Human Factors Design Considerations for Complex Systems

Dr. Daniel Wallace, PhD

Displays & Human Factors Technical Warrant Holder

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Stage setting…

- NOT here to sell you on the value of Human Factors!!! ☺
- NOT here to insult your intelligence or tell you how to do your jobs
- *DO want to open a dialog into the pitfalls of complex and automated system design and how to mitigate those pitfalls*

Background

- Role of human performance when operating complex systems and the errors that may arise when off-nominal conditions arise
- Many “complex” systems are ostensibly created to provide simplifying automation and reduce operator workload and manpower requirements
- Changes in systems and the implications of those changes on human performance and human reliability (error potential) are often not understood or assessed
- There are few ways to predict human performance reliability due to non-deterministic behavior

Develop methods for addressing human performance factors in reliability predictions for equipment modernization and automation

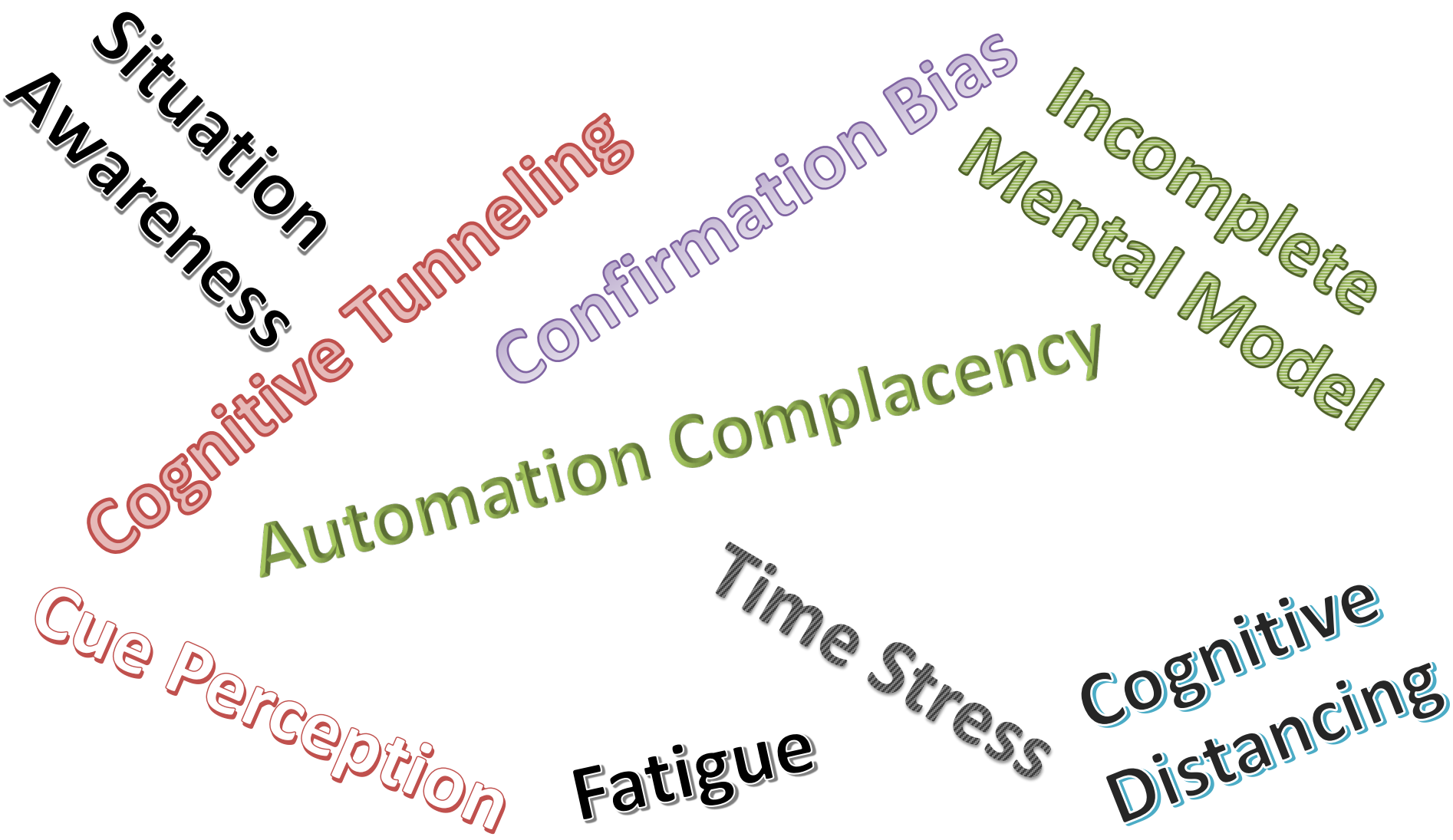
A Few Examples of Automation "Failure"

