Augmented Human Performance

Matthew M. Cooper, MD MBA FACS
Global Senior Medical Director &
Director, Patient Safety C.O.E.
3M Health Care Business Group
Presenter has the following disclosure:

- Employee of 3M
Learning Objectives

1. Understand how evolved clinical decision making and systems designed to deliver care to warfighters has been broadly applied to civilian populations and patients.
2. Be able to describe both the technologic and non-technologic benefits and derivatives of the space program that continue to return the national investment.
3. Provide examples of practices, tools, and culture that have emerged from military use to universally transform critical team performance and enterprise development.
4. Understand the challenge to prepare this and coming generations for continued participation in science.
Augmented Performance Derived from Military Experience & Expertise

Behavioral & Performance Substrate

- Systemic perspective & derivatives
  - Reason – Swiss Cheese - Trajectories
- Situational Awareness & Decision Making
  - OODA Loops – Agile/Scrum
- Optimization Beyond Recognition Primed
Augmented Performance Derived from Military Experience & Expertise

Examples & Overlays

- Clinical Necessity
- Technologic
  - Augmented Cognition
- Space exploration
  - Technology
  - Societal & Cultural
- State of Science
Fallacies

- **Fallacy:** Those who have accidents lack “the right stuff”
- **Truth:**
  - Not supported by data
  - With increasing skill take on greater challenges
  - Experts in all professions make errors
  - “…the best performers make the biggest errors.” – James Reason
- **Fallacy:** An operation is either “safe” or “unsafe”
- **Truth:**
  - Every operation has finite degree of risk
  - Identify and assess risks and develop plan of action

Dismukes, NASA
Principles of ETM

- Recognize vulnerability to errors
  - Especially decision making and prospective memory
- Identify threats –before each phase ask “What if....?”
  - Three domains of threat
    - Present in every case
    - Present only in particular cases
    - Specific to certain situations
  - Presence of multiple threats increases vulnerability
    - Treat as RED Flag
- Treat interruptions, distractions, and deferred tasks as RED Warning Flags
- Redundancy
  - Develop multiple layers of defense
  - Threats and errors much less likely to penetrate multiple layers

Dismukes, NASA
System Reorientation

- Person vs. System approach to error analysis
- Person approach blames individuals for errors
- System approach focuses on conditions under which individuals work and builds defenses to avert errors or mitigate their effects

James Reason BMJ 2000
System Reorientation

• **Person** –
  
  • *Unsafe acts result from aberrant mental processes: forgetfulness, inattention, poor motivation, carelessness, negligence, recklessness*

  • *Countermeasures: aimed at reducing unwanted variability in human behavior*

    • *However, unsafe acts cannot be separated from their operational context……*

James Reason BMJ 2000
System Reorientation

- System –
  - Humans are fallible
  - Errors seen as consequence rather than causes
  - Countermeasures: cannot change human condition, rather the conditions under which they work
    - System defenses
    - When an adverse event occurs, the issue is not who blundered but how and why the defenses failed

James Reason BMJ 2000
System Reorientation

• **Active failures:** – unsafe acts committed by people: slips, lapses, fumbles, mistakes, procedural violations

• **Latent conditions:** resident “pathogens’ within system:
  • Local workplace – time pressure, understaffing, inadequate equipment, fatigue, inexperience
  • Long lasting – untrustworthy alarms and indicators, unworkable procedures, design and construction deficiencies
  • May lie dormant for years
  • Can be identified and remedied before adverse events occur
  • Pro- vs. Re- active risk management

*James Reason 1990, 1997*
Swiss Cheese Error Model
Penetrated by Accident Trajectory

James Reason BMJ 2000
The clinical course of surgical patients is a series of events, therapeutic decisions, interventions and responses to treatment that are interdependent in determining the final outcome.

Shannon et al. 2012
Seminal Mortality Event

Pre-operative

Intra-operative

ICU

Floor

Discharge

Child’s B Cirrhosis
Dilated Cardiomyopathy
TV CAD

Hepatorenal Failure

DEATH

Shannon et al. 2012
Seminal Mortality Event

Pre-operative

Intra-operative

ICU

Floor

Discharge

Bilateral Cerebral Emboli

Aspiration Pneumonia

Septic Shock

DEATH

Shannon et al. 2012
Seminal Event

Pre-operative

• Recurrent resp failure
• 3rd resp arrest – cardiac arrest

Intra-operative

ICU

• Hypoxic brain injury

Floor

• DVT – Pulm Embolism

Discharge

Avoidable?

