The Nature of Transactive Memory Systems in Emergency Medicine Teams Based on
Observations and Communication Analysis

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by

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Abstract

Transactive Memory Systems (TMS) is one of the theoretical constructs used to account for how team members in high stress, high pressure emergency department (ED) distribute their cognitive and work load for more effective team performance. This study investigated the nature of TMS in ED teams by observing resuscitation team simulations and analyzing behaviours and communications reflecting this construct. The credibility of team members was pre-established based on the team members' titles. There was an overwhelming propagation and distribution of unsolicited information between members which indicated the efficiency of TMS in these educational settings. However, it also raised some concerns. This study has implications for training and the design of programs, tools, and electronic interfaces to help improve the efficiency of TMS and ultimately ensure the care and safety of patients.

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Transactional Memory Systems in Emergency Medicine Teams Based on Observations and Communication analysis

In Canada, over 15 million people visited the emergency department in 2010-2011, of which 21.7% of visits made were for trauma, such as falls or motor vehicle collisions (CIHI report, 2012). The emergency department is a dynamic high-risk environment that may deal with a new scenario in each case. Patel, Zhang, Yoskowitz, Green, and Sayan (2008) claim that the emergency department is a complex system which is dynamic in nature. They postulate that this system is unpredictable, both from the aspect of the patient's condition, which can vary widely from an unidentified illness to a cardiac arrest throughout the patient's stay at the resuscitation room, and from the aspect of team composition and teamwork and decision making, since the exact members of the team and their decision making are inherently unpredictable. The resuscitation room is one of the most fast paced, high risk sections of the emergency department. There are different constructs involved in any resuscitation room. We need to understand the functioning and goal of resuscitation rooms and their team members to be able to decipher the constructs that emerge as the result of the team members' interactions. In the next sections I will discuss the description of the resuscitation rooms, their goal, and the key concepts that are utilized in this study.

The Nature of a Resuscitation Room

The emergency department has different units with the goal of providing immediate care to individuals who need time-sensitive medical attention. The resuscitation room is one of the units within the emergency department which deals with critically ill individuals who have been in major traumas or life threatening situations, such as vehicle collisions, cardiac arrest,

or falls. The resuscitation rooms typically receive their patients via EMS (Emergency Medical Services) or from other emergency units.

Resuscitative care is delivered by specialized health care workers who typically function in a team environment (Mellick & Adams, 2009). The resuscitation team follows a specific protocol following the arrival of a patient to optimize time while minimizing errors.

According to Mellick and Adams, the trauma or medical resuscitation involves seven phases, anticipation phase, entry phase, resuscitation phase, maintenance phase, family notification phase, transfer phase, and critique phase. The four phases that are the focus of this study are: Anticipation phase, during which the information about the patient is transferred to the hospital by the EMS. During this phase the team is put together and team leadership is designated. Furthermore, the equipment is prepared and team members anticipate the arrival of the patient. The second phase is the entry phase, during which the information with regards to the patient's vital signs, history, and other relevant information is transferred to the resuscitation team. The resuscitation team performs the preliminary assessment of the patient to obtain the baseline. The third phase is the resuscitation phase, during which the resuscitation room team performs the primary survey which is referred to as ABC (Airway, Breathing, Circulation). The goal is to ensure that the three important resuscitation priorities have been checked. The team continues with surveying the patient and applying the needed resuscitation interventions. The fourth phase is the maintenance phase, during which the intravenous line (access lines) are inserted and catheters and tubes are stabilized. In this study, the anticipation phase and entry phase are amalgamated. Communication is a major part of resuscitation team interaction throughout the phases.

Goal of the Resuscitation Team

The goal of the resuscitation team is to provide the best care to the patient in a time sensitive manner. The team members need to make quick decisions and coordinate their activities with other members to ensure the patient's safety and survival. An obstacle in achieving this goal is the fact that, in many cases, ad-hoc teams are assembled with unfamiliar members (e.g., physicians, nurses, and respiratory technician), adding problems to the coordination and decision-making process of the team. However, it is more efficient to complete a complex task, such as an emergency scenario, through the efforts of a multi-disciplinary team.

Although errors increase as the complexity of a task increases (Patel et al. 2008), generally, teams tend to make less mistakes than individuals (Baker, Day, & Salas, 2006). Efficient teamwork is critical to the operation of a complex environment such as a resuscitation room (Risser et. al. 1999; Cosby, 2003; Dickinson & McIntyre, 1997; Baker, Day, & Salas, 2006). However, efficiency should not be achieved at the cost of an increase in the number of mistakes made. Researchers have been studying the element of teamwork within emergency departments to determine the most effective elements involved in a reliable and efficient resuscitation team.

Teamwork and its elements have been studied for over two decades. Researchers define teamwork as the behaviours, cognitions, and attitudes that facilitate the interaction and coordination of the decisions and activities of a group of two or more individuals who interdependently work on a related task (Parush, Kramer, Foster-Hunt, McMullan, & Momtahan, 2014; Beaubien & Baker, 2004; Dickinson & McIntyre, 1997). Researchers have proposed several theoretical constructs, such as team mental model, situation awareness, and transactive memory systems, as mechanisms which may be used to explain teamwork processes and the

knowledge emerging from the processes (Wildman, Thayer, Pavlas, Salas, Stewart, & Howse, 2012). Although the focus of this paper is emerging transactive memory systems in resuscitation rooms, I need to have an understanding of other constructs involved in high risk environments to be able to differentiate between transactive memory systems and other constructs. In the next section these constructs will be discussed briefly.

Team Mental Model

The team mental model (TMM) is defined as a mental representation that is shared by the team members. This mental representation is comprised of the key elements and the beliefs related to, and the knowledge of, the environment in which the team operates (Mohammed et al., 2000; Klimoski, & Mohammed, 1994). Team mental model is then the product of the cognitive process and the interaction of the team members which allows the mental model of the individuals to combine and create a shared mental model between the team members (Gutwin & Greenberg, 2004). Team mental model plays an important role in the efficiency and outcome of teams. In a review of TMM literature, Burtscher and Manser (2012) stated that out of the 28 studies they reviewed, 22 studies found a significant correlation between TMM and performance and, ultimately, patient safety in health care environment.

Situation Awareness

Situation awareness (SA) is described by Endsley (1995) as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future”. Endsley (2000) later describes team situation awareness as the dynamic mental representation and the awareness of the team members about

the current situation as it changes. In a health care environment, situation awareness is a critical component of patient care (Busby & Witucki-Brown, 2010).

Transactive Memory Systems

Transactive memory systems (TMS) will be discussed in detail in further sections of this thesis, however for the purpose of examining the relationship of TMS to other two concepts, i.e., TMM and SA, they are explained briefly in this segment. Transactive memory systems are defined as the cognitive systems that the team uses to encode, store, and retrieve information (Lewis 2003). Researchers posit that these constructs show the pattern of team-level knowledge within a team and can be used to explain the variances in teams on axes such as development and performance (Wildman et al., 2012; Klimoski & Mohammed, 1994).

Relationship of TMM, SA, and TMS

From the descriptions of the three constructs, one can extrapolate many similarities between TMM or situation awareness, and transactive memory systems. However, there are some differences that help tease TMM and SA away from transactive memory systems (TMS). Mohammed and Dumville (2001) describe TMM as a broader concept of team work. They consider transactive memory systems as a sub-dimension of TMM. Lewis (2003) explains that team members need to have a shared understanding of each other's knowledge (TMM) to be able to coordinate expertise while processing a task. However, this is only part of the development of transactive memory systems, and hence, team mental model does not reflect all components of TMS. For example, TMM does not cover the essential component of TMS which is to divide the cognitive labor of completing a task between team members. Furthermore, shared mental model does not reflect whether or not team members have developed specialized

knowledge after assessing other members' knowledge and expertise. Another distinction that needs to be made is the subtle difference between transactive memory system and situational awareness. Before looking at the similarities and differences between TMS and TSA, it is important to discuss team knowledge as described by researchers.

Variation in the type of team knowledge has been used to explain the similarities and differences between different constructs, such as TSA and TMS. Wildman et al. (2012) categorize the team knowledge into task related, team related, process related, and goal related. Task related knowledge is the knowledge related to the task work of the team. Wildman et al. consider task mental models and task knowledge as examples of static task related knowledge. Team related knowledge is the knowledge that is related to the mental representation of the characteristics of team members and the team as a whole, but not the interpersonal processes related to the team, such as communication, leadership, and coordination. These processes involved in team interaction are included in the process related knowledge category. Goal related knowledge is the mental representation of the goals and objectives, and ultimately, the achievement of those goals for the team.

Transactive memory systems consist of static team-related knowledge. Static team-related knowledge alludes to a "stable over some time" mental structure referring to the qualities and characteristics of the team members, such as their expertise. Once team members establish who has what expertise in the team, the information generally does not change until the next time knowledge of team expertise is updated. Situational awareness, on the other hand, is based on dynamic task-related knowledge. This means that situational awareness refers to the mental representation of quickly evolving information (Wildman et al., 2012). For example, in a

resuscitation situation, the patient's status may change and the team members need to be aware of the quickly changing situation (i.e., situation awareness), however, once the transactive memory system is developed, the trust in the expertise of the team leader should not change as often as the patient's status may change. These constructs are related, but not exactly the same.

Although these theoretical constructs may have differences, their efficiency and development can be affected by the same elements. One of the most important elements that can influence these constructs, and hence facilitate or hinder the performance of a team, is communication. Communication plays a crucial role in the development of team mental model, situation awareness, and transactive memory systems. For example, Hollingshead (1998) claims that members of teams share their mental model and responsibilities within the team through communication. Similarly, Jeannot (1999) posits that inconsistency in communication within a team is an indicator of an impaired situation awareness. Finally, Hollingshead and Brandon (2003) argue that communication is the basis for the development of transactive memory systems because the team members use communication to encode, store, and retrieve information from other expertise in the group to complete a task.

It is no surprise that communication also plays a critical role in health care and specifically the dynamic high-risk environment of emergency departments. Communication can contribute to a smooth operation within the health care system as well as errors and adverse clinical outcomes. A review of 14,000 deaths that occurred in hospitals in Australia revealed that it is more likely for a patient to die as result of communication errors than from lack of clinical skills of health care workers (Spencer, Logan, & Coiera, 2002).

Many researchers have been studying team mental model and situation awareness in different team settings such as health care and aviation, but, there is a paucity of literature on the development of transactional memory systems in emergency departments, specifically in resuscitation rooms. Furthermore, my search resulted only in a very limited number of studies focusing on how communication and the use of artifacts benefits or hinders the efficiency of transactional memory systems and, ultimately, the output of the resuscitation teams within the emergency department.

The present study is focused on the analysis of the aspects of transactional memory systems in emergency medicine teams. The resuscitation room is a dynamic environment with new scenarios in each case. In many situations, ad hoc teams are assembled with unfamiliar members, which has an impact on the development of transactional memory systems. It is important to understand different aspects of transactional memory systems in this dynamic high-risk environment, and look at the processes and elements that may facilitate the evolution of this construct, which consequently will affect the productivity and the outcome of the resuscitation units.

Communication between the team members was one of the major elements of transactional memory systems that was analyzed in this study. Excessive noise as the result of repetitive requests for information (i.e., questions) may hinder the efficiency of transactional memory systems in resuscitation rooms, that, ultimately, may result in costly mistakes and outcomes. Given that, I also examined the noise based on the information that was provided to team members without being requested. Furthermore, other communication patterns, i.e., verbal and non verbal behaviours and content of the communication, were identified, grouped, and finally

analyzed, to get a better understanding of TMS within resuscitation rooms. Overall, a better understanding of these systems and their critical factors, e.g., communication, leads to methods, techniques, and systems that foster more efficient team transactive memory systems, which in turn leads to better, lower risk care for patients.

In the next sections, I will review transactive memory systems and their benefits and limitations in more detail. I will discuss the role of communication in the development of TMS and continue by covering some of the measuring tools that are being used for transactive memory systems evaluation. The current study will conclude with some recommendations for future studies in this area.

