Optimizing Training Methods for Exploration Medical Crew: An Assessment of the Current Gaps

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Overview

- The current status of Exploration Medical Capability (ExMC) Gap 3.01
- Updated assessment and analysis of the training gaps
- Validation of training programs
- Metrics for quantification of training effectiveness
- What else do we know?
- Lessons learned so far
- Areas for future investigation

ExMC Gap 3.01

- **"We do not know the optimal training methods for in-flight medical conditions identified on the Space Medicine Exploration Medical Condition List [SMEMCL]** taking into account the Crew Medical Officer's clinical background."

ExMC Gap 3.01 – Why is it important?

- Majority of historical in-flight medical problems were minor
- Though all crews undergo training in more advanced emergency medical procedures, these skills remain untested in a real-life incident
  - e.g., Advanced cardiac life support (ACLS)
- How can we be sure our training procedures are effective?

1. Hamilton D, Smart K, Melton S, Polk JD, Johnson-Throop K. Autonomous medical care for exploration class space missions. *J Trauma.* 2008; 64: S354-63.)
2. "ExMC Gap Report 3.01," *NASA Human Research Wiki*. Retrieved from https://humanresearchwiki.jsc.nasa.gov/index.php?title=3.01.

The need for medical preparation

- "Historically, the difficulties associated with illness and injury have accounted for the failures of more expeditions on Earth's frontiers than any other single technical or environmental reason."
- It is only a matter of time before there is a more severe medical emergency in space
  - Integrated Medical Model (IMM) helps predict incidence rates and incidence proportions

Summers RL, Johnston SL, Marshburn TH, Williams DR. Emergencies in space. *Ann Emerg Med.* 2005; 46: 177-84.

A paradigm shift

- Exploration missions will require a paradigm shift in medical preparation due to new limitations and unknown risks
  - Current mission planning:
    - Real-time ground support
    - Evacuation to Earth contingencies
  - Future mission planning:
    - Communication delay
    - Need to treat to definitive resolution or stabilization

Current gap approach

- Can we design a theoretical way to measure training effectiveness?
- Targets:
  - Identify a necessary skill-set based on SMEMCL
    - Determine the best training method for each skill
  - Validate current and proposed training methods for both crew and ground support (flight surgeons and biomedical engineers [BMEs])

Current gap approach

- Develop a metric to quantify the effectiveness of training methods
- Integrate lessons learned from rigorous testing into exploration training methodology

Gap 3.01 – The Report

- Outlines current training flows for astronaut candidates, crew medical officer (CMO), surgeon, and BME
- Identifies limitations imposed on training algorithms by exploration missions
  - Lack of knowledge about medical conditions specific to spaceflight
  - Microgravity
  - Problems pertaining to knowledge and skill retention
- Current training methods are not adequate for exploration missions

"ExMC Gap Report 3.01," *NASA Human Research Wiki*. Retrieved from https://humanresearchwiki.jsc.nasa.gov/index.php?title=3.01.

Aiming for perfection

- The best possible medical training for crew
- The best possible preparation for ground support
- The best medical technology and equipment
- In-flight medical autonomy (ideally)

Where are we going, and how do we get there?

A new approach to the old gap

1. Existing gap report reviewed
2. Limited literature search performed
3. Areas of training defined
4. Extrapolation of a comprehensive list of questions regarding training
5. Identification of subject matter experts (SME) in training
6. Initial SME interviews to further improve questionnaire

Training gaps questionnaire

- Who better to help answer questions about training than experts in training?
  - What would we ask those experts…?
- In general, what are the tried and true best methods of medical education?
- How should we teach each specific piece of medical knowledge or individual skill?

