Age and Pilot Performance: Flying in your Golden Years

Joy Taylor PhD
Quinn Kennedy PhD, Maheen Adamson PhD, Katy Castile, Daniel Heraldez, and Jerome Yesavage MD

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Stanford/VA
Aging Pilots Longitudinal Study
1996....2012
1) What motivated our research on age and pilot performance?

2) Key finding I: Chronological age and flight simulator performance

3) Drill down into the study’s methods: Who were the pilot volunteers and what tests did they do?

4) Key finding II: Functional age and flight simulator performance

5) Key finding III: IFR and CFII proficiency ratings—how might they help during the golden years?
Motivation #1

Age 60 Rule
FAA's pre-2008 Provision for Mandatory Retirement of Airline Pilots at Age 60

June 1959 Federal Register:
“New material is learned with difficulty and retained poorly” …with age

“…the likelihood of reverting to previously learned and well-established patterns” …“is relatively great, resulting in actions not appropriate to the demands of the situation.”
# Training time for 707 Turbo Jet

<table>
<thead>
<tr>
<th>Age and flight training required:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages 55 and above and a low of 21:35;</td>
<td>An average of 30:10, with a high of 45:20</td>
</tr>
<tr>
<td>Ages 50 through 54 and a low of 17:50;</td>
<td>An average of 23:12, with a high of 36:25</td>
</tr>
<tr>
<td>Ages 45 through 49 and a low of 14:20;</td>
<td>An average of 22:12, with a high of 29:50</td>
</tr>
<tr>
<td>Ages 42 and 43 a low of 13:25.</td>
<td>An average of 18:30, with a high of 23:05 and</td>
</tr>
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</table>

Source: Smith CR (April 1959). Letter to FAA Administrator Quesada

Pilots 55 and above:
50% more flying time on average to pass 707 qualification tests.
Motivation #2

Scientific Extend Laboratory-Based Theories of Mental Ability Changes across the Lifespan to Real-World Settings

Brain Aging and Development

Cognitive Aging, e.g. slower processing speed

Expertise and Skill Training

Real-world task performance

?
Demographic Characteristics

• Entry Criteria
  – Age between 40 and 69 years
  – Current FAA medical certificate & actively flying
  – At least 300 hours of experience but no more than 15,000 hours

• Participants  N = 276
  – 86% Men
  – Mean Age 57.5 (+/- 6.7) yrs
  – Mean Education 17 yrs
  – 70 VFR, 151 IFR, 55 CFI-I or ATP
  – Median Flight hours at entry: 1300 hours
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Key Finding I:
Chronological Age and Flight Simulator Performance
Age-related change in the Flight Simulator Performance Metric: Summary Score

\[ p < .0001, n=276 \text{ subjects, 1156 data points} \]
Factors relevant to decline and stability

1) Functional Age -- Cognitive Aging Measures
   Speed of processing, Executive function, Episodic memory

2) Aviation Expertise
   Training: FAA pilot proficiency ratings
   CFII and/or ATP ..... IFR ..... VFR
   Experience: Lifetime and Recent Flight hours

3) Genetic polymorphisms
   APOE (Alzheimer disease risk), Others: BDNF, COMT

4) MRI and fMRI on a subset of participants
Methods Relevant to Functional Age

How did we measure speed of information processing, executive function and other basic cognitive abilities in the study?
CogScreen-AE Computerized Battery

- **Purpose**: Provide a sensitive and specific instrument for use in the medical recertification evaluation of pilots with known or suspected neurological and/or neuro-psychiatric conditions (Kay, 1995)

- **9 Minor Ability factors**
  1. Visual Scanning
  2. Visual Perceptual Processing
  3. Choice Visual Reaction Time
  4. Executive Function
  5. Visual Associative Memory
  6. Tracking
  7. Motor Coordination
  8. Working Memory

- **Major Ability Factors**
  - Processing Speed
  - Executive Function

- **Other Ability Factors**
  - Visual-associative Memory
  - Tracking
  - Motor Coordination
  - Working Memory
The Processing-Speed Theory of Adult Age Differences in Cognition

Timothy A. Salthouse
Georgia Institute of Technology

A theory is proposed to account for some of the age-related differences reported in measures of Type A or fluid cognition. The central hypothesis in the theory is that increased age in adulthood is associated with a decrease in the speed with which many processing operations can be executed and that this reduction in speed leads to impairments in cognitive functioning because of what are termed the limited time mechanism and the simultaneity mechanism. That is, cognitive performance is degraded when processing is slow because relevant operations cannot be successfully executed (limited time) and because the products of early processing may no longer be available when later processing is complete (simultaneity). Several types of evidence, such as the discovery of considerable shared age-related variance across various measures of speed and large attenuation of the age-related influences on cognitive measures after statistical control of measures of speed, are consistent with this theory.

