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Introduction

• Primary goal of the literature review was to develop a tool that can inform HRA
  – Specifically, to identify the relevant causes and contributors to cognitive failure
• Information gleaned from the literature review was organized into a framework that:
  – Connects explicitly the types of cognitive errors with contributing factors, supported by research
  – Summarizes and organizes the psychological literature into a tool that enables analysts to understand and systematically identify the reasons why humans make errors
• This presentation presents an excerpt from the cognitive framework and discusses how the tool may be used to inform HRA
Overview

• Purpose of the framework is to identify how failure occurs
  – For the possible causes of failures (proximate causes), what are the mechanisms for human error, and what context (PIFs) may activate those mechanisms?

• Cognitive framework is a tool to identify which causes, mechanisms, and PIFs the analyst should investigate or consider for the situation under analysis
  – i.e., which factors are likely to be relevant as indicated by psychological and human factors research
  – Other factors may still be relevant

• Cognitive framework consists of five trees, one for each macrocognitive function
  – Detecting & Noticing
  – Understanding & Sensemaking
  – Decision Making
  – Action Implementation
  – Team Coordination
Definitions of Terms

- **Macrocognitive Function**: high-level mental activities that must be successfully accomplished to perform a task or achieve a goal in a naturalistic environment (Letsky, 2007)

- **Proximate Causes**: causes of failure of the macrocognitive function that are readily identifiable as leading to the failure.
  - Result or manifestation of failure of a mechanism
  - Each cause can be associated with several mechanisms

- **Mechanisms**: processes by which the macrocognitive function works
  - Processes by which cognition takes place in the work environment (e.g., working memory)
  - If any part of the process fails (internal or external), this failure may manifest itself as a proximate cause of the macrocognitive function failure

- **Performance influencing factors (PIFs)**: contextual factors, including plant factors, that influence the likelihood that a mechanism fails and leads to a proximate cause of macrocognitive function failure
  - PIFs may either reduce or raise the likelihood of error
Cognitive Framework Structure

- Organizes all four of these elements into a tree structure that illustrates how macrocognition may fail and describes the reasons why
- Each macrocognitive function is represented with one tree
- Generic structure of each tree:

```
Failure of Macrocognitive Function
   +--- Proximate Cause 1
       |   +--- Mechanism A
       |       |--- PIF 1
       +--- Mechanism B
           |--- PIF 2
           +--- PIF 3
               +--- PIF 4
           |   +--- PIF 5
               |--- PIF 6
       +--- Proximate Cause 2
           |   +--- Mechanism C
           |       |--- PIF 1
           +--- Mechanism D
```
**Importance of the Mechanisms**

- Identification of the Mechanisms is one of the most important developments in the cognitive framework:
  - They provide explanation about *why* PIFs are important
  - They provide information about *how* PIFs influence human cognition into errors
  - The cognitive framework puts this information in one easy-to-use tool that can inform HRA and other applications

- For example, the Mechanisms provide an explanation about how and why poor safety culture may lead to errors in decision making:
  - Poor safety culture may cause decision makers to:
    - Have incorrect goals (e.g., keep operating despite degraded conditions),
    - experience goal conflict (e.g., conflict between not wanting to make waves and wanting to report a safety concern), or
    - incorrectly prioritize goals (e.g., placing safety at a lower priority than other goals)
Excerpt From the Cognitive Framework: Decision Making

• Most relevant model of decision making for NPP operations is the integrated naturalistic decision making (NDM) model (Greitzer, Podmore, Robinson, & Ey, 2010)
  – When using procedures, experienced operators will:
    • Use cues presented the situation to construct a story of what is happening (pattern matching)
    • This mental image will be used in developing a response plan and alternative actions based on goals or priorities
      – The response plan may be largely prompted by procedures or developed by the operators if procedures are not applicable
    • The response plan may be evaluated through mental simulation to determine its suitability before being put into action
  • This information was used to identify causes of failure of decision making
DM Tree: Proximate Causes of DM Failure

Incorrect goals or priorities set

Incorrect internal pattern matching

Incorrect mental simulation or evaluation of options
DM Tree: Mechanisms and PIFs (1)

