Getting Inside the Expert's Head

Getting Inside the Expert's Head: An Analysis of Physician Cognitive Processes During Trauma Resuscitations

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Study objective: Crisis resource management skills are integral to leading the resuscitation of a critically ill patient. Despite their importance, crisis resource management skills (and their associated cognitive processes) have traditionally been difficult to study in the real world. The objective of this study was to derive key cognitive processes underpinning expert performance in resuscitation medicine, using a new eye-tracking–based video capture method during clinical cases.

Methods: During an 18-month period, a sample of 10 trauma resuscitations led by 4 expert trauma team leaders was analyzed. The physician team leaders were outfitted with mobile eye-tracking glasses for each case. After each resuscitation, participants were debriefed with a modified cognitive task analysis, based on a cued-recall protocol, augmented by viewing their own first-person perspective eye-tracking video from the clinical encounter.

Results: Eye-tracking technology was successfully applied as a tool to aid in the qualitative analysis of expert performance in a clinical setting. All participants stated that using these methods helped uncover previously unconscious aspects of their cognition. Overall, 5 major themes were derived from the interviews: logistic awareness, managing uncertainty, visual fixation behaviors, selective attendance to information, and anticipatory behaviors.

Conclusion: The novel approach of cognitive task analysis augmented by eye tracking allowed the derivation of 5 unique cognitive processes underpinning expert performance in leading a resuscitation. An understanding of these cognitive processes has the potential to enhance educational methods and to create new assessment modalities of these previously tacit aspects of expertise in this field. [Ann Emerg Med. 2018;72:289-298.]

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INTRODUCTION

Resuscitation is a dynamic, complex, and time-sensitive field of medicine. Physicians who practice resuscitation medicine are tasked with the management of critically ill patients, as well as with leading the large multidisciplinary teams that care for them.[1] These facets combine to provide a uniquely complex environment in which physician leaders must operate.[2] The ability of a physician to expertly manage a resuscitation depends on a variety of parallel cognitive processes, including the application of knowledge, information gathering, and decisionmaking.[3] Identifying and categorizing these processes has been difficult, and consequently our understanding of expertise, particularly within the field of resuscitation medicine, remains limited.[3,4] Beyond the acquisition of factual or procedural knowledge, traditional notions of expert performance in resuscitation have focused on the applied principles from crisis resource management and on the avoidance of specific cognitive biases that can affect physician decisionmaking.[5,6]

Despite the limited research focusing on expertise within resuscitation medicine, there is an extensive base of literature in a variety of other fields exploring the nature of expertise and the science of decisionmaking.[7-11] The methods used to study the detailed thought processes and decisionmaking techniques of experts in various fields have become known as cognitive task analysis, whereby cognition is studied in actual contexts and professional practice at work.[12] More recently, the methods of cognitive task analysis have been applied to understand a broader range of phenomena underpinning expert performance beyond decisionmaking.[10] The term *macrocognition* has

Editor's Capsule Summary

What is already known on this topic

Expert clinicians may use specific cognitive strategies to make decisions and manage teams during resuscitation.

What question this study addressed

This observational study of 4 experienced trauma team leaders used novel eye tracking and first-person cameras to allow recall of moment-to-moment cognitive strategies used during actual trauma resuscitation.

What this study adds to our knowledge

Senior trauma physicians used and described 5 major cognitive strategies during critical cases: logistic awareness, self-awareness of uncertainty, directed visual gaze, selective attendance to information, and anticipation of pitfalls. Eye tracking and cameras provide unique training and debriefing opportunities.

How this is relevant to clinical practice

Training can emphasize development of these expert skills, and systems may be designed to facilitate and not interfere with these cognitive strategies.

been used to describe these phenomena and refers to the collection of cognitive processes and functions that characterize how people think in real-world settings. Important macrocognitive processes, derived in studying experts in other fields, include sense-making, planning, managing uncertainty, adaptation, and coordination.[12,13] Furthermore, the tools of cognitive task analysis have also uncovered the enhanced metacognition of experts compared with more novice performers. Metacognition has been broadly defined as "thinking about thinking" and includes recognition of one's own memory limitations, situational awareness, and self-assessment.[12,14,15]

Although the methods of cognitive task analysis have been successfully used to uncover expert cognitive functions in domains such as firefighting and the military,[12] there is a paucity of this type of work in the field of resuscitation medicine. The high number of decisions that resuscitation physicians must make, with limited information in challenging environments, makes this field ripe for cognitive task analysis and furthering the understanding of their cognitive processes.

