A Pilot Project for Quantifying the Effect of Medical Provider Knowledge, Skills, and Abilities on Outcomes for Spaceflight Using a Probabilistic Risk Assessment Tool

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Funding: This work was supported by NASA's Human Research Program Exploration Medical Capability Element and the Maturation and Integration Office.

Word Count: ***

Key Words: capabilities, crew medical officer, expertise, human performance, mission planning, probabilistic risk assessment, risk reduction, space exploration, spaceflight, training

Abstract

In order to enable the future of long-duration deep space exploration we must confront the uncertainty in medical risk. Limitations of communication, resupply, and evacuation in deep space will require a high degree of crew autonomy and accurate risk assessment will be critical to ensure adequate crew training and medical system design. To address this, NASA's Human Research Program Exploration Medical Capability Element has developed the Informing Mission Planning via Analysis of Complex Tradespaces Tool (IMPACT). IMPACT is a suite of tools that can provide evidence-based, data-driven trade space assessments between available medical resources in the mass- and volume-constrained environment of a deep space exploration vehicle.

In the current model, medical conditions either can or cannot be treated based on the availability of medical system resources and equipment. However, medical outcomes often depend just as much on the knowledge, skills, and abilities (KSA) of the provider operating the system. This paper presents a method for modeling and quantifying the effect of medical officer KSA on medically relevant mission risk outcomes during spaceflight.

Introduction

Deep space exploration missions will require an unprecedented degree of crew autonomy. This is particularly true for medical operations where limited or absent communication, resupply, and evacuation ability interact with unpredictability, the need for a timely response, and use of consumable materials.[1] Because of these limitations, published risk assessments for long duration exploration missions suggest as much as 1/3 of overall mission risk may be caused by medical events.[2] It is clear we must confront the uncertainty in medical risk if we are to venture further from Earth.

To address this NASA's Human Research Program (HRP) has used probabilistic risk assessment (PRA) tools to assess medical risk and inform medical system engineering since the early 2000's.[3] These tools use compiled incidence and outcomes data for anticipated medical conditions that might be encountered during a mission. A computational model runs hundreds of thousands of simulations where incidence data governs how often a given condition occurs and treated/untreated outcome risks are compared based on the availability of resources used to treat any conditions that occur. Resource availability is constrained by mass and volume parameters that mirror the proposed vehicle design. An optimizer algorithm identifies the medical system configuration with greatest medical risk reduction that fits within the assigned mass and volume constraints. Mission planners can set model parameters (e.g. number of crew, mission duration, and mission activities) as well as select the outcome to prioritize for risk reduction (e.g. loss of crew life, need for evacuation, or crew task time lost). The model outputs inform vehicle and mission design as well as research priorities. [3], [4]

To date, every medical PRA tool developed by the HRP has defined the treatment status of a simulated medical condition (i.e., as "treated" or "untreated") by the presence or absence of diagnostic and treatment resources.[3], [5], [6] If the resources are present, the condition is considered treated and the treated state outcomes are reported. If some or all resources are absent, the condition will be reported as partially treated or untreated and appropriate outcomes data is reported. These models have historically been agnostic to crew training and have assumed that the crew have all knowledge, skills, and abilities (KSA) necessary to operate the onboard medical system. This is a reasonable assumption for short-duration missions with rapid evacuation capability and for those close enough to Earth that onboard KSA can be augmented with real-time guidance by experts on the ground. However, as exploration missions travel further from Earth, real-time guidance becomes impossible, and the crew must depend on the increasingly autonomous KSA level of the crew onboard.[1] Thus, medical PRA models for exploration class missions will need to account for crew KSA to accurately predict medical risk and inform optimal system design.[7]

Terrestrial medical provider KSA is typically indicated by professional degrees or training certificates and tracked by competency assessments designed by professional organizations, or through government issued licenses.[8]–[10] This rigorous training, assessment, and oversight process provides clearly articulated required competencies and scope of practice (SoP) for a variety of training levels. Many of these are hierarchical with each subsequent certification expected to possess the KSA of the preceding certificate, e.g. certified first responder (CFR), emergency medical technician (EMT) – basic, EMT – paramedic. More advanced training such as nursing, physician assistant, and medical doctor degrees are also roughly hierarchical with regards to the minimum required competencies for each level.[9] This hierarchical KSA structure is one framework for developing a PRA model that can account for provider KSA.

