Starting to Think Like an Expert

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Starting to Think Like an Expert: An Analysis of Resident Cognitive Processes During Simulation-Based Resuscitation Examinations

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Study objective: Simulation is commonly used to teach crisis resource management skills and assess them in emergency medicine residents. However, our understanding of the cognitive processes underlying crisis resource management skills is limited because these processes are difficult to assess and describe. The objective of this study is to uncover and characterize the cognitive processes underlying crisis resource management skills and to describe how these processes vary between residents according to performance in a simulation-based examination.

Methods: Twenty-two of 24 eligible emergency medicine trainees from 1 tertiary academic center completed 1 or 2 resuscitation-based examinations in the simulation laboratory. Resident performance was assessed by a blinded expert using an entrustment-based scoring tool. Participants wore eye-tracking glasses that generated first-person video that was used to augment subsequent interviews led by an emergency medicine faculty member. Interviews were audio recorded and then transcribed. An emergent thematic analysis was completed with a codebook that was developed by 4 research assistants, with subsequent analyses conducted by the lead research assistant with input from emergency medicine faculty. Themes from high- and low-performing residents were subsequently qualitatively compared.

Results: Higher-performing residents were better able to anticipate, selectively attend to relevant information, and manage cognitive demands, and took a concurrent (as opposed to linear) approach to managing the simulated patient.

Conclusion: The results provide new insights into residents' cognitive processes while managing simulated patients in an examination environment and how these processes vary with performance. More work is needed to determine how best to apply these findings to improve crisis resource management education. [Ann Emerg Med. 2019;74:647-659.]

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INTRODUCTION

The practice of emergency medicine is dependent on effective and efficient decisionmaking. The environment of the emergency department (ED), however, with its frequent interruptions, distractions, and time pressures, makes decisionmaking challenging and error prone.[1,2] Despite these challenges, emergency physicians are tasked with regularly making critical decisions that may have life-or-death consequences for patients.[3,4] Although decisionmaking itself is central to patient care, the broader scope of crisis resource management skills, including leadership, situational awareness, communication skills, and resource utilization, is integral to providing effective patient care in the ED.[5,6] This is especially true during resuscitation cases in which the physician team leader simultaneously manages the patient, the available resources, and an interdisciplinary health care team.[7,8]

Crisis resource management skills are often taught and practiced by learners in simulation contexts, where trainees can act as team leaders while both honing and demonstrating their crisis resource management skills safely.[9,10] The simulation environment provides trainees with the opportunity to develop interprofessional team skills and to critically examine behaviors that support or detract from team performance.[11] However, the extent to which medical simulation allows learners to develop the cognitive processes that underpin the crisis resource management skills required of practitioners has been insufficiently investigated.[12] Previous studies relied on post hoc

Editor's Capsule Summary

What is already known on this topic

Resuscitating critically ill patients requires emergency physicians to exercise a complex array of interconnected skill sets.

What question this study addressed

Which cognitive skills related to team management and decisionmaking in emergency clinical settings distinguish residents with differing levels of expertise?

What this study adds to our knowledge

The authors used simulated scenarios to classify crisis resource management skills of 22 Canadian emergency medicine residents of various expertise. Residents with higher performance ratings were better at anticipating, selecting information, and pursuing a nonlinear approach to directing resuscitation efforts.

How this is relevant to clinical practice

Awareness of cognitive processes involved in crisis resource management may equip educators to adopt more systematic approaches to enhancing the development of expertise among emergency medicine learners.

interviews based on physicians' memories of simulated events,[13] which degrade over time and may lack detail.

Although some elements of crisis resource management performance are observable (and therefore able to be assessed and studied with currently available tools), other elements, such as the cognitive processes that underlie crisis resource management skills, are not.[14] Our understanding of these invisible cognitive processes remains limited. One reason is that as individuals gain expertise in a domain, a greater proportion of their decisionmaking becomes tacit, which makes explaining their thought processes challenging.[15] Furthermore, because the clarity of in situ crisis resource management memories degrades over time, individuals have difficulty remembering and analyzing subsequent events. As such, it is difficult to determine whether simulated crisis resource management scenarios evoke cognitive approaches similar to those of medical crises in actual settings.

In studying trauma team leaders in real clinical settings, we have previously demonstrated that a post hoc cognitive task analysis augmented by review of first-person video generated by an eye-tracking device is a useful technique to uncover these cognitive processes.[14] In that study, expert trauma team leaders were found to demonstrate logistic awareness, manage uncertainty, strategically direct their gaze, selectively attend to information, and exhibit anticipatory behaviors while treating critically injured patients. The use of eye-tracking technology was particularly important because it allowed participants to "relive" their experience from their own perspective, emphasizing their gaze fixations and thus allowing for more complete recall of events and cognitive processes.[16,17]

To address whether simulation as a tool to develop crisis resource management skills provides value, there is a need to describe how crisis resource management–related cognitive processes are activated in trainees through simulation. Given the wide variability in trainee performance in simulations, an understanding of how these cognitive processes might differ according to performance is necessary. Subsequently examining the relationship between these simulation-derived cognitive processes and those derived in real clinical settings may provide additional evidence for the utility of simulation as an educational modality in teaching crisis resource management skills to medical trainees.