Experts have limited insight into their specific cognitive processes when asked about them retrospectively, and often show both skewed and incomplete recall of events.[12,16] Several studies have attempted to overcome this difficulty by the use of head-mounted cameras as a way to generate first-person video data to supplement qualitative analysis of physician cognition.[17-20]

Eye-tracking technology builds on first-person video and has been used in a variety of both nonmedical and medical fields. Until recently, the application of eye-tracking technology was constrained by the bulk of the equipment and cumbersome calibration procedures. With the advent of mobile, light, and unobtrusive glasses capable of providing detailed eye-tracking information in real time, potential applications have blossomed. In particular, eye-tracking methodology has found a niche within medical education in studying visual expertise.[21,22] It has been used to explore visual and cognitive behaviors in surgery and radiology.[20,23] Eye tracking has also been used to objectively measure cognitive load[24,25] and to study visual fixation patterns of experts in simulation settings.[26]

In the current study, we present, to our knowledge, the first use of cognitive task analysis augmented by participant review of video generated by eye-tracking technology during trauma resuscitations. The primary objective of this study was to gain a better understanding of the specific cognitive processes of expert physicians while leading actual resuscitations. A secondary objective was to demonstrate the feasibility and utility of using eye tracking as a means of enhancing traditional cognitive task analysis techniques.

MATERIALS AND METHODS

A phenomenological approach was used to understand the participants' experiences and awareness of their behaviors and decisionmaking, with a focus on gaining insight into the essence of medical expertise.[27] Phenomenological interviewing and the techniques of cognitive task analysis focused on common elements of the lived experience of expertise of the team leader in the trauma bay while caring for an injured patient.

Selection of Participants

Four physicians were identified as local experts in resuscitation medicine and were specifically recruited in person to participate in this study. No potential participant approached refused or quit the study at any point. Each expert was an attending emergency or critical care physician with specific fellowship training and experience in resuscitation medicine. Beyond their daily clinical practice, they all worked specifically as trauma team leaders, with a collective experience as attending trauma physicians of greater than 30 years. Table 1 presents information on the specific qualifications of the participants. Beyond these

Table 1. Training and qualifications of the expert participants.

Participant	Qualifications
1	Emergency medicine specialist, trauma fellowship
2	Emergency medicine specialist, critical care fellowship
3	Emergency medicine specialist, resuscitation fellowship
4	Emergency medicine specialist, critical care fellowship

qualifications, they were also chosen according to collective consensus by the study authors as being physicians who are generally regarded by reputation as being excellent in their roles as trauma physicians. Unfortunately, we were unable to enroll female experts because there were no women at our institution with additional fellowship-level resuscitation training who were acting as trauma team leaders. This study was undertaken in the emergency department (ED) of a regional trauma center with a large catchment area and an annual patient volume of greater than 60,000. Ethics approval for this study was obtained from the Queen's University Faculty of Heath Sciences Ethics Review Board.

Data Collection and Processing

Cases that activate the trauma team involve by their nature high patient acuity, integration of a large number of personnel, and out-of-hospital notification by the local emergency medical services system, thereby affording time in which to outfit the expert participant with the eye-tracking glasses before the arrival of the patient.

In total, 10 trauma cases were collected during a 15-month period between July 2015 and October 2016. Two participants completed 2 cases each, and the other 2 participants each completed 3 cases. The participants did not control or select which cases were studied. All cases that were captured with the eye-tracking glasses were analyzed and included in this study. While completing the analysis, after 7 cases thematic saturation occurred, with all themes being derived at this point in the analysis. Three further cases were analyzed, confirming data saturation, and thus case recruitment was stopped after a total of 10 cases.[28]

Each participant was outfitted with Tobii Pro Glasses 2 (Tobii AB, Danderyd, Sweden) (Figure 1) and the device was calibrated according to manufacturer recommendations. Eye movements were sampled monocularly at 50 Hz. The recording was started before patient arrival and continued until a natural endpoint in the resuscitation, at which point the participant was able to remove the eye-tracking glasses without interfering with his or her role as physician leader. The recording produced a first-person video with an overlying gaze indicator showing where the participant was looking in real time (Figure 2). Each recording was uploaded to a secured study computer with the analysis software for subsequent replay and analysis (Tobii Pro Lab; version 1.55.5126 × 64).

Within 1 week of the clinical case, each participant was debriefed with the eye-tracking video recording. A cognitive task analysis was used, in keeping with a phenomenological approach to qualitative analysis. Each analysis consisted of a cued-recall, retrospective protocol while the participant watched his corresponding recording. The participants were encouraged to verbalize their internal dialogue and thought processes as they watched the replayed eye-tracking video. This method of cognitive task analysis was chosen because it was thought that the use of eye-tracking glasses would trigger the experts to remember specific thought processes they had during the case. Additionally, each debriefing was supplemented at the end with a prespecified set of questions (Appendix E1, available online at http://www.annemergmed.com). The aim of this supplement was to collect consistent information across the different participants not already captured during the cued-recall portion. Finally, all participants were asked to comment on their thoughts pertaining to the utility of the eye-tracking glasses in uncovering their tacit knowledge and to describe whether the eye-tracking glasses affected their behaviors during the resuscitation. The debriefings were between 30 and 45 minutes long, the majority consisting of the cued-recall portion.

Figure 1. Tobii Pro Glasses 2 eye-tracking device.

