The Role of Leadership in Medical Trainee Team-Regulation Dynamics in Crisis Resource Management Simulation Education

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Abstract

Medical simulation education allows trainees to work together in teams, and to practice assuming the roles of leader and followers, while completing real-world scenarios designed to develop the skills needed to be effective in clinical practice. Despite the importance of residents developing leadership skills to optimize performance and patient outcomes, gaps exist in our understanding of how leadership affects teamwork dynamics, and how leadership skills are observed during crisis resource management (CRM) medical simulation training. Research often frames medical education training from the perspective of self-regulated learning (SRL) and socially shared regulated learning (SSRL) framework, but there is a need to use theory-guided approaches to how SRL and SSRL can be used to teach leadership skills. This study explored how the SRL and SSRL strategies employed by leaders influence teams during CRM medical simulation education scenarios.

Eight second-year Internal Medicine residents were observed as they engaged in two CRM simulations within a high-fidelity medical education simulation environment. The research team observed behaviors, SRL and SSRL strategies, and the leadership and communication skills of the leaders. Behavioral and regulatory coding using the SRL/SSRL group regulation perspective showed that more successful CRM leaders made more frequent use of communication, organizational, and group regulation strategies and were thus able to utilize the assets of their team more effectively than leaders who used these skills less frequently. SRL and SSRL are under-examined frameworks in medical and simulation education. Our current case-based analyses illustrate that these frameworks can provide a valuable lens to examine and better understand team behaviours in these contexts. Future work will continue to explore the educational applications of SRL/SSRL group regulatory strategies can improve CRM leadership.

Keywords: medical education, simulation training, leadership, self-regulated learning, socially-shared regulated learning

Introduction

Crisis Resource Management in Medical Education

Crisis Resource Management (CRM) is a core set of skills and behaviors that can be applied to a variety of crisis environments, including air safety, emergency response, and medicine. Core CRM skills include leadership, communication, problem-solving, resource utilization, and situational awareness (Burke et al., 2006; Carne et al., 2012a; Fernandez Castelao et al., 2013; Marsch et al., 2004). The goal of CRM skills within a medical setting are to foster effective communication between leaders and subordinates, facilitating the prompt identification and resolution of complications before they escalate to a level that could adversely impact the patient outcome. CRM has a long and established relationship within medical simulation training (Carne et al., 2012b; Reznek et al., 2003) and is incorporated into simulation-based learning with the aim of ensuring that medical trainees develop these skills (Lai et al., 2016) in a safe and supported environment (Brydges et al., 2015; Teis et al., 2017). Different kinds of simulators can be employed across different stages of medical training, including mannequins, tissue models, computer and virtual reality-based simulations, and standardized patients. The use of simulation-training has emerged as a critical mode of instruction and is an accepted part of training, assessment, and research in all levels of medical education from novice to experienced board-certified physicians (Cooper & Taqueti, 2008; McGaghie et al., 2010).

CRM training scenarios typically cover a variety of different problems where the participants must work through initial diagnoses and have enough situational awareness to continually collect and assess information (Burden, 2020). Simulations allow these core principles and guiding criteria of CRM to be taught and practiced in a dynamic environment to help medical trainees connect these principles to practice. The goal of these CRM simulations is to prepare participants to handle the inter and intra-personal challenges brought on by cognitively demanding circumstances that surround delivering effective medical care. Recent literature supports the use of simulation learning environments to increase trainees' ability to select and employ CRM skills (Alegret et al., 2023; Lucas et al., 2020). Moreover, the inherent cognitive stressors of patient deterioration, the uncertainty of group dynamics, and the opportunity to experience the stresses of leadership and decision-making, challenge medical trainees in a way that no other CRM learning can(Ellington & Farrukh, 2020). CRM simulations train medical learners to be team leaders and team members. Medical trainees must understand the importance of effective leadership and effective followership to optimize patient outcomes, as both roles require complementary skills.

These medical learners and future clinicians are called to act in both roles throughout their careers, so developing these lifelong skills to be a good leader and a good team member are critical to their role as medical professionals. As leaders, medical trainees learn how to manage the delivery of safe and timely care while maintaining group cohesion and situational control, and to ensure that tasks do not devolve under the emotional weight of potentially split-second decisions (Fernandez Castelao et al., 2013). To succeed, leaders must organize team members and effectively manage their deployment (Gabel, 2014) throughout the course of patient care. Research into team regulation in medical simulations has suggested that medical trainees understand the value of leadership in order to manage a team, but many trainees are unsure how this regulation occurs (Bransen, Govaerts, Panadero, et al., 2022; Bransen, Govaerts, Sluijsmans, et al., 2022) beyond the need to bring self-regulatory skills to work within a group. This management has also been described as involving a distinct movement from the individual concerns of the leader, towards a clearly communicated vision of shared goals amongst a whole team(Saeed et al., 2024).

Research has suggested that CRM training positively effects leaders' ability to communicate and understand how to effectively share mental models and communication with team members (Parsons et al., 2018).The criteria for good teamwork, such as the "Big Five" teamwork traits by Salas (Salas et al., 2005), include leadership, mutual performance monitoring, backup behaviors, adaptability, and team orientation, are the types of attitudes that need to be practiced and internalized by all leaders and team members in order to effectively manage patient care. All these strategies require group regulation and the active involvement of the leader to encourage these traits so that their team performs at its peak. These strategies, when employed effectively, can help to build strong communities of inquiry (Garrison et al., 1999) that can help to guide effective teamwork and develop a team's sense of cooperation as they accomplish tasks. By examining how medical trainees regulate themselves while leading CRM scenarios, we can also better understand how their strategies and behaviors influence the performance of their team.