Transactive Memory Systems

Performing a complex task, such as patient care in an emergency department, requires a great deal of physical and mental resources which a single individual may not possess. The amount of information and expertise that is required to ensure a successful outcome may be beyond the physical and memory capacity of a single person. Generally, in these cases, a team of diverse expertise is formed to achieve an efficacious completion of the complex task (Palazzolo, Serb, She, Su, & Contractor, 2006). The members of the team divide the task of learning and remembering the knowledge which is needed to perform the task successfully. Hence, the team forms a mental entity or a “mind” (Wegner, 1986), containing its own memory system and method of encoding, storing, and retrieving knowledge. Lewis (2003) calls this cooperative partitioning of the responsibility of acquiring expertise a transactive memory system.

What Is A Transactive Memory System?

The concept of transactive memory system (TMS) was first coined by Wegner, Giuliano, and Hertel in 1985. Originally, transactive memory system referred to the cognitive and cooperative system used by close individuals to encode, store, and retrieve information or knowledge (Ren & Argote, 2011; Wildman, et al., 2012; Brandon, & Hollingshead, 2004; Liao, Jimmieson, O'Brien, & Restubog, 2012). Later, other researchers extended the concept to encompass group and team settings. The group or the team members may collaborate together in a group setting, by working on the same activity to solve a diagnostic problem or accomplish a task. Alternatively, each member can work on his or her own area and call on other expertise when needed. In an emergency department setting, the teams tend to be multi-functional in nature. This means that the team works in a non-group manner to achieve the team's goal effectively and in a timely manner.

An important note to be cognizant of is that researchers tend to distinguish between transactive memory and transactive memory systems. To differentiate between the two, it is important to look at the components that construct these concepts. Transactive memory, as defined by Wegner and colleagues (1985), is comprised of two components: 1-The organized knowledge possessed by each member of the group which is stored in his/her memory system, and 2-The transactive processes which transpire among the members of the group in the form of communication. Similarly, the transactive memory system is comprised of two components: 1-The *structural* component that maps the links between an individual's memories to the shared knowledge network using transactive memory, and 2- The *transactive processes* that happen during the encoding, storing, and retrieving of knowledge in the team's memory. In a transactive

memory, the members of a team may know the answer to “who knows what” but in a transactive memory system, the members of the team are engaged in the transactive processes (Ren & Argote, 2011). Simply put, transactive memory is in the mind of the individual, while transactive memory systems happen between individuals and develop as a result of the individuals’ transactive memory. For the purpose of this study, my focus is on the interactions between the members of the team and the transactive memory system that develops as a result of their interaction.

Like any other construct, transactive memory systems have benefits and limitations. To be able to comprehend the importance of TMS we need to examine their benefits. Likewise, to understand how to maximize the efficiency of transactive memory systems, it is important to study the elements which may hinder their efficacy. In the next section, I aim to address these aspects of transactive memory systems and look at the benefits and limitations of this construct.

Benefits and Limitations of TMS

Transactive memory systems can provide benefits to team outcomes. For example, TMS can reduce knowledge overlap and cultivate innovation by combining individual knowledge and cognitive capabilities in new and original ways. Overall, TMS can improve the effectiveness of the outcome of team work (Peltokorpi, 2008; Michinov, Olivier-Chiron, Rusch, & Chiron, 2008; Brandon & Hollingshead, 2004). TMS will also distribute the cognitive work load on the individual members of a team, allowing the team to accomplish more complex tasks. Liao, Jimmieson, O’Brien, and Restubog (2012) posit that a well-developed TMS assists the exchange of information and coordination within a team, which as a result reduces the cognitive burdens on individual team members.

Transactive memory systems may have some drawbacks. For example, in a phenomenon that Tschan, Semmer, Grtner, Bizzari, Spychiger, Breuer, and Marsh (2009) call an *illusory transactive memory system*, a member of a team may not share important information with other members. Since, in a well developed transactive memory system, members share their knowledge with the other members, a failure to communicate knowledge by one member will be assumed as an absence of important information. This will result in a misleading sense of security which may cause damaging team outcomes, especially in a health care environment. Another drawback of transactive memory systems may occur once a team member leaves the team, and the team loses the expertise in that particular area. Robertson (2009) explains that membership change results in inefficient transactive process, because the team members rely on the old transactive memory system structure that was formed by the original group members. This inefficiency will affect the performance of the team.

Another drawback of transactive memory systems lies in an incomplete transactive memory system. If transactive memory systems are not well developed, some team members may not be able to locate expertise. Wegner (1986) argues that lack of ability to locate expertise and responsibilities will cause serious problems for the information processing of team members. Another disadvantage of TMS may occur with the erroneous allocation of expertise to individuals. Peltokorpi (2008) believes that the incorrect awareness of expertise will redirect the information needed for task completion away from the true expertise. This will also create obstacles for other team members to process information.

There are several elements that may affect transactive memory systems negatively. These elements include team size, acute stress, membership change, geographic dispersion, and type of

task. Team size is negatively correlated with the coordination aspect of transactive memory systems (Palazzolo et al., 2006; Pavitt, 2003; Wittenbaum, 2003). Ren and Argote (2011) indicated that although TMS benefits groups of any size, it is more beneficial to smaller groups in terms of the quality of decisions and more beneficial to larger groups in terms of efficiency and performance speed.

Similarly, membership change can effect the formation of TMS. Membership change occurs when new members replace one or more original members of a team. In their study, Lewis et al. (2007) stated that efficiency and performance of the teams were lower in partially-intact groups vs. intact groups.

Stress is another element that can affect TMS negatively. Ellis collected data from 97 teams who worked on command-and-control simulation. The collected data showed that acute stress had a negative effect on transactive memory systems. Ellis (2006) posited that the inefficient TMS could partially explain the poor performance of the team under acute stress.

Another factor that has been the subject of much discussion among researchers is communication between team members. In the next section, the role that communication plays in transactive memory systems will be discussed.

The Role of Communication in TMS

Many researchers believe that communication is a crucial part of developing transactive memory systems (Wegner, 1996; Hollingshead & Brandon, 2003; Lewis, 2000). They argue that team members use communication to retrieve and share information, and to allocate expertise. Ultimately, communication plays a vital role in all the processes that are unique to transactive

memory systems. These processes have been identified by Wegner et al. (1985) as directory updating, allocating information, and retrieving the knowledge of team members.

Directory update refers to the process of identifying the area of expertise of the self and other members of the team. During this process, individuals recognize the experts and resources which can be accessed when needed (Wegner, 1995). According to Palazzolo (2005), communication can be an important element of this process. It will facilitate the role-identification process within a team, i.e., team members use communication to broadcast and share their area of expertise to the rest of the members.

The second process, allocation of information, is the process during which the team members use communication to transfer the information that is not part of their specialization to the member with the right domain expertise. This relieves the cognitive capacity of members from carrying non-specialization related information (Palazzolo, 2005).

The last transactive memory system specific process is the retrieval of information through communication. During this process, the team members obtain the information that they need for task finalization from the domain experts (Wegner, 1995; Palazzolo, 2005). Wegner et al. (1985) indicated that the retrieval of information process allows researchers to measure the efficiency and usefulness of a transactive memory system.

Hence, communication is regarded as a tool to enhance and augment the memory of the individual members of the team. Wegner et al. (1985) likened the communication between the members of a team to the thought process that occurs in the mind of an individual during cognitive processes.

Communication is not limited to verbal and non-verbal communication (e.g., body posture, etc.). Team members can communicate through other media such as notes, PDAs, and other electronics. Wegner, Giuliano, and Hertel (1985) note that communication involves the transfer of information and can have different forms such as written feedback. Hollingshead and Brandon (2003) argue that communication allows the memory system to be “transactive”. They suggest that communication is the transaction that happens while the transactive memory system is being established. Communication also helps to eliminate the stereotypical notions that team members might have with regards to the other members’ appearances, such as gender. The amount of communication decreases as members of a group locate expertise and become familiar with each other. Palazzolo et al. (2006) used computational models to evaluate the role of communication in transactive memory systems. They found a strong relation between communication density and well established transactive memory systems. Palazzolo et al. defined communication density as the percentage of actual communication links between dyads of team members, relative to the total possible communication links between all pairs of team members. They claimed that initial information level of the members of the team has the strongest influence on communication.

Although communication is regarded as an important element in establishing transactive memory systems, it is also believed to be a hindrance to some of the important transactive processes. For example, Hollingshead (1998) noted that communication during recall disrupted the retrieval process of the team members in transactive memory systems. Furthermore, it can hinder the encoding and storage of newly introduced information, because it will decrease the time that is available to learn novel information, particularly during the completion of time

sensitive tasks. Other researchers believe that there is no link between communication and transactive memory systems. Akgün, Byrne, Keskin, Lynn, and Imamoglu (2005) interviewed team members of 69 new product projects. They asked each team to complete a questionnaire, including 56 questions adapted from Lewis' TMS measurement (2003), Lynn's formal team communication (1988), and Lynn's informal team communication (1988). Their collected data failed to support a relationship between communication and transactive memory system. However, the teams who participated in this study had existed for at least six months, and therefore, the members might have used communication to establish the notion of "who knows what" during that period and before the study was initiated. The amount of communication is dynamic through the development of TMS. It may decrease as the team members locate expertise and establish the TMS that is needed to complete the team's goal. Yoo and Kanawattanachai (2001) noted that the volume of communication between the team members who worked on a realistic business simulation game significantly decreased once the team's TMS was developed. Similarly, Ren and Argote (2011) stated that communication is more influential in the development of TMS in earlier stages of group functions.

As noted in the previous sections, there are many factors that may affect transactive memory systems (e.g., communication, membership change, etc.). The question that emerges is how TMS is measured. How would researchers know whether a certain element has increased or decreased the efficiency of TMS? Measuring conceptual abstractions such as transactive memory systems is a challenging task. One way researchers have managed to achieve this difficult task is by measuring the manifestations of the construct, such as behavioural indicators

(Spector, 1992; Lewis, 2003). In the next section, some indicators of transactive memory systems and methods that are used to measure transactive memory systems are examined.

Study and Measures of Transactive Memory Systems

According to Liang, Moreland, and Argote (1995), there are three behavioural indicators of an established transactive memory system in a group: 1- Each member of the group remembers a different aspect of the complex task (memory differentiation/specialization), 2- Members of the group trust other members' expertise (task credibility), and 3- Members of the group coordinate their efforts effectively (coordination). To measure these indicators, Lewis (2003) developed a 15-item scale (see Appendix C).

To evaluate transactive memory systems, Lewis (2003) aggregates the scores of each team member's response to different questions in each domain. She claims that the aggregated scores can show the level of effectiveness of the transactive memory system of the team. For example, the aggregated scores regarding the statement, "Different team members are responsible for expertise in different areas" indicates the level of functionality of the transactive memory system within a team. In this case, based on Lewis's scale, lower aggregated scores of the team members shows lack of trust in the expertise between members. Conversely, higher aggregated scores of team members is indicative of distinct and differentiated information and knowledge, presumably resulting in effective transactive memories. Furthermore, she states that midrange scores suggest the inefficiency or lack of maturity of the TMS. Lewis's (2003) measures can be used in both laboratory and field environments.

Although communication can be used as a major element that plays a crucial role in determining the TMS indicators, in a health care environment, many researchers analyze

communication between the team members to measure the efficiency of transactive memory systems. For example, Sarcevic, Marsic, and Lesk (2008) analyzed and coded the communication within a trauma resuscitation team to study transactive memory systems in a hospital's emergency environment. They analyzed communication efficiency and the level of TMS to determine how communication affects transactive memory systems in resuscitation bays.

Other TMS measures that are used in the field include Faraj and Sproull's (2000) measures, which look at expertise location and how expertise is called upon in the trouble-shooting process, and Austin's (2003) measures, which look at "Group task knowledge stock", "Task knowledge specialization", "Transactive memory consensus", and "Transactive memory accuracy". There is some preliminary and subsequent work associated with Austin's (2003) measures for researchers and participants. The researcher needs to conduct an initial interview to determine the areas of knowledge applicable to the team's function. The number of cells that team members need to fill out depends on the number of members in the team times the number of expertise areas. For example, in a team of 7 members (e.g., in an emergency department resuscitation area, 3 nurses, 1 respiratory therapist, 1 physician team leader, 1 resident, and 1 anesthesiologist) and 4 expertise areas, each member of the team is required to complete $7 \times 4 = 28$ cells.