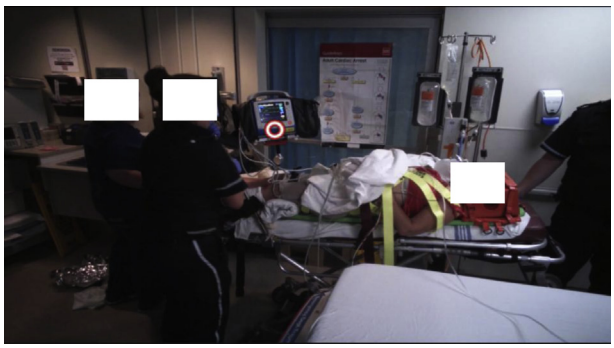

Figure 2. Snapshot of eye-tracking recording showing first-person video with the dynamic overlying gaze indicator.

The interdisciplinary research team watched the first 3 trauma videos together, focusing on (but not being limited to) potential macrocognitive processes that we had observed in our previous resuscitation-based simulation work.[26] While viewing the videos, the research team focused on observing the participants in their natural resuscitation environment. Members of the research team recorded their own individual notes for each resuscitation and then calibrated their notes after the videos. All 10 videos were then further reviewed by both the senior resident and educational doctoral-student authors. The calibrated notes generated a list of specific behaviors of the expert physicians and provided additional qualitative data to the debriefings. They also provided context for the doctoral student who completed the thematic analysis of the debriefings as described below.

All 10 debriefings were transcribed verbatim by 2 research assistants. After data transcription, the transcripts were reviewed to correct transcription errors that were mostly related to medical jargon. The debriefings were then uploaded into ATLAS ti (version 1.0.5.0) for analysis. Each debriefing was analyzed separately and then analyzed across cases, using an emergent thematic approach. The smallest unit of analysis (codes) was grouped into categories (consisting of multiple codes per category), which were then organized into themes (patterns).[29-31] These themes were observed across debriefings and experts. The videos also provided context and a preliminary platform to aid in the analysis of the transcripts. The research team met frequently to discuss results and emergent themes. The analysis process was iterative as codes and themes were consistently revised to best represent the data.

Data collection of the eye-tracking videos and all debriefings were completed by one of the authors (M.R.W.), a senior resident completing training in both emergency medicine and critical care who had trained under each expert participant in the study. The majority of the debriefings consisted of the participants' unprompted recollections of their thought processes while watching the eye-tracking video. During all analyses, a research logbook was used to note memos and biases, and maintain an awareness of the interpretations made. This reflective process helped the researchers to be mindful of their preconceptions about the data and helped to produce new insights stemming directly from the data.[32] None of the derived themes were shared with participants during ongoing debriefings, nor were the participants involved in that process.

Qualitative data analysis was conducted by an interdisciplinary research team consisting of an attending physician, senior resident, an educational psychologist and researcher, and an education doctoral student with a background in cognition. The education research members had no medical training.

RESULTS

Overall, 5 emergent themes, pertaining to the macrocognitive aspects of expert cognition, were found: logistic awareness, handling uncertainty, visual gaze behaviors, selective attendance to information, and anticipatory behaviors. Figure 3 summarizes these overall themes, as well as the specific subthemes or macrocognitive processes within each. Additionally, Table 2 summarizes the themes and respective preliminary codes, and provides further supplemental quotations from the debriefing transcripts.

Theme 1: Logistical Awareness

Expert physicians were found to demonstrate strong awareness of the logistic aspects of managing a trauma case. Repeatedly, experts commented on the need to prioritize multiple actions and the need to ensure that both diagnostic and treatment elements were being completed as quickly as possible. Expert trauma management extends beyond just knowing what to do; both prioritization and temporal awareness are necessary to enact a specific plan and see it through in the most efficient way possible. For example, participant 3 stated, "Classically, there are delays and this patient then ends up in the [ED] for *x* hours, their OR [operating room] gets delayed, everything gets delayed. I find that's the biggest thing that I'm doing in this case. And to do that I have to really understand the system and who to talk to." (P3) Participant 4 similarly stated, "…I'm mainly thinking about how to prioritize getting her to the CT [computed tomography] scanner." (P4)

This concept of "understanding the system" and nuances of the environment in which the expert works may be a critical component of expertise. In this way, an expert's performance may be contingent on his or her specific practice environment and may not be transferable to different centers with unique local practices and resources.[33] Furthermore, during the debriefings, experts frequently were aware of time and realized the need to expedite tasks. This temporal awareness was highlighted repeatedly during each debriefing and was found to be a frequent focus of the experts' cognition. Participant 1 stated, "…[Y]ou have to keep the momentum going; things happen rapidly at the outset and then people tend to lose track of time." (P1)

Furthermore, participant 3 stated. "…[We need] for things to actually be prepared and ready to go so we're not waiting around for people." (P3)

Theme 2: Handling Uncertainty

Participants were simultaneously able to acknowledge uncertainty and make decisions, and maintain an open