In the current study, we were interested in uncovering and describing the cognitive processes of emergency medicine trainees during simulation-based resuscitation examinations, using a qualitative approach and describing how these processes varied between participants stratified according to examination performance.

MATERIALS AND METHODS

This study received ethical approval through the institutional health sciences research ethics board. Participants gave informed consent and did not receive compensation.

Study Design and Setting

This qualitative study used a phenomenological approach in an effort to better understand residents' experiences and cognitive processes underpinning their crisis resource management behaviors as they acted as physician team leaders during simulation-based examinations. Phenomenological qualitative approaches to research seek to describe how human beings experience lived phenomena.[18] This approach was chosen because it aligned with the subsequently described cognitive task analysis and we thought it was best suited to answer this type of research question (as opposed to more traditional positivistic research methods). We used the Consolidated Criteria for Reporting Qualitative Research checklist[19] to ensure methodological rigor (Appendix E1, available online at http://www.annemergmed.com). As outlined below, quantitative performance data were used to stratify participants for subsequent analyses. All data were collected at our Clinical Simulation Centre.

Selection of Participants

All emergency medicine residents participating in their mandatory biannual simulation-based objective structured clinical examinations from our Canadian academic tertiary care teaching center were invited to participate in the study. Residents were enrolled in the Royal College of Physicians of Canada program, the College of Family Physicians of Canada–Emergency Medicine program, or the Resuscitation Fellowship program. In Canada, emergency physicians are trained in 1 of 2 streams: residents in the Royal College of Physicians of Canada program complete a 5-year residency and become emergency medicine specialists, whereas residents in the College of Family Physicians of Canada–Emergency Medicine program complete an additional year of emergency medicine training after completing a 2-year family medicine residency. Trainees in the resuscitation fellowship are senior residents or attending physicians who complete an additional year of resuscitation-focused training.

Participants were recruited in person once they arrived at their examination. All participants were familiar with the simulation laboratory and the examination format.

Protocol for Simulation Sessions

Trainees participated in 1 or 2 simulation-based examinations (according to scheduling and availability), each consisting of 2 scenarios. The first was conducted in August 2016 (chronic obstructive pulmonary disease exacerbation and gastrointestinal bleeding) and the second in February 2017 (ventricular fibrillation/ST-segment elevation myocardial infarction and hyperkalemia/bradycardia). The format of this simulation-based resuscitation examination and an accompanying validity argument for its use as an assessment process have been described elsewhere.[20,21]

In each examination, trainees managed a simulated patient while leading a team consisting of a nurse actor and a respiratory therapist actor (Figure 1). Before entering the room, trainees read a clinical vignette outlining relevant clinical context (example available in Appendix E2, available online at http://www.annemergmed.com). To increase the functional task alignment of the simulated scenarios with real clinical work and to assess residents' crisis resource management skills, realistic distractors were embedded, containing stimuli that a high performer would generally deprioritize.[22] For example, in one case, the nurse provided an irrelevant high glucose reading. In another, participants were tasked with answering a telephone call from a peripheral hospital, in which the caller was long-winded.

