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Understanding emergency workers' behavior and perspectives on design and safety in the workplace

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ABSTRACT

Emergency Medical Services (EMS) is a demanding and hazardous industry. Because of the changing roles in the emergency response system, EMS workers are increasingly expected to provide treatment and care in addition to transport, which increases their task load and susceptibility to harm. This paper serves to outline the EMS field from the worker's perspective with the purpose of understanding their views on health, safety, and the work environment, and identify where gaps in worker well-being are exposed. Through direct observation, field studies, and formal interviews with EMS professionals, we discuss where reluctance lies in addressing safety issues and the current efforts to address them. A high prevalence of responses regarding the inadequacy of ambulance restraining systems was reported, as existing interventions do not take into account medic needs.

1. Introduction

Emergency Medical Service (EMS) workers have difficult and hazardous professions. Although historically, ambulance systems were solely for transportation of the wounded, today it is standard practice that medical intervention be performed at an advanced level within emergency transport. Consequently, the workload for medics has increased due to the number of tasks that must be performed while with a patient.

It is estimated that EMS workers are three times more likely to suffer bodily injury and fatalities on the job than any other field (Becker and Spicer, 2007). They also have a much higher percent of Post-Traumatic Stress Disorder (PTSD) than the general population, and are frequently exposed to dangerous illnesses (Stelzer, 2012). However, little research has been done to discover the nature of these hazards. There also lacks a hierarchy of which of these crucial issues needs to be addressed the most, whether it be physical or mental, or whether these risks manifest from the environment or from the nature of the tasks. These identifiers are needed in order to develop interventions that effectively improve EMS worker conditions.

Some work on these issues has been done in isolated pockets: some researchers have consulted medics to identify serious physical hazards that have led to interventions aimed at reducing the magnitude of trunk muscle exertions and musculoskeletal loads (Lavender et al., 2007). Other research teams translated their direct observation of EMS workers and their interactions in the workplace into several recommendations at the ambulance design level (Biesbroek and Teteris, 2012). At a psychological level, research shows a connection between EMS worker perceptions of workplace safety culture and safety outcomes (Weaver et al., 2011), but few studies reveal the awareness and views of the workers on safety and risks.

In this paper, we investigate the views of EMS workers (specifically paramedics) on health and safety at work, particularly in terms of their work environment. We examine workers' ideas and experiences regarding job safety, efficiency, and workplace design, and benchmark their views against current industry solutions to their issues. Ultimately, these conclusions will be applied to the design of interventions focused on improving medic safety and workflow.

2. Background

There are two core functions that take precedence in pre-hospital care. The first is to provide medical care, and the second is to provide transport to definitive care (Son, 2002). Which function is prioritized depends on various factors, such as the geographical location of the community, population density, developmental layout, and what medical issues the patient is

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having.

In the United States, EMS services are typically overseen by a municipality or local government for funding and resource allocation. This type of organizational structure makes up 58% of the current industry. Municipalities might be local or state governments, and service fees and property taxes fund the EMS. Within this setup, EMS can be independent entities, also known as the “public utility model,” or might be a fire/police linked service where services are integrated partially or completely (Son, 2002).

Although the municipally run service is the most popular model, some municipalities, especially in rural areas, have lately been falling out of favor with some communities, partly due to reductions in funding. Increasingly, the EMS industry is seeing a shift from municipalities to contract work by private organizations. Some smaller communities that lack a tax base or population have switched to a volunteer EMS model to counteract the shrinking funds. This model usually relies heavily on donations and is difficult to maintain because of the upkeep in training standards, vehicle equipment standards, and dwindling demand of a shrinking rural population make on-call time commitments straining for workers (Barr, 2011).

Two other models have emerged to answer the difficulties of municipal services in more successful ways: hospital-based services, where hospitals and regional centers provide their own ambulance service, and community-based services (CBS), where private companies provide ambulance services with paid employees, but rely on contracts with local or national governments or hospitals (Son, 2002). A comparison of these models is shown in Table 1.

In the CBS model, contracts range in capabilities, from strictly transport to full emergency care and staff (DoH, 2016). If partnered with a hospital, the company might provide EMTs and paramedics (Son, 2002). Payment methods are typically fee-for-service. In exchange, the companies must maintain a high quality of staffing, skills, resources, and response times to keep competitive with contracts.

Research shows that the competitive nature of US based EMS systems is starting to have an impact on workers in the industry. Priorities of the staff may conflict with the goals of their employers, who may be focused on maintaining reputations with other organizations and keeping expenses low and profits high (Son, 2002). According to interviews and the workers' union NEMSA, EMS workers also want to maintain a high level of performance, but view the methods of achieving that goal differently than their employers. While medics want to have proper equipment and support, receive competitive wages and benefits, and stay safe, their organization may not have the funds to provide them with up-to-date equipment, or the resources to oversee certifications -which then must come out of the medics' pockets. Medics might also feel undue pressure to engage in risky behaviors to keep their company competitive, which might result in personal injuries or fatalities, as was the case in a US Government Accountability Office (USGAO) study of helicopter ambulance crashes in 2009, where fatalities were linked to competitive behaviors in unsafe conditions to cut down on response times (Dillingham, 2009).

The USGAO study also highlights another problem with the varied and chaotic structure of EMS within the US: the undefined categorization of EMS groups for proper tracking of worker conditions (Maguire et al., 2002). When examining cases of injuries and fatalities among medics, all of the different organizational models, plus the hybrid models that exist state to state and sometimes even town-to-town mean that EMS personnel are not “defined by a unique industry occupational code” in the eyes of the Bureau of Labor Statistics, and instead might be lumped into other industries (such as the integrated fire and police services) or are simply not counted, as is the case with some municipal volunteer workers. Therefore, statistics such as EMS injury and fatality rates, the causes of stress in their work environment, or bureaucratic pressures placed by organizations are often difficult to track or simply unavailable (Maguire et al., 2002).

3. Related studies

Much of the relevant data on EMS safety has been narrow scopes of specific EMS populations, and even then each study uses its own definitions and grading systems, which makes them difficult to compare. There have been attempts such as the review by Maguire et al. (2002) which attempted to cross compare databases and reports to assess the rate and causes of EMS fatalities. In this work, the authors concluded that EMS worker fatalities were 12.7 per 100,000 workers per year, which more than doubled the national average, and neared the rates of the classic hazardous jobs such as firefighters (16.5) and police (14.2), and was subsequently labeled a crisis (Maguire et al., 2002).

