Bridging Human Reliability Analysis and Psychology, Part 2: A Cognitive Framework to Support HRA

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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

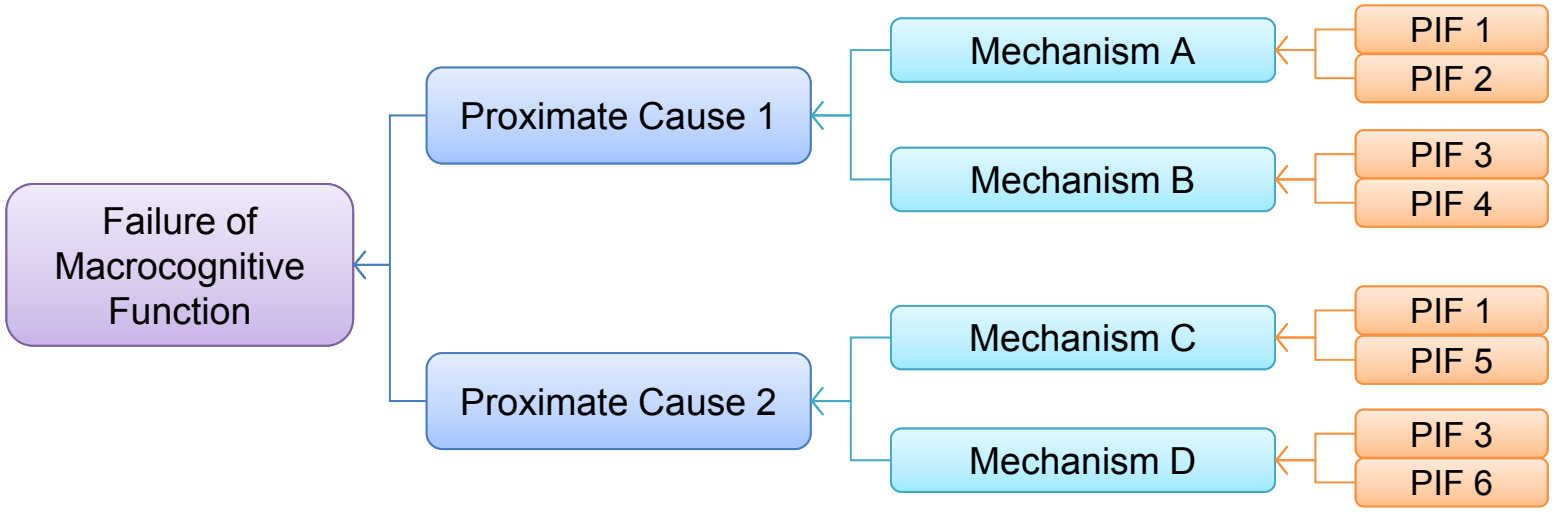
- Purpose of the framework is to identify how failure occurs
  - For the possible causes of failures (proximate causes), what are the mechanisms for human error, and what context (PIFs) may activate those mechanisms?
- Cognitive framework is a tool to identify which causes, mechanisms, and PIFs the analyst 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:



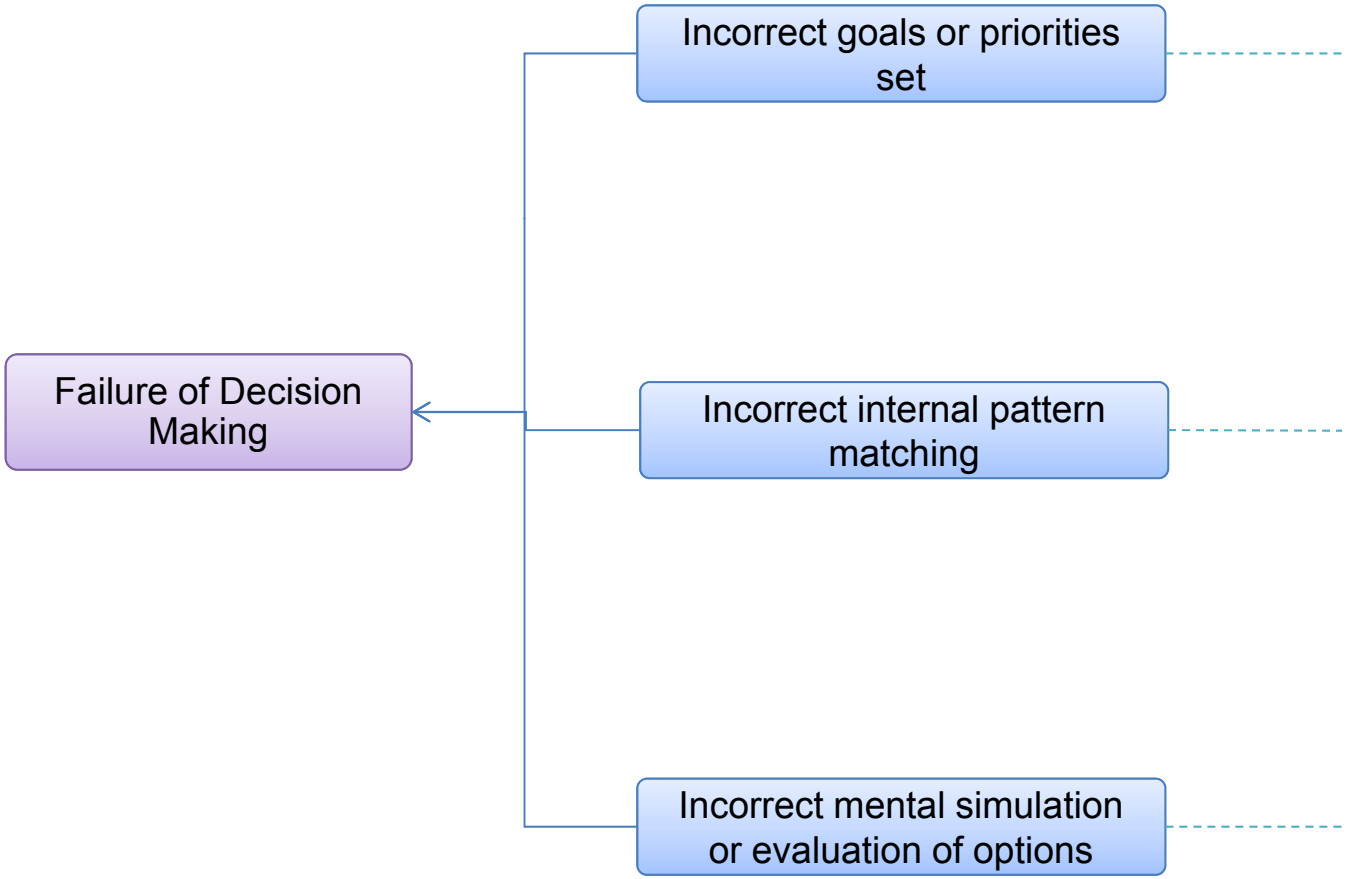
Importance of the Mechanisms

- 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)

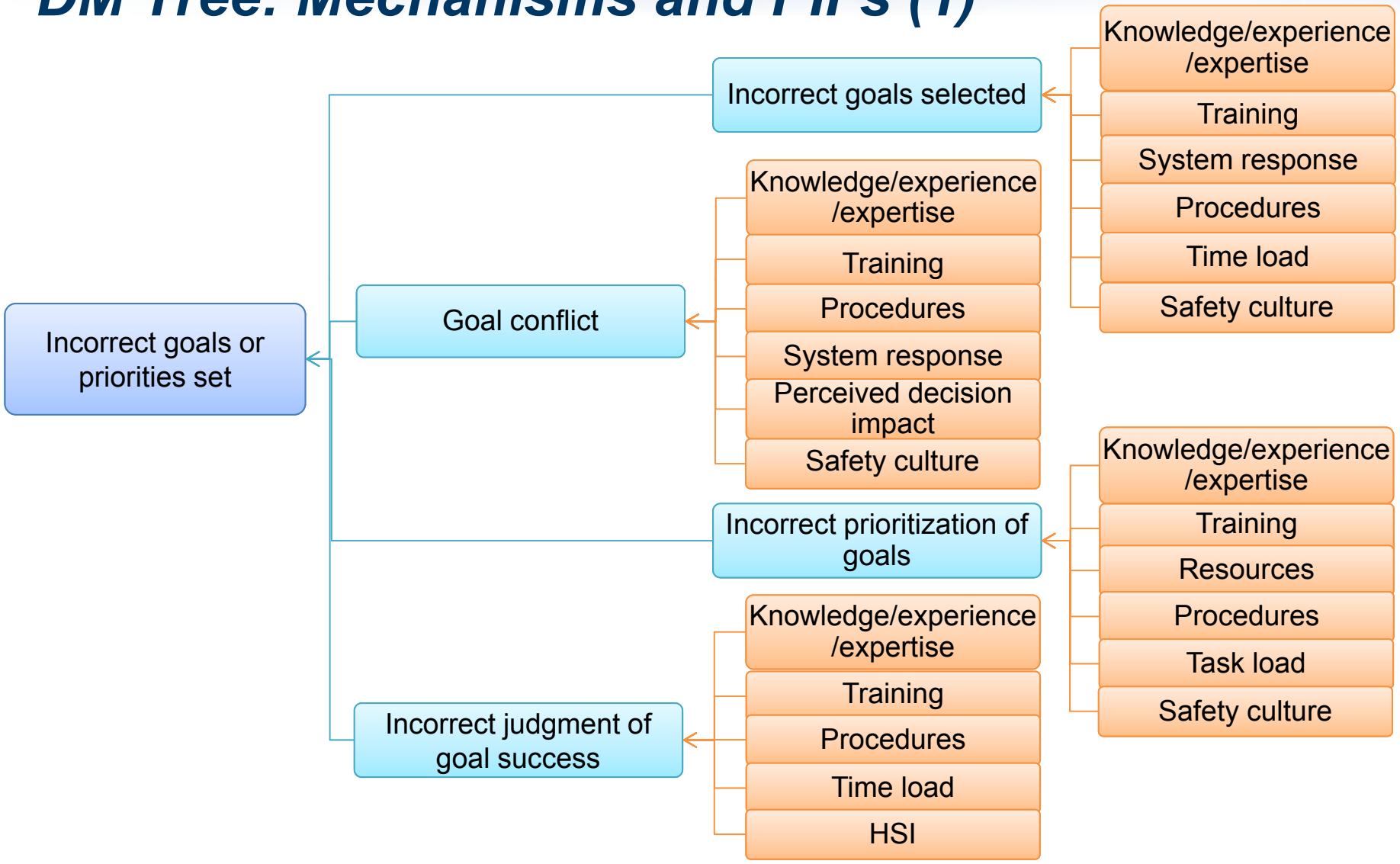
Excerpt From the Cognitive Framework: Decision Making