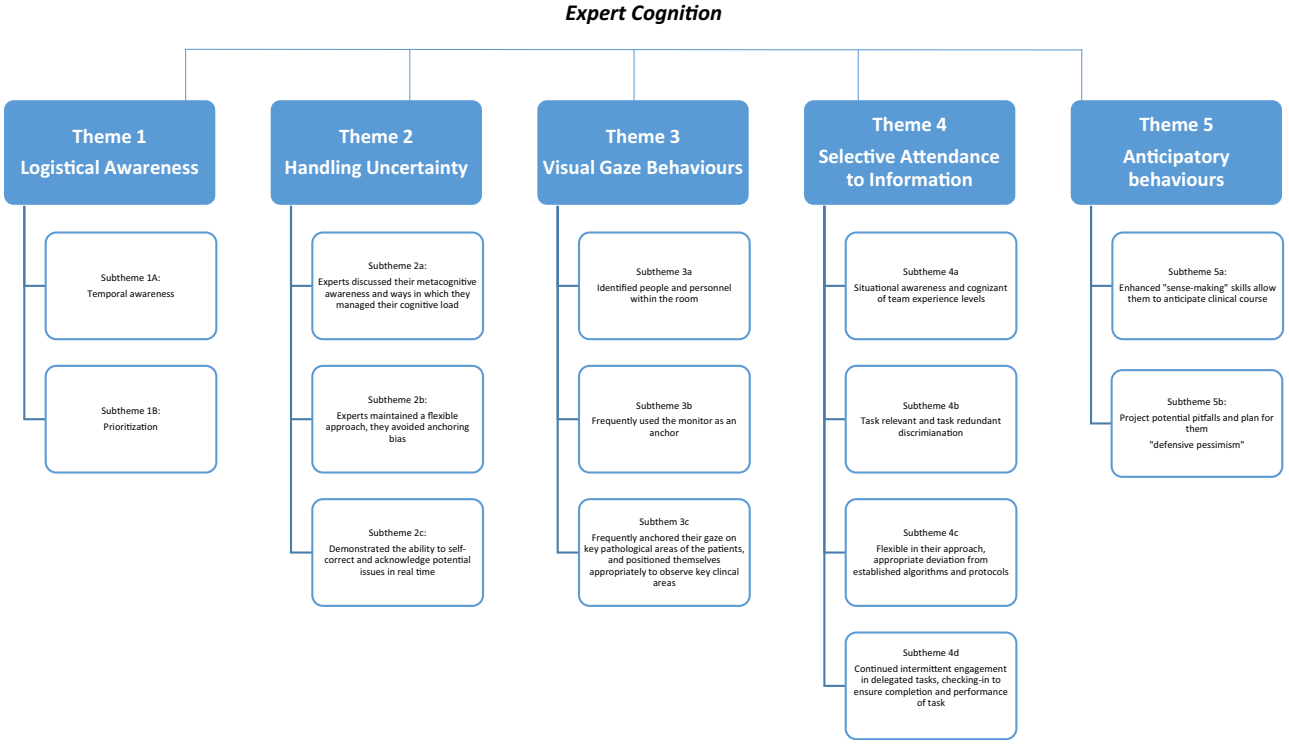

Figure 3. Summary of derived macrocognitive themes and subthemes.

framework avoiding overreliance on initial impressions (ie, anchoring bias). Participant 3 stated, "And then it was back to the knees, and it led me to kind of question a bit whether we were doing the right thing by taking him for an angiogram, just thinking pretty clearly that it's going to be behind the knees." (P3) Similarly, participant 2 stated, "Because the patient's clinical status evolved over the course of time, I think I was frequently reevaluating the treatment decisions I made." (P2) He also stated he was "adjusting [his] therapeutic plan as [he] went." (P2)

This metacognitive awareness of the participants' own uncertainty also manifested in how they recognized and managed their cognitive load. Several participants specifically mentioned awareness of cognitive load and through the debriefing realized they had deployed methods to mitigate it. Participant 2 found that "speaking about it" to the room helped, and likewise participant 3 stated, "[I]f I haven't said it, I'll forget it." Participants were also aware of the team's collective cognitive load: "Yeah, I like to kind of do short lists. I'll pick, like, 3 items usually, because, you know, people can only process [so much]." (P1)

Theme 3: Visual Gaze Behaviors

We found that experts exhibited common, specific gaze behaviors while managing trauma resuscitations. During the few minutes before a patient's arrival, participants were found to focus on the available personnel and equipment. For example, participant 2 stated he was "coming back, trying to take stock of the room again" and in reference to the environment of the trauma bay stated "…[I]s there something else that's going to be an obstacle?" Their positioning in the room with respect to other team members and physical obstacles also allowed their gaze to focus on key clinical areas while assessing the patient. Participant 4 noticed positioning himself to examine a patient's airway, "[c]hecking under the [cervical] spine, under the collar for any potential airway injuries." (P4)

They all used fixation on the monitor and vital signs as a way of maintaining situational awareness if temporarily needing to fixate on a specific task or aspect of the resuscitation. Participants 4 and 2 stated, respectively, "I go back to the monitor quite frequently; often it's something I'm just doing while I'm thinking about something else" (P4) and "Again, I'm trying to keep an eye on the vital signs." (P2)

Theme 4: Selective Attendance to Information

The fourth general macrocognitive theme pertained to the participants' selective application of attentional and cognitive resources. The amount of information, visual

Table 2. Summary of themes derived from coding of primary eye-tracking videos and debriefing transcriptions with supporting quotations.