This research in CRM medicine, examining teamwork and leadership, has traditionally relied on self-reported leadership evaluations (Hicks et al., 2008) and reports of team members in order to ascertain the quality of learning that has occurred in simulations. The challenge of assessing this comes from the difficulties in 'breaking' the continuity of simulations to assess learners' performance which may been interpreted as a "simulation artifact" which could move the learners' attention away from their task. This need to expand how CRM skills are taught has been echoed in literature detailing the field's continual move towards new and novel methods to understand how

leadership and skills development are framed in research and lab-based practice (Lucas & Edwards, 2017). This study chose to diverge from this practice, instead focusing on the use of post-simulation scoring of behavioral observations and interactions to describe the types of SRL and SSRL interactions that were occurring throughout a CRM medical simulation.

The Need for Regulation Within Medical Education

In both medical simulations and real-world clinical rotations, medical trainees often struggle to regulate their learning because of the unpredictable, dynamic, and challenging nature of their work (Bransen et al., 2020). Simulations align with themes of adult learning theory, which presupposes that adult learners are self-directed and goal oriented, and that they expect to be instructed in a timely and efficient manner (Sinz, 2005). Simulations create an environment of experiential learning where learners can engage in deliberate practice to learn and ultimately master technical and nontechnical skills. For adult learners to extract the maximum learning potential from these simulations, they must employ self-regulated learning (SRL) strategies. SRL is defined as the process wherein individuals manage their learning through preparatory planning, performance, and appraisal of their work (Jansen et al., 2019; Zimmerman, 2002). Effective SRL requires setting goals, metacognitively monitoring performance, and self-reflecting on that performance to remain motivated to continue learning. Regulation can occur within an individual at the behavioral (Kazemitabar et al., 2019), affective (Ben-Eliyahu & Linnenbrink-Garcia, 2013; Li et al., 2021), cognitive (Lajoie et al., 2021), and motivational (Efklides, 2019; Järvenoja et al., 2018) levels and plays a critical role in a learner being able to further their own learning. Once individuals can bring regulatory skills together, team members can merge their needs with that of the group to work as a team (Hadwin et al., 2018). Socially shared regulated learning (SSRL) describes how learners in a team regulate their learning together (Hadwin & Oshige, 2011; Jarvela & Hadwin, 2013), requiring individuals to negotiate personal interests, contextual factors and teamwork dynamics. SSRL focuses on the processes that lead team members to share the regulation of their collective learning activity, directed toward achieving their goals in CRM, in which a premium is put on the management of intra-personal demands of medical practice, and the need to manage the regulation of a team (Hadwin & Oshige, 2011). The need for SRL as a part of adult learning, and the demanding and dynamic nature of medical practice underscore the need for medical learners to employ SRL and SSRL as a central part of instruction, and a valid lens from which one can examine the value of medical simulations (Burden, 2020; Sinz, 2005). Medical practice, like any collaborative learning activity, involves engagement that can be momentary and dynamic, in

which coregulatory interactions may occur within episodes of SSRL and SRL (Bransen, Govaerts, Panadero, et al., 2022). Thus, learners may concurrently engage in different forms of regulation that may run in tandem during collaborative situations.

Studies examining the self-regulation skills of medical trainees have suggested that, without a foundational grasp of self-regulation, group regulation becomes difficult in medical situations (Bransen, Govaerts, Sluijsmans, et al., 2022; Goldowsky & Rencic, 2022; Tanimura et al., 2023). This lack of personal command over learning can have detrimental effects on the cohesion and effectiveness of a team once the stresses of team dynamics are present. Research into regulation amongst medical trainees, including studies by Bransen et al., (Bransen, Govaerts, Panadero, et al., 2022) have described how the application of self-regulation training to medical residents can be used to facilitate group regulation which can lead to improved performance outcomes (Greenberg et al., 2023; Innocenti et al., 2016). Indeed, studies in surgical education (Johnson et al., 2019; Turan & Konan, 2012), general practice (Sagasser et al., 2015), and pre-clinical training (Versteeg et al., 2021) have suggested that a focus on SRL helps to make medical students and residents more aware of their own thinking and how they can best help their own learning. In turn, a SRL approach can influence how medical trainees respond to situations involving patient care, and how they learn to act as team members. SRL research is too often examined from the perspective of medical trainee performance and self-report data (Bransen & Govaerts, 2020; Gandomkar et al., 2020), with more literature needed to focus on observable behaviors that are shown by medical trainees. In addition to these gaps, existing literature describing SRL and SSRL skills in medicine, much of the focus has been limited to examining SRL in clinical, residency training (Artino et al., 2014; Gandomkar et al., 2016), and there has been far less documentation of how SRL and SSRL can be used to describe CRM training in postgraduate medical simulation training.

Simulation scenarios have several benefits to medical trainees. Team-based sessions give medical trainees the opportunity to improve their technical skills and acquire the knowledgebase needed to deliver patient care. In addition to the clinical skills needed to be a board-certified practitioner, simulations also provide trainees with an opportunity to hone their interpersonal skills, such as teamwork, communication, leadership and SRL (Brydges et al., 2010; Brydges et al., 2015) through self-reflection activities and feedback from facilitators. These skills are critical in laying the foundation for trainees' lifelong learning in the medical professions, and for developing the skills they will need to succeed in their careers. These opportunities to develop critical skills through feedback help

trainees to refine the skills needed for the interpersonal and group-level regulation (Panadero et al., 2019) required to operate in fast-paced, high-stakes medical environments.