- 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

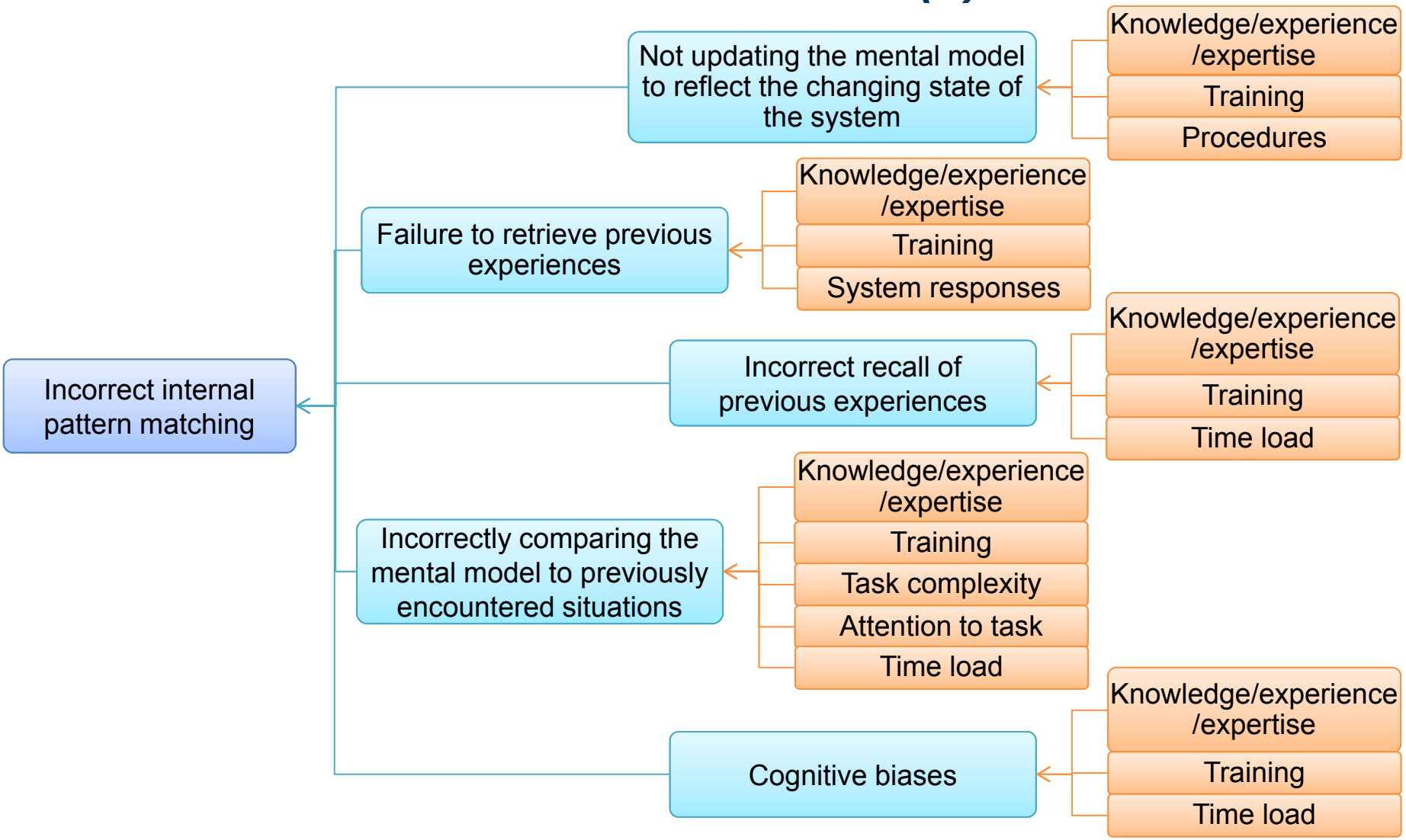
DM Tree: Proximate Causes of DM Failure



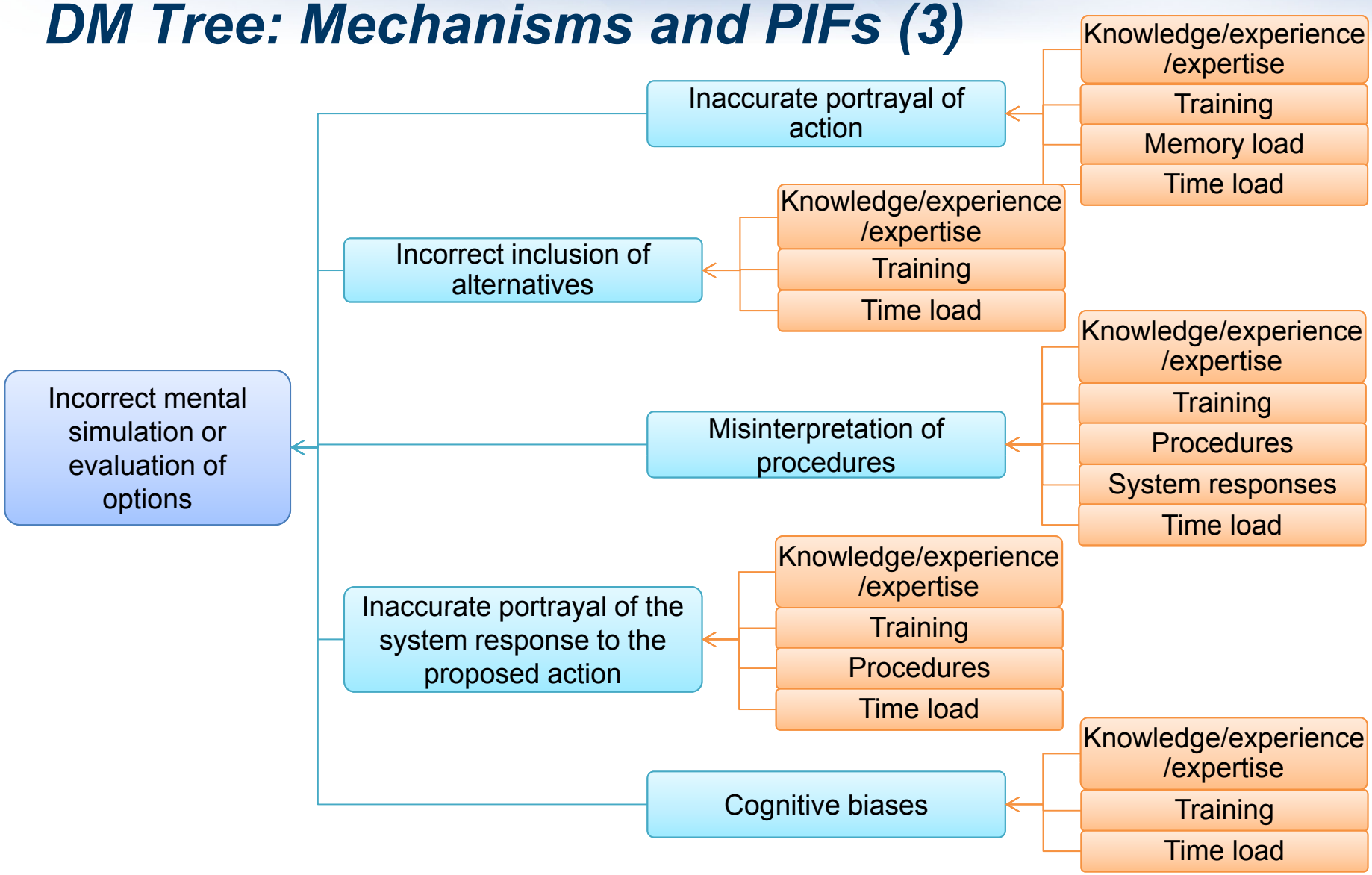
DM Tree: Mechanisms and PIFs (1)



DM Tree: Mechanisms and PIFs (2)



DM Tree: Mechanisms and PIFs (3)



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

Mechanism	Discussion	Example	Relevant PIF(s)	PIF Explanation	References
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

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