Themes and Subthemes	Example Codes	Example Quotations/Observations
Theme 1: logistic awareness 1a: Temporal awareness 1b: Prioritization	Attending physician role, logistic knowledge, anticipating delays, Prioritization, CT	"But as the attending, if you trust a resident—and most of our residents you do trust—to run these things, there's a lot of things you can do behind the scenes to expedite things, right?" (P3) "But at this point, I'm mainly thinking about how to prioritize getting her to the CT scanner. That's the main interest at this point." (P4)
Theme 2: handling uncertainty 2a: Metacognitive awareness, techniques for reducing cognitive load 2b: Flexible approach, avoided anchoring bias 2c: Self-correcting behaviors	Managing cognitive load, aware of need to unload, Patient context, reclassification, need for flexibility, Feeling, mad, should have called earlier	"Because I had realized, you know, the physician is doing a great job, he's explaining everything, but I have—I have, like, a number of things that I have to get done that I need to offload onto the appropriate people so things can get done." (P3) "And so what has been a casual approach to this point, I'm reclassifying in my mind, 'This as a not-so-sick trauma [patient]' to a 'This is a potentially sick trauma [patient] who may need something done pretty soon.'" (P2) "Because I knew that we were going to need ENT [ear, nose, and throat], and I was mad at myself for not having done this before." (P3)
Theme 3: Visual gaze behaviors 3a: Identified team members/personnel 3b: Used monitors to maintain situational awareness 3c: Frequent fixations on clinically relevant areas	Attention, team members, where, who, Orientation, positioning, vital signs, Attention, patient, need to check for airway injuries, under cervical collar	"And who do we have? Where are the people?" (P2) "I'm still trying to keep an eye on the vital signs. And I can actually see from here what they were." (P2) "Checking under the [cervical] spine, under the [cervical] collar for any, you know, potential airway injuries." (P4)
Theme 4: selective attendance to information 4a: Situational awareness and cognizant of team experience levels 4b: Task relevant and task redundant discrimination 4c: Appropriate deviation from protocols 4d: Checking in, frequent reengagement with delegated tasks	Awareness, team members, level of experience, Information reduction, irrelevant conversations, Attention, patient, gauging injuries, Attention, team members, checking work	"I may have delegated calling the vascular surgeon to the resident on service because partly that resident was someone I didn't feel terribly confident in, in the first case." (P1) "Um, and then when I was trying to listen to anesthesia, and then I was trying to give the story, it started to get really loud in the room, with multiple peripheral conversations, which I, you know, I deemed irrelevant at that point in time." (P3) "…[w]hereas if I determine that we don't have time, I completely deviate from the algorithm." "Really, the—one of the things I noticed is that the majority of the time, really what, uh, what I'm doing is just watching team members do their job and checking to make sure that it's going okay." (P4)
Theme 5: Anticipatory behaviors 5a: Enhanced "sense-making" skills allow them to anticipate clinical course 5b: Project potential pitfalls and plan for them ("defensive pessimism") 5c: Anticipated the need for experienced personnel	Role, predict, prepare resources, use as needed, Patient, initial priorities, pain management, difficult, Orientation, checking team members	"So I'm trying to really try to predict what's going to happen, have it ready so that if and when we need it, we utilize it." (P3) "But, uh, we're going to have a lot of problems managing, if he's not intubated, but anticipating, kind of walking the balance." (P1) "So I'm noticing here, there was an inexperienced general surgery resident from pathology." (P1)

stimuli, and decisionmaking density of a trauma resuscitation all serve to stress the cognitive demands of the physician leader. Participants were found to judiciously and variably apply their cognitive resources, depending on the nature of the trauma and makeup of the trauma team. For example, participants delegated multiple tasks during each trauma, but in doing so were aware of the ability of the performing personnel. Participant 1 stated, "I may have delegated calling the vascular surgeon to the resident on service because partly that resident was someone I didn't feel terribly confident in, in the first place." (P1) Likewise, participant 4 stated, "One of the things about these July resuscitations is so many of the team members are so junior and relatively unknown…. [W]ell, you're pretty sure they haven't got much experience and don't know what they're doing, so I think I'm more attentive to what they're doing because I don't totally trust them." (P4)

This process of "checking in" to ensure delegated tasks were completed effectively was common among the participants. The degree to which the participant monitored a delegated task was found to be contingent on the trust the leader had on the person to whom they were delegating. If the participant had a high level of trust in the person completing the task, he or she would cognitively unload this to a greater extent than if the task had been delegated to a less competent or experienced person. For example, in one

of the cases, the physician delegated the placement of a chest tube to a senior general surgical resident. Because the physician leader trusted that this was a straightforward task for the resident, few further cognitive resources were applied until after the procedure was completed, at which time the physician leader checked in to ensure the task was completed correctly. It was also noted that few visual fixations on the chest tube insertion procedure were made during its completion by the physician leader while he was attending to other tasks.