Although the previous study is still considered one of the best published reviews for EMS safety, it has limitations because of the difficulties of data gathering. For example, Garrison (2002) points out that depending on which database is cited, estimated employment numbers for EMS workers can vary widely: from 150,000 to 830,000, which would undoubtedly affect percentages and could possibly bring the crisis down to a statistically insignificant change from the overall worker population. Also, many states have different certifications and it is possible for EMS personnel to be qualified in more than one state, so some individuals may be listed more than once in separate databases. Other studies show similar results; for example, Becker and Spicer (2007) and Samuelson (2014) found EMS workers three times more likely to die on the job than the national average of other professions. Their fatality numbers were similar to Maguire et al. (2002). The authors found the leading causes of occupational fatalities to be, in order: vehicle crash with ground transport, air ambulance crashes, cardiovascular event, and assault/homicide against EMS workers (Becker and Spicer, 2007).

When examining safety rules governing ambulances, it is shown that mandated tests and inspections are designed by the General Service Administration's standards, and the Ambulance Manufacturers division of the National Truck Equipment Association; a private organization focusing on commercial vehicle safety. These

Table 1
EMS service structure in the US.

	Municipality	Hospital based	Private
% of industry	58%	9%	33%
Advantages to structure	Receives state and federal aid.Less variance in payment costs for patients	Hospitals better able to regulate the reliability of transport to and from their facilities	For-profit organizations better able to absorb costs of business and keep up with technology
Disadvantages regarding workers	Rural areas strained for resources.Integrated model stretches workers thin.	Demand and skillset highly dependent on the type of services being provided by the hospital (e.g. a stroke center)	Highly competitive contracts put strain on companies/workers to perform.

tests include mechanical stress, environmental control, electrical, and driving tests (AMD Standards, 2007). However, there are significant problems with current standards.

According to industry, although the ambulance has to endure static load tests, neither overseeing body requires dynamic testing, also known as impact and crash testing, for the back of the vehicle; only the cab. There were also limited regulations for equipment mountings on the inside of the box, which could pose as impact hazards in the event of a crash (Busch, 2014). According to Johnathan Benger, an emergency care expert at UEW Bristol and a former EMS worker, ambulances have "evolved organically," with new innovations tacked on as they came about. Additions such as O2 tanks and storage are installed in a bolted-on fashion with no previous consideration to ergonomics or staff and patient experience. "The result is that we now have vehicles that weigh over three tonnes, cost a fortune to run and that fail to take full account of modern developments in safety, comfort, new technologies, or carbon footprint (Breathing, 2012)."

Some manufacturing companies perform crash tests on their own accord, but many do not. Crash tests performed by third party organizations reveal the potential for debilitating injuries. For example, in 2014 the Society of Automotive Engineers (SAE) released its findings of a crash test conducted on an ambulance at just 30 mph. The results showed the side medic seat position suffered severe sideways neck flexion; the rear-facing medic seat suffered broken femurs as a result from impact from the stretcher, and concluded that any EMS worker in a standing position suffers neck, spine, and hip injuries (Busch, 2014).

Many EMS workers complain that the safety equipment in place, as well as protocols, do not coincide with their attempts to perform life-saving tasks. Tasks such as administering CPR must be done in positions over the patient, which many safety restraints do not allow. In his testimonial to National Public Radio, former EMS worker Jim Grove states "When I would ride in the back of an ambulance, it was not uncommon to stand up and be doing chest compressions on somebody and having someone be holding on to my bunker pants and going down the road at 35, 40, 50 miles per hour even" (Samuelson, 2014). Other EMS workers only wear their seatbelts in instances of immediate danger, such as harsh weather conditions that cause turbulence, but they also state "Most of us never even buckle up [in the patient compartment]. This is a practical decision. How easy is it to perform CPR or to intubate a patient while strapped in? What if you need something that is stored under the bench seat? You just have to get up to do it – or kneel down – or bend over – or reach …"

Alongside the categorization of fatalities, sprains, strains, and tears to the back were the leading cause of injuries for EMS workers reported by Becker and Spicer (2007), usually categorized by overexertion when lifting. These musculoskeletal issues resulted in forced retirement for many EMS workers, due to inability to perform duties. They found that the injury rate was 10 times that of nurses, who are the most well-known for this type of injury saturation. The rise in these injuries can be linked to the rising obesity epidemic in the patient population (Boatright, 2002). According to the Center for Disease Control (CDC), as of 2013 over a third of adults in the US were obese, and no state had less than 20% prevalence of obesity. These individuals are 6 times more likely to have health problems such as heart disease, kidney failure, and more than 10 times more likely to have diabetes, and therefore more likely to be in need of EMS services during their lifetime (CDC, 2013). Unlike in a hospital setting, where more people may be called upon to handle these types of situations, the only personnel that might be available to move a large patient out in the field would be the EMS worker and their colleague. Thus, worker injury rates due to transferring patient loads is exceedingly high in the EMS field; data from a 2000–2001 survey found 50% of annual worker compensation for EMS worker injuries was related to this issue, and it is well documented that such injuries could force an EMS worker into early retirement (Boatright, 2002).

Research also shows that EMS workers are exposed to an increased risk of blood-borne pathogens, disease, and infection when dealing with patients in a non-structured environment (Stelzer, 2012). In a study requested by the Portland Bureau of Fire Rescue and Emergency Rescue Services (PFB), Reed et al. (1993) examined 256 exposures in a two year time frame. The overall rate of incidence was 4.4/1000 EMS calls. Though only 29.3% of exposures were results of needle sticks, contact with non-intact skin or mucous membranes, blood, or bodily fluids, a majority (64%) of those suffered from infection. They were primarily at risk of contracting Hepatitis B and HIV (Reed et al., 1993).

Finally, in addition to the physical risks of the job, only recently have mental stressors started to be assessed. EMS workers often work 12–24 h shifts, often with some degree of sleep deprivation, and respond to potentially traumatic situations (Maguire et al., 2002). Situations such as gruesome victim incidents, providing care to vulnerable patient demographics such as children, exposure to death and dying, and injuries to themselves or their coworkers are the highest contributions to the high levels of stress experienced by EMS workers (Stelzer, 2012).

Authors Becker and Spicer (2007) also found many elements of the work environment, besides the nature of the emergencies, to be causes of mental health strain: Company organization and management issues accounted for almost 30% of the sources of stress in a documented study in Devon, England. Within that same study three other major factors were identified: burdens of new and unfamiliar duties, work overload, and interpersonal relations, which all indicated that the way an EMS company relates to their employees can have a drastic effect on their productivity (Becker and Spicer, 2007).