Research Objectives

We aimed to study the role of leadership and how leaders affect the SRL and SSRL strategies of a medical team during CRM simulations. Specifically, we identified and coded "key moments of leadership" in situations requiring critical decision-making from a leader, focusing on how observable behaviors and regulation strategies were employed at critical moments in the simulation. The following research question guided our inquiry:

- (1a) Which SRL, SSRL, and behavioral strategies do leaders demonstrate during variable team-based performances in CRM simulation scenarios? and
- (1b) Are leaders' SRL, SSRL, and behavioral strategies associated with their objective performance scores?

Materials and Methods

Research Methodology

Case study methodology (Creswell, 2014) was used to explore how behaviors, SRL and SSRL were exhibited during medical simulations (Apramian et al., 2017; Young et al., 2020). This case study used content analysis (Berger-Estilita et al., 2021) to code for leaders' SRL, SSRL, and behaviors. These codes emerged as a result of both inductive and deductive coding (Albert et al., 2019) to create a more authentic examination of how the leader performed during simulation. Concurrently, testing these codes on our data helped refine and enhance the research team's understanding of how SRL and SSRL relate to leadership and CRM skills.

Participants

Eight 2nd year residents in Internal Medicine program participated. They all had comparable levels of training and clinical experience. Participants were grouped into two teams of four residents and wore color-coded bracelets to identify them: Team A (Purple, Yellow, Red, and Blue), and Team B (Orange, White, Black, and Green). Each team completed the same two scenarios (e.g., Team A1 for Team A scenario 1) and had one appointed leader and three residents in supporting roles (e.g., acting as a respiratory therapist (RT) or supporting physician). Between each simulation scenario, leadership and resident roles were re-assigned.

Simulation Context

Simulations were part of the medical residents' curriculum, and the research team had no control over the selection of participants. These simulations were based on CRM training scenarios using programmable high-fidelity

mannequins as "patients". As a core part of their residency training, trainees are expected to exercise and effectively demonstrate leadership, communication and resource management 'leaders' in cases requiring in team-based care. These themes are explicitly taught during the mandatory academic half-day training activities where our study took place. Specifically, residents received a 30-min introductory lecture on crisis resource management principles (leadership, communication, problem solving, situational awareness, and resource utilization) and are specifically debriefed and assessed on these skills following participation in the simulated scenarios. Our study was observational and, as such, did not entail any additional instruction to residents. These mannequins can be monitored for evolving physiological activity and interact with trainees through a speaker located in their mouths, controlled by a live simulation technician observing the scenario through a window. In the scenarios, the mannequins showed prespecified clinical deterioration to challenge the residents' clinical and CRM skills. The simulation scenarios included major gastrointestinal bleed (Scenario 1), and status asthmaticus (Scenario 2) (Detailed descriptions in Table 1). A debriefing was conducted at the conclusion of every simulation scenario where teams involved in the simulation had the chance to discuss the simulation and get timely feedback from simulation educators and team members who participated in the simulation, about their performance in the scenario. For our study, data was collected from each team separately, with independent debriefings at the end of each scenario.

Data Collection

Data were collected from four medical simulations recorded in December 2021 at a university simulation training center. Audiovisual recordings were made of all simulations using a camera at the head of the 'patient's bed' for post hoc analysis. Each scenario lasted approximately 10 minutes and was followed by a debriefing session.

Tools

The following tools were used to analyze data:

1. **Coding scheme**. Our coding scheme included codes for 1) behaviors (posture and gestures, facial expression, and vocalics), and 2) regulation strategies (individual self-regulation and socially-shared regulation). This coding scheme borrowed established codes for behaviors (D'Mello & Graesser, 2010; Eckland et al., 2019; Frischen et al., 2007; Maedeh et al.; Mandal, 2014; Sauter et al., 2010), SRL (Hacker et al., 1998; Jansen et al., 2019; Zimmerman, 2002) and SSRL (Grau & Whitebread, 2012; Hadwin & Järvelä, 2011; Hadwin & Oshige, 2011; Harley et al., 2019; Hmelo-Silver & Barrows, 2008; Isohätälä et al., 2017; Isohatala et al., 2018; Järvenoja et al., 2018; Kwon et al., 2014; Lajoie et al., 2015; Lajoie & Lu,

2012; Lajoie et al., 2021; Lee et al., 2017; Panadero et al., 2019; Panadero & Järvelä, 2015; Sobocinski et al., 2020), which were then modified to fit a medically-based context. The codes were tested by the coding team using medical simulations and the researchers adjusted them based on input from researchers, simulation educators, and medical doctors, who provided expertise on how the codes were being described within the context of a medical simulation, to observe the constructs while coding.