NASA HRP's current PRA model, the Medical Extensible Dynamic Probabilistic Risk Assessment Tool was developed by NASA's Maturation and Integration Office (MIO) and is the computation model in the IMPACT tool suite.[5], [11], [12] Given the complexity required to perform this analysis it was used directly in conjunction with a modified version of the IMPACT Evidence Library (EL), an evidence-based database which contains 120 medical conditions.[4], [13] Each condition is associated with a list of discrete capabilities required to diagnose and manage each condition. For example, for a suspected urinary tract infection, some capabilities include collecting a history, performing physical exams such as assessing costovertebral angle tenderness, collecting and interpreting urinalysis, and prescribing antipyretics and proper antibiotics. Finally, each capability is associated with all resources necessary to perform it (e.g., urine collection cup, urine test strips, etc.). By mapping provider competencies to IMPACT capabilities, one can assign a numerical code based on well-established terrestrial training criteria that represent the KSA necessary to successfully perform the needed capability. Each crew member can then be assigned a medical KSA level as part of their demographic allowing MEDPRAT to simulate treatment by both the availability of resources as well as the medical KSA level of the crew members on-board. This paper describes the methods and results of a pilot project by the HRP to add KSA-based treatment criteria to a medical PRA model for space mission planning.

Methods

An early version of the IMPACT evidence library served as the data substrate to estimate the effect of crew KSA on mission risk outcomes. The design reference mission was 26 months long with 3 male and 3 female crew members including a 12 month stay on the destination surface and one 4-person EVA each week. Mission risk estimates are the result of 200,000 simulations.

A team of three or more physicians was tasked with assigning a SoP to each capability within the IMPACT evidence library. All three team members had expertise in the clinical capability under discussion and at least one team member was an expert in space medicine. The team used the following five terrestrial curricula as the model for determining capability SoP:

1. National Registry Emergency Medical Technician – Basic (**EMT**)
2. National Registry Paramedic (**Paramedic**)
3. Certified Emergency Registered Nurse (**CERN**)
4. Post-Intern (**PGY1**, i.e., completed intern year milestones), Physician Assistant (**PA**), or Nurse Practitioner (**NP**)
5. Fully Trained Physician (**Attending**, specialty-agnostic)

Since capabilities did not always perfectly match competencies in curriculum requirements, each SoP was discussed among a minimum of three physicians to reach consensus. Teams included physicians with expertise and experience with the capability under discussion and at least one with expertise in space medicine. Since the complexity of many capabilities varies by the condition, SoP assignments were specific to each condition (e.g., interpreting labs for a UTI vs. interpreting labs for sepsis).

Importantly, this structure assumed skill levels are cumulative with each higher level being capable of performing all capabilities in the preceding levels. For example, for the purposes of this model and in understanding the limitations of overgeneralization, a CERN (KSA Level 3) possesses all the KSA of a Paramedic (KSA Level 2) who possesses all the KSA of an EMT (KSA Level 1). While this is not necessarily realistic, the limitation was accepted for this proof-of-concept model and will be discussed in more detail later in the paper.

The physician team assigned SoPs to capabilities based on what individuals of each KSA level would be *trained* and/or *reasonably expected* to do based on their respective terrestrial training curricula. For example, both a CERN (KSA Level 3) and an attending physician (KSA Level 5) are trained to collect and interpret a urinalysis for a urinary tract infection (UTI), so those capabilities for the UTI condition would be assigned to KSA Level 3. However, the training necessary to determine which antibiotics to use is only required of physicians and exists in the curricula associated with KSA Level 4 and above. Thus, a capability to "prescribe antibiotics for a UTI" would be assigned to KSA Level 4.