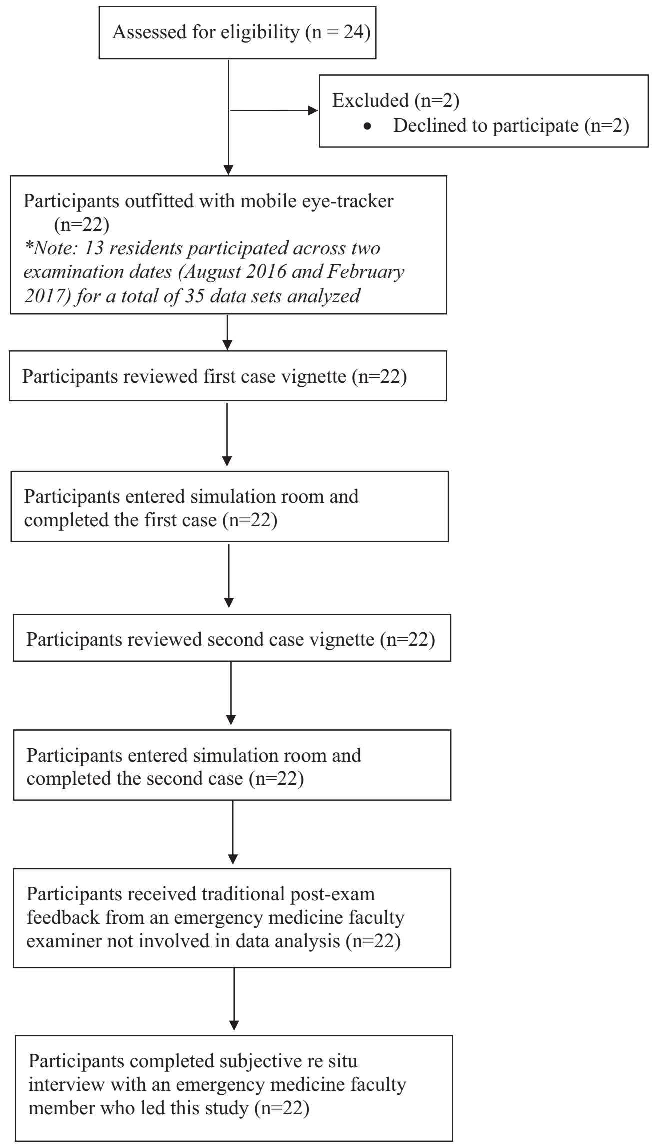

Figure 1. Overview of the study protocol.

Participants wore Tobii eye-tracking glasses (Tobii Pro Glasses 2; Tobii, Danderyd, Sweden). Output from the glasses generated a first-person video with a superimposed gaze indicator that was later used during the study interview. The own-point-of-view video generated by this tool has been shown to stimulate recall, leading to more explicit descriptions of decisionmaking resulting from improved psychological immersion of participants.[23] Figure 2 shows a screen shot of video output.

Figure 2. Screen shot of video output from the eye-tracking glasses. The white circle shown is a superimposed gaze indicator that demonstrates where the participant is looking at a particular moment.

Feedback and Cognitive Task Analysis

After case completion, trainees were given the usual postexamination feedback on their performance by an attending emergency medicine examiner (known to the participants) for 10 to 15 minutes. This feedback consisted of discussing the trainees' strengths, as well as constructive feedback related to decisionmaking, teamwork, and communication. After this traditional feedback session, residents completed an additional 30-minute individual debriefing session (the focus of this study). During this session, another emergency physician (A.S.) guided residents through a cognitive-task analysis using a subjective re-situ interview protocol,[23] in which residents viewed their first-person video performance, starting when they began to read the first clinical vignette. A.S. had previous experience with this type of interviewing technique. The video was played and then paused intermittently by the interviewer at critical junctures and resident actions (at the interviewer's discretion), as well as during the introduction of each distractor. Although the timing of the video clips differed between participants according to their actions, the segments viewed were generally similar across participants. During video replay, residents were asked to describe their thinking and to verbalize their thoughts, including decisionmaking priorities, motivations, and choices. To encourage discussion through retrospective verbalization and probing techniques, prompts such as "Describe your thinking" and "Walk me through your thoughts here" were used. These interviews were audio recorded and transcribed verbatim. In total, 35 interviews were generated (note: 13 of the 22 participants completed examinations and debriefing during both periods). Residents' reflections on the utility of this session are described elsewhere.[24]

PRIMARY DATA ANALYSIS

Quantitative Analysis

Each resident's performance was recorded with a ceiling-mounted system (Kb Port, Allison Park, PA) and was then scored by an external blinded expert reviewer with no knowledge of the trainees, their training level, or the purpose of the study. The blinded external rater used an entrustment-based[25] scoring tool, termed the Resuscitation Assessment Tool[26] (Appendix E3, available online at http://www.annemergmed.com), which was developed as a modification of the previously derived Queen's Simulation Assessment Tool, which has validity evidence in a similar context. Strictly speaking, the Resuscitation Assessment Tool itself has not been directly validated, but it was deemed to be more contextually appropriate, given its widespread use in resuscitation assessment in the emergency medicine residency program at our institution. The expert assessor received an orientation training session that involved rating a standardized sample of training video recordings of various levels of performance, using the Resuscitation Assessment Tool, and then reviewed them with one of the investigators (A.K.H.) until consensus scoring was achieved. Some of the Resuscitation Assessment Tool scores obtained during this study were subsequently used as part of a larger data set for an unrelated study.[26]

An average performance score was calculated for each participant, using their entrustment scores from the external blinded reviewer. We considered emergency medicine residents with average scores on the Resuscitation Assessment Tool of greater than or equal to 3.0 (corresponding to "indirect supervision" or better on the entrustment scale) the high performers and those receiving scores lower than 3.0 the low performers. This division was used in the subsequently described qualitative analysis, and themes were compared between these 2 groups.

Qualitative Analysis

Data analysis was conducted by nonphysician team members who were at arm's length from the participants; the researchers had no knowledge of participants' performance scores or level of training. These researchers met regularly with the physician researchers to discuss data interpretation. All interviews were transcribed verbatim. ATLAS ti software (version 1.0.5.0; Scientific Software Development GmbH, Berlin, Germany) was used to generate the codebook, code each transcript, categorize the codes, track memos, and generate a file report detailing all codes used with quotations. As part of the coding process, 4 researchers generated the initial codebook by coding 4 interviews independently and comparing their codes.