Participants also showed the ability to selectively process information, often ignoring or deemphasizing less critical information. Participant 4 noticed that he would often need to selectively interpret information fed to him by the trauma team (often composed of junior residents) in order not to be overwhelmed with extraneous information. "But [the residents] are also sometimes very keen to show that they know stuff, so they'll often tell you stuff that is not so much relevant but is more to show they know their information." (P4) Moreover, participant 4 stated, "The neurosurgery resident is reporting a change in the pupils, it wasn't there before. So to be honest, I'm hearing that report and not believing it. Not that I'm not believing it; I don't think there's a clinically significant difference. It's more perception. (P4)

In the context of severe traumatic brain injury, a potential change in pupil size may be a critical piece of information. The patient in question, however, was deemed not to have a clinically significant difference in pupil size by the expert participant, and thus this purported change was placed in the overall context of the patient (in contrast to the junior resident reporting the change).

Theme 5: Anticipatory Behaviors

The final macrocognitive theme concerned the anticipatory behaviors of participants. This related to 2 aspects of the trauma resuscitations. First, participants displayed strong sense-making skills and were able to quickly obtain a gestalt overview of the management priorities and the likely disposition of the patient. In this way, they were able to organize specific therapies and diagnostic tests quickly. Second, in accordance with their experience and knowledge, participants were able to forecast, anticipating potential pitfalls and planning for them. This "defensive pessimism" meant that participants would be prepared in the event that things went wrong, or in contrast to expectations. For example, participant 3 ensured that a physician experienced in performing surgical airways was consulted and available because the patient did not have a secured airway and had features suggesting a high-risk airway. Likewise, participant 1 ensured that the staff general surgeon (in contrast to the junior general surgery resident who was present) was immediately contacted because the participant projected that the patient was going to need an operation. Participant 1 stated, "…[T]here were a lot of things, even though, again, nothing is happening here right now, and from an untrained eye, everything is fine, but it's just, I'm finding all of this medicine, all anticipating, it's all what could happen, and if it happens, do we have a plan? Do we have this?" (P1)

Eye-Tracking Enhanced CTAs

The use of the eye-tracking glasses was found to be seamless in these actual clinical cases. None of the participants removed the glasses during the cases. Participants denied any significant discomfort associated with the device, and they did not think that it impeded patient care or altered their management of the case. For example, participant 2 stated, "Around the time I realized the patient was sick, I stopped being aware that I was wearing the glasses." And participant 1 similarly stated, "[The eye-tracking glasses] did not affect my decisionmaking or performance."

Finally, while reviewing their respective eye-tracking videos, all participants mentioned that this technique enabled to them to more accurately recall their specific thought processes during the resuscitation.

LIMITATIONS

The current work has several limitations. The relatively small sample size of 4 expert physicians and 10 trauma cases potentially limits the generalizability of our results. This being said, we reached qualitative data saturation, which makes the emergence of additional themes less likely. Moreover, this research was limited to a single center and it is possible that derived themes relate to shared traits resulting from participants' similar work environments and experiences. Another limitation is the fact that all our participants were men, and therefore we cannot rule out that female physician leaders may have slightly different approaches to crisis resource management that we did not observe.[34] This work also examined only experts and did not directly compare their cognitive processes with those of novices. Future work should involve experts at different sites, team leaders with various experience, and training and clinical cases beyond traumas such as airway management and cardiac arrest.

DISCUSSION

This study represents the novel application of mobile eye-tracking technology to enhance the ability of cognitive task analysis to uncover cognitive elements underpinning expert performance in resuscitation medicine. To our knowledge, this represents both the first application of this technology to cognitive task analysis and the first foray into

elucidating expert cognitive performance in actual resuscitation cases.

Figure 3 summarizes the 5 derived themes from the qualitative analysis, including logistic awareness, managing uncertainty, visual gaze behaviors, selected cognitive attention, and anticipatory behaviors. In another study, Schubert et al[13] characterized the macrocognitive differences in experts compared with novices working in the ED. Similar cognitive themes pertaining to expertise were derived in that study. The present work builds on the work of Schubert et al[13] in several important ways. First, we used eye-tracking glasses, which provided not only first-person video but also showed exactly where the participants were looking at all times from their own perspective. Furthermore, this work involved active resuscitations requiring the leadership of large clinical teams, which differ from the less acute cases described by Schubert et al.[13] This creates important differences in how the themes are applied.

Much of the previous work highlighting the importance of cognitive processes in resuscitation medicine has focused on borrowed principles of crisis resource management. These cognitive processes and human factor principles such as situational awareness, cognitive load management, and information processing have been previously derived in studies of other fields, particularly aviation.[35] Although some of these principles have been applied to resuscitation medicine, particularly in a simulation environment, to our knowledge the current study represents the first time they have been studied in actual resuscitation cases from a first-person perspective. We believe that this study represents a novel contribution to the field by deriving these processes from real-world data and, in doing so, showing how they are directly applied in authentic cases, beyond theoretical and simulated environments.

This work has important applications to both education and assessment. Zupanc et al[36] used video recording and cognitive task analysis techniques to derive a competency framework for colonoscopy. Using this methodology, they were able to identify 27 real-world–derived competency components, providing a principled structure for future training programs and the design of better formative assessments. Similarly, this work provides a basis for which to enhance preexisting educational and assessment techniques. Within the field of resuscitation medicine, simulation has been relied on heavily to train learners in tacit areas of performance.[37,38] The authors suggest that, based on the results of this study, some of these previously tacit areas have now been better described. Given this, there is the possibility of using the results from this study to inform more research that could in turn improve simulation education.

