Adaptive Automation: Potential for Improving Human-Automation Team Performance

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Regulatory Information Conference
March 2018

Background
- Automation Trends

- Modern automation is becoming much more broadly used and increasingly capable
  - Greater use of automation for normal operations
  - Operator aids and decision support
  - Application to interface management, e.g., automatic display retrieval
- There is very little that goes on in a modern control room that does not involve automation

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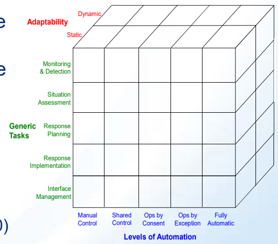
Background
- Where are We Now

- While automation technology has rapidly advanced, the technology for human-automation interaction has not
- As a result, many of the same issues that have been known for a long time still remain in new systems
  - Excessive passive monitoring raising vigilance and complacency issues
  - Added complexity for operators to understand
  - New sources of workload
  - Skill degradation and loss
  - New types of human error, such as mode errors
- Failures of human-automation interaction can impact safety
  - In all high-risk, high-reliability domains, there is concern that the increased use of automation may not achieve its benefits and may fail to minimize potential negative effects on performance and safety

Background
- Safety Concern

- Despite the critical importance of human-automation interaction to plant safety, there is limited Human Factors Engineering guidance available to safety reviewers (and designers)
- The NRC is conducting research to address this gap
  - General human-automation interaction (BNL TR-91017-2010)
  - Current research on adaptive automation

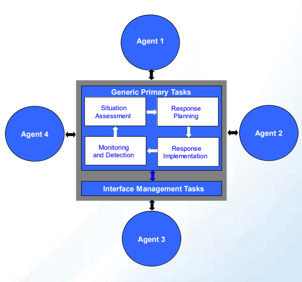


Adaptive Automation Characterization

- Adaptive automation (AA) is the dynamic, real-time change in the degree of automation (DOA) in response to situational changes
- Why would operators want higher levels of automation?
  - Pace of the event may make it difficult to perform tasks
  - Need to perform too many tasks (e.g., operators can delegate some tasks to an automated system)
- Why would operators want lower levels of automation?
  - The situational context is important to interpreting task steps
  - To ensure a high level of awareness of task details
  - To increase workload
  - To prevent/minimize boredom
  - To maintain manual skills

Adaptive Automation Characterization

- AA may be a promising means of improving operator-automation interaction and addressing automation issues
- Design automation as part of a multi-agent system where human and machine agents work cooperatively to accomplish plant safety and production goals



Example
- Adaptive Computer-Based Procedure System

- Transitions from operator aid to a fully-automatic system
- System provides configurations loosely based on IEEE Std 1786-2011 (see IEEE table below)
- Procedure Type 3 can support increasing DOAs
  - operation by consent, operation by exception, and full automation
- Different means can be used to select the desired DOA

Capability	COPS		
	Type 1	Type 2	Type 3
Select and display procedure on computer screen.	Yes	Yes	Yes
Provide navigation links within or between procedures.	Yes	Yes	Yes
Display process data in the body of procedure steps.	No	Yes	Yes
Process step logic and display results.	No	Yes	Yes
Provide access links to process displays and soft controls that reside on a separate system.	No	Yes	Yes
Provide embedded soft controls.	No	No	Yes
On operator command, initiate procedure-based automation.	No	No	Yes

Adaptive Automation Characterization

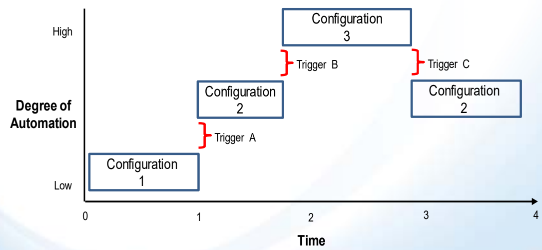
- Key characteristics of AA systems include configurations, triggering conditions, and human-system interfaces (HSIs)
- Configurations
  - A configuration is a DOA that defines the roles and responsibilities of both operators and automation
  - Configurations involve dynamic changes in automation dimensions, such as the level of automation
- Decisions that are important to configuration design
  - Configuration Definition - Should the configurations be predefined, defined in real time, or some combination of the two?
  - DOA Change Selection - What type of DOA changes should be used to support operator task performance?
  - Number of Configurations - How many individual configurations should be designed?
  - Configuration Timing - What is the minimum length of time configurations should remain in effect?

Adaptive Automation Characterization

- Triggering conditions
  - Conditions that initiate changes in AA configurations
- Types of conditions
  - Operator Command
  - Operator Performance
  - Operator Functional State
  - Can include system state and events, but these are predefined and not truly adaptive (i.e., they are based on presumed changes in the demands on the crew)
  - Hybrid – combination of triggers
- Decisions that are important to trigger design
  - Appropriateness of Trigger Categories - Which category of trigger or combination of categories is appropriate for the specific AA system?
  - Invoking Thresholds - What are the specific points at which the triggers should change the AA configuration?

Adaptive Automation Characterization

- Relationship between configurations and triggers



Adaptive Automation Characterization

- HSIs
  - The alarms, displays, controls, and communications necessary for operators to interact with AA systems
- Decisions that are important to HSI design
  - Monitoring - How is configuration awareness and the detection of degraded conditions supported?
  - Control - How do operators configure and control AA and how is workload managed?
  - Communication - How is effective and efficient communication between operators and automation fostered?

Effects on Performance

- In general, AA supports improvements in task performance
  - There are exceptions; which may have to do with mismatchs of task demands and automation support
- Some studies find improved situational awareness
  - This result may be dependent of the specific nature of the tasks
  - Varying DOAs (not just through AA) improves operator's understanding of how automation functions
- Effects on workload are mixed
  - This finding is, in part, due to what an AA system is compared with
    - If AA is compared to a manual condition, workload is likely to be lower
    - If AA is compared with a static automation condition, workload is likely to be higher
- There is some evidence that AA supports operators in the detection and management of automation failures
  - However, very little research specifically addressed this question

Conclusions

- The degree of automation has been increasing, yet many of the classic human performance issues still exist
- Research suggests AA may help mitigate these issues
  - Keeping operators in the loop (with good situation awareness)
  - Supporting vigilance (reduced complacency and boredom)
  - Maintaining workload at acceptable levels (not too high, low, or variable)
  - Maintaining skills by providing opportunities for manual performance
- AA applications are likely to become more widespread
  - As experience is gained with AA systems
  - As industry standards and guidelines identify AA as an option and provide guidance for its design

Conclusions
- Issues to Resolve

- Workload imposed by interacting with automation to achieve configuration changes
- Unexpected configuration changes (if shifts occur by non-operator-initiated triggers)
- Communicating roles and responsibilities associated with configuration changes
- Defining invoking thresholds
- Technical challenges have been noted for some operator functional state indicators, such as physiological parameters
- Operators being interrupted by automation

Conclusions
- Challenges Using the Results of Research

- How well do the findings generalize to our operational context, which is
  - Commercial nuclear power plants (high-reliability engineering, redundant and diverse systems)
  - Highly-trained professional operators
  - Complex tasks and detailed procedures
  - Full suite of HSIs
- Generalization from studies of
  - Other complex-system domains, such as aviation
  - Simple systems represented in microworlds
  - Studies with college students
  - Unrealistic representation of conditions
- Research will be needed to “validate” lessons learned