Intercoder agreement was found when codes were the same (95% of the coded quotations across 4 interviews). The 95% level of agreement represents complete agreement across researchers, in which the codes had the same meaning. For the other 5%, researchers discussed the coded quotations and made changes once agreement was reached. The consensus-built codebook was used for all remaining qualitative analyses. After the intercoder reliability check, one researcher analyzed the remaining qualitative debriefings through a phenomenological lens (focusing on understanding participants' experiences) and maintained a critical stance by making journal entries regularly and making notes about underlying assumptions. (All of the researchers involved in the initial coding process made journal entries during preliminary coding, but 3 were not involved in the remaining analyses because they were engaged only to provide a critical external perspective and check intercoder reliability.) Although data saturation occurred after analysis of 25 interviews, all 35 interviews were analyzed.

Interviews were coded with a thematic and emergent technique[27] through a descriptive phenomenological lens.[28,29] On completion of the first 3 transcripts, emergency medicine team members discussed the themes and provided interpretation. The smallest unit of analysis was the code. Codes were grouped to form categories; multiple categories were combined, forming broader themes. Language used by participants was maintained throughout coding to ensure that the interpretations were representative of participants' thoughts.

After emergent analysis, axial coding was used to find transactional themes across transcripts.[30,31] We also conducted structured coding for anticipatory behavior. To provide temporal context, the transcripts were divided into 3 stages: orientation, diagnostic, and therapeutic. Although grouped separately, these stages were not expected nor found to be chronologically sequential, and the iterative nature of these activities was respected. Peer debriefing was conducted with emergency medicine researchers who had not been involved in the analyses. These sessions were used to ensure that interpretations of the data were representative and appropriate.

Research Team and Reflexivity

The lead clinician-researcher (A.S.) conducted the interviews. He is a full-time faculty member in emergency medicine, is fellowship trained in resuscitation medicine, and is a PhD student in health professions education. All study participants were known to A.S. and had previous experience working with him in a clinical context. H.B. led the data analysis. She is a PhD student in education, with background in assessment and cognition, as well as experience in qualitative emergency medicine research. She had no personal experience with any of the study participants. The remaining researchers on the team had backgrounds in emergency medicine, simulation, and education.

RESULTS

Characteristics of Study Subjects

Twenty-two of 24 eligible residents opted to participate in the study. Of the 22 residents, 10 were men and 12 were women. Thirteen were FRCPC residents, 7 were College of Family Physicians of Canada–Emergency Medicine residents, and 2 were resuscitation fellows. Thirteen residents participated across the 2 examination dates.

Quantitative Findings

In total, 11 residents were categorized as high performers (mean Resuscitation Assessment Tool score $\geq$3.0) and 11 were categorized as low performers (mean Resuscitation Assessment Tool score $<$3.0). Resident performance (high or low) was an average across examinations. For the 11 low performers, the average entrustment score out of 5 ranged from 1.50 to 2.63. For the 11 high performers, the average entrustment score ranged from 3.00 to 4.50. Our reliability analysis indicated acceptable internal consistency, with a Cronbach's α=.730.

Qualitative Findings

Results were organized according to the 4 emergent themes (Figure 3). The Table provides a summary of the codes with examples. In the representative quotations below, *P* represents participant, *H* indicates a high performer, and *L* indicates a low performer. For additional quotations in relation to each theme, refer to Appendix E4 (available online at http://www.annemergmed.com).

Anticipatory Behaviours

Anticipating potential problems and planning accordingly are key tasks in resuscitating a patient. Generally, high-performing residents were more strategic, considering multiple steps ahead of their current task. For example, one resident (P1H) stated, "So I'm anticipating for his melena stools and decreased [level of consciousness] that potentially he's bled out so much that he's quite hypovolemic and not perfusing his brain well. So in anticipation of potentially needing a massive transfusion, fluids, etc, I want the best access on him I can with getting

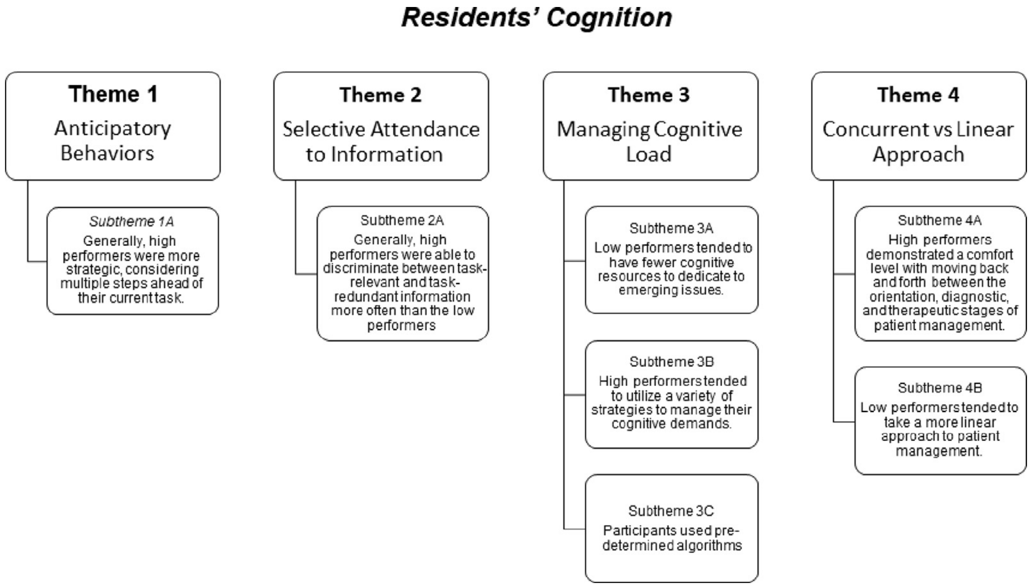

Figure 3. Summary of themes and subthemes derived.