DEATH

Shannon et al. 2012
NASA Model of “Threat and Error” in Pediatric Cardiac Surgery: Patterns of Error Chains

- Tracked expected stepwise risk de-escalations during recovery from surgery
- Unintended increments/failed de-escalations highly associated with errors
  - Consequential vs. nonconsequential errors - - unintentional state
- Propagating error chains that originate in operating room; often amplified by additional ICU errors
Situation Awareness

Decision Making
Situation Awareness (SA)

“The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future.”

- The highest levels of SA, integration in relation to goals and projection of future states, allows decision makers to function in a timely and effective manner
- Loss of SA results in ambiguity, confusion, decreased communication

TeamSTEPPS 2007
OODA Loop

Figure 2 OODA Loop (from [11])

Endsley & Jones 1997
OODA + SA

Figure 5  Situation Awareness in the OODA Loop

Endsley & Jones 1997
OODA Loops - Col John “40 Second” Boyd
  - Energy & Maneuverability

Agile/Scrum – Jeff Sutherland
  - Self directed teams
  - Based on work done
  - Definitions of “Done”
  - Removal of impediments
  - Internal testing and quantum release
Cognition, Decision Making, Performance

• *Situation Awareness is the foundation of Effective Decision Making*

• *Effective Decision Making is at the heart of Effective Action*

Endsley & Jones 1997
## Cognitive Biases and Heuristics

<table>
<thead>
<tr>
<th>Anchoring &amp; adjustment</th>
<th>Expectation bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assimilation bias</td>
<td>Familiarity bias</td>
</tr>
<tr>
<td>Availability heuristic</td>
<td>Favor of causal explanations</td>
</tr>
<tr>
<td>Base rate fallacy</td>
<td>Framing effect</td>
</tr>
<tr>
<td>Confirmation bias</td>
<td>Fundamental attribution bias</td>
</tr>
<tr>
<td>Conjunction fallacy</td>
<td>Future discounting</td>
</tr>
<tr>
<td>Conservatism</td>
<td>Omission bias</td>
</tr>
<tr>
<td>Endowment effect</td>
<td>Prior hypothesis bias</td>
</tr>
<tr>
<td>Reasoning by analogy</td>
<td>Recency bias</td>
</tr>
<tr>
<td>Escalation of commitment</td>
<td>Est. of overconfidence</td>
</tr>
<tr>
<td>Representative heuristic</td>
<td></td>
</tr>
</tbody>
</table>

Dismukes, NASA
Recognition Primed Decision Making

- Identified in terms of prototypes from memory
- Appropriate solution pops into mind
- Rapid, but prone to serious failure in unusual or misidentified circumstances
- Reveals critical difference between experts and novices

Klein 1989
However, you need flexibility in response:

“...the survivor...does not impose pre-existing patterns on new information, but rather allows new information to reshape (his mental models). The person who has the best chance of handling a situation well is usually the one with the best...mental pictures or images of what is occurring outside the body.”

Siebert A. The Survivor Personality
Upgraded Belief Vectors & DM

- Recognition Priming: Those who lack both skills in recognition & in experience are at a distinct performance disadvantage.

- Stankiewicz has shown that information integration is the potential weakness in context of incomplete information & criticality rather than memory or decision making...

  - Integration of new information is needed to create a reliable belief vector & “upgrade” the prior recognition priming.
Reduce Vulnerability to Decision Biases

–Ask: “Is there anything different today from previous encounters?”

–If several unusual aspects present, think how they may interact to produce downstream consequences

» Individual factors may be benign but combine to produce threat

» Red Flags!

–Always have a back door

Dismukes, NASA
Agility, Speed, Responsiveness
- Modified rules of engagement

Decentralized Decision Making
- Commander’s Intent
- SOP
- Trust
- Transparency
“Our systems are too complex to expect merely extraordinary people to perform perfectly 100% of the time.”

James Conway, IHI Vice President
Hardwired Safety Tools
Why Hardwire Safety Tools?

- **Ensure reproducible behavior, shared best practices**
- **Performance without fail in a predictable way among team members**
- Overcome human limitations
  - Prevent, trap and mitigate error
- **Easy to do the right thing, difficult to do the wrong thing**
SBAR

- Standardized format for hand-over communication
- Addresses a Joint Commission Safety Goal for 2006
- Used by RNs, Attendings, and House staff

From Nuclear Subs to Hospitals...
“The purpose of the review was to learn everything we possibly could about what we had just done – the good, the bad, and the ugly. We dissected problems and we came up with solutions – and the whole group profited from what we learned.

