SITUATIONAL AWARENESS AND WORKLOAD IN THE EMERGENCY DEPARTMENT

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Abstract

The objective of this study is to determine the relationship between situational awareness (SA) and workload in an emergency department (ED). SA was measured using the Situational Awareness and Global Assessment Technique (SAGAT) with questions answered at a 25.2% false response rate. Question probes were administered concurrently with collected workload measures. Workload measures included counts of patients managed and pre-defined work events occurring within a 1-hour preceding time interval. Significant factors influencing SA included: patient handed-offs (OR: 1.56), resident in final year of training (OR: 0.53), number of patients managed (OR: 1.18), and number of work events (OR: 0.97), when adjusting for correlation within patients and questions.

Overall, this study demonstrates a novel approach toward diagnosing factors contributing to emergency physician SA. SA studies in health care may provide evidence for targeted intervention strategies to improve patient safety.

Background

Emergency Department Crowding and Patient Safety

Emergency departments (ED) are notable for being inconsistent work environments frequently stressed by crowding. National trends demonstrating increases in volume and complexity of patients has placed hospital-based emergency care "at the Breaking Point". This phrase used in the literal title of the Institute of Medicine's 2006 report on the future of emergency care.[1] Recently proposed health care reform threatens to burden overwhelmed emergency departments even further.[2]

Despite wide-ranging research, a clear relationship between ED crowding and patient safety has not been substantiated. The adverse effects of crowding have been under intense scrutiny, but with little effect.[3,4] However, methods to delineate this relationship are complex and not fully developed. An intermediary step in understanding this relationship may be to determine how individual providers' situational awareness (SA) is effected by workload.

Situational Awareness

Situation Awareness is defined by Endsley as "the perception of 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.[5]" Thus, SA is comprised of three dependent levels: (1) perception of current situation, (2) comprehension of current situation, and (3) projection of future state.[6] Questions used in this study evaluated the foundation level 1 of SA (i.e., perception) exclusively. SA has been examined extensively in aviation, nuclear power and warfare environments but applications may be extended to any operational setting.[7,8] SA applications in health care have been limited. However, non-medical environments have shown a relationship between measures of SA and operator performance .[9]

Workload

Workload is a multidimensional concept that is difficult to define and measure.[10] A widely accepted definition by O'Donnell and Eggemeir is that mental workload "refers to that portion of operators' limited capacity required to perform a particular task.[11]" This follows the assumption that humans have a fixed processing capacity and work tasks demand processing resources. More difficult tasks consume more resources and if at any time task demands exceed capacity, performance degrades. Given this theory, many factors affect health care providers' actual and perceived workload. Workload measures may capture workload objectively by monitoring tasks performed and behavior. Perceived workload may be measured subjectively through self assessment or physiologically by monitoring, for example, heart rate, galvanic skin response, or brain activity[12,13].

This study measured workload objectively, by identifying work demands and distinct work events that require physician time, decision making, and action (i.e., processing resources). Several ED crowding studies used similar measures of workload.[14]

Objective

The primary objective of this study was to evaluate the relationship between emergency medicine resident physician SA and workload in an ED. A secondary objective was to develop a methodology for measuring SA in a health care setting and determining environmental factors associated with it.

Methods

Study Design

The pilot study was performed at an urban, academic ED over a three-week period. The ED is a level 1 trauma center and sees approximately 55,000 patients annually.

Study participants consisted of eight residents in either their first, second, or third year of training. Each resident was observed over a 5 to 6 hour observational period. Two residents were observed twice. Thus, 10 sessions were conducted totaling approximately 50 hours of observation. The Johns Hopkins University School of Medicine, Institutional Review Board approved this study and all participants provided written consent prior to each observational period.

Situational Awareness Measurement

SA was measured using the Situational Awareness Global Assessment Technique (SAGAT).[10] A pool of 106 questions was developed by an expert emergency physician panel. Questions were designed to assess residents' awareness of information (i.e., SA Level 1) concerning; diagnostic tests (47), medical interventions (11), patient history (19), and patient and emergency department management (29). Examples of questions within each category include:

Diagnostic:

- *Which of your patients has had a sodium less than 126 during their visit?*
- *Which of your patients has had a systolic blood pressure of 90 or less during their ED visit?*

Medical Intervention:

- *Which of your patients has peripheral IV access?*
- *Which of your patients has received or is currently being treated with IV antihypertensive medication during their ED stay?*

Medical History:

- *Which of your patients has a history of cancer listed?*
- *Which of your patients has a primary chief complaint of shortness of breath listed at triage?*

Management:

- *Which of your patients is currently waiting for hospital admission?*
- *Which of your patients was in the waiting room for over 3 hours?*

In addition, each question was subjectively assigned a safety factor between 1 (lowest) and 5 (highest) by the expert panel. Safety factors were designed to assess the importance of the information asked as it relates to patient safety. For example, a question asking whether a patient's troponin level was above 0.06 ng/ml, indicating acute myocardial ischemia was ranked a five. Comparatively, a question asking about the status of a social work consult received the lowest rank of one.