a central [intravenous] line." A low-performing resident described another example of anticipation: "Even though it was [pulseless electrical activity] arrest…we're going down the route of asking for the epi[nephrine]. But then, just wanting to have pads in case it—anything changed" (P4L). Anticipatory behaviors were observed across high- and low-performing residents but were noted more often in high performers, as determined through coding frequencies.

Selective Attendance to Information

The ability to prioritize relevant stimuli while appropriately deprioritizing less relevant stimuli is an essential skill during resuscitation cases. Generally, high performers were able to discriminate between task-relevant and task-redundant information more often than the low performers, according to coding frequencies. More specifically, when participants were given distractors (task-redundant information), some struggled with prioritizing their therapeutic actions, whereas others appropriately disregarded the nonessential information. An example of appropriate attendance to relevant stimuli was demonstrated by a high-performing resident when she was told about a high glucose level: "I'm more concerned about his airway at this point and getting interventions that way" (P17H). Similarly, another high-performing resident (P8H) quickly dismissed the incidental hyperglycemia distractor: "Weird. But, like, nothing that I needed to deal with imminently, so I was kind of like, 'I'll just store this in the back."

Another high-performing participant described how she was simultaneously orienting herself and considering diagnostic possibilities: "So I was listening, looking at what was happening.… I heard what I needed to hear in the first 5 seconds; I didn't need him to talk any further, but [the paramedic] was giving me all of the details, and in my head, I already said, 'Okay, this is probably [myocardial infarction]'" (P12H).

In contrast, there were instances in which the distractors caused residents to fixate. For example, a low-performing resident (P18L) stated, "…But then I got a bit distracted by the ECG and the bundle branch block and I thought maybe there was an anterior [myocardial infarction]."

Residents of all experience levels demonstrated the ability to selectively attend to information. However, the extent to which these behaviors were demonstrated tended to vary across residents, with higher performers exhibiting these behaviors more often.

Managing Cognitive Demands

Inherent to expert resuscitation is the ability to balance cognitive processing with the emergent needs of patients, family members, and team members. A lower-performing resident summed up this struggle by describing the "…demand in terms of mental resources, and [that] it can be sort of difficult to organize and compartmentalize that when there's a lot of stuff flying up in the air and a lot of decisions; then it's hard to prioritize them, I think" (P11L). In contrast, a high-performing resident described his experience with managing cognitive demands: "Yeah, so I can delegate the roles better because I shouldn't, like, I don't [want to] task myself with drawing up medications and inserting IVs [intravenous lines] [be]cause of the cognitive load, and [performing] CPR [cardiopulmonary resuscitation] just seems like a terrible idea" (P1H).

Overall, we found that low-performing residents tended to focus on remembering algorithms associated with a given disease state, resulting in potentially fewer cognitive resources to dedicate to emerging issues. For example, a low-performing resident stated, "I want her on the monitors. I mean I'm also thinking I don't really know; it's not a huge deal I'm doing compressions right now [be] cause it's a pretty simple point of the algorithm right now" (P15L).

Linear versus Concurrent Approach

Although all residents moved through the orientation (initial information gathering and actions on entering the room), diagnostic, and therapeutic stages, low-performing residents demonstrated a linear approach, whereas high-performing residents demonstrated a concurrent approach to patient management. The concurrent approach allowed high-performing residents to initiate treatments early while gathering information.

An example of the linear approach was described by a low-performing trainee: "Yeah, so I ended getting type and cross with all of my blood work because I knew that the patient needed blood. But then in my head I was waiting for those results to come back before I gave blood and completely [forgot to give] him O positive or O negative in the meantime" (P2L). This resident approached the decision of when to transfuse according to the result of a blood test instead of ordering the test and simultaneously starting the transfusion with universal donor blood.

Another resident (P12H) stated, "This could still just be a calcium channel or β-blocker [overdose], and then I was thinking, either way, calcium is not dangerous. And I should've just given it empirically before I got any blood work back…but as I was thinking that, I had already ordered a few things and [was] going down my bradycardia algorithm. The way you learn it is atropine, pace, and then think about other things. And so I think this is me trying to step out of the algorithm but going back to the algorithm anyways." In reflecting on the case, this resident recognized the limitations of a linear approach.