- Eastern Airlines 401 – Everglades
  - Nosegear indicator light failure
  - Autopilot disengaged
  - Ground proximity alarm ignored as pilots were focused on the indicator
- Boeing 737 MAX and MCAS
  - Hidden functionality
  - Incomplete mental model of system
  - Pilots fought the automation without realizing it was automation
- Three Mile Island
  - Initial loss of coolant water
  - Automation would have addressed issue
  - Operators had a faulty understanding of cause
  - Fatigue may have played a role
- Air France 447
  - Extensive automation in the Airbus A330
  - Displays provided accurate information (pilots knew pitot tubes were iced)
  - Cognitive tunneling
- Other Examples…

These Systems Used Automation to…

- Reduce workload
- Simplify interfaces
- Improve performance
- Compensate for other design constraints

So, what happened???



So, what happened???

Typical Design Considerations

- Cost
- Schedule
- Manning
- Existing interfaces
- Basic functional capability
- Performance requirements

… under implicit assumption of nominal conditions

Critical Explicit Design Considerations for Automated and Complex Systems (Discussion)

- What is the operator's mental model of the system likely to be?
  - Intuition? Engineers don't think the same as humans ☺
  - Imparted via training?
  - Reinforced by system design?
- How are off-nominal conditions anticipated?
- How are off-nominal conditions presented to the operator?
- How does the system design anticipate the human biases and failures mentioned earlier? Should it override the user? Use cases for these?
- How does the "new system" differ from the old, and is there negative transfer?
- What implications does the design (or change in design) have for human reliability? Is it possible to predict reliability?

Human Performance & Reliability

- Human reliability is inherently multi-faceted (more complex than 10^{-3})
  - Variability in Human Performance Shaping Factors (PSFs)
    - Available time
    - Stress and stressors
    - Complexity
    - Experience and training
    - Procedures
    - Ergonomics (including the human-machine interface)
    - Fitness for duty
    - Work processes
  - Variability in scenarios
  - Variability in personnel
- Any changes in automation (increase or decrease) may impact human reliability
- Predictive (pre-release) reliability assessment is integral to the systems engineering process

Example: Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H)

- NUREG/CR-6883 & INL/EXT-05-00509, SPAR-H Human Reliability Analysis Method (Aug 2005)
  - Estimates Human Error Probability (HEP) using probabilistic risk analysis models for operator and crew actions and decisions
  - Can be used early in the SE and design process
  - The worksheets can be used by personnel with minimal HRA/Human Factors experience
  - Methodology does not require extensive data to execute
- Estimate HEP for each potential human failure event

Example: Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H)

HRA Worksheets for At-Power
SPAR HUMAN ERROR WORKSHEET

Plant:_____ **Initiating Event:**_____ **Basic Event :**_____ **Event Code**

Basic Event Context:_____

Basic Event Description:_____

Does this task contain a significant amount of diagnosis activity? YES☐ (start with Part I–Diagn
Part I – Diagnosis; start with Part II – Action) Why?_____

PART I. EVALUATE EACH PSF FOR DIAGNOSIS

A. Evaluate PSFs for the Diagnosis Portion of the Task, If Any.

PSFs	PSF Levels	Multiplier for Diagnosis	Please note specifi PSF level selection column.
Available Time	Inadequate time	P(failure) = 1.0 ☐	
	Barely adequate time (≈2/3 x nominal)	10 ☐	
	Nominal time	1 ☐	
	Extra time (between 1 and 2 x nominal and > than 30 min)	0.1 ☐	
	Expansive time (> 2 x nominal and > 30 min)	0.01 ☐	
	Insufficient information	1 ☐	
Stress/ Stressors	Extreme	5 ☐	
	High	2 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Complexity	Highly complex	5 ☐	
	Moderately complex	2 ☐	
	Nominal	1 ☐	
	Obvious diagnosis	0.1 ☐	
	Insufficient Information	1 ☐	
Experience/ Training	Low	10 ☐	
	Nominal	1 ☐	
	High	0.5 ☐	
	Insufficient Information	1 ☐	
Procedures	Not available	50 ☐	
	Incomplete	20 ☐	
	Available, but poor	5 ☐	
	Nominal	1 ☐	
	Diagnostic/symptom oriented	0.5 ☐	
	Insufficient Information	1 ☐	
Ergonomics/ HMI	Missing/Misleading	50 ☐	
	Poor	10 ☐	
	Nominal	1 ☐	
	Good	0.5 ☐	
	Insufficient Information	1 ☐	
Fitness for Duty	Unfit	P(failure) = 1.0 ☐	
	Degraded Fitness	5 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Work Processes	Poor	2 ☐	
	Nominal	1 ☐	
	Good	0.8 ☐	
	Insufficient Information	1 ☐	