2. **Leadership scale adapted from the Ottawa CRM Global Rating Scale (Ottawa GRS)** This scale is regularly used within CRM simulations to assess the leaders' overall performance (Kim et al., 2009). The tool includes scales for the five core principles: 1) leadership, 2) situational awareness, 3) communication, 4) problem solving, and 5) resource utilization. These cognitive skills are an implicit as well as explicit part of medical trainees' CRM training and are expected to be employed in an increasingly sophisticated manner as they advance from novices to competent practitioners. Each of these criteria are assessed via a 7-point Likert scale rated from 1 (implying a 'novice' level rating) to 7 (implying an 'expert' level rating), with all categories rated as equal factors of a composite measure of all core principles. Researchers modified the questionnaires by eliminating three categories (problem solving, situational awareness, and resource utilization) that were outside of the focus of the study, focusing on 1) leadership and 2) communication. The categories used to code the appointed leader in every team were: ***Leadership*****:** A) calm and cool during crisis; B) prompt and firm decision-making; and C) maintaining a global perspective of the scenario; and ***Communication*****:** A) communicates clearly and concisely; B) directed verbal/non-verbal communication; C) listens to team input. The research team separated each rating criterion for 'leadership' and 'communication' into three subcategories. Kane's validity model (Tavares et al., 2018) suggests that the modification of the Ottawa GRS can fulfill a specific need for this project without compromising the integrity of the measure as well as our research questions. Since that the Ottawa GRS was not used in a clinical assessment of a learner, removing extranious components that would not help the research team answer its questions resulted in us removing the ratings of 'problem solving', 'situational awareness', and 'resource utilization'. This allowed the research team to avoid spending extra time to rate components of the measure that would never be used to answer our research questions.

Coding Process

In the first iteration, researchers began by coding the group interaction of each video individually. The codebook contained codes for behaviors, SRL, and SSRL strategies that could be observed in the simulation recordings. Codes were iteratively adjusted to make them easier to use and more explicit in coding the target constructs. Three raters were trained in how to use the coding book, to ensure that any agreement/disagreement could be negotiated. Raters were instructed to look at the "key moments of leadership" that were a central focus of this study. These "key moments" (segments for analysis) were determined by using the learning objectives for each simulation scenario, which included the identification of 1) clinical deterioration of the patient requiring a prompt medical intervention to correct the situation; 2) management of the team; and 3) resource deployment, wherein the leader had to use medical supplies and available equipment to manage the clinical case. Table 2 describes the raters and their coding of key leadership moments before and after deliberation. Amongst the raters, M.M. and K.G. come from educational and medical education research backgrounds, while L.P. is a medical doctor and provided input on content-specific questions. These perspectives and relationships to the medical simulations and the nature of medical training provided the team with contrasting and complementary perspectives to observe the simulation's leaders. The use of both medical and non-medically trained raters in the Ottawa GRS have validity support (Kim et al., 2009), as the criteria, categories, and language used by these designers are meant to be accessible to non-medical specialists. In addition, the input from our team of medical doctors and simulation educators allowed us to ask questions and seek content-specific medical information that was needed to clarify interactions and events within the simulation videos.

Raters coded videos individually, and then came together to negotiate the "key moments of leadership" they observed, and which behavioral and regulatory strategies surrounded those moments. The code book that raters used was organized in the form of 1) a superordinate category, 2) a definition of that category, 3) an example of what that definition may look like, 4) followed by subordinate codes that were embedded in these categories, and 5) were followed by definitions and examples, identical to the superordinate codes. Raters tested these codes and refined the definitions and examples to help ensure that they were clear enough for a non-expert to score. The code book drew upon, and modified, existing codes and definitions that researchers who had engaged in a similar coding process used, thereby allowing our research team to expand on this established literature. Raters coded the events by examining the videos and comparing what they saw in the videos to the codes that best matched those interactions and decisions made by the leader. A "key moment of leadership" involved the rater noting the time of the event,

followed by the code(s) that were present during that event. Differences in the events and codes were negotiated by observing the period in question jointly and re-examining the codes applied. Cohen's Kappas after the first negotiation are reported in Table 3 with ranges from 0.73 to 0.85 before deliberation, representing 'moderate-to-strong'. Perfect agreement was reached after deliberation.

In a second iteration, raters coded the "key moments of leadership," using the Ottawa GRS scale according to the coding categories of 'leadership' and 'communication'. When differences arose, the raters came together to negotiate scores, and it was decided that any score difference within 1 point (on the 7-point scale) would not be altered and would be considered valid. Cohen's Kappas for *Leadership* and *Communication* are reported in Table 3. Cohen's Kappa ranged from 0.79 to 0.89 before deliberation, representing 'moderate-to-strong' agreement (McHugh, 2012) (Table 3), and perfect agreement after deliberation. Interrater reliability scores for these measures fall within the acceptable limits of those reported in the previous publication of the Ottawa CRM (Kim et al., 2009). The final ratings can be seen in Table 4.

The final codes' descriptive statistics can be seen in Table 5. All codes were calculated and presented as a frequency and percentage to indicate how many times a code appeared, and the percentage of overall codes represented by that code; for example, (15/.30) would indicate that a particular code appeared 15 times, which accounts for 30% of all the codes for that scenario. For analysis, teams were compared based on the scenarios that they completed.

