pre-questionnaire
• Informed consent form
• Eye tracking device calibrated
• Practice flight (~ 7min)
• Map study time (up to 10 min)
• Main flight (~ 5min)
• AAR, post-questionnaire

1 ~ 1.5 hrs
Experimental set-up
Lab diagram

- X-Plane 8.6
  - Image Generator
  - Terrain & Map DB
  - Data Logger
  - faceLAB OTW
  - faceLAB MAP
  - OTW display
  - MAP display
  - Stereo-head cameras
  - Joystick control
Participants

<table>
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<tr>
<th>I.D.</th>
<th>Age</th>
<th>Branch</th>
<th>Total flight hours</th>
<th>Overland navigation hours</th>
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RESULT
Flight path and visual scan patterns

Elapsed Time = 0.13351 sec
Dwell duration distribution

- Log-normally distributed dwell durations
Multiple regression model

\[ y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \]

\( x_1 = \) instructing experience

\( x_2 = \) total flight hours

<table>
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<th>Variable name</th>
<th>beta1 (SE)</th>
<th>beta2 (SE)</th>
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<th>adjusted R(^2)</th>
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<td>RMS</td>
<td>-.28 (.32)</td>
<td>-.09 (.32)</td>
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<td>Median OTW dwell</td>
<td>-.11 (.24)</td>
<td>-.68** (.24)</td>
<td>4.36**</td>
<td>.38</td>
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<td>OTW and MAP view changes</td>
<td>-.08 (.27)</td>
<td>.61** (.27)</td>
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** p<.05
* p<.1
Conclusion

• Phase 1 completed.
  – Provided a promising result for training simulation improvement.

• Future work
  – How to present the findings to the instructors?
  – Extend to Wide Field-of-view simulator
  – Develop a haptic map interface
  – Modeling cognitive processes
  – And more!
Future work- dwell parameter estimation

Elapsed time = 0.2003 sec
total number of dwells = 1

Estimated $e^{\mu} = 1.7356$ sec

Estimated $e^{\sigma} = 1$ sec
Wide FOV and Smart MAP display
Assess cognitive processes
Want to know more??

• Don’t forget to stop by WA212B tonight for the live demo!

• You will be able to hear more details and original findings of our study at CDR Sullivan’s Ph.D. thesis defense!
Thank you!

Q & A
Backup slides
Interactive MATLAB movie if possible

- Dwell estimation
- Check if we can run MATLAB at the conference room.
Expert: visual scan patterns
Qualitative analysis

- Lead/Lag pattern
- Compare expert/novice scan patterns
Visual scan pattern comparison

Expert

Novice