Poster Showcase #IAEM24

HAZMAT Technician Radiological Incident Response Readiness: Assessing Mental Model Gaps[1]

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Abstract

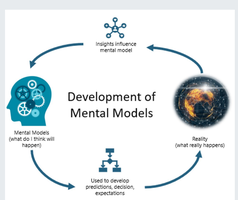
Understanding how Hazardous Materials (HAZMAT) Technicians think about radiation risk and Radiological Dispersal Device (RDD) incidents provides unique insights into where additional training focus could enhance responder readiness. How people think is captured in a mental model, which is like a map in someone's head that helps them understand how things work and predict what will happen next. It consists of beliefs, knowledge, and assumptions about aspects of the world, such as how to open a door, how a car works, or what will happen to them in a hazardous situation. Using an Expected Mental Model State (EMMS) Diagnostic Matrix, which is a tool designed to elicit responder mental models and compare them against an ideal or expected knowledge state, HAZMAT Technicians from fire departments across the US were assessed for gaps in understanding.

The analysis revealed four pivotal areas of misunderstanding: (1) overestimation of radiation health risks, (2) overreliance on personal protective gear, (3) confusion around radiation measurement units, and (4) limited understanding of radiation characteristics and dispersal mechanics.

By using these insights to adapt training to target and improve responders' mental models, we can bolster their readiness for RDD incidents, ensuring a more effective emergency response. This study serves as a repeatable framework to identify misunderstandings and focus training, ultimately fostering a more competent and prepared HAZMAT response.

Mental Model Introduction

Mental models are cognitive frameworks that people create based on their experiences and learning, helping them understand and navigate the world.[6] Mental models allow individuals to quickly predict outcomes, achieve goals, and make sense of new information rapidly without needing to analyze millions of data inputs to know how to operate in the world. When actual real-world events differ from the expectations driven from these existing mental models, the brain revises these mental models to better reflect what has been experienced. If these mental models are created with incorrect or incomplete information, individuals may not have the necessary frameworks for effective problem-solving or decision-making.



In radiological emergency response, we rely primarily on training and other life experiences to build our mental models on radiation risk because there are limited real-world experiences to mold and form proper mental models. Understanding the role of mental models in our preparedness activities is an important key to ensuring that training and experiences are tailored in a way that can build strong mental models related to radiation incidents and risk.

Acronym Key

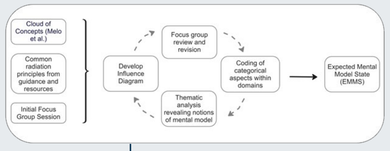
EMMS - Expected Mental Model State
MMS - Mental Model State
PC - Personal Computer
PPE - Personal Protective Equipment
RDD - Radiological Dispersal Device
SCBA - Self Contained Breathing Apparatus

Methodology

Evaluating for Gaps in HAZMAT Responder Mental Models

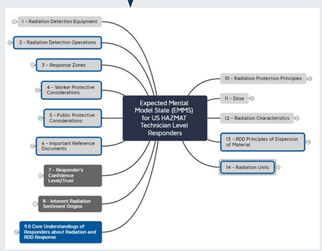
1 Establish Expected Mental Model

What should HAZMAT Technicians understand about RDD incidents and radiation risk?



We identified the essential knowledge HAZMAT Technicians need regarding radiation, risk, and RDD response. Using Melo et al.[4] and other key sources[5], we convened a focus group of radiological emergency and health physics experts to create an influence diagram outlining key concepts.

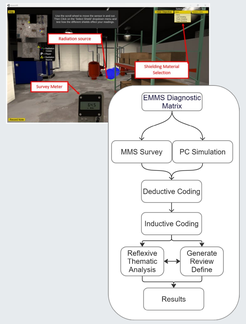
The Expected Mental Model State (EMMS) was documented as an map of 14 conceptual domains.



The derived EMMS for HAZMAT technicians identified 14 key conceptual domains: (1) radiation detection equipment, (2) detection operations, (3) response zones, (4) worker protection, (5) public protection, (6) reference documents, (7) responder confidence/ trust, (8) origins of radiation sentiment, (9) core RDD response, (10) radiation protection, (11) radiation dose, (12) radiation characteristics, (13) RDD dispersion principles, and (14) radiation units. These domains, from which 301 subtopics emerged, are summarized in the figure, with the full EMMS available at https://doi.org/10.25380/iastate.24602094.v1.[2]

2 Elicit Individual Mental Models

What to HAZMAT Technicians actually understand about RDD incidents and radiation risk?



Data were collected from HAZMAT responders in four U.S. states—California, Texas, Iowa, and New York—across large and mid-size departments. Participants, all meeting NFPA 470 HAZMAT technician qualifications, completed activities to assess their current mental model related to the EMMS conceptual domains.