Other high-performing residents demonstrated comfort moving between the stages of patient management. "And here I've decided…that it's an unstable bradycardia. Blood pressure was awful; he's quite brady[cardic], [with an] altered [level of consciousness]. Um, normal glucose. I didn't have further information at this point to suggest that it was something else, so if not, then to improve this gentleman's hemodynamics, I should just pace him" (P13H).

LIMITATIONS

This study has several limitations. Participants were grouped according to performance at one instant. We did not longitudinally follow trainees to determine how their cognitive processes evolved over time. As a result, we are unable to discuss how cognitive processes evolve at the individual physician level. Another limitation is that only one rater was used to score participants' performance with the Resuscitation Assessment Tool. This being said, the Queen's Simulation Assessment Tool (on which the Resuscitation Assessment Tool is based) has been shown to have an acceptable interrater reliability in the same simulation-based objective structured clinical examination context,[21,32] which suggests that using multiple raters would likely have produced similar results.

The traditional debriefing session (that preceded the study interview) was not standardized, and it is possible that this session influenced participants' responses in the subsequent interview. Participants' responses in the interview may also have been biased by the Hawthorne effect, by their relationship with the interviewer, or both. In addition, our previous research into the cognitive processes of physicians, as well as our background in educational psychology, likely colored our qualitative analysis, which was meant to be emergent. As a result, we may have had more difficulty recognizing themes alternate to what we were expecting to find. Despite this unavoidable bias, which should have made our data converge on these biases, we found differences between the cognitive processes of high- and low-performing participants. We believe that this adds to the credibility of our findings.

DISCUSSION

In this study, we found that the cognitive processes of high-performing trainees differed from those of low-performing trainees in a simulated resuscitation-based examination. High performers described more effective anticipatory behaviors, an improved ability to selectively attend to information, the ability to better manage their cognitive load, and they exhibited a more concurrent (rather than linear) cognitive approach to patient management compared with low-performing trainees.

These findings provide insight into the cognitive processes that underpin crisis resource management skills within a simulated resuscitation context. Deriving these elements from within this context (as opposed to borrowing crisis resource management principles from

Table. Summary of themes, subthemes, categories, codes, and example quotes.

Themes and Subthemes	Example Categories	Example Codes	Low Performers	High Performers
Theme 1: Anticipatory behaviors Subtheme 1A: Generally, high performers were more strategic, considering multiple steps ahead of their current task.	Strategic	(Anticipatory behavior, advanced) (Anticipating need for pacing) (Anticipatory behavior, moderate) (Anticipatory behavior, strong) (Need for intubation) (Anticipatory behavior, weak)	"So there I was, just thinking to myself, 'You know, this is a guy who is altered and is possibly going to need intubation.'" (P6, ES=2.63, hyperkalemia/bradycardia case)	"…I'm thinking ahead of the game. I'm, like, this guy looks really sick, he's got COPD, he's old. This guy may not bounce back just with supportive care, so I need to know if we're going to go all the way through to intubation or not. So I have that kind of in the back of my head: which direction I'll be taking him if he continues to get sick." (P1, ES=3.25, COPD case) "…[He's] losing level of consciousness, [and] then he's not protecting his airway, so I decide that it's time to actually make more full preparations. I probably should've right at the start said, 'Can we have ketamine and succinylcholine or rocuronium ready just in case we're going that way?'" (P3, ES=3.00, COPD case)
Theme 2: Selective attendance to information Subtheme 2A: Generally, high performers were able to discriminate between task-relevant and task-redundant information more often than the low performers.	Ignored distractors	(Information reduction) (Critical venous oxygen saturation) (Distractor) (Avoided fixation) (EMS long history) (Distractor) (Cut off) (Nephrology telephone call) (Distractor) (Avoided fixation) (Telephone call, avoided)	"I just tucked that away in my head: if we had to intubate him, just be careful with using succinylcholine." (P14, ES=2.50, hyperkalemia/bradycardia case)	"Oh, she told me the glucose, and I was, like, that's not important. So fleetingly looked at her…[laugh]." (P12, ES=3.50, COPD case) "So [the nurse] had a phone call that she was trying to get my attention for. There was a physician from Perth that wanted to have a conversation with me. Going through my mind at the moment, it was the most critical part of the resuscitation, with me literally just about to have a look and having him fully ketaminized, so I shut it down pretty quickly." (P19, ES=4.50, COPD case)
	Fixated on distractors	(Scenario distractions, fixated) (Acetylcholinesterase) (Fixated) (Confused with other deficiencies) (ECG, fixated) (Left bundle branch block, fixated)	"So the certain things, certain decisions that I made that I think were based on things that I got distracted by… [I was distracted] [b]y things that came up as the situation unfolded that maybe led me astray a little bit. And I think a lot of that is reflective to my level of training and not being comfortable to let things go as they come up and maybe overprocessing it. Like the ECG and the glucose at one point." (P2, ES=1.75, COPD and GI bleeding)	"Yeah. Right. So this was the point where I was trying to decide that, that's tachycardic, is he going, do I think it's actually just sinus tachy[cardia]…. [I]t looks like he's going too fast, so then I started to get a bit confused. Is this actually just a narrow complex tachycardia, is it a flutter, is it a fib[rillation]?" (P3, ES=3.00, COPD case) In regard to the acetylcholinesterase deficiency distractor: "I spent a little bit of mental energy trying to think of things that that could have meant. And it was, like, 'Okay, can't give him [succinylcholine]. Could this in some way cause hyperkalemia?' And [I] couldn't come up with anything." (P5, ES=3.25, hyperkalemia/bradycardia case)

Table. Continued.