There is no better way for an organization to improve itself and move forward in a professional manner. But it is a process that must be fundamentally rooted in trust and mutual respect. The very instant it becomes a weapon rather than a lens for diagnostic analysis, the process is dead.”

TOPGUN

+ —

“goods”  “all others”
**Debrief Form**

*Circulating Nurse*

records comments

*Retained by the Nurse Manager for review, routing, feedback, and trend analysis.*

<table>
<thead>
<tr>
<th>What went well &amp; why?</th>
<th>What can be improved?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Timeline/delays</td>
</tr>
<tr>
<td></td>
<td>Room Prep</td>
</tr>
<tr>
<td></td>
<td>Patient Prep</td>
</tr>
<tr>
<td></td>
<td>Team Prep</td>
</tr>
<tr>
<td></td>
<td>Records</td>
</tr>
<tr>
<td></td>
<td>Time-out Brief</td>
</tr>
<tr>
<td></td>
<td>Equipment</td>
</tr>
<tr>
<td></td>
<td>Instruments</td>
</tr>
<tr>
<td></td>
<td>Medications</td>
</tr>
<tr>
<td></td>
<td>Other Services</td>
</tr>
<tr>
<td></td>
<td>Special Request</td>
</tr>
<tr>
<td></td>
<td>Procedure</td>
</tr>
<tr>
<td></td>
<td>Complications</td>
</tr>
<tr>
<td></td>
<td>Critical Events</td>
</tr>
<tr>
<td></td>
<td>Interruptions</td>
</tr>
</tbody>
</table>

How can that improvement happen?
Clinical Necessity

➢ War’s role as a laboratory of science

➢ Combat medicine requires decision making and the development of techniques that ultimately have broad application to civilian populations.

➢ Advances in casualty care including point of injury, prehospital settings, and resuscitation

➢ Continuously learning health system with:
  - improvements in clinical decision making
  - enhanced outcomes
Clinical Necessity - Examples

➢ Vascular reconstructive techniques
  - WWII – 50% amputation rate
  - Korea: attempted immediate repair 88%, Vietnam 99%
  - Limbs saved; lives impacted

➢ “Enlightened” use of Tourniquets

➢ Hemostasis & Biofilm

➢ Percutaneous aortic occlusion (REBOA – resuscitative endovascular balloon occlusion of the aorta) and endovascular interventions
Evolution

- A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury. June 17, 2016 – National Academy of Sciences, Engineering, and Medicine

- Shared aims, infrastructure, system design, data, best practices, and personnel

- 2015 “Stop the Bleed” Campaign (derived from Tactical Combat Casualty Care guidelines)
Augmented Cognition – Challenges

➢ Increasing complexity of environment
  - Increased cognitive load as threat to SA
  - Load increases when must sort and process influx of information

➢ Human brains are superior at visual recognition; inferior at processing
  - ? Inattentional Blindness
Augmented Cognition – Goals

➢ Facilitated incorporation of new information with change in decision vector
  - Build on Recognition Primed DM (Training)

➢ Ideally need to predict adversary’s next move
  - Imperfect or incomplete information
  - “…right information to the right person at the right time and
    in right format……(to) actually take some kind of action.”
  - With precision and speed

David Spirk, Jr., Chief Data Officer, SOCOM
Augmented Cognition – Technology Developments

- DARPA Augmented Cognition Technical Integration Experiment
  - Feasibility of using psychophysiologic measures of cognitive activity to guide real time human-computer interfaces (e.g., eye blinks, respiration, heart rate, galvanic response, electroencephalogram)

- AugCog
  - Nanotech
  - Biotech
  - Robotics
  - Information & Communication Technology
  - Applied cognitive science

- Sense/adapt to human cognitive state in terms of
  - Command surveillance
  - Mode of information delivery, etc.
Augmented Cognition – Technology Developments

➢ Tactical Assault Light Operator Suit (TALOS) – significant attribute is ability to enhance SA

➢ Augmented Reality of the Battlefield – combining physical & digital (e.g. GDMS) – handling the cognitive load to maintain SA

➢ AI Dev at DARPA
  - First wave: “describe” – rules-based; commercial products such as TurboTax;
  - Second wave: “recognize” – machine learning (current)
    - Can classify objects of interest into actionable information
    - Still maturing; theory for the technology dates from the 1970s
  - Third wave: “explain” – adding context and trust – future systems