For example, to highlight the concept of selective attendance to information (theme 4), simulation scenarios could purposely present extraneous information to challenge advanced learners to decide on their relevance in the management of a scenario. Selective cognitive attention demonstrates the ability of experts to place information in its appropriate context. This aligns well with the information reduction hypothesis,[39,40] which holds that experts in a given field are able to distinguish between task-relevant and task-redundant information. Thus, the improved performance of experts may at least be partially attributable to their ability to decrease the amount of irrelevant information that they have to process. In accordance with the results of this study, our simulation education group has begun incorporating these types of "distractors" in simulation education and has found that better-performing residents are better able to appropriately discard task-irrelevant clinical stimuli while focusing on more relevant stimuli that may have an effect on patient management.

A particularly germane application of this work is the way in which trainees are assessed. Currently, medical education is transitioning to a competency-based framework of assessment. Competency-based medical education focuses on specific predefined abilities and activities that a trainee should be able to perform.[41] Traditional formal assessment paradigms emphasize assessment of mostly factual knowledge. By using actual cases to derive a set of cognitive processes characterizing expert performance, as did Zupanc et al,[36] these processes could be applied in designing more rigorous assessment tools.

In addition to our primary objective of deriving cognitive processes of experts, this study also demonstrates the utility of cued recall augmented by eye tracking as a method of enhancing real-world cognitive task analysis. The use of eye tracking allowed the participants to more easily recall details of their internal thought processes during each trauma case. The first-person video generated with the gaze indicator allowed each participant to "go back in time" and retrace their cognitive steps. This yielded a rich amount of data to be analyzed, which would not have been previously available for study. Beyond the enhancement of cognitive task analysis, this study demonstrates other potential applications for eye tracking in actual resuscitation medicine cases. Because the participants found the eye-tracking glasses to be minimally invasive and not an impediment to their ability to manage trauma resuscitations, we believe that the methodology described herein could be applied to other clinical cases in

various contexts for research, as well as potentially for quality improvement purposes and critical-incident reviews. In addition, after appropriately addressing privacy issues, first-person videos generated during clinical cases could be used during educational rounds as a means to coach junior learners and as focal points for discussion during continuing medical education sessions.

In this study, the cognitive processes of expert physicians leading actual trauma resuscitations were studied with the novel combination of eye-tracking glasses, using the qualitative tool of cognitive task analysis. Overall, 5 cognitive themes were derived, including logistic awareness, handling uncertainty, visual gaze behaviors, selective attendance to information, and anticipatory behaviors. Furthermore, we found that cued recall augmented by eye-tracking technology was a practical, unobtrusive, and useful technique for cognitive task analysis in the resuscitation bay. With more study, these tools could enrich simulation education and provide a framework to aid the assessment of previously tacit aspects of expertise.

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REFERENCES

1. Szulewski A, Brindley P, van Merrienboer J. Decision making in acute care medicine. In: Brindley P, Cardinal P, eds. *Optimizing Crisis Resource Management to Improve Patient Safety and Team Performance*. Ottawa, Canada: Royal College of Physicians & Surgeons of Canada; 2017:13-22.
2. St Pierre M, Hofinger G, Buerschaper C, et al. The challenge of acute healthcare. In: *Crisis Management in Acute Care Settings*. 2nd ed. Berlin, Germany: Springer; 2011:23-39.
3. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. *Acad Med*. 2015;90:1471-1486.
4. Norman G, Eva K, Brooks L, et al. Expertise in medicine and surgery. In: Ericcson KA, Charness N, Feltovich P, et al, eds. *The Cambridge Handbook of Expertise and Expert Performance*. New York, NY: Cambridge University Press; 2006:339-353.
5. Carne B, Kennedy M, Gray T. Review article: crisis resource management in emergency medicine. *Emerg Med Australas*. 2012;24:7-13.
6. Croskerry P. From mindless to mindful practice—cognitive bias and clinical decision making. *N Engl J Med*. 2013;368:2445-2448.
7. Klein G. *Sources of Power: How People Make Decisions*. Cambridge, MA: MIT Press; 1999.
8. Ericsson KA, Pool R. *Peak: How to Master Almost Anything*. Boston, MA: Penguin; 2016.
9. Kahneman D. Thinking, Fast and Slow. *Doubleday Canada*. 2011. Toronto, Canada.
10. Klein G, Associates K, Ara D. Naturalistic decision making. *Hum Factors*. 2008;50:456-460.
11. Kahneman D, Klein G. Conditions for intuitive expertise: a failure to disagree. *Am Psychol*. 2009;64:515-526.
12. Crandall B, Klein G, Hoffman R. *Working Minds: A Practitoner's Guide to Cognitive Task Analysis*. Cambridge, MA: MIT Press; 2006.
13. Schubert CC, Denmark TK, Crandall B, et al. Characterizing novice-expert differences in macrocognition: an exploratory study of cognitive work in the emergency department. *Ann Emerg Med*. 2013;61:96-109.
14. Ross K, Shafer J, Klein G. Professional judgments and "naturalistic decision making.". In: Ericsson KA, Charness N, Feltovich P, et al, eds. *The Cambridge Handbook of Expertise and Expert Performance*. New York, NY: Cambridge University Press; 2006:403-419.
15. Flavell JH. Metacognition and cognitive monitoring: a new area of cognitive-developmental inquiry. *Am Psychol*. 1979;34:906-911.
16. Ericsson KA. Protocol analysis and expert thought: concurrent verbalizations of thinking during experts' performance on representative tasks. In: Ericsson KA, Charness N, Feltovich P, et al, eds. *The Cambridge Handbook of Expertise and Expert Performance*. New York, NY: Cambridge University Press; 2006:223-242.
17. Pelaccia T, Tardif J, Triby E, et al. How and when do expert emergency physicians generate and evaluate diagnostic hypotheses? a qualitative study using head-mounted video cued-recall interviews. *Ann Emerg Med*. 2014;64:575-585.
18. Pelaccia T, Tardif J, Triby E, et al. From context comes expertise: how do expert emergency physicians use their know-how to make decisions? *Ann Emerg Med*. 2016;67:747-751.