A set of 10 randomized questions stratified by category was administered hourly by a trained assistant. Over a typical 5 hour observation session, 50 random questions were asked. Questions were applied to all patients the physician was managing at that instant in time. Therefore, a physician managing 6 patients would have 60 opportunities (10 questions x 6 patients) to respond correctly or incorrectly. All responses were recorded on standardized data collection forms. Currently assigned patients and question responses were verified immediately following each question set using patients' electronic medical records. Binary classification statistics were used to evaluate SA performance.

Workload Measurement

Workload was measured each time a SA question set was administered. Workload measures included: (1) the number of patients the resident physician was managing, (2) the number of work events occurring during the previous 1-hour, and (3) the corresponding weighted workload score. The events shown in Table 1 are unequal in their overall contribution to workload. Thus the expert panel weighted each event on a scale from 1 (minimal work effort) to 10 (maximum work effort).

Table 1. Work Events and Weights

Work Event	Workload Weight
Admit to hospital	4.75
Bed change within ED	1.75
Consult	4.5
Discharge	3.5
Lab Order	1
Medication order	1.5
Medical history intake	6.75
Physical exam	5.25
Procedure	9.75
Radiology order	1.25
Progress note	4.25
Treatment order	2

Physicians input this information into the clinical information system as they care for patients. These events are tagged by providers and tracked with time-stamps in patients' medical records. Data were extracted to obtain physician event counts over time, which was used as a measure of workload. Weighted workload scores were calculated by summing event weights over time.

Modeling Situational Awareness

Mixed-effects logistic regression was used to determine the relationship between SA and environmental factors, including workload. The model outcome variable was encoded as a true or false (i.e., type I or type II errors) response. This method allows for the relationship between workload, patient factors, physician factors and temporal factors to be determined while controlling for correlation within patient, provider, and SA question.

Results

Situational Awareness

A total of 508 questions were asked over all observations. The error (i.e., false response) rate was 25.2%. If a question was answered incorrectly for any patient managed, it was considered false. These questions were applied to 72 unique patients creating 2,262 distinct patient-question data points. Table 2 displays SA performance by patient-question using binary classification.

Table 2. SA performance by patient-questions

Characteristic	N	FN (%)	FP (%)	TN (%)	TP (%)
All	2262	5.2	2.2	79.2	13.4
Handoffs*	825	8.2	2.5	75.9	13.2
Non-Handoffs	1437	3.4	2.0	81.1	13.5
Acuity 1	259	6.2	1.9	80.3	11.2
Acuity 2	1155	4.4	2.3	79.0	14.2
Acuity 3	839	6.0	2.1	78.8	13.1
Training (Yr 1)	585	5.1	2.7	76.8	15.4
Training (Yr 2)	973	6.5	2.9	78.4	12.1
Training (Yr 3)*	704	3.4	0.9	82.2	13.5
Diagnostic	936	3.2	3.4	79.5	13.9
Medical Hist*	498	8.2	0.6	82.5	8.6
Management*	366	7.9	2.2	72.1	17.5
Medical Interv.	462	3.7	1.5	80.5	14.3
Safety (1)	196	5.6	3.1	66.8	24.5
Safety (2)	587	6.5	1.7	73.6	18.2
Safety (3)	507	5.3	2.2	79.5	12.8
Safety (4)	590	4.6	1.5	85.3	8.6
Safety (5)	382	3.7	3.7	84.3	8.4

* indicates significant differences in false response rates

Higher levels of error rates were observed for patient hand-offs, physician training level, and medical history and management question categories. No differences were observed across patient acuity level (i.e., measure of severity of illness) and question safety factor.

The top five questions that most frequently elicited false responses were:

1. *Which of your patients has a drug allergy?*
2. *Which of your patients has a primary care physician documented at triage?*
3. *Which of your patients has had a heart rate of 100 or greater during their ED visit?*
4. *Which of your patients was in the waiting room for over two hours?*
5. *Which of your patients has a previous history of abdominal surgery?*

However, the relatively small sample size created variability in frequency of random questions generated which may skew these findings.

Workload

The distribution of 563 work events documented may be seen in Table 3. Their corresponding contribution to weighted workload is also displayed.

Table 3. Distribution of Workload Events

Event	Event (%)	Weighted Workload (%)
Admit to hospital	3.0	6.8
Bed change within ED	1.6	1.3
Consult	1.4	3.0
Discharge	2.1	3.5
Lab Order	43.2	20.5
Medication order	5.9	18.8
Medical history intake	20.4	14.6
Physical exam	5.2	12.8
Procedure	0.4	1.6
Radiology order	3.4	6.8
Progress note	7.6	4.5
Treatment order	5.9	5.6

Physician workload over time varied dramatically. For each hour observed, physicians undertook an average of 11.6 (range: 0 – 35) events and experienced an average weighted workload score of 21.3 (0 – 51.5).