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Plant:_____ **Initiating Event:**_____ **Basic Event :**_____ **Event Coder:**_____

Basic Event Context:_____

Basic Event Description:_____

Part II. EVALUATE EACH PSF FOR ACTION

A. Evaluate PSFs for the Action Portion of the Task, If Any.

PSFs	PSF Levels	Multiplier for Action	Please note specific reasons for PSF level selection in this column.
Available Time	Inadequate time	P(failure) = 1.0 ☐	
	Time available is ≈ the time required	10 ☐	
	Nominal time	1 ☐	
	Time available ≥ 5x the time required	0.1 ☐	
	Time available is ≥ 50x the time required	0.01 ☐	
	Insufficient Information	1 ☐	
Stress/ Stressors	Extreme	5 ☐	
	High	2 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Complexity	Highly complex	5 ☐	
	Moderately complex	2 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Experience/ Training	Low	3 ☐	
	Nominal	1 ☐	
	High	0.5 ☐	
	Insufficient Information	1 ☐	
Procedures	Not available	50 ☐	
	Incomplete	20 ☐	
	Available, but poor	5 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Ergonomics/ HMI	Missing/Misleading	50 ☐	
	Poor	10 ☐	
	Nominal	1 ☐	
	Good	0.5 ☐	
	Insufficient Information	1 ☐	
Fitness for Duty	Unfit	P(failure) = 1.0 ☐	
	Degraded Fitness	5 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Work Processes	Poor	5 ☐	
	Nominal	1 ☐	
	Good	0.5 ☐	
	Insufficient Information	1 ☐	

er:_____

exity x Experience

_ =

npute a composite
multiplier greater
is computed by
the HEP:

Diagnosis HEP with Adjustment Factor =

C. Record Final Diagnosis HEP.

If no adjustment factor was applied, record the value from Part B as your final diagnosis HEP. If an adjustment factor was applied, record the value from Part C.

Final Diagnosis HEP =

Example: Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H)

Plant:_____ **Initiating Event:**_____ **Basic Event :**_____ **Event Coder:**_____

Basic Event Context:_____

Basic Event Description:_____

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	Time available is ≥ 50x the time required	0.01 ☐	
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Scope and Applicability

- New or modified displays, controls, or user interfaces
- Changes in manpower, personnel, or other staffing impacts
- Training deltas
- Maintenance deltas
- Process/Procedure deltas
- Changes in level of automation
- Changes in system complexity with respect to human interaction (e.g., decision-making, communications, situation assessment, user actions, level of automation)

Proposed Review Key Words

- Human Systems Review Keywords to Search:
  - Human System Integration or HSI
  - Human Machine Interface
  - User Interface
    - GUI
    - Human Interface
    - Display
    - Monitor
    - Keyboard
    - Mouse
    - Trackball
    - Joystick
    - Throttle
    - Controls
  - Automation
  - Workload or Manpower Reduction
  - Redesign

Proposed Review Questions

- Review Questions to ask related to Key Words
  - Will the design make changes that require new training or updates to existing training courses (operator or maintainer)?
  - Will the design make changes that require any new or updated Preventative Maintenance System (PMS) procedures?
  - Will the design make changes that require new repair or trouble shooting procedures?
  - Will the design make changes to how the operator inputs (controls & interfaces) data into the system?
  - Will the design make changes to how information is presented (colors, location, format, sound, etc.) to the operator or maintainer (graphical interfaces, displays, light boards, etc.)?
  - Does the design relocate, remove, resize, or add any displays, monitors, or other user interface?
  - Will the design make changes the location of any operator locations/stations?
  - Will the design make changes that fundamentally change the system architecture or the operators' mental model of the system?

Summary

- With automation comes an inherent level of system complexity
- Operators *do not* generally have accurate mental models
- Off-nominal conditions must have design use cases (pre-mortem)
- Users will tend to have poor diagnostic ability for system failures
- Cognitive tunneling and other maladaptive actions are most common under off-nominal conditions

- Mitigations
  - Conduct Human Reliability Analyses (HRA) early in design
  - Use HRA to inform interface and system design
  - Develop use cases for failure conditions
  - Ensure system model is not hidden to user
  - Consider role of training to recognize failure conditions

Questions & Discussion