19. van Gog T, Paas F, van Merriënboer JJG, et al. Uncovering the problem-solving process: cued retrospective reporting versus concurrent and retrospective reporting. *J Exp Psychol Appl*. 2005;11:237-244.
20. Gegenfurtner A, Lehtinen E, Jarodzka H, et al. Effects of eye movement modeling examples on adaptive expertise in medical image diagnosis. *Comput Educ*. 2017;113:212-225.
21. Gegenfurtner A, Kok E, van Geel K, et al. The challenges of studying visual expertise in medical image diagnosis. *Med Educ*. 2017;51:97-104.
22. Gegenfurtner A, Van Merriënboer JJG. Methodologies for studying visual expertise. *Front Learn Res*. 2017;5:1-13.
23. Kok EM, Jarodzka H. Before your very eyes: the value and limitations of eye tracking in medical education. *Med Educ*. 2017;51:114-122.
24. Szulewski A, Gegenfurtner A, Howes DW, et al. Measuring physician cognitive load: validity evidence for a physiologic and a psychometric tool. *Adv Health Sci Educ Theory Pract*. 2016;22:951-968.
25. Szulewski A, Roth N, Howes D. The use of task-evoked pupillary response as an objective measure of cognitive load in novices and trained physicians. *Acad Med*. 2015;90:981-987.
26. Szulewski A, Howes D. Combining first-person video and gaze-tracking in medical simulation: a technical feasibility study. *Sci World J*. 2014;2014:1-4.
27. Svensson L. Theoretical foundations of phenomenography. *High Educ Res Dev*. 1997;16:159-171.
28. Francis JJ, Johnston M, Robertson C, et al. What is an adequate sample size? operationalising data saturation for theory-based interview studies. *Psychol Health*. 2010;25:1229-1245.
29. Boyatzis R. *Transforming Qualitative Information: Thematic Analysis and Code Development*. Thousand Oaks, CA: SAGE Publications; 1998.
30. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006;3:77-101.
31. Creswell J. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA: SAGE Publications; 2014.
32. Johns C. *Becoming a Reflective Practitioner*. 3rd ed. San Francisco, CA: Wiley-Blackwell; 2009.
33. Gegenfurtner A, Szulewski A. Visual expertise and the quiet eye in sports—comment on Vickers. *Curr Issues Sport Sci*. 2016;1:1-4.
34. Dayal A, O'Connor DM, Qadri U, et al. Comparison of male vs female resident milestone evaluations by faculty during emergency medicine residency training. *JAMA Intern Med*. 2017;177:651-657.
35. Flin R, Maran N. Identifying and training non-technical skills for teams in acute medicine. *Qual Saf Health Care*. 2004;13(suppl 1):80-84.
36. Zupanc CM, Burgess-Limerick R, Hill A, et al. A competency framework for colonoscopy training derived from cognitive task analysis techniques and expert review. *BMC Med Educ*. 2015;15:1-11.
37. Petrosoniak A, Hicks CM. Beyond crisis resource management. *Curr Opin Anaesthesiol*. 2013;26:699-706.
38. Szulewski A, Braund H, Egan R, et al. Through the learner's lens: eye-tracking augmented debriefing in medical simulation. *J Grad Med Educ*. In press.
39. Haider H, Frensch PA, Black C, et al. The role of information reduction in skill acquisition. *Cogn Psychol*. 1996;30:304-337.
40. Haider H, Frensch P. Eye movement during skill acquisition: more evidence for the information-reduction hypothesis. *J Exp Psychol Learn Mem Cogn*. 1999;25:172-190.
41. Frank JR, Snell LS, Cate O Ten, et al. Competency-based medical education: theory to practice. *Med Teach*. 2010;32:638-645.

Future Meetings of the American College of the Emergency Physicians

The following are the planned sites and dates for the future annual meetings of the American College of Emergency Physicians:

2018	San Diego, CA	October 1-4
2019	Denver, CO	October 28-31
2020	Dallas, TX	October 26-29
2021	Boston, MA	October 25-28