Survey Task: Participants completed 50 online MMS survey questions based on the EMMS Diagnostic Matrix. These questions covered aspects of each EMMS conceptual domain, assessing the participants' basic mental models without leading prompts. For example, questions 16 and 28 focused on the health impacts of a 25 rem radiation dose, with question 16 being open-ended and question 28 offering multiple-choice options like cancer, acute radiation syndrome, skin burns, death, or no health effects.

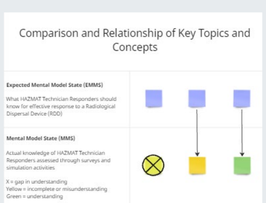
Simulation Activity: Participants completed a task in the AssessRadVR PC-based simulation, featuring a machine room with three radiation sources. Using simulated detection equipment, shielding materials (paper, plastic, lead), and cones for a restriction zone, they verbalized observations, assessed risks, and provided an overall risk evaluation of the scene.[3]

Table 3. Participant Demographics

Variable	Count	Percentage
Demographic Variable (N)	112	
Location (State)		
New York (NY)	64	57%
California (CA)	13	12%
Texas (TX)	15	13%
Iowa (IA)	20	18%
NFPA 470 HAZMAT Certification Level		
Technician	96	86%
Specialist	13	12%
Other	3	3%

3 Identify Gaps in Understanding

Comparing the expected and individual mental models, where do gaps emerge?



All data were coded and analyzed using NVivo 14 with grounded theory coding and reflexive thematic analysis, following Braun and Clarke's[7] six-phase model: (1) data familiarization, (2) initial coding based on the EMMS Diagnostic Matrix, (3) theme generation through deductive and inductive coding, (4) theme review, (5) theme definition, and (6) findings presentation. The EMMS framework, comprising conceptual domains, subtopics, and key concepts, provided the foundation for creating survey and simulation tools to elicit responder mental models. The EMMS Diagnostic Matrix offered a structured approach for identifying and measuring gaps between responder and expected mental models.[3]

Results

Results and Discussion

The thematic analysis revealed four major themes across all three notions of the mental model over 7 of the 14 EMMS conceptual domains. These four themes highlight significant patterns in responders' MMS that showed notable inconsistencies with the EMMS.

1. **Overestimation of Radiation Dose and Health Effects**
2. **Overreliance on Responder Protection (PPE/SCBA)**
3. **Misunderstanding of Radiation Detection and Units**
4. **Incomplete Understanding of Radiation Characteristics and Dispersal Properties**

The identification of these four themes is significant due to their substantial interconnections within the technical components of these concepts. This interrelatedness likely explains why these themes stood out more prominently than other partially formed ideas identified under the notions of the mental model. A tendency to overestimate the health impacts at operational dose levels, combined with a partial understanding of how radioactive materials disperse and their elemental characteristics, might be leading to an excessive dependence on PPE and SCBA for worker protection. This issue could be exacerbated by a lack of clear comprehension regarding radiation units, prefixes, and dose principles, hindering the ability to appropriately assess the risks associated with various dose levels.

The incomplete understandings observed in these thematic areas have been informally recognized by many professionals in the radiation emergency response field. Thus, these findings are not entirely unexpected.

Nonetheless, the prevalence of these themes across a diverse group of responders from different regions of the country, as revealed through this rigorous analysis, underscores the need for training and response professionals to focus attention on these particular areas.

This research lays the foundation for the development of more effective experiential training strategies that can improve the confidence of emergency responders by building a complete mental model about radiation incident response and risk. In turn, this fosters greater preparedness and resilience, resulting in increased safety for both responders and the communities they serve. Ultimately, the goal is to create a well-prepared response force capable of handling the complexities of radiological incidents with the same confidence and precision as other hazards like flammable liquids or structural fires.[3]

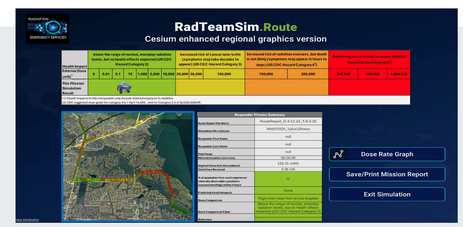
Responders need a robust mental model to make effective real-time decisions.

Future Initiatives

Complete the Mental Model

Can training be enhanced or developed to improve the mental model?

Given that over 300 survey questions would be needed to fully cover all EMMS subtopics, it's unrealistic to explore a responder's full MMS in a single study session. A more detailed, focused exploration of each mental model and its associated domains is a logical next step. Gaps in understanding radiation and risk could significantly affect decision-making, response strategies, and overall emergency effectiveness. Leek et al. [1,8] further evaluated these gaps. Virtual reality simulations, combined with after-action review tools, provide responders with realistic scenarios to assess how they apply their mental models in high-stress situations.



https://www.radiationemergencyservices.com/radteamsim-route

Citations & Acknowledgements

Scan to access Dr. Leek's full dissertation.

[1]Leek, A. (2023). The hidden factor: Characterizing the influence of responder mental models on the quality of radiological dispersal device incident response (Publication No. 21285)[Doctoral dissertation, Iowa State University]. Iowa State University Digital Repository.

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