Results

Scenario 1: Major Gastrointestinal Bleed

In scenario 1, Team A1's leader, Purple, used executive monitoring strategies (C.2.4. executive monitoring) to manage their team, such as *checks for knowledge* and *confirmation of task directions* (10, 24%; these codes appeared 10 times, accounting for 24% of all the codes for Team A in Scenario 1), to encourage team members to report, collect, and share information. For example, during the opening 2-minutes of the simulation, the leader ordered team-member Blue to call the laboratory and report on the patient's previous bloodwork. Blue quickly executed this task and relayed that information to all members of the team, ensuring that they were all aware of the most up-to-date information. This information allowed leader-Purple to use effective, directed attention (12, 8%) when issuing orders and speaking with team members and take information that Blue provided to team members Red and Yellow as the leader sought team feedback on the diagnosis. This facilitated the information flow towards the leader during

moments of patient deterioration, allowing them to make accurate and prompt decisions (12, 29%; C.2.2.) 5-minutes into the simulation to stabilize the patient. When delivering treatment, the leader employed orientation strategies (C.2.1.) (10, 24%), allowing them to come up with a treatment plan (C.2.2. planning) (12, 29%) that incorporated active feedback from all team members, which, when executed effectively, controlled the patient's bleeding and clinical deterioration (C.2.3. execution) (7, 17%). The timely use of collecting information, vocalizing that information and delegating tasks was important to the execution of this scenario for the team.

In contrast, Team B1's leader was far less involved with collecting information from teammates (related to collecting and effectively using the crash cart resources; C.2.1. orientation; 2, 5%). This was evident through less frequent face-to-face contact (7/ 4%) with team members to solicit information, which was followed by a lack of regular updates or checks for understanding during the clinical scenario. For example, the leader was located at the foot of the bed, a common location for the lead-physician to be located to control the flow of care and information, but they too often did not make active eye contact with teammates when collecting information and providing orders. This contributed to less information being gathered by the leader, and less pertinent information reaching team members, hindering prompt clinical decision-making and negatively affecting the patient's outcome. Additionally, the leader was seen using inhibitory (C.3.2.) (1, 3%) and negative social interactions (C.3.6.) (4, 11%) when managing team members. Approximately 4-minutes into the scenario, the leader formulated their diagnosis and did not seek input from their teammates. During this, team member Green asked to see if they can be of any help as the patient begins to deteriorate, and the leader actively discouraging participation even though they had potentially vital information about the patient's medical condition that could be used. This inability to socially-regulate and share a mental model for how the patient could be treated persisted throughout the scenario. This could have contributed to poorer performance. Notably, there were no coded leadership behaviors or strategies observed during the management of the patient's deterioration, as the leader did not engage with their team.

Team A1 diagnosed the gastrointestinal bleed and its etiology almost 2 minutes before Team B1 (The scenario lasted approximately 10 minutes). Team A's leader asked for the patient's chart from the outset, allowing the team to make a prompt diagnosis. On the other hand, Team B1's leader waited several minutes before gathering the same information. In examining the Ottawa GRS ratings, Leadership global scores were higher for Team A1's leader than Team B1's leader, which could help explain the differences in the simulated patient's outcome, that

resulted from their leadership performance. Communication scores were higher for Team A1 (*M*= 7) than Team B1(*M*=4.67), reflecting the clearer communication and directions provided by Team A1's leader.

Scenario 2: Status Asthmaticus

In scenario 2, Team A2's leader regularly engaged their team by collecting information (C.2.1. Orientation; 10, 12%) and setting clear plans (C.2.2; 6, 7%) for their team to follow, as they worked to diagnose the status asthmaticus. These actions were highlighted by asking team members Red and Blue to collect as much information on the patient's past and current condition as possible in the opening 2 and a half minutes of the scenario. When the patient began deteriorating at approximately 3 minutes and 38-seconds into the scenario, the leader changed their approach and utilized a few execution strategies (C.2.3.; 3, 4%) including ordering Purple to provide IV access and Red to get chest x-rays to examine any obstructions in the patient's airway. This led them to undertake tasks such as collecting and delivering life-saving medication- a task that the leader could have delegated to another team member. It was during this time, approximately 7 minutes and 50-seconds into the scenario, that team member Purple began to spontaneously direct other team members while the leader was fixated on collecting medications for intubation. Difficulties emerged as the patient began to desaturate and oxygen levels decreased. This resulted in the team identifying the problem but led to difficulties in determining the best intervention to help the patient. The leader decided to intubate the patient approximately 9 minutes into the scenario, which is a measure of last resort, as there are other less-invasive treatment options that were not contemplated by the leader before making this therapeutic decision. During this process, the leader remained calm and spoke in a clear tone to the group (4/ 3%), but there were underlying difficulties in their response. Despite collecting information on the patient's status (11/14%), the leader did not involve team members in the decision to intubate. While beginning the process of intubation, the leader did not delegate team members to get the materials and failed to give them directions (3/ 2%), reflecting the loss of global perspective in successfully planning the course of action (C.2.2.; 0, 0%).

Team B2's leader was able to use their team to collect information on the patient's condition (C.2.1. orientation; 7, 16%) and plan accurate interventions for the patient (C.2.2. planning; 3, 7%). This facilitated the information flow and permitted the team to manage the resources, including the timely delivery of a crash-cart and preparations of medication that occurred within the first 4-minutes of the scenario. This helped to organize the personnel needed to stabilize the patient. This flow of information was invaluable during the patient's deterioration, when the collection and flow of information (C.2.1. orientation; 16, 26%), successful planning (C.2.2.; 14, 31%),

and execution (C.2.3.; 4, 9%) of medical treatment allowed the team to meet the needs of the patient. Once an intervention to support the patient's respiration was required, the leader passed on to the respiratory therapist (RT; team member Orange) a certain amount of authority to manage the hands-on treatment of the patient as well as the organization of team members Orange and White, which allowed the RT to obtain additional assistance from other teammates to complete the complex task of airway management. This freed the leader from directing other teammates to support the RT's work, thereby allowing the leader to better maintain a global perspective. This decision played a role in helping the team develop their social interactivity (C.3.4. Interactive Social Presence (ISP); 4, 10%), and indicated the flexibility of the leader to respond to the needs of the patient and team. The SSRL use of ISP and facilitation codes (C.3.1) allowed for the leader to organize the groups' ability to confirm the direction of their shared treatment goals to stabilize the patient.