The purpose of the current article is to describe, and discuss the evidence relevant to, the processing-speed theory of cognitive aging phenomena. The fundamental assumption in the theory of established reliability and span a broad range of cognitive abilities, the general phenomenon of negative relations between age and Type A or fluid cognition can be considered unit
Processing Speed Assessments: CogScreen AE Pathfinder bears similarity to Trail Making Part A
## CogScreen-AE Computerized Battery

<table>
<thead>
<tr>
<th>Taylor-Yesavage Composite Scores (name in papers)</th>
<th>Kay factors (Item z-scores)</th>
<th>Chronbach alpha</th>
<th>ICC across 3 annual timepoints</th>
<th>corr w/ age n = 277</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processing Speed</strong> (Kay Factors 1 and 3)</td>
<td><strong>Visual Scanning_1</strong></td>
<td>.74</td>
<td>0.86</td>
<td>-0.40 &lt; .0001</td>
</tr>
<tr>
<td></td>
<td>Pathfinder Letter, Number, and Combined speed; Shifting Attention Arrow Direction and Color throughput <strong>Visual Perceptual_3</strong> Divided Attention Sequence Comparison, Visual Sequence Comparison, Matching to Sample, Symbol-Digit Coding, Manikin, and Shifting Attention Instruction throughput *</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Divided Attention Alone & Dual RT excluded because not correlated with age = -0.08
An Application of Prefrontal Cortex Function Theory to Cognitive Aging

Robert L. West
University of South Carolina

The purpose of this review is to extend the existing application of the frontal lobe hypothesis of cognitive aging beyond the limited work on inhibitory control (F. N. Dempster, 1992) to include memory processes supported by the prefrontal cortex. To establish a background for this analysis, I review existing models of prefrontal cortex function and present a synthesized model that includes a general function of temporal integration, supported by 4 specific processes: prospective memory, retrospective memory, interference control, and inhibition of prepotent responses. I found the frontal lobe hypothesis to perform well, with the exception of an inability to account for age-related declines in item recall and recognition memory, possibly a result of age-related declines in medial temporal function.

In the past decade, a rapidly expanding body of evidence from the field of geriatric neuropsychology has provided evidence suggesting that there are related declines in prefrontal cortex function, particularly in the 56.62 years were "impaired" relative to a group of individuals with a mean age of 27.71 years on 10 of 12 measures of prefrontal cortex function, indicating an age-related difference in the
CogScreen AE Shifting Attention Discovery

Trial 1

Later Trial

Trial 2
# CogScreen-AE Computerized Battery

<table>
<thead>
<tr>
<th>Taylor-Yesavage Composite Scores (names in papers)</th>
<th>Kay factors (Item z-scores)</th>
<th>Chronbach alpha</th>
<th>ICC across 3 annual timepoints</th>
<th>corr w/ age n = 261</th>
</tr>
</thead>
</table>
| Interference Control / Executive Function        | **Attribute Identification_2**  
Shifting Attention Discovery: rule shifts completed, accuracy, failures to maintain set * | .90 | .52 | -0.14  
0.0270 |
| Kay Factor 2                                      |                             |                 |                               |                      |

Perservative errors excluded because not correlated with failures to maintain set and numbers of rules shifts completed (cf. Taylor 2005)
What did pilots do when they came in each year? And what was our “measuring stick”? 
Flight Simulator
Flight Simulator Scenario

75-minute flight

- ATC communications
- Engine emergencies
- Conflicting traffic
- Visual approach
- FLIGHT SUMMARY SCORE

Two 75-minute flights at each annual test
Flight Scoring

- Take-Off
  - Lift Off Heading
    - Altitude
      - Distance
      - Squawk
  - Air Speed
- Traffic Avoidance
  - Heading
  - Altitude
  - Radio
- Communications
  - Heading
  - Altitude
  - Squawk
- Emergencies
  - Oil Pressure RT
  - Carburetor Ice RT
  - Aileron
  - Elevator
- Approach
  - Course
  - Altitude
  - Distance to Touch Down
- Landing
  - Vertical Speed
  - Landing Heading
  - Distance to Centerline
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Key Finding II:
Functional Age and Flight Simulator Performance
**Speed × Executive Function Interaction**

- 184 total cases
  - 50% ≥ median rate of decline in Overall Flight Performance

  - > -0.30 Processing Speed
    - 63 Cases
      - Processing Speed < -0.30
      - 20/63 or 32% have slow overall decline
    - 121 Cases
      - Processing Speed ≥ -0.30
      - 72/121 or 60% have slow overall decline