Often with EMS workers, stress is exhibited as high job dissatisfaction, depression, anxiety, and hostility, and can affect the way the workers interact with patients. EMS workers might also report nightmares, flashbacks, and hyper vigilance while on the job, which are all characteristics of PTSD. PTSD symptoms are reported 15–20% of EMS workers, which ranges from 4 to 10 times that which the general population will experience in other professions (Becker and Spicer, 2007). Burnout rates for EMS workers also outpace that of all other healthcare workers, with some sources citing paramedic careers lasting as short as 4 years (Stelzer, 2012). EMS workers who suffered PTSD and burnout and cut their careers short are a huge concern for the industry, because it directly affects the EMS industry's ability to retain highly trained, knowledgeable, and experienced staff. It also strains EMS companies financially to constantly train new EMS personnel that may only last a short time (Stelzer, 2012). However, because of the growing awareness of the risks, the EMS profession has seen a push in several areas to improve working conditions, safety, and other areas that might negatively impact those working in the field.

In this paper, we first investigate paramedic behavior and their relationship with the work environment, and explore the EMS industry from the workers' perspective. Our ultimate goal is to understand how workers carry out their daily tasks, identify the factors that may cause stress, injury, or harm, and determine whether those risks can be minimized through better workplace design. We examine some benchmark designs claiming to improve worker safety and efficacy, and offer suggestions for considerations within future interventions.

4. Methodology

4.1. Observational study

Because of the specific nature of EMS systems based on geography and culture, the structure of the research was a multi-phase, mixed methods comparative study. The research used a transformative framework by giving voice to the respondents, representing them accurately, and discovering and acknowledging how the respondents' views of their experiences correlated or differed with the observations made by the researching third party. The research methods of shadowing and direct observation are methods that involve the direct interaction of the researcher with the people under study. They provide a unique insight into the rich, complex, and diverse thoughts, perspectives, and activities of human beings (Spradley, 1980). Direct participant observation methods have been successfully used in similar studies involving emergency medical workers such as Lavender et al. (2007), Patterson et al. (2011) and Weaver et al. (2015) because they provide contextualized information regarding the nature of the medics' behavior and experiences. Similarly, shadowing methods offer the reviewer a way to capture hindrances which the EMS workers might not be aware of due to workarounds established over time.

The comparative study format provides concentrated, in depth observations across available EMS systems and is useful for identifying differences or correlations between EMS groups, individuals, or within the same individual across several types of calls and conditions. The goal of this study is to identify important threats to EMS workers, both in fresh observation and to confirm or contradict the findings of similar studies (Biesbroek and Teteris, 2012), in a way that can be generalized and applied to a designed solution.

4.1.1. Study 1: Methods

The methods in our study were both qualitative and quantitative. Qualitative data was recorded in the form of researcher observations and semi-structured interviews. Documentation included field notes and workload scales. Qualitative data were obtained alongside quantitative measures of physiological stress, visual documentation of equipment, environment, and timeframes in which tasks were performed. The purpose of collecting both quantitative and qualitative documentation was to develop a correlative story of researcher-observed obstacles and medics' behavior toward those problems, as well as their physiological stress-response to those obstacles. For example, a medic might not look stressed during a task, but a spike in heart rate might indicate their internal struggle. The NASA Task Load index (TLX) was also used to assess what aspects of the tasks being performed were eliciting responses in EMS workers; such as if problems were physical or mental in nature, or if it was impeding time constraints or perceived effort that resulted in rising frustration levels.

Participants were selected from a pool of EMS groups with an established ride-along/observer program across 5 locations within central and eastern Texas. These EMS groups were metro and rural, municipal and private, deliberately selected for cross-comparison. Efforts were made to ride with both municipal rural and urban, and privately run rural and urban. Recruitment letters were sent to the organizations outlining the purpose of the study, and confirmation of participation and scheduling were done via email. Participants were selected based on their correlation of shifts to available observation time slots.

In total, five EMS groups participated, and twelve participants were shadowed, as shown in Table 2. The timeline breakdown of each ride-along shift is illustrated in Fig. 1. All medics observed were Paramedic-level with one advanced EMT completing their Paramedic training. Two participants were shadowed for a full 24 h shift, two for a full 16 h shift, two participants were observed for their full 14 h shifts, and six participants were shadowed for their full 12 h shifts. The mean level of experience and the mean age of the paramedics observed were 10.5 years and mid-30s, respectively.

The objective of our first study was to determine when and how medics experience threats to their safety, and where the causes of mental and physical detriment to workers originate. We focused on three areas: equipment, tasks, and environment to provide insights into critical issues, such as identifying whether the most critical threats occur inside or outside the patient compartment or whether the medics' current practices create adverse outcomes, which align with findings by Maguire et al. (2002).

Formal interviews and observational data including documentation of equipment used and ambulance layout were taken. Quantitative data about individual calls and TLX forms were recorded and photographed for later reference. In some instances, the time taken to complete a task was recorded. EMS workers' heart rates were monitored with a Polaris H7 heart rate monitor worn underneath the uniform around the ribcage. For every shift, heart rate data was collected only for the medic that would spend the most time in the back of the ambulance with the patient while en-route. A total of four participants agreed to wear the heart rate monitor. Others were excluded because of existing heart conditions or the use of beta blockers. Some data was excluded because of inadequate pairing between the monitoring hardware devices.

Our general methodology involved a pre-shift outline of what the research would entail. Participants put on the heart rate monitor and base-rate was collected (resting). A semi-structured interview was then conducted; interview questions pertained to their experience in the field, frequency of types of calls taken, personal preference of equipment and tasks, main points of stress/frustration in their daily work, and perceived positives/negatives of their job.

Observations and note taking began the moment a call was received, and started with the time of day, nature of call, and length of time it took to get on-scene as well as a brief description of the scene and number of people involved. Task details such as time taken to complete a task, number of people involved in the task, or number of attempts at a task (such as starting an IV or moving a patient from the stretcher to the hospital bed) were taken on a separate dry erase sheet. The information collected was based on its relevancy to the task, as shown in Table 3, and would later help pinpoint sources of frustration identified by the workload scale responses. Once a call was complete and the team had returned to their station, medics completed workload scales on dry erase sheets for each individual task they performed during the call.

The NASA Task Load Index (TLX) was the workload scale used to evaluate medics' performance and experiences during individual task conditions, and assess what aspects of the tasks being performed were eliciting responses in EMS workers. The NASA TLX rates captured workload according to 6 factors: mental demand, physical demand, temporal demand, performance, effort, and frustration on a scale from 1 to 100 with steps in increments of 5 (Hart and Staveland, 1988). The medics filled out a separate dry erase TLX sheet for each task performed during each call. Each sheet was prepared by writing call number, task, date, initials and picture of which paramedic filled out the form.