Other elements that may be used to measure transactive memory systems are team performance outcome and team members' satisfaction. Team performance outcome has been positively associated with TMS (Wegner, 1987; Faraj & Sproull, 2000; Ren & Argote, 2011). The ability to recognize and locate expertise is related to better performance and outcome of teams (Faraj & Sproull, 2000). Similarly, more effective transactive memory systems are associated with job satisfaction and a positive perception of team effectiveness. Michinov,

Olivier-Chiron, Rusch, and Chiron (2008) conducted a cross-sectional study among 77 nurse anaesthetists and 74 physician anaesthetists in eight French hospitals. They used a questionnaire to measure TMS, work attitudes, and perception of team effectiveness. Michinov and colleagues found a strong correlation between TMS and perception of team effectiveness and job satisfaction. This correlation may demonstrate that job satisfaction and team effectiveness can be indicative of TMS within teams.

Purpose of The Study

The objective of this study was to evaluate and analyze TMS within resuscitation teams to discover the patterns associated with the transaction of memory contents of the team members and external memory devices, such as PDAs and information sheets. This will facilitate the development of protocols and tools to improve the elements related to the construct, such as communication. This improvement may contribute to better patient care and safety within the emergency department. To help meet this objective, I evaluated teamwork in resuscitation rooms, and analyzed the nature of transactive memory systems within the team. Furthermore, I examined the efficiency of TMS in resuscitation simulation teams by examining communication noise (i.e., repetitive requests for information which may hinder the efficiency of transactive memory systems).

This research addressed the following questions:

- What is the nature of transactive memory systems processes in resuscitation teams?
- How do TMS behavioural indicators distribute throughout resuscitation scenarios?
- Are TMS in simulated resuscitation rooms efficient?
- Who are the main information receivers and providers?

- What type of information is exchanged most regularly during a scenario?
- What are the artifacts and devices used during resuscitation events?

By addressing these questions, it was hoped that this study could provide needed data for designing programs and tools to improve TMS and increase the success and efficiency of the dynamic high-risk environment of resuscitation units. This will help to achieve the ultimate goal of the emergency departments, which is to provide the best and most efficient care for the patients in a time sensitive manner.

Method

Research Approach Overview

This study was designed using a mix of qualitative and quantitative research methods. The collection and analysis of data for this study was based on a cognitive ethnography approach (Ball & Ormerod, 2000; Williams, 2006; Patel et al., 2008). Patel and colleagues believe this approach is a suitable method for data collection and analysis for studies of workflow in critical care studies. This approach involves monitoring the interaction between the resuscitation team members, including their verbal and non-verbal communication and use of artifacts.

The current study was based on the archival research of recorded resuscitation simulations. During this approach, pre-recorded educational simulation videos were observed and the communication between the team members participating in a simulation of an emergency scenario was analyzed.

This study was approved by both Carleton University and the Ottawa Hospital research ethics boards (REB). Prior to the study, a preliminary interview with the key players and confederates of the resuscitation unit at the emergency department was conducted so that the

main members in a resuscitation team could be identified and the responsibility of each member could be determined. Ultimately, I used the aggregated findings of the preliminary interviews and communication analysis of the pre-recorded scenarios to address the research questions.

Preliminary Interviews

Specialization is one of the behavioural indicators of transactive memory systems. This indicator is apparent when members of the resuscitation team have differentiated areas of expertise. Furthermore, emerging TMS in the resuscitation team depends on the team members being able to identify and locate expertise in the team, which is the directory update process. To get a better understanding of the resuscitation team specialization behaviour indicator, team composition, ability to locate expertise, and the mental model of each team member, I interviewed different resuscitation room team members. Another purpose of the preliminary interviews was to get an understanding of the roles and responsibilities of each member involved in resuscitation events. The results of the interviews were also used in another student's thesis (Hobin, 2013). Based on the result of the interviews and the subsequent emerged mental model of the resuscitation team members, Hobin was able to draw a network diagram which displayed the pair-wise communication within the emergency medicine teams (Appendix A).

Participants

For the preliminary interview, 18 emergency department team members were interviewed. The interviewees were from different professions, including emergency physicians, nurses, specialists, clerks, patient care assistants (PCA), social workers, paramedics, and residents. Variables such as gender, age, and years of service did not have any significance in the study and were not controlled.

Setup and Apparatus

The participants were asked a series of questions with regards to the nature of their job and the role that each individual is expected to play within the emergency team (see Appendix B). The questionnaire was designed after a consultation with an attending emergency physician and a resident. The interviews were recorded on an iPhone. The recordings were later replayed to take notes about the roles and responsibilities of the team members and the interaction between them.

Procedure

The preliminary interviews were conducted a few months earlier than the rest of the research. The office of the associate scientist at the Ottawa Hospital Research Institute assisted with the recruiting of the volunteers. An e-mail was sent by the associate scientist at the Ottawa Hospital Research Institute to the emergency department of the Civic Hospital asking for volunteers from different professions who participate in the emergency team during emergency scenario.

Archival Research of Recorded Resuscitation Simulations

Participants

The participants for this stage of the study were 112 residents and nurses who had participated in 30 educational simulations. There was an average of four interns and nurses per scenario, with a minimum of three (two interns and one nurse) and maximum of five (three interns and two nurses). Each simulation consisted of one resident who was acting as a team leader, at least one nurse, and other residents who acted as consultants. The resident participants were physicians in various years of their residency at the emergency department. The year of residency varied from the first year to the final or 5th year. As per ethics approval terms, the

gender, age, and ethnicity of the participants were not recorded. Furthermore, for the same reason the participants' activities could not be controlled. The residents had given consent for their simulation video to be analyzed for this study.

Setup and Apparatus

The simulations were recorded at the University of Ottawa Skills and Simulation Centre, located at the Ottawa Civic Hospital, for the purpose of educational training and evaluation of the emergency physician residents. The emergency department interns participated in resuscitation simulations, during which they interacted with a robotic mannequin which was controlled by instructors who was situated in the control room. The instructors were behind a one way mirror, so they could not be seen or heard by the interns. The nurses who were participating in the simulations acted as confederates. The instructors transmitted certain information to the confederate nurses through an earpiece, based on the required information to progress the scenario further. Each simulation followed a certain script. There were a few different scripts that were being used for simulations. The number of scripts used for simulations and the events of the scripts could not be acquired because these simulations are also being used for evaluation purposes and the University of Ottawa Skills and Simulation Centre did not wish to make the information available to maintain the integrity of the evaluation process.

Typically, each simulation event was recorded in four mp4 format videos from 3 different angles of the emergency room, and a video of the monitor showing the patient's vital sign. Each group of videos were packaged together using Owl video player software. The video player allowed the viewer to observe four videos in four different windows at the same time. A snap shot of a sample video is shown in Figure 1. The videos were viewed and transcribed using two

different computers, a MacBook Air running OSX and an HP Pavilion desktop running Windows XP. Internal speakers of the computers were used for listening to the conversations during the simulations. The transcriptions were typed in separate worksheets for each video, using Numbers and Excel in three categories: Time/Duration (hh:mm:ss), Source-Destination, Info Conveyed, and Action (see Figure 2). The transcription files were named based on the original video file, so that they could be cross checked by the physician resident who was cooperating in this study for accuracy if needs be. The videos were deleted permanently at the end of the study.

Figure 1. A snap shot of a simulation video.

	A	B	C	D
1				
2	Time/Duration	Source-Destination	Info Conveyed	Action
3	0:00:23			Physician comes in
4	0:00:24	TL to Nurse	Hi xx, I'm Dr. yy, with the emerge and this is yy my night shift resident	Ph moves to the side of the bed pointing to the resident. Resident moves to the foot of the bed
5	0:00:29	Nurse to TL	This is Mr. Major here from triage	Hands the patient info sheet to the physician
6	0:00:31	TL to Patient	Hi Mr. Major	
7	0:00:35	TL to Nurse	says here, he's been unwell for a week with gastric pain, black stool for two days, ok, these are the vital signs here?	
8		N to TL	I got them on the monitor here	

Figure 2. A snap shot of the transcription entry, using Numbers

Measures and Analysis

In the current study, the data from the pre-recorded resuscitation simulation videos were analyzed with a focus on several components. The recorded resuscitation simulation videos were transcribed and the behavioural indicators of the team members were recorded and analyzed. These indicators are: communication elements, i.e., content and verbal behaviour, and use of devices and artifact by the team members.

Procedure

Communication. The study's communication analysis was focused on the information flow between the team members. Development of TMS strengthen as team members use communication to detect expertise, broadcast their expertise status, retrieve and share information, and coordination of patient care with other members of the team (e.g., Hollingshead & Brandon, 2003).

The analysis of the team communication was based on the Conversation Analysis framework (e.g., Pomerantz & Fehr, 1997) and Communication Observation Method Manual (Spencer, Logan & Coiera, 2002). Using these approaches, the videos were transcribed into raw conversation transcripts in which the verbal communication of the team members were segmented into intelligible sequences of events within a given context. A sequence of events is described as the combination of one or more utterances or messages that are produced during a verbal interaction by any team member or between at least two individuals using a communication channel (Parush, Kramer, Foster-hunt, McMullan & Momtahan, 2014; Spencer, Logan & Coiera, 2002). Parush and colleagues state that the utterance is the basic element from which the sequences are built (e.g., see the “Information conveyed” column in Table 1). The communication channels include: face-to-face, telephone conversation, text entries on paper based or electronic based hospital forms or medical records, and messages written on paper. The areas of communication that were the centre of my focus in the data analysis were content, verbal behaviour, role of artifacts as means of communication, and non-verbal communication.

Table 1.

Examples of utterances. Each row of the “Information conveyed” column is an utterance.

Time/Duration	Source-Destination	Information conveyed
0:03:43	TL to N	“could we give some oxygen for the patient too.”
0:03:45	TL to N	“start at 3 litres please.”

Direction of utterances. To determine the direction of the utterances, the source and destination of the utterances were determined (see Tables 2 for source and destination codes and examples of the direction of utterances in Source-Destination column of Table 5). Among other information, the direction allowed the researcher to determine the team members who provided the most information or asked the most number of questions.

Table 2.

Source and destination codes

Code	Long form
N	Nurse
P	Patient
Ph	Physician
C	Consultant
R	Resident
RT	Respiratory therapist
TL	Team leader
A	Anaesthetist

Coding

The transcribed data were coded based on the definitions of communication elements and transactional memory systems processes and behavioural indicators which are described in the following sections. As TMS could not be evaluated directly (Lewis, 2003), I used verbal behaviours and the content of communication to code the TMS processes as indirect indicators of the construct (see Table 7). Furthermore, I used Lewis' (2003) TMS 15-items scale as a

guideline to identify and code TMS behavioural indicators (see Table 6). Lewis claims that the scale indeed reflects the three indicators of TMS (i.e., specialization, coordination, and credibility).

The inter-rater agreement was calculated based on the coding of one randomly selected simulation video by a volunteer student. I used the formula (Gisev, Simon Bell, and Chen, 2013):

$$\text{Percent agreement} = \frac{\text{Number of concordant responses}}{\text{Total number of responses}} \times 100\%$$

The inter-rater agreement was 74.4% for communication content, 74.4% verbal behaviour, 63.8% primary TMS, and 18.8% for secondary TMS. Although the inter-rater agreement is low for secondary TMS behavioural indicators coding, it needs to be noted that the second rater did not code a large segment of the data (36.7% uncoded).

Content. Content is defined as the subject that is dealt with through communication. Weakland and Beavin (1967) describe content as the information about object or subject, or the context of the communication.

In the current study, the content categories included: patient history, equipment, drug administration, treatment, patient status, diagnostics, assistance request, time, access, and medical action. An example of content categories of sample data is presented in Table 3. One of the applications of content categorization was to determine the most frequent communication context between the team members. This allowed me to examine certain patterns of content throughout the scenarios and compare them to the information collected from the preliminary

interviews. The goal was to ascertain whether the observed patterns are in accordance with the patterns that was described by different resuscitation room team members.

Table 3.