Differences in Teams A2 and B2 emerged in how they regulated their responses to the patient's deterioration. When Team A2's leader became fixated on performing tasks and ineffectively communicated their directions to the team, a new leader had to emerge to manage the group. Meanwhile, Team B2's leader managed their team by relinquishing some of their control to respond to the patient's need for more delegated care. The communication (M= 7) and leadership (M= 6) Ottawa GRS ratings reflected higher ratings for Team B2.

Discussion

To address our first research question "Which SRL, SSRL, and behavioral strategies do leaders demonstrate during variable team-based performances in CRM simulation scenarios?", that across all four teams, we observed that SRL and SSRL strategies were employed by all leaders to maintain control in a critical situation. Leaders in Teams A1 and B2 tended to exhibit higher Ottawa GRS scores for Leadership and Communication, which could be an indicator of the use of these strategies to organize and lead their teams to greater effect. These qualities echo the behaviors needed to support a team through engaged leadership, adaptability to meet patient demands, and a team orientation (Salas et al., 2005), where leaders were able to get everyone on the team to cooperate to accomplish their task. In comparison, leaders in Teams A2 and B1 employed similar SRL and SSRL strategies including monitoring (C.2.4.), orienting (C.2.1.), and planning (C.2.2.), but they also used negative SSRL strategies that compromised their abilities to share information and promote team cohesion. When examining the behaviors exhibited by leaders, a leader must have the physical presence to command their team. Using direct eye contact with others (B.1.d. gaze towards others) was a powerful tool to collect information and offer team members directed instruction to complete

tasks. The use of many of these behaviors by leaders in teams A1 and B2 could suggest that using direct eye contact was a central behavior in helping the leader command the group and offer psychological cohesion (Luft et al., 2022).

The ability of leaders to regulate their own behaviors and learning can be a useful step towards advancing their teams' performance. These results suggest that CRM simulations can help advance the training of CRM skills through the development of SRL and SSRL strategies that can be used by individuals to influence the team's performance. These findings support the existing literature of the role of regulation within CRM simulations as a vehicle to manage the intra-personal demands of medical practice (Hadwin & Oshige, 2011) that emerge from how team leaders interact with their teammates. This study adds to the literature on CRM medical simulations (Burden, 2020; Sinz, 2005) by placing SRL and SSRL strategies at the forefront of how teams interact. As this case study has suggested, the presence of regulatory codes that encourage group cohesion, the sharing of information, and organization of shared mental models while engaging in simulations, may be a path towards advancing how we see the effectiveness of leadership and performance in medical simulations.

To answer our second research question "Are leaders' SRL, SSRL, and behavioral strategies associated with their objective performance scores?", results suggest that team leaders who had higher Ottawa GRS scores tended to use more SSRL strategies to collect and share more information, helping to manage their group performance (Järvelä et al., 2016) (Jarvela & Hadwin, 2013). The use of effective SRL and SSRL strategies by leaders in Teams A1 and B2, who scored the highest ratings of communication and leadership, demonstrated that through effective use of team organization, communication, and clear decision making, they can contribute to positive simulated patient outcomes. While the goal of this study is not to determine the generalizability and correlations between scoring, SRL, and SSRL behaviors in leaders, these results do suggest that the presence of more regulatory codes may help to explain differences in performance.

This work makes an important conceptual contribution to the field by using SRL and SSRL as a framework for leadership skill development in medical CRM simulations. Even though SRL and SSRL are traditionally used to look at the regulatory strategies to enhance learning, these same strategies can be used to understand how teamwork, communication, and leadership skills occur in medical simulations. A novel contribution of this study is the development and testing of a coding scheme for examining both leadership and regulation that is suitable for use in the context of intense team-based medical simulations. These findings help to expand our existing findings on the framing of regulation in medical simulation (Brydges et al., 2015) by focusing on the leader and how their

regulation shapes their team performance. This helps to address a gap in the literature surrounding the use of coded data to move beyond self-report (Tanimura et al., 2023) in our study of SRL in medical education. These regulation skills can contribute to better leadership by helping leaders become more aware of how to use their team to collect and process patient information, and how to use the assets of the team members to deliver critical care.

Findings may have important contributions for medical education in simulation environments because this study has the potential to enrich future debriefing sessions to consider the interplay of group regulation and leadership strategies. For example, by understanding behaviors and group regulation strategies, medical trainees can have explicit discussions within their debriefings that make reference to specific strategies that they did or did not employ, and how those would improve their ability to manage their team and achieve their best performance. These finding expand upon the existing pedagogical values of debriefings in simulation education (Greenberg et al., 2023) by expanding the range of debriefing topics and what learners can gain from discussions about SRL. Our findings suggest that the increased presence of regulation strategies provides an indicator of how effective a leader may be as communicators with their teams, indicated by the Ottawa GRS ratings of communication.