After each shift, all TLX scores were entered into a spreadsheet. Anonymized demographic data was included in the spreadsheet. This data included sex, approximate weight (rounded to the nearest 10), height, and age documented as “early, mid, late” decade. The reason for including this data was to offer insight between possible variance in TLX responses (e.g. a 5′2″, 250 lb female medic in her

Table 2
Medic Demographic Data of sample for our study.

Medic	Sex	Height	Weight (lb)	Age	Experience (years)	Observation time (hours)
1	M	6′	–	late 40s	20	24
2	M	5′9″	–	mid 20s	5	24
3	M	5′10″	–	mid 20s	6	24
4	F	5′2″	200	mid 40s	15	14
5	F	5′6″	150	mid 40s	10	14
6	M	6′1″	230	late 30s	15	12
7	M	6′	200	late 30s	15	12
8	M	5′10″	–	late 40s	15	16
9	M	6′2″	–	early 20s	6	16
10	M	5′9″	–	mid 30s	5	24
11	M	6′1″	–	late 30s	11	24
12	F	5′3″	120	mid 20s	5	24

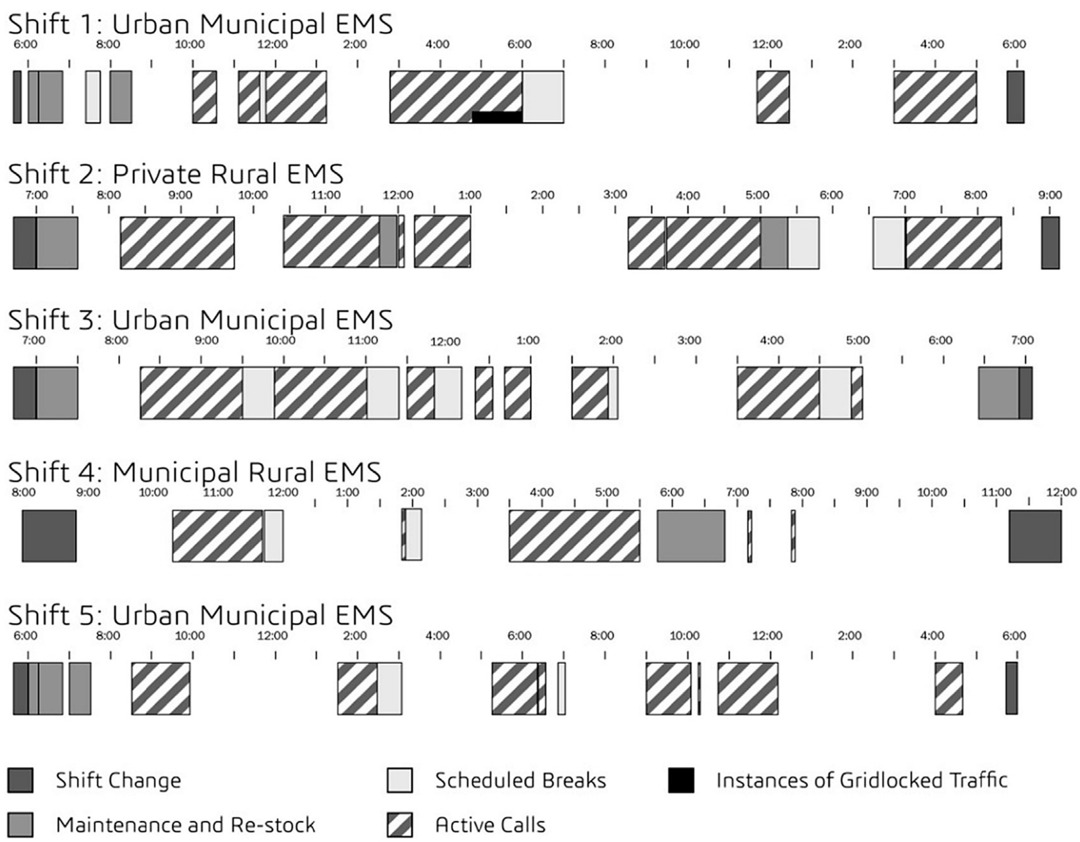

Fig. 1. A Visual breakdown of time during each shift.

Table 3
Examples of relevant information recorded for tasks: starting an IV, moving patient on and off the stretcher and turnover to hospital.

Task type (n = 7)	Attempts (Std. Dev)	Duration (min:sec)	People involved	Success rate (%)	Notes
IV Start	M: 2.43 SD: 2.44	N/A	N/A	66%	veins were inaccessible in some patients due to being "rock hard" or in states of severe dehydration
Moving patient on/off stretcher	N/A	M: 2:46 SD: 2:39	M: 3 SD: 1.41	100%	Some patients were combative, or obese, and small bedrooms or crowded living rooms made it difficult to maneuver
Turnover to hospital	N/A	M: 12 SD: 9	N/A	100%	delays were caused by rooms not being ready or miscommunication between EMS and ED staff

mid-40s reporting more physical difficulty and effort with manual loading of a stretcher than a 6′ male medic in his mid-20s). This difference is important when assessing the standard deviation of the data collected, and where the true, solvable issues lie. An example of an individual TLX sheet is shown in Fig. 2.

A total of 28 calls were observed, yielding 116 TLX sheets for 30 types of tasks. The top ten most arduous are presented in Table 4. The complete table is provided as an appendix at the appendix of