Training gaps questionnaire

OPTIMIZATION OF TRAINING: STRATEGIZING CLOSURE OF GAP 3.01

Validation

- How are education and training validated in general?
- How are medical education and medical training validated?
    - How are medical objective standardized clinical examinations (OSCEs) designed and validated?
    - How are interactive case-based simulations, educational tools, and assessments created and validated (e.g., United States Medical Licensing Exams)?
- How can we use the standards established in the validation of medical education teaching and evaluation methods to validate training methods for exploration class missions?
- How can we validate training methods prior to implementation of a training program for an exploration class mission?

Metrics/Quantification

- What metric do we use to assess the effectiveness of our training programs, strategies, and techniques?
- How do outside groups (e.g., EMTs, military) certify CREW and GROUND SUPPORT?
- How do we design studies to test the following:
    - The best training methods and techniques for a defined skill/topic?
    - The effectiveness of our training programs?
    - The metrics with which we evaluate our training programs?

Training gaps questionnaire

Training Methods – Telemedicine

- What are the gold standards for training users of telemedicine in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

Training Methods – Just-in-Time Training

- What are the gold standards for just-in-time training programs in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

Training Methods – Dental

- What are the gold standards for dental-focused training in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

Training Methods – Medical Knowledge

- What are the gold standards for medical knowledge training in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

Training Methods – Medical Skills/Procedures

- What are the gold standards for training in medical skills/procedures in a terrestrial environment?

Locating subject matter experts

Locating subject matter experts

- Internal organization (NASA and Wyle)
  - Current training leads and those already directly involved with training
- External experts
  - Previous participants in summits on training (e.g., dental)
  - SciVal Expert Locator ® (aka Collexis)
  - Literature search
- Resulted in a spreadsheet of contacts organized by area of expertise

Improving the questionnaire

- Initial meetings conducted with internal training experts for feedback on the questionnaire
  - Some modifications made to wording and specificity of questions
  - General consensus… a potentially useful approach

Addressing the questions…

Initial research: Validation and metrics

VALIDITY

Does the test or measurement actually quantify the attribute it is intended to quantify?

"…a test is valid if it measures what it purports to measure…" (Kelly, 1927)

Colliver JA, Conlee MJ, Verhulst SJ. From test validity to construct validity… and back? *Med Educ.* 2012; 46: 366-371.

Validity vs. validation

- Validity is a *property* of a attribute
  - Similar to the concept of truth
  - i.e., Are our methods of training valid?
- Validation is a *process* of theory testing to determine if an attribute possesses the characteristic of being valid
  - i.e., How can we test our methods of training to determine their validity?

Borsdoom D, Mellenbergh GJ. The concept of validity. *Psychol Rev.* 2004; 111: 1061-1071.

Reliability

- The consistency of measurement outcomes over multiple iterations of a test
- Quantifies the degree of variation in scores to determine if the test is *reproducible*
  - An assessment of the amount of random error
- Necessary but not sufficient for establishing validity

Downing SM. Reliability: on the reproducibility of assessment data. *Med Educ.* 2004; 38: 1006-1012.

How can we validate or measure effectiveness of training methods ?

- Types of evaluations used in medical education
  - Written assessment (knowledge/cognitive ability)
  - Rating of directly observed performance
  - Standardized performance-based evaluation
    - Observed standardized clinical encounters (OSCEs)
    - Simulated or standardized patients
    - Computer-based simulations
- Other methods of evaluation
  - Review of written documentation (e.g., notes, orders)
  - Other statistics (e.g., complications, mortality, awards)

1. Downing SM. Reliability: on the reproducibility of assessment data. *Med Educ.* 2004; 38: 1006-1012.
2. Kreiter CD, Bergus G. The validity of performance-based measures of clinical reasoning and alternative approaches. *Med Educ.* 2009; 43: 320-325.

Knowledge assessments

- Written test format (e.g., multiple choice questions)
  - One of the simplest of the medical evaluation tools
  - Relatively straightforward to establish moderate reliability and validity
  - Limited applications beyond basic assessment of knowledge acquisition and retention

1. Crossley J, Humphries G, Jolly B. Assessing health professionals. *Med Educ*. 2002; 36: 800-804.
2. Downing SM. Reliability: on the reproducibility of assessment data. *Med Educ.* 2004; 38: 1006-1012.