  - < -0.50 Executive Function
    - 29 Cases
      - Executive Function < -0.50
      - 12/29 or 41% have slow overall decline
    - 86 Cases
      - Executive Function ≥ -0.50
      - 55/86 or 64% have slow overall decline

Yesavage et al 2011 J. Gerontology: Psychological Sciences
## Speed × Executive Function Interaction

### Confirmatory Mixed Effects Growth Curve Analysis of Longitudinal Flight Simulator Performance Using Predictors Identified by Exploratory Signal Detection (ROC)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate (SE)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Performance (I)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept (mean, η₁)</td>
<td>0.071 (0.042)</td>
<td>0.095</td>
</tr>
<tr>
<td>Processing Speed (β₁₁)</td>
<td>0.264 (0.074)</td>
<td>0.0006</td>
</tr>
<tr>
<td>Executive Function (β₁₂)</td>
<td>0.065 (0.049)</td>
<td>0.188</td>
</tr>
<tr>
<td>Expertise (β₁₃)</td>
<td>0.247 (0.058)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Processing Speed × Executive Function (β₁₄)</td>
<td>-0.053 (0.074)</td>
<td>0.476</td>
</tr>
<tr>
<td><strong>Change in Performance over Age (S)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept (mean, η₅)</td>
<td>-0.019 (0.004)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Processing Speed (β₅₁)</td>
<td>0.021 (0.008)</td>
<td>0.010</td>
</tr>
<tr>
<td>Executive Function (β₅₂)</td>
<td>0.003 (0.006)</td>
<td>0.642</td>
</tr>
<tr>
<td>Expertise (β₅₃)</td>
<td>0.005 (0.006)</td>
<td>0.351</td>
</tr>
<tr>
<td>Processing Speed × Executive Function (β₅₄)</td>
<td>0.021 (0.008)</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Yesavage et al 2011 J. Gerontology: Psychological Sciences
Faster processing speed (at baseline) predicted less age-related decline in flight performance.

Yesavage et al 2011 J. Gerontology: Psychological Sciences
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Key Finding III:
Expertise and Flight Simulator Performance
Proficiency Ratings:  Higher performance across the age range
No evidence, however, of reducing the effect of age
Key Findings of Stanford/VA Aging Pilots Study

- **Age-related decline in flight simulator performance**
  - Considerable variability in rate of change

- **Longitudinal rate of change can be predicted by initial assessment of cognitive abilities**
  - In particular, processing speed and executive function.

- **Aviation expertise**
  - Pilot proficiency ratings: associated with better performance across the age range
Other Research on Age and Pilot Performance

- **Causse & associates (ISAE, Toulouse France)**
  - Association of age with flight path deviations were fully mediated by processing speed and executive function (Causse et al. 2011, *IJAP*, 21, 217-234)

- **Morrow & associates (U. Illinois)**
  - Age and expertise predictive of ATC communication readbacks. Yet, with note taking, read-back accuracy intact for older pilots (Morrow et al. 2003, *Psychology and Aging*, 18, 268-284)

- **Van Benthem, Herdman & associates (ACE)**
  - Extensive research on age, cognitive function and prediction of various aspects of flight performance
Cognitive Screening
Recommendations for “Mature Pilots”

The FAA has recommended CogScreen-AE⁴, among a long list of other neurocognitive test batteries¹. The FAA and Civil Aviation Safety Authority (Australia) has also recommended the MoCA³ as a screening tool by AMEs².

RELATIONSHIPS OF COGSCREEN AND THE MONTREAL COGNITIVE ASSESSMENT SCORES TO LANDING PERFORMANCE

Kathleen Van Benthem, PhD  
Chris M. Herdman, PhD  
Carleton University, Ottawa

kathy_vanbenthem@carleton.ca
ACE Lab GA Study: Phase Two

45 Volunteer GA Pilots
Cross-Country Flight
- Landing Quality
- Critical Incidents
- Situation Awareness
- Radio Calls
- Diversion Management
Mental Flexibility (Executive Skills)

\[ r = .643, \ p = .018 \]
Montreal Cognitive Assessment

$r = .615, p = .019$
Montreal Cognitive Assessment

Auditory Working Memory
Vigilance (auditory information)
Mental Calculation
NIA Expert Panel on Strategies for Reducing Risk of Cognitive Decline

• How do we know what actually might prevent or reduce risk of cognitive decline or dementia as we age?

• NIA commissioned a panel of experts through the National Academies of Sciences to conduct an extensive scientific review and provide recommendations.

• The committee panel did not find sufficient evidence to recommend specific interventions.

• However, the Panel did note “encouraging” evidence for three types of interventions:
  - cognitive training,
  - blood pressure control for people with hypertension,
  - increased physical activity.


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  Jerome Yesavage MD

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