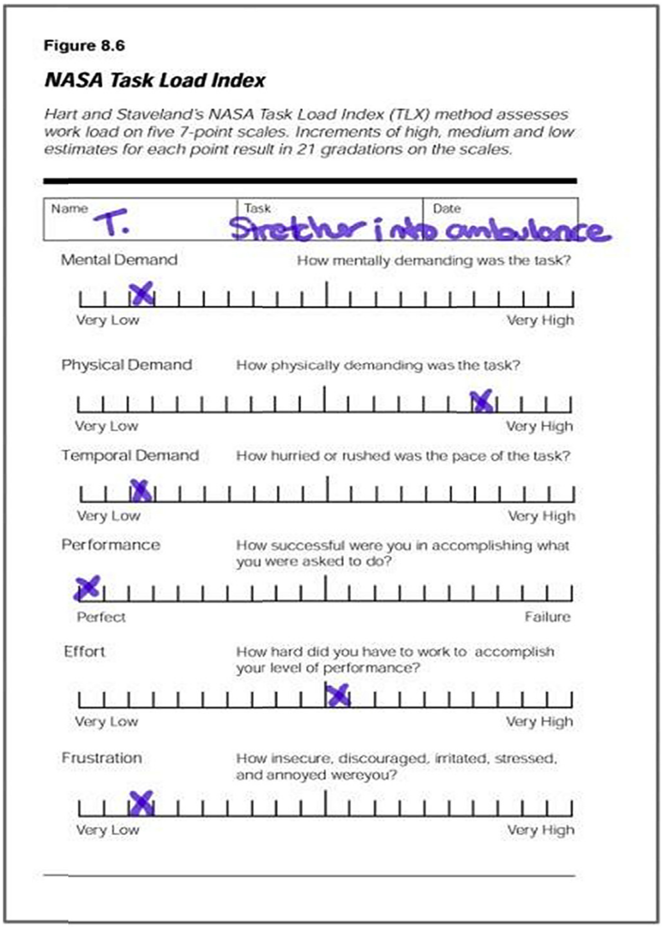
Figure 8.6

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name T. | Task Stretcher into ambulance | Date

Mental Demand — How mentally demanding was the task? — Very Low / Very High

Physical Demand — How physically demanding was the task? — Very Low / Very High

Temporal Demand — How hurried or rushed was the pace of the task? — Very Low / Very High

Performance — How successful were you in accomplishing what you were asked to do? — Perfect / Failure

Effort — How hard did you have to work to accomplish your level of performance? — Very Low / Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou? — Very Low / Very High

Fig. 2. Example of Individual TLX Sheet completed by a female medic while doing a physical task.

the paper. The weighting portion of the TLX procedure was discarded for this study based on current conventional practices, as similar validity for workload can be obtained without the weighting step. Instead the TLX ratings from various instances of the same tasks were averaged to ascertain overall workload. This method is also known as Raw TLX (RTLX) and is also shown to save time in the process (Hart, 2006).

Finally, personal interviews were conducted throughout the day relating to situations observed. A brief closing interview of final thoughts was conducted with the medics at the end of the shift and observational period, and medics were offered the opportunity to reaffirm their willingness or declination for follow-up questions.

4.1.2. Study 1 results and discussion

Using a heart rate monitor alongside the TLX scales and observations provides a quantitative component to our study. The intent was to determine if a medic's physiological signs of stress correlated with our observations. For example, a medic might look calm and collected to the researcher while performing an intricate task, but their heart rate might indicate that they were experiencing stress or strain.

In our study, the number of medics from the original observation pool that qualified for wearing a heart monitor was small. Some medics had to be excluded because of pre-existing heart conditions or the use of beta blockers, and occasionally, failure in Bluetooth pairing resulted in incomplete data sets. As a result, the remaining complete data offered no clear correlation between shifts, tasks, and heart rate, so the component was discarded. However, the TLX scales proved useful. As shown in Table 5, the task of extraction was the most physically and mentally demanding for the paramedics, as shown by the Raw TLX value and small standard deviation. This task had the highest "mental demand," "physical demand," and "effort" scores. In this instance, the extraction process from a crashed car happened in the mud down a steep ditch, and the patients were elderly and already fragile from

Table 4
TLX Results (mean and standard deviation) for top 10 highest Raw TLX score of 30 grouped task types. Scale from 1 to 100, with higher scores indicating more strain.

Task type	Mental demand	Physical demand	Temporal demand	Performance	Effort	Frustration	Raw TLX score
Category Definitions (as defined by Hart and Staveland, 1988)	How much calculating, remembering, assessing required?	How much physical exertion required?	How much time pressure was felt, satisfaction with rate/pace?	How successful [were you] at accomplishing the task?	How hard [did you] have to work to accomplish your level of performance?	How insecure, discouraged, irritated, stressed vs. secure, gratified and relaxed [did you feel] during the task?	Averages across categories for overall score per task.
Extricate	M: 73.33	85	83.33	11.67	83.33	25	60.28
	S.D: 5.77	5	5.77	7.64	2.89	13.23	1.27
Car seat	43.75	48.75	32.5	36.25	67.5	72.5	50.21
	28.98	7.5	24.66	31.46	24.66	29.01	12.68
Apply leads	M: 51.67	30	68.33	11.67	38.33	23.33	37.22
	40.41	31.22	42.52	5.77	20.21	31.75	10.55
C spine immobilization	50	25	100	20	10	10	35.83
	0	0	0	0	0	0	0
IV Start.	30	17.86	30.71	55.71	38.57	36.43	34.88
	21.6	19.97	29.5	43.63	35.56	24.78	18.63
Nitro	45	10	70	15	50	15	34.17
	0	0	0	0	0	0	0
Communication	50	12.5	55	17.5	50	15	33.33
	49.5	10.61	56.57	3.54	56.57	7.07	30.64
Bandaging/ splinting	30	5	100	10	25	10	30
	0	0	0	0	0	0	0
Patient on/off stretcher	17.78	47.78	23.33	8.33	36.11	20	25.56
	13.79	31.14	18.37	5.59	30.08	21.07	17.53
Assessment	31.07	17.86	30.71	23.21	22.5	21.43	24.46
	27.61	21.64	35.62	20.06	16.61	15.62	16.6

Table 5
Percentage of medics that agreed with the following list of tasks that could not be performed while seated and buckled in.

Answer	Percent responses	Response count (n = 103)
Intubation	89.3%	92
CPR	97.1%	100
Supplies Retrieval	89.3%	92
Defibrillation	43.7%	45
Restraining patients	89.3%	92

chemotherapy, so care and strategy were paramount.

The second most problematic task was dealing with the car seat while on a pediatric call. A child was having obvious difficulty breathing but the ambulance could not deliver to definitive care until the seat was properly secured to the stretcher while on a pediatric call. When asked to explain the exceptionally high "frustration" and "effort" ratings, it was clear that this issue was a definite product design usability failure, as a task that was expected to be performed simply and easily was unusually difficult to set up, attach to the stretcher securely, and put away after the shift was done in any sort of usable or time-efficient manner.

Applying leads, communication, and starting an IV all came close in their median ratings but their standard deviations varied wildly. The situation in which these tasks were performed contributed to this, for the calls in which these tasks were performed ranged from mundane to high-intensity, which affected the TLX score. This is evident by the corresponding temporal ratings. For example, for individual instances within the category of "application of leads", instances rated highly in temporal demand almost always had a high mental demand score, therefore it can be hypothesized that the rushed, time-sensitive nature of the situation added pressure to the mental strain. Additional highly rated temporal tasks correlated to incidents that related to trauma: particularly car crashes and auto-pedestrian incidents. In these instances, the medics often performed most of their care while en-route to the hospital.