Factors that influence situational awareness

Mixed-effects logistic regression was applied to determine factors that influence SA while adjusting for correlation that may exist within provider, patient, and question. Multiple models were tested using fixed and random variables (Table 4). Odds ratios for fixed variables deemed significant ($p < 0.1$) and variances for random variables that must be adjusted for are input in Table 4. All other variables displayed were not significant.

Table 4. SA Mixed-effects logistic regression model

Fixed Variables	Odds Ratio (95% CI)	p
Hand-off	1.56 (1.08 – 2.27)	< .001
Training level (3 yr)	0.53 (0.33 – 0.88)	.021
Patients managed	1.18 (1.00 – 1.41)	.085
Work events	0.97 (0.95 – 1.00)	.082
Patient acuity	-	-
Question category	-	-
Safety factor	-	-
Time from resident start of shift (hrs)	-	-
Time from patient arrival to bed (hrs)	-	-
Weighted workload score	-	-
Random Variables	**Variance**	
Question	0.74	
Patient	0.03	
Provider	-	

After adjusting for correlation within question and patient, error rates were substantially higher for questions about patients who had been handed-off. Resident physician experience proved to decrease the likelihood of errors, which is expected. Third year residents performed significantly better compared to first and second years. The workload measures of: (1) patients managed, (2) work event counts, and (3) weighted workload were tested individually and in combination. Number of patients managed was the only workload measure that had a significant impact on error rate. Each additional patient resulted in an average of 18% increase in risk for error, indicating an inverse relationship between workload and SA.

Discussion

Limitations

There were several limitations to the design and implementation of this pilot study. The small sample size of residents and observation hours allows only limited conclusions to be drawn regarding the relationship between SA and environmental factors including workload. Despite the small sample, key factors did arise as significant contributors to SA.

The chaotic nature of the ED also creates difficulties in definitively capturing provider workload. There is distinct variability in the way individual provider's document specific patient care items and no set of distinct rules for what must be documented in every scenario. Only some of the items required electronic information system interaction to affect the desired response (e.g., medication orders). Others lie documenting history could be significantly delayed from time of actual occurrence. This presents the potential for bias in the electronic capture of workload on the basis of work event. However, ample workstations in each patient care area mitigate such potential delays. These limitations also do not apply to workload captured simply as the number of patients managed. This may be why this was the only workload measure determined significant in the mixed-effects analysis.

Conclusions

To our knowledge, this study represents the first attempt to measure provider SA in a live health care setting. SA studies have long benefited other industries such as aviation, nuclear power, and defense. Challenges EDs face with crowding and often highly complex patients in teaching environments, creates a particularly apt environment for SA studies.

Growing evidence suggests a relationship between crowding and patient safety, although direct and substantial links have not been uncovered. Despite this, emergency providers continue to have strong inclinations that their patients are adversely affected when their environment consists of unmanageable workload. This SA study delved into how crowding (i.e., workload) may affect provider performance. It examines the micro-environment that providers experience as opposed to the macro-environment (ED system) that's typically studied. In addition, information about other factors that decrease SA may be diagnosed (e.g., hand-offs). Further analysis on question types and patient characteristics may be able to hone in on information flow deficiencies and be used to develop strategic improvements to ED operations.

EDs and health care service in general stands to benefit greatly from human factors work much like other industries have in the past. At present, there is a remarkable gap in human factors applications to health care. The pilot study conducted represents an introduction of SA human factors methods to emergency medicine and demonstration of potential benefits.

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Biographical Sketch

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Dr. Levin is an Assistant Professor in the Department of Emergency and holds a joint appointment in the Department of Applied Mathematics and Statistics. He also works as a member of the Department of Operations Integration to forward operational, quality, and financial improvement initiatives within the Johns Hopkins Health System.

Upon finishing his PhD in biomedical engineering at Vanderbilt University, Dr. Levin joined the Hopkins faculty in 2008. Dr. Levin's research focuses on the use and development of systems engineering tools to study and improve the effectiveness, safety and efficiency of health care delivery. Research is directed toward determining how scarce health care resources may be managed and deployed to best care for patient populations. This includes an emphasis on systems engineering techniques aimed at improving quality of care, access to care, and medical decision making.

Dr. Levin is actively involved in research efforts for the National Science Foundation (NSF), National Institutes of Health (NIH), and Department of Homeland Security National Study Center for Preparedness and Catastrophic Event Response (PACER). Dr. Levin has authored and reviewed numerous publications which apply systems engineering methods to medicine.