Content categories definitions and examples

Category	Definition	Example
Patient status	Information about the patient.	She is only sat'ing at 94.
Medical action	Information related to established medical procedures	Can we get some suction as well for the airway?
Drug administration	Request for or information with regards to administering drugs	Did we give one milligram of epi?
Assistance request	Request for involvement of other people who are not present at that time.	Can you also call GI please.
Treatment	Non-drug treatments	Call for 4 units [blood]
Tests	Information about tests such as blood or urine	Yeah, Get CBC 'lytes and lactate as well, CK/InI (Blood work)
Patient history	Information about what happened to the patient	She's an 18 year old female. Cough and cold symptoms for 3 days and today her breathing's getting worse with some chest pains
Equipment	Information about resuscitation room equipment	can you just pull over the crash cart for me?
Diagnostics	Information that may be used to deduce what the cause of the patient's medical problem is.	We think it might have been Lanacane toxicity.
Consultation	Information with regards to consulting with other team members	sorry, uhh, feel free to jump in, if anybody has any thoughts of the things that I haven't thought of yet.
Time	Time related information	it usually takes about 20 minutes for the lab to inaudible Maybe inaudible or type specific blood.
Access	Information related to the procedure that establishes access to the patient's blood stream	ok, do you mind starting a line?
Introduction	The information related to introducing self or someone else to the team	Hello, hi there, I'm xx

Verbal behaviour. The events were identified within transcripts and the utterances were coded by assigning them to different verbal behaviours such as question, directive, report, acknowledgement, clarification, instruction, statement, and suggestion (see Table 4 for definitions and examples). An example of a coded transcript is presented in Table 5.

Table 4.

Verbal behaviour categories definitions and examples

Category	Definition	Example
Report	something that one has been observed, heard, done, or investigated	We have a pulse
Directive	Authoritative instruction	get more bicarb ready.
Question	A sentence to elicit information	so you are concerned about hypovolemia?
Acknowledgment	Confirming an action or the existence of something	Yes, second IV is in.
Clarification	The action of making a statement or situation more comprehensible.	I agree with you. Sounds like crackling on the right here.
Statement	Clear expression of something	thinking of what might be toxin.
Instruction	Detailed information telling how something should be done.	IV infusion protocol is 5-15 micrograms per minute.
Suggestion	An idea or plan set forward for consideration	ok, so give him antibiotics? (R->TL)

Table 5.

Excerpt from a coded transcript

Time/Duration	Source-Destination	Information conveyed	Verbal behaviour	Behaviour
0:03:43	TL to N	Give him a litre of normal saline	Directive	Physician looks at the nurse.
0:03:45	TL to N	start at 3 litres please.	Directive	looks back at the monitor.
0:11:54	N to TL	so in 3 minutes you want another dose of Epi?	Question	
0:11:57	TL to N	yeah, another Epi in 3 minutes please.	Acknowledgment	

The verbal behaviours were counted per team member to determine the possible expertise location (i.e., the person who answers the most questions), or the progress of the transactive memory system through questions that are directed to the experts (specialization), possibility of second guessing the person in charge (credibility), and the flow of the process (coordination).

Primary and secondary transactive memory system indicators. Each utterance was assigned to one of the three behavioural indicators of transactive memory system (i.e., specialization, credibility, and coordination). See Table 6 for definitions and examples of TMS indicators. The goal was to detect the transactive memory system indicators within the resuscitation teams and to analyze this construct within those teams. For example, the communication between the nurse and physician in Table 5 at 0:11:54 was categorized as “credibility”, because the nurse trusts the expertise of the physician to know whether or not the medication should be administered .

Table 6.

TMS indicators categories definitions and examples

Category	Definition*	Example
Specialization	Utterances indicating one of these conditions: 1-Each member has specialized knowledge of some aspect of the project that no other team member has. 2-Team members know which team members have expertise in specific areas. 3-Different team members are responsible for expertise in different areas. 4- Specialized knowledge of several different team members was needed to complete the project.	Ok, let's not intubate, let's just bag her. (TL -> N)
Credibility	Utterances indicating one of these conditions: 1-Team members were comfortable accepting procedural suggestion from other team members. 2-Team members trusted other members' knowledge about the project. 3-Members were confident to rely on the information that other team members brought to discussion. 4-Team members did not double-check information given by other members.	Can you please start compressions. (TL -> C)
Coordination	Utterances indicating one of these conditions: 1-Team worked together in a well-coordinated manner. 2-Team had very few misunderstanding about what to do. 3-Team did not need to backtrack and start over a lot. 4-There was not much confusion about how the team would accomplish the task.	Okay so you got the solumedrol; he's got the benadryl;

* Based on Transactive Memory System 15-items Scale, Lewis (2003).

Ultimately, the goal was to determine whether or not there is a pattern in the flow of TMS within the resuscitation teams. Depending on how the data is interpreted, each utterance could be coded into at least two TMS indicators. For example, when the team leader asks the nurse “okay, can we call RT to come up?” we can assume the team leader trusts the RT to be able to take care of the respiratory issues of the patient (i.e., credibility), we can also assume that they

are coordinating their effort as a team (i.e., coordination). To ensure that both possible codings were considered, each segment of utterances was coded into two different columns of indicators, primary and secondary TMS indicator.

TMS processes. The verbal behaviour and content of the utterances were analyzed with respect to the TMS processes. A verbal category with a specific content was assigned to each process and the number of processes were counted. For example, all utterances with the verbal category “report” with the content category “patient history”, before a request for the information, were assigned to information allocation process, because in this case, the team members distributed the information about the history of the patient that they assumed other experts may need. Similarly, all utterances with the verbal category “report” with the content category “patient status”, after a request for the information, were assigned to information retrieval process. For example in Table 7, the response of the team leader (TL -> Res: It is [the pulse] thready) to the resident after the request for the information from the resident (Res -> TL: Are you getting a pulse?) is assigned to information retrieval process. The goal was to look at the prevalence of each process in the 30 scenarios. Furthermore the information was used to create histograms so that the distribution of the processes through out the scenarios are identified. The definition and the criteria for each process are presented in Table 7.

Table 7.

Description and the criteria for the analysis of TMS processes.

Process	Definition	Criteria	Example
Directory update	Team members identify and locate expertise	Statement verbal behaviour with the content of assistance request or the utterances containing “Hi” or “Hello” (from any member but the team leader)	1-Consultant -> TL: We’re Cardiology. 2-CT -> TL: Hi, CT.
Information allocation	Team members transfer information that is not related to their expertise to the expert	Report, clarification, and instruction verbal behaviour with the content of, patient status, patient history, tests, treatment, time, access, equipment, and drug administration before the information was requested, or after but not in response to the person who asked the question.	N -> TL: Patient has been unwell for a week with gastric pain, black stool.
Information retrieval	Team members retrieve information from other members to complete their task	Report, clarification, and instruction verbal behaviour with the content of, patient status, patient history, tests, treatment, time, access, equipment, and drug administration after the information was requested (after a question, spoken to the person who asked the question)	Res -> N: Is he on any medication at home? N -> Res: Umm yes he is...he is on, I believe, hydrochlorothiazide.

Sharing of information and anticipation ratio. Sarcevic, Marsi, Lesk, and Burd (2008) claim that inquiries and responses were the primary means of using transactive memory system in a trauma team of an emergency department. Furthermore, they posit that low awareness of information needs by team members (i.e., having to pull information through questions vs. having information being pushed to the relevant members) in the resuscitation room will degrade communication between team members and hence limit the development of the transactive memory system of the team.

The cognitive tasks such as memorizing information about the patient, recalling the last drug administration, and monitoring the vital signs of the patient for any changes are delegated to different members of the team. In the study done by Sarcevic et al. the physician and EMS paramedics were typically the top information seekers and providers.

In a well coordinated team, team members anticipate the information needs of other members and provide the information without being probed (i.e. pushing information). This will decrease the amount of noise (i.e., fewer questions being asked), and will improve the communication and ultimately, the transactive memory system of the team.

To monitor the obstacles in the efficiency of the transactive memory system within resuscitation teams, the “anticipation ratio” (Entin & Serfaty, 1999) within the communication of the team was measured. The anticipation ratio (AR) refers to the ratio of number of information transmissions transferred (i.e., push) to a team member (T) versus the number of information requests (i.e., pull) from the team member (P). Entin and Serfaty argue that an AR of greater than one indicates that the information is being pushed without receiving a request. Sarcevic and colleagues posit that an anticipation ratio of greater than one is an indication of a more efficient

transactive memory system. In the current study, my focus was on the main figure in the resuscitation team with the most information exchange, i.e., the team leader. I used the number of questions that the team leader asked as information requests or pull (P) and the number of reports, acknowledgments, clarifications, directives, suggestions, instructions, or statements, that team members provided to the team leader without a prior question with regards to the content of information as information transmission or push (T).

Non-verbal behaviour. As part of the transcription of the simulation videos, the non-verbal behaviour such as body language and gestures of the team members, was recorded. The focus was on the non-verbal behaviour that was relevant to TMS indicators (i.e., specialization, credibility, and coordination).

Use of artifacts and devices. My preliminary observations and interviews indicated that, aside from the medical devices that the members of the team may use, external memory aids, such as iPads and PDAs, may be utilized for the purpose of information look-up. These devices can play a substantial role in the development of team's transactive memory system, because they can be considered as an extended memory or an "expert" that can be accessed during the resuscitation task completion. I took notes of the actions of each member of the team and marked down the usage of artifacts and the condition or reason under which they were used. The purpose of each usage was also recorded so that it could be categorized.

Analysis

A computer program was written in Perl script (Unix environment) by a volunteer programmer to parse through over 2600 lines of coded data to count the occurrences of different coded data. Subsequently, histograms were plotted based on the collected statistics.

For the main section of the study, the residents were contacted by a second year resident who is a member of the research team. He asked for the residents' permission to use the recorded simulation in which they had participated. They were offered the option of opting out with no penalty. After acquiring their permission, the recorded simulations were transferred using an external hard-drive to a MacBook Air.

Results

Preliminary Interviews

The preliminary interviews facilitated the understanding of the nature of the emergency teams and the interaction between the team members. Wegner (1995) suggests one of the processes in the emergence of TMS is “directory update”. This term refers to the process of identifying the area of expertise of the self and other members of the team. The preliminary interviews allowed the researchers to gain an understanding of the directory mapping of the members of the resuscitation team. In this section, the findings with regards to the resuscitation room team members and their roles and responsibilities within the team are presented.

Roles and responsibilities of the resuscitation room team members. The emergency team in the resuscitation room is typically assembled once the information about a new patient is patched in to the emergency department. The patients end up in the resuscitation room in many ways. For example they can be brought in by the Emergency Medical Services (EMS) paramedics, a family member or from another department in the hospital. In the case of a patient who is brought in via EMS, a nurse and, depending on the severity of the medical problem, an emergency physician meet the EMS team at the entrance of the resuscitation room. One of the EMS team members gives the reason the patient has been brought to the emergency and the

patient's medical history while handing over the patient care to the emergency team. The emergency physician who assumes the role of team leader (TL) will assess the patient and call for assistance from other medical professions. In situations where the patient is brought to the emergency department for a known issue such as cardiovascular failure, a specialist, in this case a cardiologist, may receive the patient and assume the role of team leader. Team members who are involved in an emergency scenario may include 2 or 3 nurses, a respiratory therapist, an emergency physician, various residents, specialists, a clerk and patient care assistant(s) (PCA).

Team leader. Once the patient is in the resuscitation room, either the emergency physician or a specialist will take over the role of team leader (TL) or most responsible person (MRP). In this study I have used the terms TL and MRP interchangeably. Typically, the patient is received by an emergency physician. The emergency physician goes through a pre-determined assessment protocol, based on Advanced Trauma Life Support or ATLS protocol, to ensure that the critical issues, such as a blocked airway or difficulty breathing, are addressed. The TL then assesses the extent of the injury or the problem and may request for a specialist to take over if needs be. If the physician determines that the extent of the problem is outside the scope of the capacity or specialty of an emergency physician, the nurse or the clerk is asked to page a specialist for consultation. Only the team leader has the decision making responsibility. The TL can consult with different members of the team but the final decisions are made by the team leader.