While it is possible to individually assign capabilities based on what an individual at a particular training level *could* do, individual variability in skill and experience makes it difficult to generate a standardized approach without extensive research.[14], [15] Similarly, this project used level 5 as a specialty-agnostic placeholder for fully trained physicians. Given the wide variability among physician specialty training, this is not reflective of reality. However, given the colossal effort adding such nuance to the KSA levels would take to achieve a marginal improvement in fidelity, no attempt was made to account for specialty training.

Capabilities were divided into 2 groups, those that were primarily cognitive in nature (e.g., interpreting test results) and those that were primarily procedure-based (e.g., placing an intravenous line). However, crew KSA was assigned a single value to align with the terrestrial training described above. A capability was available for treatment if the crew KSA level equaled or exceeded both the maximum required cognitive (C-SoP) and procedural (P-SoP) SoP scores. If one, or both, of the on-board SoP scores were less than the capabilities' required SoPs, the capability was considered unavailable for treatment. A table of relative risk reduction by C-SoP and P-SoP from the fully untreated state (KSA 0) was generated for each outcome using the following equation:

$$1-\frac{\text{SoP score outcome combination}}{\text{0 SoP score outcome}}$$

Two different treatment paradigms were used. The first used an absolute treatment paradigm where if any capability was unavailable for treatment due to insufficient crew KSA, the entire condition went 'untreated' and had fully untreated outcomes. This is the first number in the table. The second simulation used a partial treatment paradigm where the treatment benefit is proportional to the percentage of condition-specific capabilities the crew could perform up to their maximum KSA.

Consider, as an example, that a simulated crew has an assigned KSA level of 3 and 'Condition A' occurs once during the mission. This condition has an untreated mortality rate of 100%, a treated mortality rate of 0%, and requires 10 capabilities to treat. Eight of these capabilities require KSA level 3 while 2 require KSA level 5. Under the absolute paradigm, this crew could not treat the condition, and the affected crew member would die 100% of the time. Alternatively, under a partial treatment paradigm, the crew would get "partial credit" for the 8 capabilities they could perform and the conditioned would be 80% diagnosed and managed; mathematically, the model would predict that the affected crew member would only die 20% of the time even if the most important two capabilities for diagnosing or managing the capability required an attending physician. Neither of these paradigms reflects the real world which is most likely to fall somewhere in between. For the purposes of this proof-of-concept study, both numbers were provided to estimate a minimum and maximum benefit.

While MEDPRAT does not provide the direct functionality to represent and modulate treatment by KSA within the model, an approximation to an exact implementation can be achieved by appropriately modifying the Evidence Library data.[6], [11], [12] To do this, 36 unique simulations must be configured, each one representing the combination of the highest available C-SoP and P-SoP scores, (0-5). While typically the model simulates the individual medical resources and their availability, to perform this analysis requires that treatment data be representable and modifiable at the capability level. As such, the individual resources and their relationships are removed from the treatment data, and instead the capabilities themselves treated as mission resources on the top of the resourcing hierarchy.[7]

By doing this, MEDPRAT can simulate the effect of each combination of KSA level by setting capabilities which exceed the KSA scenario of interest as unavailable in the model medical set at the onset of the simulation. For example, in the case where the highest KSA of any crew member is C-SoP Level 3 and P-SoP Level 2, any capability requiring KSA exceeding 3 and 2 is set to have an initial quantity of 0 in the resource input, thereby making it unavailable to provide treatment and hence approximating the effect of not having adequate provider skills to render the capability.

One additional challenge is that a capability does not necessarily have a universal C-SoP or P-SoP score but is context dependent. For example, one can imagine that the knowledge, skill, and ability required of a physical exam or ultrasound may differ depending upon the type and severity of the condition. As such, it is insufficient to merely represent each capability as a mission resource which is either available or unavailable depending on KSA level, as this configuration cannot represent the scenario where a capability has more than one KSA dependent on the condition. It is therefore necessary to utilize a mechanism by which condition-dependent capability KSA's can be distinguished and differentiated. To do this, all resource capabilities were replaced by a capability pre-pended with the condition name, which was then mapped to the treatment file for consistency. With this structure, initial quantity/availability can be set per condition per capability, expanding the total resource capabilities from ~600 to ~3200.