Communication also had a high correlation with temporal score. Follow-up with the medics revealed that in instances with multiple patients that were being handled by multiple teams, coordination and organization in a timely manner was key, but often not achieved. In these situations, effort and temporal demand scored highly because the medics felt out of control of the situation. For example, having to wait for help to arrive, and not being able to be en-route to the hospital quickly drove up their time crunch, and it took a lot of mental effort to organize the handling of patients quickly once support arrived.

The lowest rated performance was seen with IV tasks, particularly initial insertion. In follow up interviews with medics that rated this task highly, and correlation to call stats taken in these instances, it was discovered that the poor scores were due to the large percentage of failed attempts at tapping a vein (see Table 4). The high amount of stress this failure rate caused was usually correlated with a time crunch the medic was experiencing to get fluids back into the patient quickly after trauma, as seen by the corresponding temporal demand scores.

The biggest risk factor captured in the interviews and through observation was the usage of seat belts. When reflecting back on the studies conducted by Becker and Spicer (2007), we recall that ground transportation accidents were the leading cause of EMS fatalities. By examining the tasks and behaviors that correlated with the issue during the ride-along activities, it was observed that the majority of the medics (11 out of 12) did not wear or attempt to wear their seatbelt in the back of the ambulance while with a patient. When asked during exit interviews, the common answer pointed to the difficulty in doing their job effectively while being buckled in.

Overall it was clear that time restrictions and organization (both on-scene and policy-wide) were the biggest factors that impacted TLX scores, and subsequently the largest contributing factor to EMS workers' stress and perceived competence. However, though the TLX scores helped construct a picture of what was plaguing the medics the most regarding task load and equipment, it failed to capture several other factors noted during the ride-alongs through interviews and observations. Many medics discussed their grievances with company policies, shift organization, and lack of support from the greater healthcare community, which confirm the findings by Weaver et al. (2011) and Stelzer (2012). Because ground transportation accidents were the leading cause of EMS fatalities, we focused on the tasks and behaviors that directly correlated with the issue. We observed that the majority of the medics (11 out of 12) did not wear or attempt to wear their seatbelt in the back of the ambulance while with a patient, citing the difficulty in doing their job effectively while being buckled in as the reason why they did not. To identify what it was about seatbelts that made their job difficult, or what about their job made it "impossible" to comply with safety standards, a survey focused on the topic was distributed.

4.2. Survey

4.2.1. Study 2: Methods

The goal of our second study was aimed at identifying the reasoning behind medics' decisions not to wear seatbelts, and identify the issues in the patient compartment that made it difficult for tasks to be completed while being buckled in. In order to obtain comparative psychometric data, a survey was constructed based on relevant sections of Sexton et al.'s instrument (Sexton et al., 2006), starting with questions about general tasks and narrowing into medics' reasoning. The survey was reviewed by medical and EMS personnel to determine validity based on expert consensus and distributed to the EMS companies that were originally selected for ride-alongs, as well as other medics who were not part of the original study. The survey started with an affirmation or rejection of the tasks that made restraint-wearing particularly difficult that were identified in stage 1 interviews and observations, (CPR, intubation, Supplies retrieval, restraining patients, and defibrillation) as shown in Table 5, and then gave an opportunity for elaboration or to add to the original compiled list. A total of 103 medics completed the survey.

A list of all the tasks that medics reported could not be done while staying seated and buckled in is shown in Table 6. Finally, Table 7 includes the top responses to an open-ended question asking the medics to explain what it was about these tasks that made it difficult for them to stay seated and buckled in. The medics responses were analyzed, tallied, and grouped into seven distinct categories that developed over the course of the analysis.

4.2.2. Study 2 results and discussion

As shown in Table 5, CPR rated the highest among tasks that could not be done while sitting, followed closely by intubation, restraining patients, and supplies retrieval. Only 43% of medics agreed that defibrillation could not be done unless standing. Of the tasks that were self-reported in Table 6, starting an IV and examining and adjusting the patient were ranked the highest, being included in roughly 50 and 25 percent of responses respectively.

When asking for reasoning why medics do not buckle up (Table 7), 77% reported that they unbuckled while caring for the patient because they could not reach what was needed. Roughly a third of respondents also cited that they did not have the proper

Table 6
Top third of 18 self-reported tasks that cannot be performed from a sitting, restrained position.

Tasks	Percent responses	Response count (n = 71)
Setting up an IV	56.3%	40
Examining patient	25.4%	18
Repositioning the patient	23.9%	17
Medication administration	15.5%	11
Airway suction	12.7%	9
Splinting/bleeding management	12.7%	9

Table 7
Categories of medics' reasoning for why staying seated/buckled hinders tasks.

Issue with task	Percent responses	Response count (n = 81)
Reach	77.8%	63
Positioning (angle)	35%	28
Leverage	32%	26
Ill-timed auto-locking seatbelt	22%	18
Hearing	3.7%	3
Lack of convenient space	3.7%	3
View	1.2%	1

angle to complete a task such as intubation or inserting an IV, and re-adjusting to proper positioning required unbuckling. Leverage was also reported by almost a third of respondents surrounding tasks such as restraining a patient, conducting CPR, or re-positioning a limp patient. Almost a fourth of medics also reported simply unbuckling because of an auto-locking seatbelt jamming at inopportune times: they valued their freedom of movement over the risk of injury in the event of an accident.

Our results suggest that much of the blame lies within the nature of the tasks that medics must perform. For example, tasks such as CPR, starting an IV, or adjusting the patient when sliding down the stretcher, cannot be carried out without a proper combination of reach and leverage, which staying in a seated, buckled position does not accommodate for. Yet these are critical tasks that cannot be eliminated from the workflow; therefore, medics feel as if they are left with no choice but to unbuckle to perform their duties.

5. Current solutions

Our first study suggests that a contributing factor in the fatalities among EMS workers in ground transportation accidents is the lack of seatbelt usage in the patient compartment of an ambulance. Our second study builds on this knowledge by identifying the problem within the tasks medics must perform paired with medics' mindsets. Often these tasks are staples of an EMS run; some tasks, such as starting an IV, are done in almost all instances of a patient transport. It is clear that when developing interventions to prevent or reduce fatalities among EMS workers, the lack of seatbelt usage must be accounted for. To put context to our findings, we examined industry's attempts aimed at mitigating the risks medics face when not buckling up.

Industry organizations have made many attempts at reducing fatalities of EMS workers in the field, largely centered around the instances of ambulance crashes. Some groups have re-designed components meant to be incorporated into the ambulance; others have re-designed the ambulance as a whole. Each solution presented in this article focuses on a different aspect of the problem.