Peter Highnam, Deputy Director, DARPA
“Captured Value” from the US Space Program
Technology

➢ Improve Lives
➢ Productivity
➢ Health
➢ The Economy
➢ National Security
Value Capture

~7:1 ROI for every dollar spent for Space R&D; in the form of corporate and personal income taxes from increased jobs and economic growth

- Digital imaging
- Laser angioplasty
- Virtual reality
- Cordless tools
- Home insulation
- Water purification
- Joy sticks
- Memory foam
- Smoke detectors

...and yes, Speedos!
Global Capture

➢ Environmentally friendly technology enhancements
  - Solar energy
  - Forest management
  - Oil spill control

➢ Global consciousness ➔ stewardship of the planet
"Mystery creates wonder and wonder is the basis of man's desire to understand."

Neil Armstrong
Space programs such as Apollo demonstrated our capacity to unite behind a goal and surmount human and technological obstacles to achieve mission success.
Societal & Cultural

- Satisfied Core need to Explore
- Motivated a generation of Innovators, Technologist, Mathematicians, Dreamers, Scientists & Engineers
- Demonstrated that almost anything could be accomplished
- Pride
- Wonder
- Unity
- Instilled/Reinforced a belief in the Power of Science & Technology
Science needs champions

By 2050, the world population is expected to surpass **9 billion people**.

Science will be more important than ever to address the challenges we face as our world continues to grow.
## State of Science Index

<table>
<thead>
<tr>
<th>Image of science</th>
<th>Around the world, people are <strong>fascinated with science</strong>, but a clear and powerful <strong>skepticism exists</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of science</td>
<td>People <strong>appreciate science</strong> from a distance, <strong>but it is taken for granted</strong> in everyday life.</td>
</tr>
<tr>
<td>Expectations of science</td>
<td>People have <strong>high hopes for what science can achieve</strong>, but there are <strong>barriers to overcome</strong>.</td>
</tr>
</tbody>
</table>
Where we surveyed

Developed
Canada, France, Germany, Japan, Singapore, UK, US

Emerging
Brazil, China, India, Mexico, Poland, Saudi Arabia, South Africa

*Based on the MSCI Market Classification 2017: https://www.msci.com/market-classification

- ~1000 participants per country
- At the 95% confidence level
  - 14-country total: +/- 0.83 percentage points
  - Each individual country: +/- 3.10 percentage points
The image of science is complicated

Nearly 40% of people say that if science didn’t exist, their everyday lives wouldn’t be that different…

And about one-third are science skeptics…
A strong-minded group — skeptics who distrust science

32% are science skeptics

- Indifferent towards the future of science (26% vs. 18% of non-skeptics)
- Think science is boring (49% vs. 12% of non-skeptics)
- Believe if science didn’t exist, everyday life wouldn’t be that different (60% vs. 27% of non-skeptics)

Q12: How much do you agree or disagree with the following statements? Base=Total (14,036)
Science is taken for granted in one’s everyday life

Women are significantly less likely than men to think about the impact of science in their lives
(71% of women think about science a little or never versus 63% of males)

64%
Think science will have a small impact to no impact on their industry*

82%
Agree that if science didn’t exist, their everyday life wouldn’t be that different

How much do you think about the impact of science in your everyday life?

- A little or never
- A lot

Q14: How much do you think about the impact of science in your everyday life? Select one. Q15. How much do you agree or disagree with each of the following statements? - If science didn’t exist, society wouldn’t be all that different. Base=Total (14,036) Q29. Thinking about the industry or field you work in specifically, how much of an impact, if any, do you believe science will have in the future of your industry/field? *Among those who are employed n=7,730
Millennials are the most divided in their views related to science

51% are science supporters

36% are skeptics

Q11. Thinking about the present day, how important do you feel science is to you in your everyday life? Base=Total (14,036)
Among the greatest derivatives of military collaboration with academia and industry are accumulating learning and techniques applied to augmenting human performance and cognition.

Enhanced situational awareness optimizes decision making and fosters agile response to the continuum of challenges in contexts from health care to corporate strategy.

The potential of this synthesis is far reaching in application across all pursuits. Harnessing the practices of system design, preparation, and critical performance will accelerate the evolution of enterprises and enable future unifying focus for generational achievements.
How to Earn CE – If you would like to earn continuing education credit for this activity, please visit: http://amsus.cds.pesgce.com

Hurry, CE Certificates will only be available for 30 days after this event!
Thank You!