Nurses. Depending on the severity of the case, there may be several nurses present during an emergency. One nurse takes the responsibility of documenting all the events, such as the history of the patient, who is the team leader, the other team members who are present, the type

of drugs that were administered and the time of administration. If the team leader needs to know when a certain drug was administered, she or he will ask the transcribing nurse to refer to his or her notes for the information. Other nurses perform other operations such as connecting the patient to the monitor for vital signs and setting up IV access for treatments and drug administrations as per the team leader's request. If the team leader needs to engage the help of a consultant, the nurse can call or ask the clerk, if present, to page the requested consultant.

Consultants or specialists. The respiratory therapist is usually present at all emergency scenarios. The responsibility of the RT is to make sure that the patient can breathe comfortably. Other specialists who may become involved in the emergency scenario could be, among others, the anesthesiologist, cardiologist or gastroenterologist. The specialist can take over the leadership of the team or act as a consultant to help the TL stabilize the patient before transferring the patient to other sections such as the ICU or surgery.

Residents. Residents are physicians who are in the process of specializing in emergency medicine. As part of their training they participate in emergency cases. Depending on their year of training, they may take the position of the TL under the emergency physician's supervision. They can also serve as the helping hand to the emergency physician during the emergency scenario.

Other team members. There may be other individuals participating in an emergency event. These include the clerk whose responsibilities include paging specialist and services needed during the emergency scenario, and the patient care assistant (PCA) who is responsible for log rolling, moving, restraining aggressive patients, or other physical and non-medical interventions and assistance.

Preliminary interviews summary. The preliminary interviews identified the location of expertise in the mental directories of resuscitation team members. The expected expertise is depended on members titles. Based on the data collected from the interviews, Hobin (2013) outlined a network of communication between the team members (see Appendix A). This network showed that the TL or MRP is acting as the main hub for communication within resuscitation teams. Hence, the majority of information is transmitted to the team leader. However, the team leader has the most number of information exchanges with the nurse, resident, and consultants, respectively.

Archival Research of Recorded Resuscitation Simulations

General Communication Distribution. The 2506 instances of utterances were analyzed across all 30 scenarios. The utterances were bundled into meaningful sequences. The term “meaningful sequence” refers to the sequential utterances that constitute a meaningful communication exchange consisting of a specific topic. An example of “meaningful sequence” is illustrated in Table 8. The first five rows of utterances in the table create a meaningful sequence. The team leader and the nurse discuss about a single topic, which is performing certain blood tests on the patient. Once the topic of utterances changes, a new meaningful sequence starts. Hence, the next two rows of utterances are considered as another meaningful sequence, in which the team leader and the nurse discuss the treatment of the patient. In the 30 pre-recorded scenarios, there were 1320 meaningful sequences, an average of 44 per scenario.

Table 8.

Example of meaningful sequences

#	Source-Destination	Meaningful sequence	Content	
1	TL to N	Yeah, Get CBC 'lytes and lactate as well, CK/InI (Blood work)	Tests	Meaningful Seq. I
2	N to TL	Sure. [inaudible]	Tests	
3	TL to N	Yeah, get an INR as well.	Tests	
4	Ph to TL	And get a VBG.	Tests	
5	TL to N	Get a VBG as well.	Tests	
6	TL to N	We are giving a litre [Saline] right now?	Treatment	Meaningful Seq. II
7	N to TL	Yeah I have a litre up.	Treatment	

The intervals for examining communication distribution. One of the objectives of the analyses was to examine patterns of communication and TMS. There was a need to define the basic units for examining such distribution. Time intervals would have been the obvious unit for that, however, the different scenarios varied in their durations and number of utterances. In order to overcome this variance, intervals of 5% of the total number of utterances were selected.

TMS processes distribution. The three processes of TMS include the directory update (during which team members identify and locate expertise), information allocation (during which team members transfer information that is not related to their expertise to the expert), and information retrieval (during which team members retrieve information from other members to complete their task). Information allocation was the most prevalent TMS process in the resuscitation room simulations, followed by information retrieval. Directory update was the least

prevalent TMS process in the resuscitation room simulations (see Table 9). The histograms showed that directory update spiked at the 100th percentile. Information update and information retrieval spiked at 5th percentile and 30th percentile, respectively (see *Figure 3*).

Table 9.

Prevalence of TMS processes.

Process	Prevalence
Information allocation	594
Information retrieval	189
Directory update	17

Information allocation had the highest prevalence compare to either directory update and information retrieval (see *Figure 3*).

Figure 3. Showing the prevalence of the three TMS processes as a function of the 5% intervals of utterances throughout the scenarios

TMS indicators general distribution. In the primary TMS indicator category, there were 996 instances of specialization (mean percentage = 40), 959 instances of coordination (mean percentage = 38) and 547 instances of credibility (mean percentage = 20). “Not coded” refers to the instances during which the utterances were inaudible (see Table 10).

Table 10.

Frequency of primary TMS indicators (utterance).

Primary TMS indicator	Frequency	Percentage of the total utterances	Mean percentage	Standard deviation
Specialization	996	40	40	11
Coordination	959	38	39	10
Credibility	547	22	20	10
Not coded	4	0.2	0.3	0.9
Total	2506			

In the secondary TMS indicator category, there were 1435 instances of coordination (mean percentage = 58), 729 instances of credibility (mean percentage = 29) and 334 instances of specialization (mean percentage = 13) (see Table 11).

Table 11.

Frequency of secondary TMS indicators (utterances).

Secondary TMS indicator	Frequency	Percentage of the total utterances	Mean percentage	Standard deviation
Coordination	1435	57	58	16
Credibility	729	29	29	10
Specialization	334	13	13	8
Not coded	8	0.3	0.4	0.90
Total	2506			

Primary TMS category distribution. For each 5% interval of the 2506 utterances between the team members, the indicators of transactive memory systems were identified and histograms were plotted. The histograms show the distribution of primary transactive memory systems indicators through the scenarios. The histograms indicate that through the scenarios, coordination was at its lowest at the 45th percentile interval, however, specialization was at its highest at the same point (*Figure 4*). *Figure 4* displays the combined histogram of the three TMS indicators, so that each TMS indicator can be compared with other indicators at each 5% intervals.

Figure 4. Showing the frequency of the three primary TMS indicators as a function of the 5% intervals of utterances throughout the scenarios.

Secondary TMS category distribution. Just as for the primary TMS indicators, for each 5% interval of the 2506 utterances between the team members, the indicators of transactive memory systems were identified and histograms were plotted. The histograms show that as cooperation bottomed out at the 55th-60th percentile intervals, the credibility and specialization peaked at that point in the scenarios (see *Figure 5*). *Figure 5* displays the combined histogram

of the three TMS indicators, so that each TMS indicator can be compared with other indicators at each 5% intervals. The histograms show that in secondary TMS indicators, specialization had a lower rate of occurrence than coordination or credibility.

Figure 5. Showing the frequency of the three secondary TMS indicators as a function of the 5% intervals of utterances throughout the scenarios.

Sharing of information and efficiency of TMS. In the 30 scenarios, the team leader asked the most number of questions, followed by the nurse. The next team member who asked the most number of questions was the resident. Furthermore, the team leader answered the most number of questions, followed by the nurses and the residents (see Table 12). The most sought for information (i.e., content of questions) was related to drug administration, followed by medical action (see Appendix H).

Table 12.

Frequency of questions asked and answered by team members

Member	Frequency (Asked Questions)	Frequency (Answered Questions)	Percent of the total questions asked	Percent of total questions answered
Team Leader	246	151	54	41
Nurse	141	128	31	35
Resident	46	58	10	16
Consultants	12	17	3	5
Respiratory Therapist	7	11	2	3
Total	452	365	817	

To evaluate the efficiency of TMS in resuscitation room scenarios, I analyzed the anticipation ratio (AR). The AR was analyzed by using the information push and pull between the main player in information exchanges and transactions, i.e., team leader. The team leader asked 246 questions ($P = 246$) and the team members transmitted 428 reports to the team leader without being probed for information ($T = 428$). The Anticipation ratio (AR) was calculated as: $AR = P/T = 428/246 = 1.7$.

Initiators of meaningful sequences. From the total of 1320 meaningful sequences, the team leader initiated the majority of them, followed by the nurse. The resident and consultants (including ICU, anesthesiologist, gastroenterologist and intensivist) initiated the next most instances of meaningful sequences respectively after the nurses (see Table 13).

Table 13.

Frequency of initiation of a meaningful sequence by team members

Team member	Frequency	Percentage	Average per scenario
TL	985	75	33
Nurse	197	15	7
Resident	80	6	3
Physician	11	1	0
Respiratory Therapist	11	1	0
Consultants	36	3	1
Total	1320		

The team leaders had 484 instances of initiating a meaningful sequence with the nurses, 108 instances with the residents, and 66 instances with the RT and other consultants and specialists.

There were 167 instances of a nurse initiating a meaningful sequence with the TL and 7 instances of the nurse initiating a meaningful sequence with the consultants or other specialists (see *Figure 6*). The team leader had 327 instances of initiating a meaningful sequence with all team members. In 161 instances, either the nurses, the residents, or the consultants initiated a meaningful sequence with other team members, or other nurses, residents, or consultants.

Figure 6. A network diagram of all pair-wise communications within the teams, where each arrow indicates the direction of the communication and number of meaningful sequences.

Content categories - general statistics. Overall in the 30 scenarios, “patient status” was the most frequently used content of the meaningful sequences, followed by “drug administration”, “medical action” and “assistance request” (see Table 14).

Table 14.

Frequency of content categories used in the 30 scenarios

Content category	Frequency of the content in 30 scenarios	Percent of the total number of utterances	Mean percentages	Standard deviation
Patient status	322	24	21	8
Medical action	244	18	18	8
Drug administration	202	15	19	11
Assistance request	128	10	9	7
Treatment	102	8	8	6
Tests	79	6	7	6
Patient history	67	5	6	5
Equipment	62	5	4	4
Diagnostic	48	4	3	3
Consultation	22	2	1	1
Time	21	2	2	2
Access	16	1	1	1
Introduction	5	0	0	1
Announcement	2	0	0	0
Total	1320			

Distribution of content categories. Histograms were plotted for the content of each 5% percentile interval. The histograms show each content category peaking at certain percentage interval(s). For example a peak is seen in the “drug administration” category at 45th and 55th

percentile intervals and a peak in the “medical action” category at 65th percentile intervals (see *Figure 7*).

Figure 7. Showing the histograms of content categories distribution with regards to the total meaning sequences between the team members.

Verbal behaviour category distribution. Overall in the 30 scenarios, report was the most frequently used verbal behaviour category with 638 instances, followed by “directive” with 618 instances and “question” with 452 instances. Acknowledgment was used in 359 instances (see table 15).

Table 15.

Frequency of verbal behaviour categories used in the thirty scenarios

Verbal behaviour category	Frequency	Percentage of the total utterances	Mean percentage	Standard deviation
Report	638	25	26	7
Directive	618	25	25	7
Question	452	18	17	7
Acknowledgment	359	14	14	5
Clarification	317	13	12	5
Statement	64	3	3	4
Instruction	36	1	1	1
Suggestion	22	1	1	1
Total	2506			

Verbal behaviour category. Similarly, the 2506 utterances between the team members were divided into 5% intervals and the percentage frequency of the verbal behaviour categories of each 5% were identified. A histogram was plotted for each verbal behaviour category. The histograms showed drops and peaks in different categories. For example, they show peaks in the

“report” verbal behaviour at 5th and 100th percentile intervals, and a peak at 75th percentile interval in the “question” category (see *Figure 8*).

Figure 8. Showing the histograms of verbal behaviour categories with regards to the total utterances between the team members.

Non-verbal behaviour and use of artifacts and devices. There were a negligible number of non-verbal behaviour such as pauses and body languages during the scenarios which were analyzed in the current study. Other non-verbal behaviours involved looking at artifacts and devices which were used as memory aids, such as medical charts or monitor to obtain information with regards to the patient's vital status, such as blood pressure and heart rhythm. The distribution of uses of artifacts and devices is shown in Table 16.

Table 16.