The magnitude of data manipulation required to produce this model setup for 36 individual simulations is extensive and challenging to perform by hand. A number of scripts written in the programming language Python were developed to appropriately format, configure, organize, and post-process the Evidence Library data and other MEDPRAT required input/output files. A simple bash script automates the deployment of each simulation, of which each was run for 200,000 parallelized trials on a computer cluster with 156 cores with a total run time of 3 hours.

The following assumptions and limitations were used to simplify this analysis:

1. Only median values were used for each condition data point (incidence, mortality rate, etc…). No ranges nor measures of variability were included
2. The mission lasts 26 months with a 7-month transit to the destination, 12 months on the surface, and 7-month transit back to Earth,
3. The mission has 3 male and 3 female crewmembers,
4. All conditions can occur to any crewmember at any point during the mission, except;
    a. Extravehicular Activity (EVA): the model assumes 1, 4-person EVA per week over a 12 month period for a total of 624 person EVAs. EVA conditions can only occur while on EVA,
    b. Space Adaptation Syndrome conditions can only occur during the 5 days after launch from either Earth or the destination,
    c. Gravity Well Adaptation Syndrome conditions only occur within 5 days of landing at the destination,
    d. Surface Operation Conditions only occur during the 12-month stay on the destination surface,
    e. Male/Female specific conditions can only affect 3 of the 6 crewmembers,
5. Mean probability of occurrence for each condition is constant throughout the mission,
6. Capabilities required to treat a condition can only be performed by a provider whose KSA equals or exceeds the required SoP level,
7. All crew in this simulation have the same KSA
8. Treatment resources are unlimited, and there are no mass or volume restrictions on the medical system,
9. Task impairments sum linearly and are evenly distributed across the crew.

Results

Results displayed are notional and do not represent verified data for operational use. These data were generated to test the conceptual function of the KSA model and rely on data from an early version of the IMPACT Evidence Library. Table 1 shows the distribution of SoP scores across all capabilities within the notional database used for this project.

Table 2 illustrates how this model affects risk for each KSA based on notional data for a 26-month mission with 3 male and 3 female crew involving a 12 month stay on the destination surface and 1 EVA per week per crewmember during that time. Reported numbers represent percent relative risk reduction from the fully untreated state. The top row represents procedural SoP with the first column showing the effect of cognitive SoP. The first number in each box is the absolute treatment simulation result with the second number in each box representing the partial treatment simulation result.

Discussion

For low-Earth orbit missions with real time communications with Earth, it is possible to provide medical support from the ground.[1], [16] However, for Lunar missions and beyond, physician-level expertise may be needed on-board to achieve the same level of risk reduction due to challenges with communication latency, limitations on resupply, and prolonged or impossible evacuation. [1], [17]

Provider Knowledge, Skills, and Abilities and Scope of Practice

The addition of the SoP parameter for each capability and a KSA level for each crew member allows a PRA model to estimate how risk changes with different levels of provider skill by defining "treatment" as both having the required resources *and* the KSA necessary to use them. The results from this notional dataset appear to validate the function of this model addition and demonstrate its potential to increase the accuracy of medical risk calculations.

These results are illustrated in Figure 1. Compared to the "0/0" condition (e.g. a fully resourced medical system without the on board KSA to operate it) the "5/5" condition (e.g. resources plus required KSA) reduces task time lost by 73%, evacuation by 76%, and loss of crew life by 98%. Relative risk reduction also increase as KSA increases from 1 to KSA 5.

The risk reduction is more prominent in the relative model (the second number in Figure 1). This is because most conditions require medical decision making, which is predominantly trained in KSA level 4 and 5. Since the absolute model considers only the highest KSA for each condition this leaves most conditions untreated until KSA 4 and 5.

While the absolute model which does not provide partial treatment credit is easier to conceptualize, it is not likely to be realistic. Care providers may be able to improvise a higher level of care than their training, and treatment capabilities may reduce some outcome risks even if high KSA capabilities cannot be performed e.g. splinting but not casting a broken limb. For this reason the relative KSA model may be a closer approximation of actual risk even though it may generate an incomplete list of medical system capabilities.