In conclusion, this study contributes to establishing the conceptual use of SRL and SSRL as a framework for leadership skill development in medical CRM simulations. Our use of an integrated coding scheme allows for researchers and simulation educators to examine regulation within medical simulations, which can have a positive contribution to expanding the discussions surrounding debriefings to focus on regulation and it's applicability to team performance.

Limitations and Future Study

This study builds upon existing findings within SRL in medical education by moving beyond medical trainee self-report (Bransen et al., 2020; Gandomkar et al., 2016; Gandomkar et al., 2020) and performance evaluations, to describe the regulation strategies exhibited by leaders. With any study, there are limitations to the design and outcomes that can be considered for future exploration. First, the research team did not examine how individuals set goals as part of SRL or as a team at the SSRL level. The exploratory nature of this protocol and novel examination of team-based medical simulations did not lend itself to examining how individuals set goals for the simulation and how the groups worked to established, and then complete or not achieve those goals. The exploratory nature of this study design opens avenues for further investigation into the dynamics of leadership and regulation in medical education simulations, but the current findings should be interpreted with caution due to these limitations.

Furthermore, greater examination of leadership should be undertaken to explore how medical trainee-specialty and years of training shape the type of regulation strategies that leaders use, and how those strategies are employed within the unique culture of medical communities. We did not ask or have the opportunity to collect data on issues that residents, whom were playing the role of leaders (or others), identified or struggled with. Further, we did not examine learning about leadership. That would require measurement at two or more points in time. In future research, we could examine self-report measures prior to and after the simulation, or semi-structured interviews post-simulation after the debriefing that prompt medical residents to think about leadership what leaders identified and struggled with. In a longitudinal study, we could examine leaders' performance as a leader over time, though, due to the high cost of simulations and the need for medical residents to have the opportunity to be a leader and team members, this would not likely be easily feasible. SRL and SSRL can be good models to understand and in the future teach leadership for medical professional. To implement this, we could teach residents these models and draw on their concepts within debriefings to help explain what worked well and what did not. In future studies, the opportunity to collect data from more medical trainees will allow for greater generalizations, enabling researchers and medical simulation facilitators to implement these findings to train their residents to develop better leadership and regulation practices. This study contributes to the emerging research in the field of group regulation in medical simulations and advances our understanding of how medical trainees develop leadership skills, and how those skills affect group regulation within simulation environments.

Declaration of Interest Statement

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Tables

Table 1

Summary of CRM Simulation Scenarios

Scenario	Condition	Summary
1	GI (gastrointestinal) bleed	The scenario involved the patient, "Mrs. Smith", an elderly woman, hospitalized, diagnosed with gastrointestinal cancer and other comorbidities, who developed hemodynamic instability and clinical deterioration, secondary to gastrointestinal bleeding worsened by anticoagulant medication. The simulation required residents to make a prompt diagnosis of the bleed, initiate resuscitation to stabilize the patient, reverse the anticoagulation, activate the medical emergency code calling the appropriate specialists to solve the condition and initiate massive-transfusion protocol to prevent the patient's death.
2	*Status Asthmaticus* (respiratory failure)	This scenario involved the patient, "Mr. Smith", who is an elderly, non-smoker, obese man without a history of respiratory illness who complained of shortness of breath. Gradual deterioration of the patient occurred to the point where advanced ventilatory support was needed. This scenario required the team to accurately diagnose the medical problem, call a code-blue, and maintain a patent airway to stabilize the patient.

Table 2

Rater Agreements on Key Leadership Moments

Rater	Videos coded	Key leadership moments identified- Before deliberation		Key leadership moments identified- After deliberation	
M.M.	4	Team A	19	Team A	16
		Team B	23	Team B	14
		Team C	29	Team C	15
		Team D	15	Team D	12
K.G.	3	Team A	19		
		Team B	22		
		Team C	12		
L.P.	1	Team D	25		

Table 3

Cohen's Kappa values for Agreement in Simulation Observations, and Ottawa GRS Ratings of Leadership and Communication in Key Leadership Moments

Simulation	Events both raters included	Events both exclude	Rater 1 included	Rater 2 included	Cohens' Kappa
Simulation Observations					
Team A	16	10	1	1	.85
Team B	14	4	1	1	.73
Team C	15	7	1	1	.81
Team D	12	3	1	0	.82
Ottawa GRS- Leadership					
Team A	47	15	2	3	.81
Team B	34	10	3	0	.84
Team C	36	8	1	2	.80
Team D	37	7	2	1	.79
Ottawa GRS- Communication					
Team A	39	11	2	2	.81
Team B	31	11	1	1	.89
Team C	24	6	1	1	.82
Team D	34	9	1	2	.82

Table 4

Ottawa GRS Scores

Team	Calm & control during crisis	Prompt and firm decision-making	Global perspective	Leadership-Overall	Communicates clearly and concisely	Directed verbal/non-verbal communication	Listens to team input	Communication-Overall
A1	7	7	7	7	7	7	7	7
A2	5	5	4	4.67	5	5	5	5
B1	7	5	5	5.67	5	4	5	4.67
B2	6	5	7	6	7	7	7	7