Rating of directly observed performance

- An expert evaluation of clinical performance in a real-world setting (e.g., on the wards)
  - Oral examinations attempt to mimic clinical context
- Used to assess the following:
  - How the subject integrates knowledge and skill into behavior
  - Clinical judgment
  - Professional competencies
- Outcomes are expert ratings the performance of subject
  - Point scale (e.g., 1-5)
  - Dichotomous checklist

Rating of directly observed performance

- Limitations
  - Competencies and behaviors are difficult to define and not easily measured
  - High degree of variability
  - Time intensive
- Reliability and validity evidence in medical education literature moderate, but format widely used

1. Lurie SJ, Mooney CJ, Lyness JM. Commentary: pitfalls in assessment of competency-based educational objectives. *Acad Med.* 2011; 86: 412-414.
2. Tabuenca A, Welling R, Sachdeva AK, Blair PG, Horvath K, Tarpley J, Savino JA, Gray R, Gulley J, Arnold T, Wolfe K, Risucci DA. Multi-institutional validation of a web-based core competency assessment system. *J Surg Educ.* 2007; 64: 390-394.

Standardized performance-based evaluations

- Attempt to model a real-world expert evaluation while eliminating or controlling variables
  - Designed to assess similar attributes, behaviors, and competencies
- Examples:
  - U.S. Medical Licensing Exam Step 2 Clinical Skills
  - Primum Clinical Case Simulation ®
  - OSCE for board certification in Family Medicine

Standardized performance-based evaluations

- Limitations
  - Behaviors and competencies hard to define
    - Useful to assess demonstrable skills
  - Poor generalizability beyond specific skills tested
    - The broader the inference based on outcomes, the less valid
  - Time and cost intensive
- Reliability and validity evidence in medical education literature moderate, but format widely used

1. Cuddy MM, et al. Assessing the validity of the USMLE step 2 clinical knowledge examination through an evaluation of its clinical relevance. *Acad Med.* 2004; 10: S43-S45.
2. Kreiter CD, Bergus G. The validity of performance-based measures of clinical reasoning and alternative approaches. *Med Educ.* 2009; 43: 320-325.
3. Jefferies A, et al. Using an objective structured clinical examination (OSCE) to assess multiple physician competencies in postgraduate training. *Med Teach*. 2007; 29: 183-191.

Applications to training for exploration spaceflight

What are we going to teach?

- Subcategories of training
  - Medical knowledge
  - Medical procedures and skills
    - Dental procedures and skills
  - Use of telemedicine
  - Just-in-time training
  - Hardware use
  - Behavioral health

Current medical training

- 2 CMOs from among the crewmembers for each International Space Station (ISS) mission
- No previous medical background
- Receive 40 hours of lecture and training
  - Medical diagnostics (4 hours)
  - Medical therapeutics (5.5 hours)
  - CPR and ACLS (10.5 hours)
- *Optional* clinical component

1. Hamilton D, Smart K, Melton S, Polk JD, Johnson-Throop K. Autonomous medical care for exploration class space missions. *J Trauma.* 2008; 64: S354-63.
2. CMO Training Flow, Wyle Laboratories, April 2010.

Medical training for exploration spaceflight

- Must adapt the current training paradigms for the limitations of exploration missions
  - Inability to return to Earth for evacuation
  - Communication delays and blackouts
  - Resource constraints
    - Time
    - Volume, mass, weight, power
    - Cost
  - As yet unperceived risks inherent in extended duration missions beyond low Earth orbit

1. Barsten K, Watkins SD, Otto CA. "Telemedicine workshop summary report," *NASA TM 2012-xxxxxx*, 2012.
2. Risin D. "Risk of inability to adequately treat an ill or injured crewmember," in Human Health and Performance Risks of Space Exploration Missions. Ed. McPhee JC and Charles JB. NASA; 2009: 239-252.