Cognitive vs. Procedural KSA

This proof-of-concept study appears to show that C-Sop scores have a greater effect on mission risk reduction than P-SoP. This is likely because every included medical condition requires interpretation of clinical data and making management decisions while only a subset require manual procedural skills such as placing IV lines, intraabdominal drains, or invasive airway adjuncts.

This division of C-SoP and P-SoP also raises an interesting point that some conditions may impair one but not the other. For example, an exploration medical officer with a broken wrist will likely still be able to interpret imaging and suggest splinting (C-SoP) but will have significant difficulty placing the splint without help (P-SoP). Future versions of PRA models may wish to account for this in estimations of crew disability outcomes as well as estimations of resilience to medical events that affect KSA.

Limitations

The data used for this analysis is from a preliminary version of the IMPACT evidence library, it is internally consistent but was not verified or validated and should be considered notional. Aside from this, the method itself accepts several limitations.

The first is that it assumes a fixed 1:1 correlation between a crewmember's assigned KSA level (and SoP) and their real-world ability to perform condition-specific capabilities. For example, this approach captures neither the estimated learning potential nor the gradual erosion of unused KSA which have been measured for some KSAs on Earth.[18]–[20]

The model also does not account for the specialized ability of some individuals to perform at a higher level than their stated training due to prior experience, training, or their own innate abilities. As there are over 6 thousand different capabilities built into this large model, this level of nuance would be difficult to account for. This model assumes that all individuals of a given terrestrial KSA level are equally capable of performing all capabilities with an equal or lower SoP code, regardless of their relevant experience and/or cultivation of crossover skills. It may also be possible to run the medical PRA tools in reverse to identify which capabilities, and which KSA levels, are likely to effect the greatest risk reduction for a given mission.

While this may be true based on the curricula and expected training, terrestrial KSA training are often complementary rather than hierarchical. For example, a CERN (KSA Level 3) is likely to be far more practiced with placing intravenous lines than an attending physician (KSA Level 5).[14], [21] This may be addressed by adding a "probability of success" metric which can be adjusted to better reflect real world performance characteristics.

An alternative solution might be to treat the PRA tool as a curriculum and training guide to determine which capabilities are likely to have the greatest effect on mission outcomes and develop a custom training program to supplement the existing crew KSA. This could save time on pre-mission training.

Another significant limitation of this model is that KSA Level 5 is agnostic to attending specialty; thus, all fully trained physicians share the same KSA regardless of specialization and can perform every medical capability in the database. This is not an accurate representation of the team-based approach of terrestrial healthcare, and it omits the wide variation in physician training after medical school. Future efforts may wish to address this limitation by adding additional SoP levels that are reflective of physician specialty training as outlined by specialty board core competencies and/or American College of Graduate Medical Education milestones. However, the vast majority of capabilities included in IMPACT fall into the KSA of a procedure-trained generalist physician such as a Family Medicine or Emergency Medicine attending.[22], [23] While some capabilities, such as placing an intrabdominal drain, are clearly beyond the scope of practice for these physicians, these conditions occur rarely within the model and do not appear to significantly affect outcomes within this dataset. This model also assumes there is sufficient volume to successfully perform the required capabilities. While this is not assured, available literature supports this assumption.[15]

The model also uses a binary approach that assumes each crewmember will perform all capabilities within their SoP with 100% effectiveness and is able to treat any relevant condition without decrement or error. This was necessary due to the paucity of evidence-based estimations of capability success rates for various KSA levels and partial treatment models to account for outcomes in the absence of all necessary capabilities. This binary approach is also consistent with how terrestrial scope of practice designations are used terrestrially for credentialling purposes. Professionals either are or are not permitted to perform particular interventions based on the expectations set forth by their accrediting body.[9], [10]

Finally, this model assumes all crew members have the same KSA. In a more realistic scenario only one or two crew members will have high level KSA while the rest of the crew may have significantly less KSA. This can be mitigated by assigning KSA levels specific to each crewmember. Existing medical PRA tools model conditions affecting individual crew members. By adding a KSA parameter to each crew member these tools could use the highest KSA for crew members not affected by medical conditions in the simulation. In this way medical PRA tools could model the risks associated with various crew KSA configurations. If medical PRA tools were expanded to include other skills-based mission risks, such as equipment failure and repair, additional nonmedical KSA parameters could be used to better model risks of mission loss using various crew configurations.