Incorrect goals or priorities set

Goal conflict

Incorrect goals selected

Knowledge/experience/expertise
- Training
- System response
- Procedures

Perceived decision impact

Safety culture

Incorrect prioritization of goals

Knowledge/experience/expertise
- Training
- Resources
- Procedures

Task load

Safety culture

Incorrect judgment of goal success

Knowledge/experience/expertise
- Training
- Procedures

Time load

HSI
DM Tree: Mechanisms and PIFs (2)

Incorrect internal pattern matching

- Failure to retrieve previous experiences
  - Knowledge/experience/expertise
  - Training
  - System responses

- Incorrect recall of previous experiences
  - Knowledge/experience/expertise
  - Training
  - Time load

- Incorrectly comparing the mental model to previously encountered situations
  - Knowledge/experience/expertise
  - Training
  - Task complexity
  - Attention to task
  - Time load

- Cognitive biases
  - Knowledge/experience/expertise
  - Training
  - Time load
DM Tree: Mechanisms and PIFs (3)

Incorrect mental simulation or evaluation of options

- Inaccurate portrayal of action
  - Knowledge/experience/expertise
  - Training
  - Memory load
  - Time load

- Incorrect inclusion of alternatives
  - Knowledge/experience/expertise
  - Training
  - Time load

- Misinterpretation of procedures
  - Knowledge/experience/expertise
  - Procedures
  - System responses
  - Time load

- Inaccurate portrayal of the system response to the proposed action
  - Knowledge/experience/expertise
  - Training
  - Procedures
  - Time load

- Cognitive biases
  - Knowledge/experience/expertise
  - Training
  - Time load
Using the Cognitive Framework and Associated Tables

- Each cognitive framework tree has associated tables\(^1\) that detail the literature support for each item on the tree
  - Discussion of each mechanism
  - Example of the mechanism
  - Identifies the relevant PIFs (taxonomy adapted from Groth & Mosleh, in press)
  - Explains
    - *Why* the PIF is important,
    - *How* the PIF impacts the mechanism, or
    - Where possible, what characteristics of the PIF are likely to lead to failure of the mechanism

- Together, the trees and tables are a tool that analysts can use to understand what can lead to cognitive failure in a situation, and to identify PIFs that are likely to be relevant

\(^1\)The cognitive framework and associated tables are presented as two appendixes in NUREG-2114 (Whaley et al, in press)
## Excerpt From the Mechanism Tables

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Discussion</th>
<th>Example</th>
<th>Relevant PIF(s)</th>
<th>PIF Explanation</th>
<th>References</th>
</tr>
</thead>
</table>
| Incorrect goals selected      | During goal setting, the operator chooses the wrong goal(s) to work toward. The wrong goal(s) may be selected due to an improper understanding of the situation. | Although the operator may initially have classified the situation correctly (i.e., had a correct mental model), the situation may evolve to something different and the operator does not update the goals to reflect this new situation. | • Procedures  
• Knowledge/Experience/Expertise  
• Training  
• System Reponses  
• Safety culture | • Procedures may mislead the operator to believe the situation is changing slower than it really is.  
• Experience with this situation may be lacking and the operator does not expect the situation to change so quickly or to evolve to the new state at all.  
• Training with this type of situation may be non-existent or have been given too long ago to be relevant.  
• The cues and responses being presented by the system may be ambiguous making it difficult for the operator and crew to diagnose the situation and develop the correct response plan. | Cacciabue, et al., 1990  
Klein, 1993  
Lipshitz, 1993  
Orasanu, 1993  
Reason, 1997 |
Conclusion

• Based on an extensive review of psychological, cognitive, and human factors literature, we developed a cognitive framework to:
  – Organize the psychological concepts related to human performance in NPP operations,
  – Identify relevant PIFs that may lead to crew failures
  – Establish a link between the PIFs, mechanisms, proximate causes of failure, and ultimately the macrocognitive functions
  – Serve as the foundation for the IDHEAS hybrid HRA method presently being developed
  – Inform HRA qualitative analysis and quantification approach

• The cognitive framework and associated tables may be relevant to other HRA and non-HRA applications
References