Medical procedures and skills training

- Minor procedures currently incorporated into CMO training
- Ongoing investigations into how to best perform procedures in microgravity

Medical procedures and skills training for exploration spaceflight

- Define a list of procedures and skills necessary for each condition on the SMEMCL
- Prioritize procedures and skills based on urgency priority of the condition
- Determine level of experience necessary for each condition
  1. Recognize and describe symptoms
  2. Make initial diagnosis
  3. Implement initial treatment intervention
  4. Treat to stabilization
- Determine how to optimize training for each procedure or skill given its priority

Dental training

- ExMC gap 4.11: Limited dental care capabilities
- Dental working group held Mar 2012
  - Participants were JSC /Wyle personnel, private dental practitioners, and an Army special forces dentist
  - Addressed the following:
    - Specific dental skills identified and prioritized
    - Terrestrial training standards reviewed with emphasis on analogous environments (e.g., special forces medics)
    - Areas for improvement in current crew training identified (e.g., hands-on experience in a high volume setting)
- Serves as a model for other SME panels

Menon A, Barsten K, Watkins SD. "Dental working group meeting summary report," *NASA TM 2012-xxxxxx*, 2012.

Telemedicine training

- Telemedicine Workshop hosted by ExMC in 2011
  - Participants were internal personnel, external experts in telemedicine, and users of telemedicine
  - Goal: Create a medical operational concept for a near-Earth asteroid mission

Barsten K, Watkins SD, Otto CA. "Telemedicine workshop summary report," *NASA TM 2012-xxxxxx*, 2012.

Just-in-time (JIT) training

- Current use of "just-in-time training"
  - CMOs trained by computer-based tutorials with real-time telemedicine guidance at point of care
  - Used for ultrasonographic investigations on ISS with good results
- Need to develop a database of resources usable without real-time ground support
- Design optimized training programs for instruction in and practice with how to use resources

1. Cermack M. Monitoring and telemedicine support in remote environments and in human space flight. *Br J Anaesth.* 2006; 97: 101-14.
2. von Lubitz DKJE. "Medical readiness training – just in time." Medical Readiness Training Team; U.S. Navy Advisory Team, University of Michigan. Retrieved from http://www.med-smart.org/downloads/NAVY_MEDICINE.pdf.

Training in hardware use

- Current CMO training includes instruction on ISS medical hardware
- Need to engineer new hardware and software to address unique needs of exploration missions
- Need to design optimized training programs for new technology

Behavioral health training

- Behavioral health of crew critical to mission success
- Crew medical officer must be able to diagnose and treat
- Best way to train yet to be elucidated
  - Analysis of training for personnel in analogous remote and high-stress environments

Prevention of knowledge and skill decay over time

- Extensive studies in literature pertaining to ACLS
  - Rarity of events and infrequent or inadequate training are contributing factors
  - Initial overtraining is a potential countermeasure
- Will need to be individualized
- Will need to be adapted to the timeline and the time constraints of the mission

1. Barsten K, Watkins SD, Otto CA. "Telemedicine workshop summary report," *NASA TM 2012-xxxxxx*, 2012.
2. von Lubitz DKJE. "Medical readiness training – just in time." Medical Readiness Training Team; U.S. Navy Advisory Team, University of Michigan. Retrieved from http://www.med-smart.org/downloads/NAVY_MEDICINE.pdf.