For example, ambulance manufacturer Horton Ambulance (http://www.hortonambulance.com) looked at airbag usage instead of seatbelts to improve the outcome for medics in the event of a crash. They used crash tests data to develop specialized airbags for the ambulance "box." These airbags are not only thoughtfully placed to prevent injuries such as head strike, but are also equipped with rollover sensors that calculate the angle and speed of the vehicle's roll for strategic deployment (see Fig. 3).

Another ambulance manufacturer in Canada, Crestline, also addressed user safety by implementing small but crucial changes. For example, they incorporated lighted cabinets for easy way finding to reduce the time spent up and about retrieving items instead of buckled in. They also and made brake lights and blinkers visible from the inside of the box so EMS workers attending to a patient in the back would be able to anticipate the driver's actions, such as a hard brake, and brace for it.

However, the question remains as to whether these incremental changes are enough, or if they still fall into Johnathan Benger's defined "tacked on innovations" trap discussed in the background of this article. Some organizations have recognized this, and taken a step back to analyze the ambulance space as a whole. In the case of the Massachusetts Institute of Technology's EMS program, the design team worked with Massachusetts EMS to design a safer ambulance interior. They eliminated the possibility of head strike injuries by removing overhead cabinets, and replaced benches in favor of swivel chairs that utilized five-point harnesses, as shown in Fig. 4. The flexibility of the chairs theoretically adds more freedom for EMS worker movement than conventional seating designs, while increasing their security in the event of an accident (Forgues, 2014). The MIT seating configuration has now been adopted by many ambulance organizations. This re-design is a good example of examining and tackling a problem from the source, instead of mitigating the after-effects in regards to head injury.

Lastly, EMS equipment manufacturer Ferno expanded on the idea of inner-compartment flexibility by addressing the issue of "reach" that 77% of our survey respondents self-reported. Their carefully considered design included a rail-mounted equipment storage system within the patient compartment, so the medic could move equipment suited for each call nearer to them for quick and

Fig. 3. Horton Ambulance airbag design.

Fig. 4. MIT ambulance bench & seat reconfiguration (Forgues, 2014).

easy access without having to get up (Fig. 5). However, both this and the MIT configurations now come with strict protocol changes that require all personnel to remain seated and restrained while the ambulance is in motion (Forgues, 2014). Though these overall solutions did take into account EMS workers' movement when considering the chairs and storage systems, the question remains whether the protocol solution will actually curb EMS workers' old habits of unbuckling and standing up to administer aid.

These existing solutions focus primarily on solving issues of reach; designing around tasks such as supplies retrieval and access to areas of the patient. Although in some instances, such as the reconfigured storage and dual-captain's chair compartment, medics themselves were involved for validation purposes (Forgues, 2014), the efficiency of the outcomes is unclear since these designs require a sitting-only policy implementation. In fact, some of the ambulances in which our first study was conducted had similar configurations to the MIT layout, yet the medics discarded the policy implementation and sat on top of the harnesses instead of buckling in. It remains to be seen whether replacing the bench seat for the captain's chair, even if the medics fail to buckle in, increases safety within the patient compartment. Also, with the addition of the captain's chair, the safety net which is used to catch medics who might be free-moving on a bench seat configuration has been removed. Therefore, this configuration may actually result in a more dangerous environment for unrestrained medics.

6. Discussion

It is evident that medics make the care of their patient a priority over their own safety in the back of the ambulance, to the extent that even though ambulance crashes are the number one cause of medic fatalities, medics will not buckle up in lieu of being able to quickly reach their patient. This is consistent with the sentiment captured by Samuelson (2014). Current industry attempts to address this issue still focus on keeping the medic seated and buckled though it is clear they have many reasons not to comply with procedure. Therefore, new methods to keep medics safe that do not involve staying seated and buckled in should be explored. Per interviews from our first study, particular attention must be paid older generations of EMS workers, as their reluctance to changes in their workflow (compounded with the issue that personal safety and wellbeing have only just now started to be addressed when training younger medics), means that older medics who have not already been weeded out by burnout and injury might be at a disadvantage when their working procedures and environment get overhauled by design teams.

Although not ergonomic in nature, most interviews with medics revealed high levels of frustration with current organizational systems, both with company policies, hierarchy, and at an overarching legislative level. This is consistent with the findings of Becker and Spicer (2007) and Stelzer (2012). In our studies, a significant portion of the self-reported burnout and was a result of poor company camaraderie, overwork, and abuse of the system by patients who use EMS for non-emergency calls, such as using ambulances and emergency departments in situations where a primary physician would be more appropriate, or embellishing psychiatric episodes to gain access to medications. In this context, a systems level examination of methods to relieve burdens on medics and mitigate situations in which medics are put into stressful or confrontational roles should be developed, yet should be avoided when interfering or going against medics priorities while attending to a patient.

In terms of physical safety and wellbeing, it is clear that medics

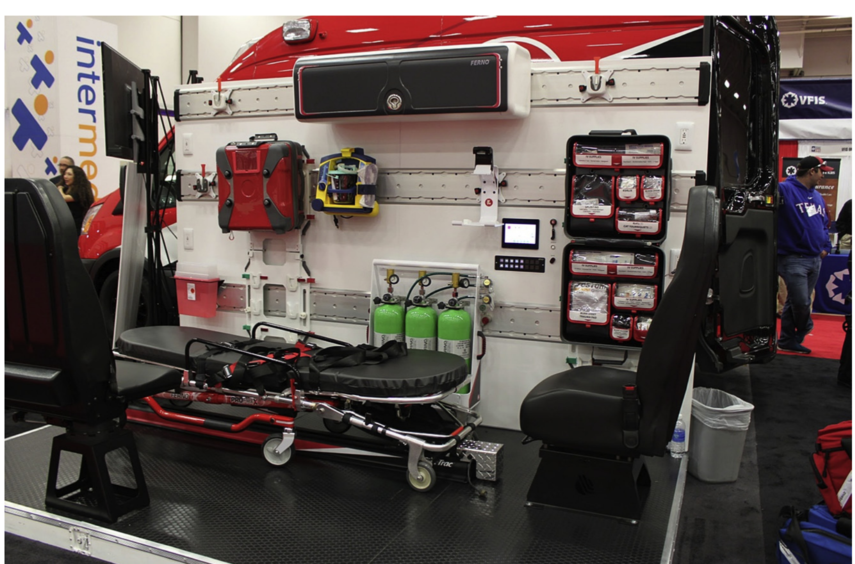

Fig. 5. Ferno modular rail system, presented at the 2015 EMS conference in Dallas.

are aware of the risks of their profession, though through our interviews and observations, there appears to be a divide between younger and older medics regarding the interventions they are willing to take to ensure their personal wellbeing. This might be a result of changes in educational methods over the past decade, where physical wellbeing such as diet, exercise, and physical safety are now being emphasized heavily in medic training. Older medics also reported noticeable attitude changes in younger EMS personnel, where mental wellbeing is taken more seriously.