Conclusion

The medical challenges of deep space missions are significant and accurate risk prediction is essential to ensuring mission success. Since medical systems depend on both the human provider as well as the available resources no risk prediction tool is complete without accounting for the providers' knowledge, skills, and abilities. This analysis demonstrates one way to do this as well as the dramatic effect it has on risk reduction when combined with medical system resources.

Additionally it shows that cognitive skillsets may have a greater effect on outcomes than procedural skills which can help inform future crew training and clinical decision support resources.

Limitations notwithstanding, the KSA model outlined in this study has the potential to significantly enhance mission risk assessment and inform medical system design, crew training, and research planning. Similar model structures may be used to estimate risks in activities beyond spaceflight as well as crew skillsets beyond medicine. It lays a foundation upon which future systems can assess comprehensive risks in any mission that relies on human system integration.

Declarations of Interest

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Thank you to NASA's Human Research Program, the Exploration Medical Capability (ExMC) element for the support and resources to complete this project. The authors would like to thank Dr. Ben Easter, Dr. Kris Lehnhardt, and Dr. Jay Lemery for their contributions and support of this work.

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Tables and Figures

Scope of Practice with Discrete Capability List			
KSA Level	Associated Training Level	Number	Percent
1	National Registry Emergency Medical Technician – Basic	142	24%
2	National Registry Paramedic	204	36%
3	Certified Emergency Registered Nurse	253	45%
4	Post-Intern	430	76%
5	Attending Physician (Not Specialty-Specific)	566	100%

Table 1: Distribution of SoP scores across all capabilities used for this proof-of-concept study

		a. Patient Task Time Lost Relative Risk Reduction by KSA Level					
	Procedural SoP						
		0	1	2	3	4	5
Cognitive SoP	0	(0.0, 0.0)	(0.0, 0.05)	(0.01, 0.05)	(0.0, 0.06)	(0.0, 0.21)	(0.0, 0.21)
	1	(0.02, 17.42)	(0.01, 17.59)	(0.01, 17.61)	(0.01, 17.6)	(0.01, 18.83)	(0.01, 18.86)
	2	(0.04, 17.83)	(0.04, 18.0)	(0.04, 18.02)	(0.04, 18.03)	(0.04, 19.27)	(0.04, 19.34)
	3	(0.08, 21.41)	(0.12, 21.61)	(0.11, 21.63)	(0.18, 21.65)	(0.18, 23.17)	(0.18, 23.24)
	4	(10.46, 60.05)	(10.62, 60.66)	(10.62, 60.72)	(10.77, 60.76)	(34.17, 66.14)	(34.16, 66.53)
	5	(15.92, 66.0)	(18.27, 66.68)	(18.28, 66.76)	(18.51, 66.79)	(67.92, 72.84)	(73.32, 73.31)

		b. Removal To Definitive Care Probability Relative Risk Reduction by KSA Level[*]					
	Procedural SoP						
		0	1	2	3	4	5
Cognitive SoP	0	(0.0, 0.0)	(-0.11, 4.07)	(0.06, 4.05)	(0.02, 4.07)	(0.15, 4.1)	(0.13, 7.95)
	1	(0.13, 27.48)	(0.06, 32.49)	(0.03, 32.45)	(0.06, 32.46)	(-0.04, 32.71)	(0.12, 37.27)
	2	(0.07, 27.57)	(0.04, 32.63)	(-0.01, 32.63)	(0.09, 32.61)	(-0.01, 32.77)	(0.04, 37.5)
	3	(-0.07, 39.24)	(0.06, 44.53)	(0.03, 44.38)	(0.05, 44.4)	(-0.1, 44.62)	(-0.13, 49.51)
	4	(-27.29, 49.0)	(-25.36, 54.27)	(-25.37, 54.33)	(-25.31, 54.45)	(-23.45, 54.5)	(-23.45, 59.55)
	5	(-18.74, 65.03)	(-15.65, 70.41)	(-15.61, 70.41)	(-15.75, 70.49)	(-13.38, 70.6)	(75.66, 75.6)