Table 5

Summary of Coding Observations Frequencies

			B. 1 Attention Tendency				
Simulation	**Member**	**Critical Leadership Categories**	***B.1.a. Gaze towards the patient***	***B.1.b. Gaze towards an information source***	***B.1.c. Gaze away***	***B.1.d. Gaze towards others***	***B.1.e. Gaze directed downward***
Team A1	Leader	Clinical deterioration of patient	7/.04	5/.03	4/.02	9/.06	2/.01
		Team management	3/.02	11/.07	0/.00	12/.08	2/.01
		Resource deployment	2/.01	4/.03	4/.03	2/.01	2/.01
Team A2	Leader	Clinical deterioration of patient	5/.04	5/.04	6/.04	4/.03	0/.00
		Team management	3/.02	3/.02	1/.01	3/.02	2/.01
		Resource deployment	4/.03	5/.04	0/.00	4/.03	0/.00
Team B1	Leader	Clinical deterioration of patient	2/.01	1/.01	2/.01	1/.01	5/.03
		Team management	5/.03	6/.03	3/.02	7/.04	1/.01
		Resource deployment	2/.01	5/.03	2/.01	2/.01	3/.02
Team B2	Leader	Clinical deterioration of patient	7/.04	8/.04	2/.01	7/.04	4/.02
		Team management	7/.04	8/.04	8/.04	8/.04	5/.03
		Resource deployment	6/.03	9/.05	1/.01	8/.04	5/.03

Note: This table is to be read left to right

B.2 Vocalics				**B.3 Bodily Expression**					
B.2.1. Volume of speech	***B.2.2. Speed of speech***	***B.2.3. Verbal filters***	***B.2.4. Pitch of speech***	***B.3.1. Facial expression***	***B.3.2. Head***	***B.3.3. Shoulders***	***B.3.4. Hands***	***B.3.5. Standing posture***	***Total***
3/.02	2/.01	3/.02	4/.03	4/.03	3/.02	4/.03	6/.04	2/.01	
3/.02	4/.03	2/.01	3/.02	4/.03	5/.03	4/.03	5/.03	1/.01	161/1
3/.02	3/.02	4/.03	3/.02	5/.03	2/.01	2/.01	3/.02	5/.03	
4/.03	6/.04	4/.03	2/.01	5/.04	5/.04	6/.04	4/.03	3/.02	135/1

0/.00	3/.02	3/.02	1/.01	2/.01	3/.02	0/.00	3/.02	3/.02	
1/.01	5/.04	0/.00	3/.02	4/.03	5/.04	5/.04	5/.04	5/.04	
6/.03	5/.03	5/.03	2/.01	2/.01	12/.06	1/.01	11/.06	0/.00	
5/.03	6/.03	5/.03	2/.01	6/.03	20/.10	3/.02	11/.06	2/.01	192/1
4/.02	4/.02	6/.03	2/.01	2/.01	10/.05	4/.02	5/.03	4/.02	
10/.05	5/.03	9/.05	1/.01	8/.04	9/.05	10/.05	10/.05	4/.02	
4/.02	2/.01	0/.00	2/.01	2/.01	3/.02	4/.02	1/.01	4/.02	196/1
7/.04	8/.04	0/.00	0/.00	0/.00	0/.00	0/.00	0/.00	0/.00	

C. 2 Individual Regulation strategies						
C.2.1. Orientation	***C.2.2. Planning***	***C.2.3. Execution***	***C.2.4. Executive monitoring***	***C.2.5. Evaluation***	***C.2.6. Elaboration***	***Total***
10/.24	12/.29	7/.17	6/.14	4/.1	2/.05	
9/.22	5/.12	7/.17	5/.12	4/.1	3/.07	41/1
4/.1	0/.00	7/.17	5/.12	4/.1	0/.00	
10/.12	11/.14	3/.04	4/.05	2/.02	2/.02	
10/.12	6/.07	3/.04	3/.04	0/.00	0/.00	81/1
10/.12	11/.14	1/.01	2/.02	3/.04	4/.05	
3/.07	4/.09	0/.00	0/.00	0/.00	1/.02	
8/.19	11/.26	2/.05	0/.00	2/.05	2/.05	43/1
2/.05	0/.00	1/.02	0/.00	1/.02	2/.05	
16/.26	14/.31	4/.09	1/.02	4/.09	5/.11	
7/.16	3/.07	1/.02	3/.07	0/.00	0/.00	45/1
4/.09	4/.09	0/.00	0/.00	0/.00	1/.02	

C.3 Socially-Shared Regulation strategies

C.3.1. Facilitation	*C.3.2. Inhibition*	*C.3.3. Affective Social Presence (ASP)*	*C.3.4. Interactive Social Presence (ISP)*	*C.3.5. Cohesive Social Presence (CSP)*	*C.3.6. Negative social interactions*	*Total*
2/.06	0/.00	5/.15	3/.09	2/.06	0/.00	
2/.06	0/.00	0/.00	4/.12	2/.06	0/.00	34/1
3/.09	0/.00	5/.15	6/.18	0/.00	0/.00	
4/.06	3/.04	7/.10	15/.21	6/.08	0/.00	
1/.01	4/.06	2/.03	7/.10	3/.04	0/.00	71/1
6/.08	0/.00	0/.00	7/.10	6/.08	0/.00	
0/.00	3/.08	3/.08	7/.19	1/.03	0/.00	
2/.05	1/.03	1/.03	6/.16	3/.08	4/.11	37/1
0/.00	0/.00	0/.00	1/.03	1/.03	0/.00	
3/.07	3/.07	5/.12	10/.24	6/.14	0/.00	
1/.02	0/.00	1/.02	1/.02	0/.00	1/.02	42/1
1/.02	0/.00	3/.07	4/.10	1/.02	0/.00	