Themes and Subthemes	Example Categories	Example Codes	Low Performers	High Performers
			"I wasn't sure if I was supposed to manage this person on the phone; then I quickly realized he was telling me that a somewhat stable patient needs a [computed tomography scan]. And I probably could have got there quicker and said I can't deal with this right now." (P9, ES=2.25, COPD case)	
Theme 3: Managing cognitive load Subtheme 3A: Low performers tended to have fewer cognitive resources to dedicate to emerging issues.	Overloaded	(Experiencing cognitive load) (Diagnostic stage) (B lines) (Overloaded) (Therapeutic actions) (Overloaded) (Delayed management)	"…I guess it's large cognitive load. And in your thinking about things, I mean, your ABC is the thing, the immediate. It's very distracting and glamorous to be thinking about CPR, right, and about the resuscitation, and thinking about the underlying cause, especially when you know that the underlying cause is hypovolemia, and you've begun treating it. It can be sort of easy to focus on getting circulation back because what does it matter if there's blood coming out if the heart isn't pumping?" (P11, ES=2.00, GI bleeding case)	"And I think I was just thinking about that so much that I…stopped at ordering the hemoglobin, and didn't think about all the other things…. I was so stuck. I definitely got cognitively stuck on the hemoglobin and whether…I was trying to decide resuscitation vs GI bleed treatment…. And so I think I felt disorganized on this one…." (P3, ES=3.00, GI bleeding case)
Subtheme 3B: High performers tended to use a variety of strategies to manage their cognitive demands.	Cognitive flexibility	(Managing cognitive load) (Cognitive reminder)		"That proved a bit difficult in my mind, though. Kind of figured out, I gave up after a while what I can get [the nurse] to do, [be]cause that was taking too much of my cognitive load." (P19, ES=4.50, COPD case) "Kind of helps me talk to the team and where we're going and gives me a bit of time to think through where my next steps are…as we're getting ready for these steps." (P12, ES=3.50, ventricular fibrillation/STEMI case)

Table. Continued.

Themes and Subthemes	Example Categories	Example Codes	Low Performers	High Performers
Subtheme 3C: Participants used predetermined algorithms.	Cognitive resources	(Therapeutic stage) (Following predetermined algorithm) (Algorithms, cognitive demands) (Algorithms, forgot) (Considering algorithm) (Algorithm) (Predetermined) (Did not follow through)		"…I have my predetermined or pre-thought-out algorithm, so, okay, this is what COPD is; then I go on to my COPD box that I've learned in medical school and then… This is what I [want to] do, and I'm afraid that if I don't do it, then [I'm going to] lose it. So I [want to] get it out, start that treatment, and then reassess, and then I have time to think about things. I think it [kind of] has to do with this cognitive load. Once that's done, then I can offload that information that I'm storing that's still in pieces instead of [in] an easy-to-access box." (P12, ES=3.50, COPD case)
Theme 4: Linear vs concurrent approach Subtheme 4A: High performers demonstrated a comfort level with moving back and forth between the orientation, diagnostic, and therapeutic stages of patient management.	Management approach	(Patient management) (Concurrent) (Move out of stepwise approach)		"So [is the patient] sick or not sick?… When I walk in the room, [I'm] looking at the patient first, is he awake? Is he opening his eyes, [is he] talking? [I'm checking to see] what they had already done for me. So [I'm] planning what I need to ask for immediately...and then I noticed that he was sick but not needing, you know, chest compressions or any immediate intervention" (P19H, ES=4.50, GI bleeding) "He's hypotensive. Yeah. And here I'm just trying to assess, like, neurologically what just happened." (P17, ES=4.00, hyperkalemia/bradycardia case)
Subtheme 4B: Low performers tended to take a more linear approach to patient management.		(Patient management) (Linear) (Treatment management) (Linear approach) (Therapeutic stage) (Stepwise approach)	"I've never actually paced anyone in real life, so maybe I'm a bit hesitant to go that route…. I think early med[ical] school is always like, 'Did you give any pain meds before you paced him?' Oh, my God, he's [going to] die! Pace him. So I think I'm still, you know, maybe a little hesitant on pacing." (P15, ES=2.38, hyperkalemia/bradycardia case)	

P, Participant; *COPD*, chronic obstructive pulmonary disease; *EMS*, emergency medical services; *GI*, gastrointestinal; *STEMI*, ST-segment elevation myocardial infarction.

other fields, such as aviation) may give medical educators a more authentic view into the way that medical simulation challenges trainees to think during a crisis.