		c. Loss of Crew Life Probability Relative Risk Reduction by KSA Level[**]					
	Procedural SoP						
		0	1	2	3	4	5
Cognitive SoP	0	(0.0, 0.0)	(0.05, -0.11)	(-0.1, 0.06)	(-0.08, 0.16)	(-0.05, 0.13)	(-0.08, 0.38)
	1	(-0.14, 67.72)	(-0.19, 67.72)	(0.01, 67.74)	(-0.2, 67.71)	(-0.08, 67.88)	(-0.07, 67.85)
	2	(-0.04, 67.91)	(-0.19, 67.86)	(0.01, 67.9)	(-0.19, 67.91)	(-0.11, 67.99)	(0.02, 68.14)
	3	(0.15, 84.37)	(0.2, 84.2)	(0.11, 84.23)	(0.09, 84.41)	(0.14, 84.42)	(-0.23, 84.52)
	4	(93.85, 97.48)	(93.82, 97.44)	(93.82, 97.42)	(93.83, 97.46)	(93.92, 97.48)	(93.91, 97.73)
	5	(94.49, 97.93)	(94.1, 97.84)	(94.05, 97.84)	(94.1, 97.86)	(94.89, 97.95)	(98.19, 98.14)

[*] *Negative values reflect higher KSA allowing reduction in mortality, increasing potential evacuation events.*

[**] *Negative values are an artifact of how lower bounds are calculated.*

Table 2: Relative Risk Reduction presented as (absolute paradigm relative risk reduction, partial treatment paradigm relative risk reduction)