Seat belt use in the back of the ambulance, however, is still a pervasive risk to EMS workers, regardless of the medic's years of experience. According to our interviews and observations, the strongest indicator to whether a medic would wear a seatbelt was if that medic had previously been involved in an accident. The general sentiment among the majority of the medics was that patient care took priority: “You either sit, buckled in, or you attend to your patient. Pick one,” one interviewee said. This is contradictory to the point of view industry leaders have adopted when designing interventions, where they place priority on the seated buckled position while only offering limited ways to access the patient. There remains great opportunity for a solution that takes into account medics' concerns and priorities and also the need within the industry to keep their workers safe.

7. Conclusion

In this paper, we examined how the roles of EMS workers have changed over time, and explored the views of EMS workers on their personal health and safety at work. To determine whether there was a perceived issue among EMS workers, a mixed methods multiphase study was conducted. Special attention was given to the work environment, tasks, and equipment used to determine the factors that had the most significant effect on performance. Workers' ideas and experiences regarding job safety, efficiency, and workplace design were also reported.

TLX data, observations, and interviews indicate that there are several areas for improvement in terms of design. More importantly, a systems approach should be taken to avoid the precedent of piecemealed, tacked on solutions that do not work well together. Eliminating redundancy or ill-cooperating equipment has the potential to save time and reduce temporal demand, and has great potential to ease the mental burden on EMS workers.

With direct input from EMS personnel, a better understanding of medics' thoughts and motivations can be developed when it comes to personal safety in the workplace. Medics, and not just patients, should be considered early on in the design process when pursuing efficient ergonomic solutions for EMS environments. Clearly, these solutions must be better aligned with medics' workflow, since certain situations that put medics at risk cannot be avoided if the medic wishes to do their job effectively. The results presented in this study also raise questions about current ergonomic interventions, particularly regarding the success of adoption and implementation.

As a natural progression of this study, future work will explore and validate ergonomic solutions for the issue of seat belt safety. Particularly, we are interested in examining strategies to keep medics safe in the back of an ambulance without the need to be in a sitting position and without interfering with the existing workflow.F.

APPENDIX A. Appendix

TLX Results for grouped task types sorted alphabetically. Scale: 1–100, with higher scores indicating more strain.

Task type	Mental demand	Physical demand	Temporal demand	Performance	Effort	Frustration	Raw TLX score
Category definitions (as defined by Hart and Staveland, 1988)	How much Calculating, rememberin, assessing required?	How much physical exertion required?	How much time pressure was felt, satisfaction with rate/pace?	How successful [were you] at accomplishing the task?	How hard [did you] have to work to accomplish your level of performance?	How insecure, discouraged, irritated, stressed vs. secure, gratified and relaxed [did you feel] during the task?	Averages across categories for overall score per task.
Apply leads	M: 51.67	30	68.33	11.67	38.33	23.33	37.22
	SD: 40.41	31.22	42.52	5.77	20.21	31.75	10.55
Assessment	31.07	17.86	30.71	23.21	22.5	21.43	24.46
	27.61	21.64	35.62	20.06	16.61	15.62	16.6
Bandaging/ splinting	30	5	100	10	25	10	30
	0	0	0	0	0	0	0
Blood sugar	5	5	5	5	5	5	5
	0	0	0	0	0	0	0
Breathing treatment	10	5	40	17.5	22.5	7.5	17.08
	7.07	0	35.36	3.54	17.68	3.54	7.66
C spine immobilization	50	25	100	20	10	10	35.83
	0	0	0	0	0	0	0
Cardiac monitor	6.88	7.5	18.13	21.25	13.75	12.5	13.33
	3.72	4.63	21.54	16.85	14.82	13.09	8.02
Communication	50	12.5	55	17.5	50	15	33.33
	49.5	10.61	56.57	3.54	56.57	7.07	30.64
Driving	38.89	14.44	35	10	16.11	15	21.57
	31.6	15.9	36.74	9.68	11.93	11.73	15.61
Extricate	73.33	85	83.33	11.67	83.33	25	60.28
	5.77	5	5.77	7.64	2.89	13.23	1.27
Gathering meds	5	10	10	15	10	5	9.17
	0	0	0	0	0	0	0
Getting information	35	5	32	24.44	29.44	20.56	24.44
	34.73	0	34.01	22	32.92	18.95	21.3
Give 02	8.75	6.25	21.25	8.75	23.75	21.25	15
	4.79	2.5	4.79	4.79	21.36	22.87	6.77
IV Start.	30	17.86	30.71	55.71	38.57	36.43	34.88
	21.6	19.97	29.5	43.63	35.56	24.78	18.63
Logging info writing reports	33.33	14.17	22.5	14.17	27.5	34.17	24.31
	26.01	3.76	6.12	7.36	15.41	30.24	11.47
	24	7	38	9	13	7	16.33

(*continued*)

Task type	Mental demand	Physical demand	Temporal demand	Performance	Effort	Frustration	Raw TLX score
Med administration	12.94	4.47	34.75	8.2	10.37	4.47	7.51
Nitro	45	10	70	15	50	15	34.17
	0	0	0	0	0	0	0
Patient contact	17.5	6.25	18.75	16.25	15	20	15.63
	21.79	2.5	20.97	4.79	9.13	17.8	11.43
Patient on/off stretcher	17.78	47.78	23.33	8.33	36.11	20	25.56
	13.79	31.14	18.37	5.59	30.08	21.07	17.53
Put car seat	43.75	48.75	32.5	36.25	67.5	72.5	50.21
	28.98	7.5	24.66	31.46	24.66	29.01	12.68
Staging	5	5	5	5	5	5	5
	0	0	0	0	0	0	0
Temp	5	7.25	10	7.5	7.5	7.5	7.5
	0	3.54	7.07	3.54	3.54	3.54	3.54
Turn patient hospital	21.67	10	24.17	10	20	14.17	16.67
	27.14	6.35	20.1	7.75	21.91	10.21	12.57
Vitals	16.67	11.67	43.33	8.33	26.67	15	20.28
	2.89	7.64	27.54	5.77	12.58	5	7.56

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