The first derived theme was that of anticipatory behaviors. The ability to anticipate and plan for contingencies is a key skill in managing a medically complicated patient requiring resuscitation.[33] By considering multiple steps ahead and planning for potential failures, high-performing trainees in this study consistently described this ability. As expected, low performers generally described less elaborate contingency plans. In both the simulated and clinical context, it is usually clear when a trainee exhibits inadequate anticipation and his or her plan does not progress as expected. What is less clear to an outside observer is when the case progresses as the trainee expected and a lack of appropriate anticipation does not become apparent. The ability to delve into the thought processes of trainees as was done in this study may allow educators to better assess and teach these otherwise critical (but hidden) cognitive processes.

A second theme that was identified was selective attendance to information, which refers to the ability of physicians to filter the innumerable stimuli of a resuscitation case and focus their attention on what is relevant while appropriately deprioritizing what is not. This phenomenon has been previously termed the *information reduction hypothesis*.[34] An improved ability to reduce extraneous information and focus on the most relevant environmental cues has been correlated with examination performance in another simulation-based study.[22]

The third theme revolved around managing cognitive load. In a resuscitation case, appropriately dealing with cognitive demands is an important skill, given the demands and pressures imposed on the team leader by these types of cases.[1] In this study, high performers were more aware of their cognitive load and used a variety of strategies to manage cognitive demands, including capitalizing on shared mental models, using algorithms, and delegating tasks to others.

Finally, higher performers in this study described a concurrent (as opposed to linear) approach to patient management. A traditional linear approach (typically taught to medical students) consists of performing a history and physical examination, ordering and analyzing tests, generating a diagnosis, and then initiating a treatment plan. This contrasts with the approach of simultaneous diagnostic and therapeutic actions that is characteristic of actual patient care in the ED.[35]

We hypothesize that the identified cognitive skills relate in different ways to the management of cognitive load that is observed with expertise development. With experience, learners gain the ability to create and automate new mental schemas.[36] This results in cognitive efficiency, effectively increasing available cognitive capacity, leading to better cognitive management: the ability to anticipate, use a concurrent approach, and selectively attend to information.

Several parallels can be drawn between these results and those of a previous study conducted by our research team that focused on describing the cognitive processes underpinning crisis resource management skills by expert trauma team leaders while leading real trauma resuscitations. Comparing the results of these 2 studies is informative. Two of the themes derived in the current study (selective attendance to information and anticipatory behaviors) also emerged in the trauma team leader study.[14] In addition, the theme of managing cognitive demands found in the current study aligns with the cognitive load subtheme of that article. These 3 parallel themes were more developed in the high-performing group in the current study, which is consistent with expertise development theory.[37] According to the information that this study provides, it appears that the cognitive processes that underpin actual crisis resource management skills develop and become more expertlike as residents' performance improves in the simulation laboratory. The parallels between the cognitive processes observed in residents in the simulated test setting and those of expert trauma team leaders in a real clinical setting[14] suggest that, to some degree, simulation provides the learning environment necessary for trainees to immerse themselves in resuscitation, which should positively affect their education.[12,38]

It is also important to discuss the differences between the themes derived here and those derived in real clinical settings. In real clinical settings, the transition to a concurrent patient management strategy was not observed,[14] most likely because expert trauma team leaders have developed an expert blind spot: they are so removed from the traditionally taught linear approach to patient management that they may be unaware that they have abandoned it.[39] Related to this idea is the concept of unconscious competence in the context of expertise development, in which task performance becomes second nature for experienced practioners.[40] Furthermore, the themes of logistic awareness and visual gaze behaviors were also absent in the current study, which is most likely related to differences between simulated and actual contexts. The awareness of time and prioritization of real-world tasks characteristic of logistic awareness, as well as visualization and recognition of individuals and equipment that constitute directed visual gaze, are artificial in a simulated environment, in which delays do not exist and equipment and personnel are predictably available and reliable.

This discrepancy is worthy of further analysis. If the goal of resuscitation-based simulation examinations is to assess learners' abilities to perform the tasks required in real clinical practice, then as simulation educators we should aim to create scenarios that incorporate realistic time constraints and delays that better simulate the messiness of the real world. Doing so has the potential to further improve the functional task alignment of simulation.

Additional attention should focus on the process of debriefing learners after both simulated and actual experiences. Cheng et al[41] recently summarized educational strategies to improve resuscitation outcomes. A key approach that was identified was focusing on learner debriefing after resuscitation. The method of debriefing used in the current study serves as one novel example of how this can be implemented successfully.

By providing insight into the cognitive processes of residents managing simulated patients during examinations, this study supports the current practice of using simulation in residency training. At the same time, the study suggests that simulation training offers an imperfect representation of the messiness of the real clinical environment. Future studies are needed to test whether as educators we can improve simulation teaching and assessment to better prepare and arm our learners with the crisis resource management skills required for actual practice.

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