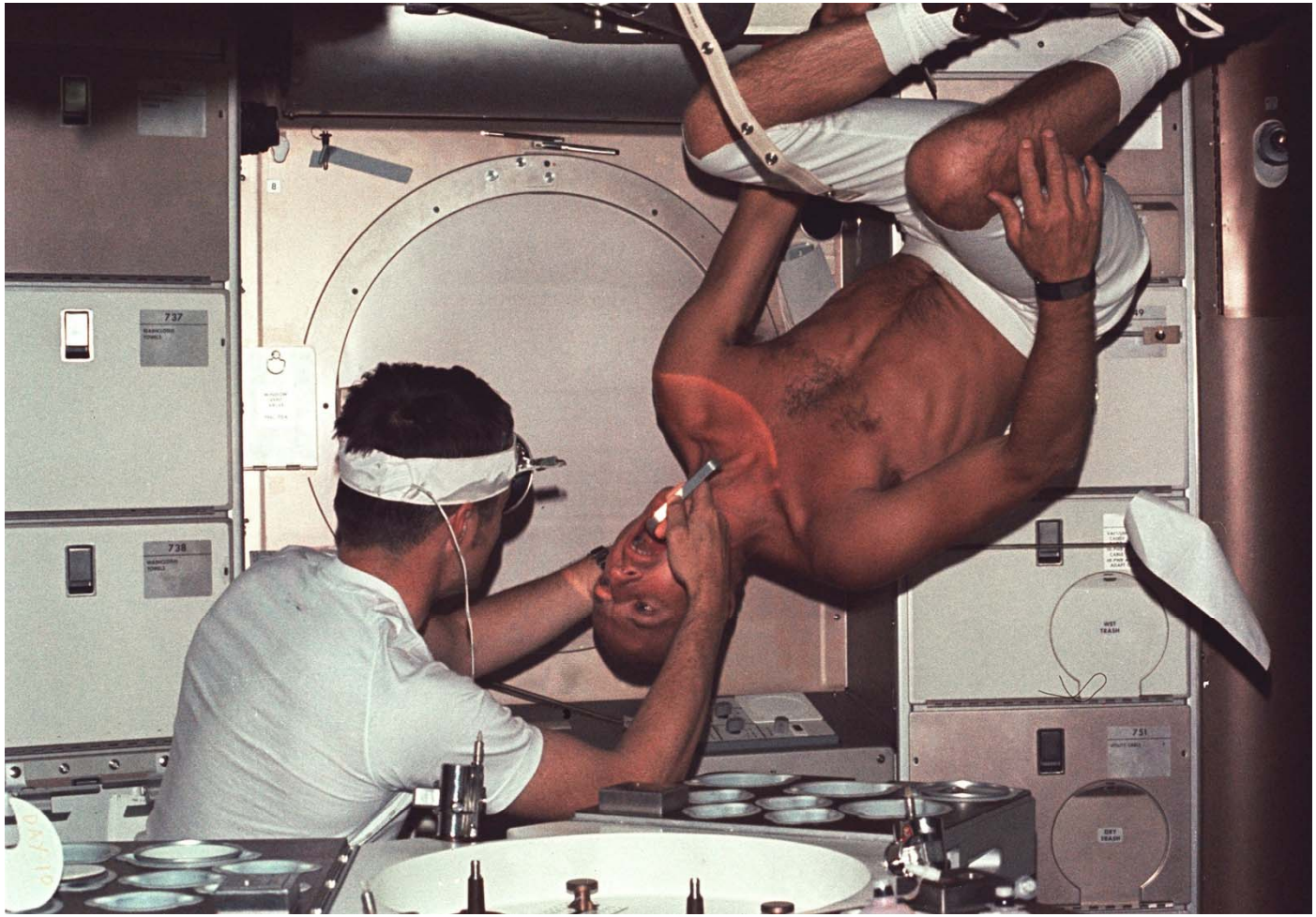
Key lessons learned

- There are no gold standards for training
- Must balance validity and reliability with feasibility and practicality
- Medical training optimization is an ongoing area of current research in analogous environments
- Any training procedures will require flexibility and constant adaptation to rapidly changing science of medicine

Areas for future investigation

- Prioritize skills by the criticality and urgency of the associated condition
- Define to what experience level each skill must be taught

Questions?



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