Frequency of non-verbal behaviour of team members

Non-verbal behaviour	Frequency	Average per scenario
Information sheet (including medical chart)	75	3
Monitor	34	1
PDA's	9	0.3

Discussion

The purpose of this study was to get a better understanding of TMS and their processes, and other elements emerging in medical teams in resuscitation rooms, by answering six research questions. The study of TMS processes demonstrated that information allocation was the most prevalent process in the resuscitation room simulations. Furthermore, the study showed that the most frequently used TMS indicator was specialization. Other findings in this study were indicative of the efficiency of the emerging TMS within the resuscitation room simulations. With regards to communication patterns, the results of the current study were aligned with the

preliminary interview results, showing that team leaders acted as hubs in which they received and distributed the most information. They also asked and answered the most number of questions. The information that was most commonly requested was related to “drug administration”. The key finding in communication pattern analysis was that the patient status content of communication was the most frequently expressed content emerging throughout the scenarios. Similarly, acknowledgement, directive, and question were the most frequently used verbal behaviours that materialized throughout the sessions. The final key finding during the current study was the usage of different artifacts and devices, i.e., information papers and PDAs, as extended memory aids. These findings that answer the six research questions will be discussed in detail in the next few section. This thesis will continue with the implications of the current study and ends with limitations and future directions of the study.

What is the nature of transactive memory systems processes in resuscitation teams?

The preliminary interviews implied that the transactive memory systems processes in resuscitation rooms are initiated before the resuscitation team starts working together. The resuscitation team has a distinctive trait in that the team members have a set of suppositions with regards to other team members’ specialization and credibility. The resuscitation team members follow well defined procedures during an emergency. These procedures include ATLS (Advanced Trauma Life Support) protocol. This gives rise to a unique type of TMS within these high risk teams.

Furthermore, the preliminary interviews showed that the two major team characteristics which may have negative effects on the development of TMS, and hence, team performance and efficiency, i.e., high levels of stress in the team (Ellis, 2006) and membership change (Lewis et

al., 2007), are a natural property of emergency teams. The emergency teams do not work with the same set of members during each event. In addition, the team may have a new member added or lose a member, depending on the nature of the trauma or emergency. Moreover, these teams are responsible for the high stress job of making decisions that may increase the possibility of survival or demise of the individuals under their care. The communication analysis combined with the preliminary interviews in the current study provided a possible explanation of the nature of TMS processes and how they compensate for these possible setbacks. The nature of these processes within resuscitation room simulation is discussed below.

The first process is the directory update, during which the members of the team identify and locate expertise so that they can access it when needed. In the teams that have been studied so far, team members communicate their own expertise and/or ask about other members' areas of proficiency. Based on my research, directory update had the least prevalence in resuscitation room simulations. An explanation for the sparsity of this process is that the team members extracted the information with regards to the area of expertise of other members through other means. According to the preliminary interviews, this process has been facilitated by already established assumptions about the specialization and credibility of other team members based on their titles. As an example, once a member is identified as a respiratory therapist (RT), the team leader and other members of the team know that breathing issues could be assigned to the RT. During the resuscitation simulation, it was evident that each team member's area of expertise and credibility is known by all team members, and the specialization of team members is not questioned. Team members did not ask for detailed descriptions of the areas of expertise of other members. In a few cases, to confirm the member's expertise in an area which did not necessarily

fall under his or her title, the team leader asked if the team member can perform a procedure. For example, the team leader asked if the RT was comfortable with performing a tracheotomy. This presumption of the team members' areas of expertise and credibility decreased communication related to the directory update process, i.e., there were no broadcasts of the members' expertise per se. Once new members joined the team, they announced their name and their title. Their titles encompassed a series of assumptions with regards to the expertise of the members. For example, in one scenario, a person enters the resuscitation room and introduces himself to the team leader; "hi there, I'm from ICU". The team leader continues with reporting the patient history and what had been done for the patient thus far. She does not ask whether the person from ICU possesses certain expertise. Similarly, the person from ICU did not explain what his areas of expertise were. Hence, the process was much more efficient and to the point with only 17 occurrences. This finding confirmed the information acquired from the preliminary interviews. As it was expected, the directory update was less prominent during the emergence of TMS within a resuscitation team. The fact that there were not many directory update processes may be a possible explanation of how the resuscitation team deals with the negative effect of membership change. By stating their title, the new members do not need to re-introduce their areas of expertise, hence, decreasing the amount of time and cognitive resources for re-learning the detailed specialization of each new member. It is important to acknowledge that because of the way that the videos were recorded, some scenarios did not start with an introduction of the team leader or did not end with the introduction of the next level of support. Keeping that in mind, the level of directory update will not be anywhere close to the high number of information allocation or information retrieval processes.

The second process that is an element of TMS is allocation of information, during which the team members transfer the information that is not related to their specialization to the team member with the right expertise. Based on the findings of this study, the information allocation was the most prevalent process with 594 instances. This means that team members sent the information that was not related to their area of expertise to other members who could utilize the information for their task completion. The anticipation ratio (discussed in future sections) also indicated that team members foresaw the need of the team leader for certain information and provided it before it was requested. This improved the team efficiency and outcome (Entin & Serfaty, 1999). In a trauma scenario, the history of the patient and preliminary tests that may have been done by the EMS team will be transferred to the team leader and the nurse, or the consultant who may be called for, during the handover report. As an example, the nurse informed the team leader about the history of the patient, which included the incident which resulted in the patient being transferred to the resuscitation room, as soon as the team leader entered the room. The fact that members propagated the information that was not related to their expertise to the experts may help decrease the level of stress of team members with regards to their cognitive stress of making sure that they have all the information they need to complete their task. However, the very high number of information allocation processes in the resuscitation simulations raises two concerns. The first concern is with regards to the amount of information that is being propagated to other members. The magnitude of the amount of information may overwhelm the expert and cause cognitive overload. The second concern is with regards to the timing of information allocation. The information is not allocated based on the need of the expert, but is allocated when team members acquire information which is not

related to their areas of expertise. This means that when the information is allocated to another expertise, they have to hold the information in their memory until the time they may need to recall the information. This will cause excess cognitive load for team members, so the information may degrade by the time they need to recall it. One suggestion as to how to cope with these hindrances is to use an electronic situational display. The information that is accessed most frequently can be displayed and updated by the scripting nurse. As it was discovered through the preliminary interviews, there is always a scripting nurse available in every resuscitation event who takes note of every event, such as the drug or the medical action administered. This will allow the experts to concentrate on their task rather than using their cognition to remember information that was transmitted to them at some point. Furthermore, the display will prevent information degradation or staleness. The most recent information will be displayed based on the most recent assessment of the patient.

Finally, the third transactive memory system specific process is the retrieval of information, during which the team members obtain information from the domain experts to finalize their task (Wegner, 1995; Palazzolo, 2005). The communication analysis indicated that there were 189 instances of information retrieval, in which team members in the resuscitation room asked for particular information so that they could complete their task. The preliminary interviews indicated that the team members are specialized exclusively in a certain area, with little areas of crossover. After being called upon to assist the team, they will be informed about the history of the patient. If they need more information, they typically ask the nurse. Once they have diagnosed the medical issue, they inform the team leader, and if the team leader decides that it is urgent, based on the condition of the patient at that time, they may be asked to take measures

to stabilize the medical problem. The team members focus on their own tasks as orchestrated by the team leader.

How do TMS behavioural indicators distribute throughout resuscitation scenarios?

The information collected from the current study demonstrated that within the primary TMS indicators, “Specialization” was the most frequently used indicator. This finding is aligned with the preliminary interviews, because the team members are highly specialized in some aspect of the emergency team goals. Furthermore, each team member is responsible for expertise in different areas. The team members know which member has expertise in a specific area, and finally, the specialized knowledge of different team members was needed to complete the task during a resuscitation event.

The secondary TMS indicators showed that “Coordination” was the most frequently used indicator. This finding is evidence that the activities of the team members are generally coordinated. The team members tend to be well organized, with little or no confusion about how should a task be completed. There were no misunderstandings about what to do and the members did not need to backtrack and restart procedures.

Prevalence of the credibility indicator was relatively similar in both primary and secondary TMS. This indicated that the team members trusted the knowledge of other members and they were confident enough to rely on the information that other members shared during the event. Team members were generally comfortable accepting procedural suggestions from other members. Moreover, there were no instances during which team members needed to double-check the information given by another member.

Distribution of TMS behavioural indicators. Another major finding of this study points to the distribution of the primary TMS behavioural indicators throughout the scenarios. This finding showed that specialization was at its lowest at the beginning of the the scenarios, i.e., 5th percentile, while coordination was at its highest at the same interval. This discovery is indicative of the coordination efforts that are in place when the patient arrives in the resuscitation room. The initial coordination is typically in the form of patient history and status reports to ensure everyone is familiar with what has happened to the patient and what symptoms the patient is displaying. Once resuscitation team members have a clear understanding of the history of the patient, they utilize their specific expertise and specialization to decide what tests are needed to be able to diagnose the medical problem (at 25th percentile interval). Hence, as expected, specialization behaviour indicator increases as the coordination decreases at the 10th to 15th percentile of the scenarios. During those intervals there is an increase in specialized behaviour such as the discussions about access lines and tests.

The credibility behavioural indicator was generally used at a lower frequency than the other indicators all through the scenarios. There was a noticeable spike at the 55th percentile interval for credibility. At the same time, there was a drop in the frequency of coordination indicator. When we observe the distribution of the verbal behaviours at the same interval of the scenarios, it is evident that at that point in the scenarios, there is a spike in acknowledgment verbal behaviours. This coincides with the definition of credibility as acceptance of procedural suggestions from other team members and acknowledgement of the information that other members gave without double-checking.

Are TMS in simulated resuscitation rooms efficient?

The anticipation ratio was greater than one ($AR = 1.7$). This information could have two possible explanations. First, in an educational environment, such as the resuscitation room simulation, the instructor may want to provide some help and at the same time evaluate the knowledge of resident team leaders, making sure that they ask the right questions. In that case, the nurse may have been instructed to give certain clues and provide some unrequested information, to allow the team leader to diagnose the medical problem with some assistance. A second possible explanation is related to information transmission, and consequently, the efficiency of TMS in the resuscitation simulations. Based on Sarcevic et al.'s (2008) study, the anticipation ratio of greater than one ($AR > 1$) indicates that the team members anticipated the information that the team leader needed, causing a decrease in the amount of questions asked (i.e., noise) and an increase in the efficiency of TMS in the resuscitation room. In this case, the team members in the resuscitation room simulations anticipate the required information and push the information to members who need it.

Who are the main information receivers and providers?

The assessment of communication within the emergency teams provided an understanding about the details of TMS. Based on the preliminary interviews, the team members follow a communication flow and the team leader is typically the focal point of the team members' communication. The communication network that was mapped based on the data from pre-recorded simulations was compared to the communication network which was plotted based on the preliminary interviews. Both networks show that the team leader or the MRP (Most Responsible Person) communicates the most with the nurse and the resident, respectively. The

team leader's next point of communication in both networks is the consultant. This finding was emphasized by the information collected from the pre-recorded scenarios.

The team leader initiated most of the communication during the events in the resuscitation room. Overall, more than half of the questions that were asked during events were asked by the team leader. Similarly, the team leader answered the most questions. These results confirm the previous finding that the team leader or MRP is the central figure and the hub in the resuscitation room. The content and the verbal behaviour of what was communicated during the events is discussed in the future sessions. In this study, the analysis of verbal behaviour revealed that the team leader and the nurse were the top information receiver and provider, respectively. This finding proves to be in congruence with the study done by Sarcevic, Marsic, and Lesk (2008). In Sarcevic et al., the main information provider, aside from the patient, was also the team leader. Similarly, in this study the team leader asked and answered the most number of questions. The information that was sought by the team leader or other team members such as the patient's history or patient status was typically answered by the nurse. It is no surprise that the nurse would be the second top information provider. In this study, the information that was commonly discussed during a resuscitation event was related to the patient's status (most often pulse), followed by drug administration (most often epinephrine).

What type of information is exchanged most regularly during a scenario?

One of the findings of the current research was the content of the communication and the verbal behaviour of the team members that were most frequently used during resuscitation events. Based on the findings, "Patient status" in the content category and "Report" in the verbal behaviour category were mostly used during resuscitation scenarios. This is in agreement with

the information collected during the preliminary interviews and the protocols that are in place within the resuscitation room. Furthermore, the result of this study indicated that the most common content of the question asked was related to drug administration, followed by patient status. Based on my observation of the scenarios, the majority of the questions were related to how much, when, and what type of drugs needed to be administered. This result may partially be due to the fact that some of the physicians who were involved in the simulations were not familiar with the dosage of certain drugs.