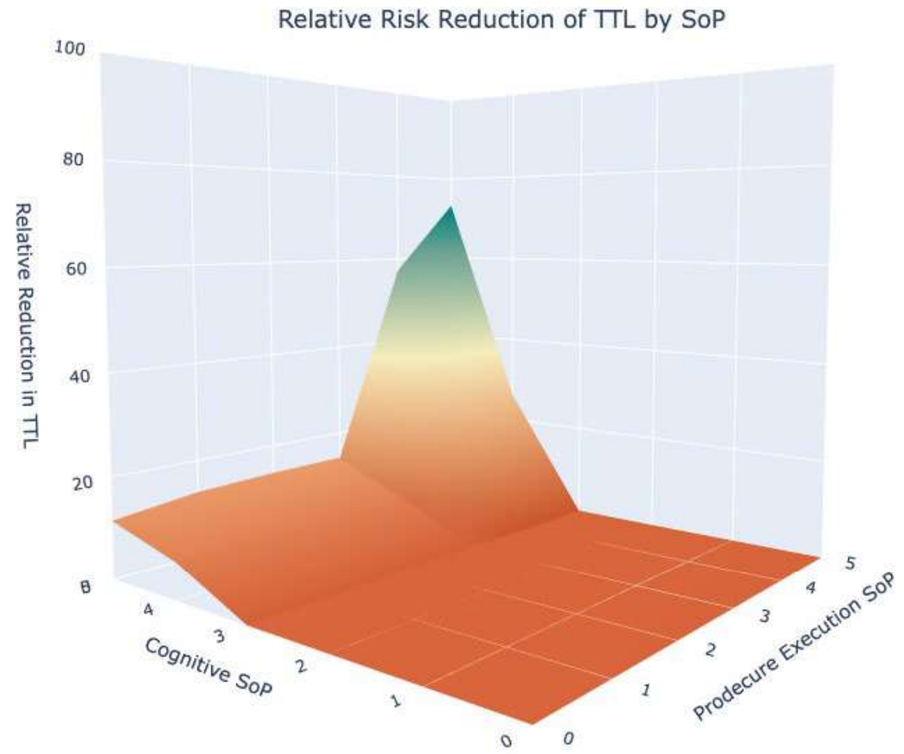

Figure 1: Graph of relative risk reduction for Task Time Lost (TTL – a model outcome measure in days which represents the total time the crew is unable to perform tasks due to being afflicted by a medical condition) by C-SoP and P- SoP using the absolute treatment paradigm. The risk reduction is calculated using MEDPRAT results from a fully untreated baseline and the results of the 36 KSA specific runs. Each point on the graph represents an individual simulation with a combination of C-SoP and P-SoP scores. As an example, for interpretation, the simulated scenario where the crew had C-SoP Level 5 and P-SoP level 1 produced an ~13% reduction in TTL vs the untreated scenario. It is noteworthy that increasing P-SoP level alone provides very little in terms of risk reduction, whereas increasing the C-SoP does buy down some amount of risk, though the combination of both provides the best buy down. As this is the result for the absolute treatment paradigm, it is expected that these results are extreme, and possible represent the lower bound, or worst case estimate.

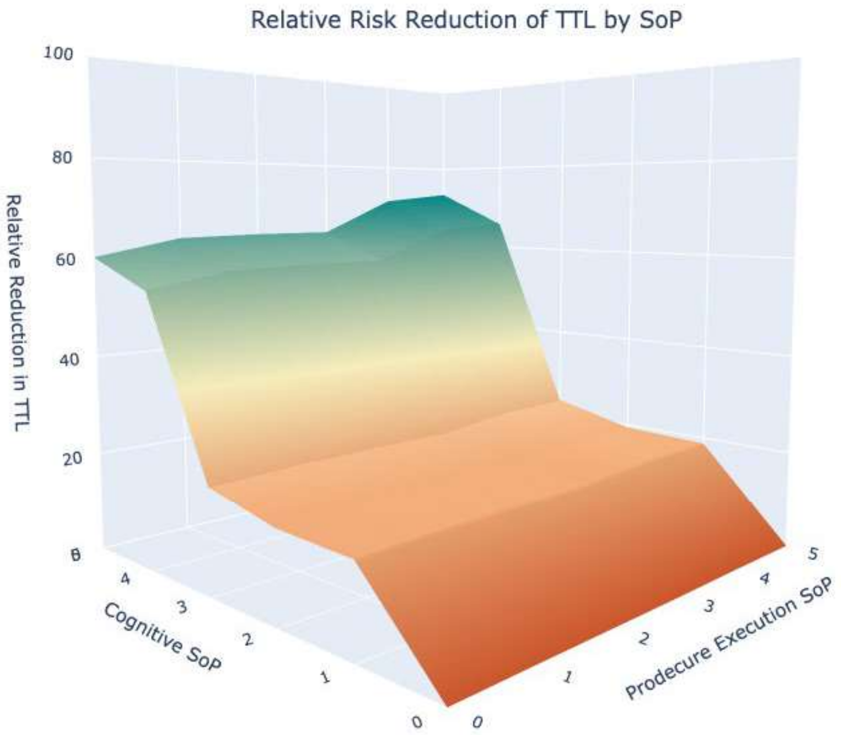

Figure 2: Graph of relative risk reduction for Task Time Lost (TTL – a model outcome measure in days which represents the total time the crew is unable to perform tasks due to being afflicted by a medical condition) by C-SoP and P- SoP using the partial treatment paradigm. The risk reduction is calculated using MEDPRAT results from a fully untreated baseline and the results of the 36 KSA specific runs. Each point on the graph represents an individual simulation with a combination of C-SoP and P-SoP scores. As an example, for interpretation, the simulated scenario where the crew had C-SoP Level 5 and P-SoP level 1 produced an ~62% reduction in TTL vs the untreated scenario. As these scenarios use the partial treatment paradigm, the result is smoother and less severe, as expected. Partial treatment reflects an upper bound/best case representation of the risk. Observe that though the risk values themselves are significantly different, the same plateauing effect is present as in the absolute treatment results, indicating that regardless of treatment paradigm, C-SoP provides the most opportunity for risk reduction, and that P-SoP alone has very little ability to mitigate risk.