Content patterns. The information collected showed that the access lines were set up or checked primarily at the beginning (5th, and 10th percentile) of the scenarios and then half way through the scenarios (45th to 60th percentile). At the same time, drug administration was increased in the middle (50th and 55th percentile) of the scenarios. Although treatments such as blood and saline IV are given to the patient throughout the scenarios, there is a spike in the early part of the scenarios (5th to 30th percentile) and then again at the end of the scenarios (95th to 100th percentile). Based on my observations, when the patients arrive, there is a request for availability of access lines. The goal is to ensure that there is an intravenous access available so that drugs and treatments can be given immediately, when needed. Similarly, there is a verbal request for administration of the required treatments. Generally, some type of saline or blood is given through an IV to the patients, either by the EMS or at their arrival in the resuscitation room by the nurse, to ensure that their fluids levels are stabilized. As the event proceeds and the team has gained certain knowledge about the status of the patient through the patient history or status reports, other verbal requests are given so that different drugs are administered to the patient as required.

Patient status is constantly reported throughout the scenarios, with a spike early in the scenarios (the 5th and 20th percentile), and then at the end (85th to 100th percentile intervals) of the scenarios. From my observations, along with the patient's history, the patient's status is reported to team members as they become involved, early in the scenario. Later, towards the end of the scenarios, the patient's status is reported more often as more consultants get involved or the patient is transferred to the next level of support.

Requests for assistance spiked at the beginning (15th, 25th and 45th percentiles) and again at the end of the scenarios (100th percentile), when the team needed to hand off the patient to the next level of care. The team members asked for consultants' involvement primarily in the last half intervals of the scenarios (i.e., 55th to 100th percentile). One possible interpretation is that the resuscitation team makes an initial effort to diagnose the patient's problem and then later in the scenario, the team decides which other specialists they may need to involve to stabilize the patient.

Verbal behaviour patterns. The acknowledgment verbal behaviour was relatively constant throughout the scenarios. This indicated that the team members acknowledged other members' comments on a relatively constant basis, to decrease critical information loss.

Similarly, the current study showed that directive and question verbal behaviours followed a relatively constant pattern, with a spike in an early stage of the scenarios. With respect to question verbal behaviour, a spike towards the end of the scenario was also observed. These findings were aligned with the expectation of resuscitation room team members that was presented during the preliminary interviews.

What are the artifacts and devices used during resuscitation events?

Although resuscitation team members conveyed critical information with regards to the patient verbally, they also used charts, information sheets, and the monitor as external memory aids. Furthermore, in at least seven instances, team members used personal digital assistants (PDAs) to acquire specialized information that none of the team members possessed. The prevalence of the use of the monitor was much lower than expected, however, the camera angle in the videos did not capture all instances of looking at the monitor. For example, if the team member's back was to the camera, it was very difficult to detect the direction of the team member's gaze. Hence, it is expected that many instances of the use of the monitor were missed. The information that was looked up on the PDAs primarily concerned drug dosages. It is an important implication of this study that the extended memory of the team was expanded by electronic devices. These non-verbal behaviours may indicate the extension of TMS to the external environment. The use of information sheets or PDAs as part of the collective memory of the ED team.

Implications

This paper examined the nature of transactive memory systems and their indicators and processes within high stress resuscitation teams. I analyzed the TMS processes in resuscitation rooms and looked at the trend of TMS indicators. Furthermore, verbal and non-verbal communication between the team members was analyzed and connected to transactive memory systems indicators in those environments.

This study showed that information allocation process is the dominating process in resuscitation room simulations. The overwhelming propagation of information may cause an

increase in cognitive load and may cause information degradation. This information may be used to design protocols or devices so that team members are able access the information as they need.

The information with regards to the pattern of communication could be used to educate the emergency medical staff so that they may be able to maximize the efficiency of their interaction. This information can be used as a start point for further investigation of the outcome of resuscitation events, to determine whether or not there is room to minimize verbal communication of reports such as patient history or patient status without jeopardizing the integrity of the information so that the information is transmitted to the team in a concise way to ensure the safety of the patient. The findings of this study could also be used to design programs or technologies to enhance communication and efficiency of transactive memory systems in the emergency department with the goal of amalgamating the extended memory devices used, i.e., information sheets, monitor, and PDAs, into one device to decrease errors and ultimately, saving lives. By implementing cognitive aids in the emergency units of hospitals, the cognitive demand on the team members will decrease, allowing them to provide better service to patients. Moreover, such programs can improve the efficiency of the resuscitation team and decrease the occupancy time of the resuscitation rooms per patient. This, in turn, will contribute to financial savings in hospitals. A long term implication of this study will be to use the findings in designing an electronic medium to display the most critical and frequently accessed information. This will limit the number of communication errors and save time and resources.

Limitations and future direction of the study

Due to the nature of the emergency department, the data collected was solely extracted from the pre-recorded resuscitation room simulations. Although efforts are made to ensure that the simulations are as close as possible to real resuscitation events, there are certain aspects of trauma or non-trauma events that simulations cannot replicate. For example, the simulated scenarios did not include the outcome of medical interventions. Hence, it was not possible to determine the efficacy of the emergent TMS and subsequently, the efficiency of ED teams.

Another limitation is that due to the nature of the simulations, the role of consultants may have been played by other residents. Hence, the interaction between consultants and team leaders may not be a fair representation of live trauma event. Finally, it has to be noted that the factors such as gender, age, cultural differences, or year of study of team members were not accounted for by the current study. The requests for permission to view the pre-recorded scenarios were sent to the general population of the emergency department residents, however, only some residents gave consent to have their recorded simulations viewed by the researcher. It is possible that the sub-population who consented may have certain characteristics related to their style of communication that was not factored in to this study.

For future studies, it is recommended to utilize live resuscitation events to address some of the obstacles that were inherent in the current study. By documenting the outcome of live events and relating them to TMS and communication benefits or degradation within resuscitation teams, the degree of development and effectiveness of TMS can be evaluated. The results from this future study can help with the development of tools and training programs to increase the resuscitation team efficacy with the ultimate goal of saving lives.

One of the most important findings of the current study was the communication patterns and most frequently used contents of communication within resuscitation teams. It is hoped that this information could be a catalyst to further research the possible implementation of electronic devices which could improve communication and decrease errors in these high stress environments.

References

- Ackerman, R.K. (2005). Army intelligence digitizes situational awareness. *Signal*. Retrieved from <http://www.afcea.org/content/?q=node/985>.
- Akgün, A. E., Byrne, J., Keskin, H., Lynn, G. S., & Imamoglu, S. Z. (2005). Knowledge networks in new product development projects: a transactive memory perspective. *Information & Management*, 42, 1105-1120.
- Austin, J. R. (2000). Knowing what and whom other people know: Linking transactive memory with external connections in organizational groups. *Academy of Management Proceedings*, F1-F6.
- Baker, D. P., Day, R., & Salas, E. (2006). Teamwork as an essential component of high-reliability organizations. *Health Research and Educational Trust*, 41 (4). 1576, 1598.
- Beaubien, J. M., & Baker, D. P. (2004). Use of simulation for training teamwork skills in healthcare: how low can you go? *BMJ Quality and Safety in Health Care*, 13 (Suppl. 1), i51-i56. DOI: 10.1136/qshc.2004.009845
- Brandon, D. P., & Hollingshead, A. B. (2004). Transactive memory systems in organizations: Matching tasks, expertise, and people, *Organization Science*, 15(6), 633-644.
- Burtscher, M. J., & Manser, T. (2012). Team mental models and their potential to improve teamwork and safety: A review and implications for future research in healthcare, *Safety Science*, 50, 1344-1354.
- Canadian Institute for Health Information 2012 report. Retrieved from https://secure.cihi.ca/free_products/DAD-NACRS_Highlights_2010-2011_EN.pdf

- Cosby, K. S. (2003). A framework for classifying factors that contribute to error in emergency department. *Annals of Emergency Medicine*, 42(6), 815-823.
- Dickinson, T. L., & McIntyre, R. M. (1997) A conceptual framework for teamwork measurement. In: Brannick, M. T., Salas, E. Prince C (eds) Team performance assessment and measurement. Lawrence Erlbaum Associates, Mahwah, pp 19–43.
- Ellis, P. J. (2006). System breakdown: the role of mental models and transactive memory in the relationship between acute stress and team performance. *Academy of Management*, 49(3), 576-589.
- Endsley, M. R. (1995a). Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37(1), 32-64.
- Endsley, M. R. (2000). Theoretical underpinnings of situation awareness: A critical review. *Situation Awareness Analysis and Measurement*. Endsley, M. R. and Garland, D. J., Mahwah, NJ: Lawrence Erlbaum Associates.
- Entin, E. E. and Serfaty, D., 1999. Adaptive team coordination. *The Journal of the Human Factors and Ergonomics Society*. 41 (2), 312-325.
- Fracker, M. (1991). Measures of situation awareness: review and future directions. Report No. AL-TR-1991–0128, Wright Patterson Air Force Base, Ohio: Armstrong Laboratories: Crew Systems Directorate. Retrieved from <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA262672>
- Gisev, N. Simon Bell, J., and Chen, T. F. (2013). Interrater agreement and interrater reliability: key concepts, approaches, and applications. *Research in Social and Administrative Pharmacy*, 9, 330-338.

- Hobin, T. (2013). Shared mental models in emergency department : Looking toward an information display. Unpublished undergraduate thesis.
- Hollingshead, A. B. (1998). Communication, learning, and retrieval in transactive memory systems. *Journal of Experimental Social Psychology*, 34, 423-442.
- Hollingshead, A. B., & Brandon, D. P. (2003). Potential benefits of communication in transactive memory system. *Human Communication Research*, 29(4), 607-615.
- Jeannot, E. (1999). Situation awareness: Recommendations to project leaders, EEC Draft Note. Brétigny-sur-Orge, France: EUROCONTROL Experimental Centre.
- Jeannot, E., Kelly, C., & Thompson, D. (2003). The development of situation awareness measures in ATM systems. *European Air Traffic Management Programme*. Retrieved from <http://www.eurocontrol.int/humanfactors/gallery/content/public/docs/DELIVERABLES/HF35-HRS-HSP-005-REP-01withsig.pdf>.
- Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor. *Journal of Management*, 20(2), 403-437.
- Lewis, K. (2003). Measuring transactive memory systems in the field: scale development and validation. *Journal of Applied Psychology*, 88(4), 587-604.
- Liang, D. W., Moreland, R., & Argote, L. (2005). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin*, 21(4), 384-393. doi: 10.1177/0146167295214009.
- Liao, J., Jimmieson, N. L., O'Brien, A. T., & Restubog, S. L. D. (2012). Developing transactive memory systems: Theoretical contributions from a social identity perspective. *Group & Organization Management*, 37(2), 204-240. doi: 10.1177/1059601112443976.

- Mellick, L. B. and Adams, B. D. (2009). Resuscitation team organization for emergency departments: A conceptual review and discussion. *The Open Emergency Medicine Journal*, 2(18), 18-27.
- Michinov, E., Olivier-Chiron, E., Rusch, E., & Chiron, B. (2008). Influence of transactive memory on perceived performance, job satisfaction and identification in anaesthesia teams. *British Journal of Anaesthesia*, 100(3), 327-332.
- Mohammed, S., Klimoski, R., & Rentsch, J. R. (1994). The measurement of team mental models: We have no shared Schema. *Organizational Research Methods*, 3(2), 123-165.
- Parush, A., Kramer, C., Foster-Hunt, T., McMullan, A., & Momtahan, K. (2014). Exploring similarities and differences in teamwork across diverse healthcare contexts using communication analysis. *Cognition, Technology & Work*, 6 (3), 47-57. DOI: 10.1007/s10111-012-0242-7.
- Patel, V. L., Zhang, J., Yoskowitz, N. A., Green, R., & Sayan, O. R. (2008). Translational cognition for decision support in critical care environments: A review. *Journal of Biomedical Informatics*, 41, 413-431.
- Palazzolo, E. T., Serb, D. A., She, Y., Su, C., & Contractor, N. S. (2006). Coevolution of communication and knowledge networks in transactive memory systems: Using computational models for theoretical development. *Communication Theory*, 16, 223-250. doi: 10.1111/j.1468-2885.2006.00269.x.
- Palazzolo, E. T. (2005). Organizing for information retrieval in transactive memory systems. *Communication Research*, 32, 726-761. doi: 10.1177/0093650205281056.

- Pavitt, C. (2003). Colloquy: Do interacting groups perform better than aggregates of individuals? Why we have to be reductionists about group memory. *Human Communication Research*, 29(4), 592-599.
- Peltokorpi, V. (2008). Transactive memory systems. *Review of General Psychology*, 12 (4), 378-394. doi: 10.1037/1089-2680.12.4.378.
- Ren, Y., & Argote, L. (2011). Transactive memory systems 1985-2010. An integrative framework of key dimensions, antecedents, and consequences. *The Academy of Management Annals*, 5(1), 189-229.
- Risser, D. T., Rice, M. M., Salisbury, M. L., Simon, R., Jay, G. D., and Berns, S. D. (1999). The potential for improved teamwork to reduce medical errors in the emergency department. *Annals of Emergency Medicine*. 34(3). 373-383.
- Rousseau, R., Tremblay, S., & Breton, R. (2006). Defining and modelling situation awareness: a critical review. *A Cognitive Approach to Situation Awareness. Theory and Application*. Ashgate Publishing Limited, Hampshire.
- Salmon, P., Stanton, N., Walker, G., & Green, D. 2006. Situation awareness measurement: a review of applicability C4i environments. *Applied Ergonomics*, 37(2), 225-238.
- Smith, M. and Feied, C. (1999). *The emergency department as a complex system*. Retrieved July 30, 2013, from <http://www.necsi.edu/projects/yaneer/emergencydeptcx.pdf>
- Spector, P.E. (1992). *Summated Rating Scale Construction: An Introduction*. Newbury Park, CA: Sage Publications.
- Spencer, R., Logan, P., & Coiera, E. (2002). *Communication Observation Method Manual*. Sydney: Centre for Health Informatics, The University of New South Wales.

- Stanton, N. A., et al. (2006). Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. *Ergonomics*, 49, 1288-1311.
- Tschan, F., Semmer, N. K., Gurtner, A., Bizzari, L., Spychiger, M., Breuer, M., & Marsch, S. U. (2009). Explicit reasoning, confirmation bias, and illusory transactive memory. A simulation study of group medical decision making. *Small Group Research*, 40(3), 271-300. doi: 10.1177/1046496409332928.
- Weakland, J. H., & Beavin, J. (1967). Communication in behaviour and behavioural science. *American Behavioural Scientist*, 10(8), 4-8. Retrieved from <http://web.uvic.ca/psyc/bavelas/1967Formalaspects.pdf>
- Wegner, D. (1986). Transactive memory: A contemporary analysis of the group mind. *Theories of Group Behaviour* (pp. 185-208). New York: Mullen, B., Goethals, G. R. Springer-Verlag.
- Wildman, J. L., Thayer, A. L., Pavlas, D., Salas, E., Stewart, J. E., and Howse, W. R. (2012). Team Knowledge research: Emerging trends and critical needs. *Human Factors*, 54 (1), 84-111. doi: 10.1177/0018720811425365.
- Williams, R. F. (2006). Using cognitive ethnography to study instruction. *Proceedings of the 7th International Conference of the Learning Sciences*. Mahwah, NJ: Lawrence Erlbaum Associates. Retrieved from <http://hci.ucsd.edu/102b/readings/williams-coethno.pdf>
- Wittenbaum, G. M. (2003). Putting communication into the study of group memory. *Human Communication Research*, 29(4), 616-623.
- Yoo, Y. & Kanawattanachai, P. (2001). Developments of transactive memory systems and collective mind in virtual teams. *The International Journal of Organizational Analysis*, 9(2), 187-208.

Appendix A

Communication network diagram based on the preliminary interviews with resuscitation room team members (Hobin 2013).

Appendix B

Preliminary interview questionnaire

Questions:

1. What is your official role?
2. What is your responsibility in the team?
3. What is the team's goal as a whole? (we need to get something more concrete such as to do things as fast as possible, as accurately as possible, with as much comfort to the patient as possible, etc...)
4. When was the last time you participated in a resuscitation scenario (Trauma/non-trauma).
5. What are the types of scenarios that you may encounter?
6. What are the different types of trauma?
7. Is difficulty breathing part of trauma?
8. Who are the members of the team? The different people and stake-holders involved in each of the scenario types.
9. What is the goal of each member of the team?
10. Choose one scenario and take us through the steps you would take, including the typical sequence of each scenario and the exceptions, Where is the team and what is the physical position of each team member.
11. Give more details about the sequence of scenarios.
12. What devices would you need and where are the artifacts and devices?
13. Talk about your role and your interaction with others.
14. What kind of information would you receive from others in the team? How do you receive the information?
15. What kind of information is recorded? How? By whom?
16. Who does what, when, and where during the sequence of the scenario.
17. What is the most important info you need to get from someone? Who is that person?

18. Would you need devices that may not be located in the room? How would you acquire a device that is not in the room?
19. How would you involve others who are not present in the room? What kind of information do you need to pass on to those individuals? Who sends them the information? How?
20. Are there any non-verbal interaction between the team members.
21. How long each scenario may take.
22. How do you keep time? Are there any time limits for any particular procedure?
23. What information do you need to pass on to the next stage when the patient is moved from the resuscitation area? Who transfers the information and to whom?
24. Talk about a situation that you may have not received a vital information?

Appendix C

Transactive Memory System Scale Items (Self-reporting survey), Lewis (2003) measures.

Specialization

1. Each team member has specialized knowledge of some aspect of our project.
2. I have knowledge about an aspect of the project that no other team member has.
3. Different team members are responsible for expertise in different areas.
4. The specialized knowledge of several different team members was needed to complete the project deliverables.
5. I know which team members have expertise in specific areas.

Credibility

1. I was comfortable accepting procedural suggestions from other team members.
2. I trusted that other members' knowledge about the project was credible.
3. I was confident relying on the information that other team members brought to the discussion. .
4. When other members gave information, I wanted to double-check it for myself. (reversed).
5. I did not have much faith in other members' "expertise." (reversed)

Coordination

1. Our team worked together in a well-coordinated fashion.
2. Our team had very few misunderstandings about what to do.
3. Our team needed to backtrack and start over a lot. (reversed)
4. We accomplished the task smoothly and efficiently.
5. There was much confusion about how we would accomplish the task. (reversed)

Note. All items use a 5-point disagree–agree response format, in which 1 strongly disagree, 2 disagree, 3 neutral, 4 agree, and 5 strongly agree.

Appendix D

Resuscitation room communication statistics

Session	Utterances	Meaningful sequences
1	103	56
2	104	59
3	72	42
4	44	26
5	91	42
6	125	69
7	77	49
8	88	42
9	150	69
10	29	18
11	34	22
12	38	25
13	92	48
14	53	34
15	80	40
16	105	55
17	116	43
18	66	36
19	67	40
20	70	45
21	88	45
22	76	35
23	98	42
24	91	48
25	64	37
26	92	56
27	52	26
28	70	33
29	108	56
30	163	82
Total	2506	1320
Average per session	84	44

Appendix E

Frequency of content categories in utterance as a function of 5% intervals.

Percent	Access	Announcement	AssistanceRequest	Consultation	Diagnosis	DrugAdministration	Equipment	Introduction	MedicalAction	PatientHistory	PatientStatus	Tests	Time	Treatment
5	7	0	3	0	2	6	11	1	9	31	16	5	0	7
10	8	2	3	0	3	6	6	0	14	6	21	18	0	14
15	0	0	7	1	3	14	8	0	6	2	25	23	0	10
20	2	2	6	0	0	16	6	1	11	11	22	10	2	11
25	0	0	15	0	8	25	1	0	11	7	15	7	2	10
30	1	0	10	0	2	25	0	1	18	7	18	8	0	10
35	1	0	13	0	6	35	1	0	14	6	17	3	2	2
40	0	0	11	4	4	27	2	0	16	2	17	11	1	3
45	2	0	13	0	1	20	4	0	21	2	20	9	1	9
50	3	0	11	0	2	18	2	1	25	4	19	6	1	7
55	2	0	11	1	1	34	1	1	17	5	20	4	0	3
60	1	0	10	0	1	26	1	0	25	4	20	5	2	6
65	0	0	6	2	5	27	6	0	19	0	23	2	0	10
70	0	0	3	2	9	20	1	0	21	1	24	5	5	10
75	0	0	4	2	2	22	7	0	23	6	20	3	2	7
80	0	0	8	3	1	23	5	0	19	5	15	5	5	11
85	0	0	9	2	5	19	9	0	18	1	24	5	5	4
90	0	0	7	2	3	16	2	0	27	0	29	2	3	8
95	0	0	12	2	2	13	3	0	15	2	25	5	2	18
100	0	0	23	4	1	9	7	0	14	3	22	3	0	15
Total*	27	3	185	24	60	402	82	4	344	105	410	140	31	174

* Total is out of 2000 (20x100) intervals

Appendix F

Frequency of verbal behaviour categories in utterance as a function of 5% intervals.

Percent	Acknowledger	Clarification	Directive	Suggestion	Instruction	Question	Report	Statement
5	12	8	22	0	1	17	36	4
10	17	9	26	0	1	23	24	1
15	15	8	42	0	0	13	19	2
20	17	15	27	1	0	18	21	2
25	14	12	28	2	2	16	20	6
30	14	11	25	2	2	20	26	2
35	13	14	25	2	0	20	23	2
40	15	19	20	1	2	16	25	2
45	17	11	26	2	2	20	23	1
50	13	16	18	1	2	21	28	2
55	18	21	22	0	2	16	18	3
60	13	14	23	0	4	21	22	3
65	15	10	23	0	2	18	28	4
70	17	9	24	2	2	19	22	5
75	12	15	26	1	0	25	17	5
80	12	19	22	0	2	16	27	2
85	11	15	20	1	2	19	31	2
90	13	12	25	1	2	16	27	3
95	11	8	28	3	1	16	31	2
100	18	9	21	1	0	11	37	4
Total*	287	252	491	17	28	360	505	53

* Total is out of 2000 (20x100) intervals

Appendix G

Frequency of primary TMS indicators in utterance as a function of 5% intervals.

Percent	Specialization	Credibility	Cooperation	Not coded
5	24	13	64	0
10	45	22	33	0
15	46	18	37	0
20	37	25	38	0
25	35	19	46	0
30	44	19	37	0
35	45	16	39	0
40	39	28	33	0
45	49	22	27	2
50	35	22	41	3
55	38	33	29	0
60	37	21	42	0
65	43	27	30	0
70	48	24	28	0
75	32	30	37	1
80	45	23	32	0
85	37	19	44	0
90	37	19	44	0
95	41	20	39	0
100	37	19	43	1
Total*	792	436	763	6

*Total is out of 2000 (20x100) intervals

Appendix H

Frequency of secondary TMS indicators in utterance as a function of 5% intervals.

Percent	Cooperation	Credibility	Specialization	Not coded
5	63	29	8	0
10	52	33	15	0
15	60	29	11	0
20	61	26	13	0
25	65	22	13	0
30	62	29	8	0
35	58	31	10	0
40	62	29	9	0
45	52	35	12	2
50	52	32	13	3
55	60	28	11	0
60	47	37	15	0
65	57	31	12	0
70	51	27	23	0
75	55	26	18	1
80	61	26	13	0
85	62	21	17	0
90	51	31	18	0
95	54	31	14	0
100	59	27	14	1
Total*	1143	581	267	6

*Total is out of 2000 (20x100) intervals

Appendix I

Prevalence of the contents of “question” verbal behaviour.

Verbal Behaviour	Content	Prevalence
Question	DrugAdministration	112
Question	MedicalAction	72
Question	PatientStatus	70
Question	AssistanceRequest	38
Question	Treatment	36
Question	Tests	33
Question	PatientHistory	30
Question	Equipment	23
Question	Consultation	15
Question	Access	10
Question	Time	7
Question	Diagnostic	5
Question	Announcement	2