Concept Maps: Theory, Methodology, Technology
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I KNOW WHAT YOU'RE THINKING: ELICITING MENTAL MODELS ABOUT FAMILIAR TEAMMATES

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Abstract. Research involving team mental models in the past has often focused on cross training fundamentals (correctness to a procedure) for the sharedness shown between teammates. However, evidence has shown that this may not be the best measure to distinguish a proficient team from a non-proficient team. Instead some believe that more emphasis should be placed on other cognitive factors being more closely related correctness to a teammates' schema. This paper attempts to tackle this task through the use of concept mapping and simulated tasks that require team efficiency. It is theorized that teams exhibiting the highest levels of both correct mental models toward and expert model (task correctness) and correct mental models toward teammates' mental models (familiarity) will perform at greater levels than those teams that are lacking in one or more of these areas.

1 Introduction

"I am convinced modeling and simulation technologies available today will enable us to significantly change the way we train in the future. We are at a crossroads where simulator technology today will be critical in the success of our effective use of follow-on weapon systems… We need to take a hard look at how this technology will change our training philosophy as well as how we develop future weapon systems." (Fogleman, 1996, p.1)

While certainly applicable in a variety of domains, the research theories being proposed here have a distinct practical relationship with crew coordination in aviation teams and in creating successful teams in military operations. In addressing recruits at Fort Jackson, Defense Secretary Bill Cohen shared his feelings on teamwork in the military. "Our military is the muscle behind America's will, and it is teamwork that makes that muscle strong…trust and teamwork are the only real guarantees that you can complete the mission." His sentiments echo across the services and surely into the domain of aircrew coordination. The need for trust and teamwork are evident for continued advances in safety and security.

This need extends beyond our borders, as well. As the need for policing actions on foreign soil increases, American servicemen are being asked to interact with multi-national teams of military "police" in order to keep the peace in many troubled countries.

Not only are our servicemen and women expected to interact with members of their own squad, but also with members of other groups, even other services and nations. Additionally, military units are sometimes being required to interact with a team which is not physically present and with people they may have never met before. According to Montoya-Weiss and her colleagues (2001), though there is an inherent value in being able to bring people who are not in the same geographic location together, it is also accompanied by its own unique problems. One of the most prominent is in poor coordination between team members (Wittenbaum, et al., 1998). This becomes even more important when one considers the fact that most group coordination occurs implicitly (Gersick, 1988).

In special operations combat teams, the need to have both explicit and implicit coordination is absolutely essential. If any differences exist between team members, there is generally not enough time to work out these differences. Members of those teams, therefore, plan very carefully, trying to address any and all possible problems. They realize, however, that no amount of planning will cover all scenarios. According to the Doctrine of Joint Special Operations "detailed mission planning, based on specific detailed, comprehensive, and accurate tactical intelligence is vital to successful mission execution and also to the very survival of the operational element"(DOD, 1996). So, these teams recognize the value of explicit pre-task planning. Additionally, team leaders are told that the objective of the planning process "is to develop a comprehensive plan that provides for flexible execution. S(pecial)O(perations) force commanders cannot tie themselves to a rigid plan. They must anticipate the unexpected and remain flexible enough to modify their plans, as required, to achieve their higher commander's intent" (DOD, 1996). This coincides very well with the concept of in-process tacit coordination, which is detailed by Wittenbaum and her colleagues (1998). Gersick and Hackman (1990) would also seem to agree, since their finding that groups who coordinated implicitly freed up more time for tasks to be performed, and time is of the essence in Special Operations missions, requiring precise actions at key moments.

The question that is really at hand here is, what factors contribute [most] to mental models being shared between team members, in an extremely efficient manner? Synthetic task environment systems should enable more controlled investigations while capturing performance phenomena in complex, multi-operator, expert-based operational performance (Driskell & Salas, 1992).

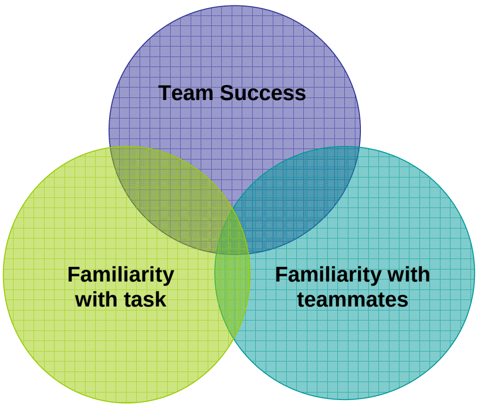
In addition to allowing its officers and men to play certain military-related commercial computer games on base computers (DMSO, 1997), the Marines have also been busy creating some training games of their own. Using a version of the commercial game DOOM adapted with the help of Lt. Scott Barnett, Marine fire teams have been training at computer labs in Virginia, Georgia, and North Carolina learning battlefield tactics and decision-making. "It's funny, because at the end of the day I had to kick my Marines out of there and send them home," Barnett says. "The Marines know they're learning, but they're also having fun. I think that's critically important to get them to want to learn" (Prensky, 2001, p. 311). In the Marine version of the game, four member "fire teams" are networked together and play at four individual computer stations. Their goal is to coordinate their movements and eliminate an enemy bunker. The communication that occurs is verbal, as each team member can shout to their comrades. However, the most effective teams have less but more direct communication, a sign that their familiarity with one another has lead them to less need for explicit communication. Instead these soldiers anticipate teammates' actions and coordinate their actions accordingly.

The idea of team performance being linked to shared mental models among teammates has been a topic of research that has gained substantial popularity over the past decade. Cooke, et al (2000) state that, "the growing complexity of tasks frequently surpasses the cognitive capabilities of individuals and thus necessitates the team approach"(p. 151). This statement is becoming increasingly true in many different team environments in today's world, from professional sports to complicated military action. The standard knowledge in this line of research is that the teams with the 'most shared' mental models (or knowledge, knowledge structures, cognition, etc.) will be the teams that perform at the highest levels. Cannon-Bowers & Salas (2000) also reported that team members could actually have several different models depending on the topic area, such as an equipment model and a procedure model. It is believed that these shared mental models are what give teammates the ability to coordinate efforts when traditional methods of communication are not an option. The most commonly used example of this type of effort is the 'no-look' pass performed between basketball teammates. This task requires that teammates not only anticipate a pass but know when and where to anticipate either their teammate being or the pass coming from. Even in this simple example a complex interaction of teammates and their knowledge of both their duties and the tendencies of their teammates are required. For more complex and increasingly technological tasks this interaction only becomes that much more complicated.

The task for researchers came to be how to measure these mental models in a way that comparisons could be made to other teammates and then to other teams. While many options exist, including repertory grids, verbal protocols, and card sorting, concept mapping (Marks et al., 2002) is the knowledge elicitation technique that will be focused on here. First it is important to note that the recent research has use *text-based* concept mapping techniques. These techniques employ the use of cards used as conceptual terms that are then linked together in some fashion that is meant to be a physical representation of the participants' mental models of a given topic or subject area. Some of the believed advantages of concept mapping over other elicitation methods, such as card sorting include the ability to capture procedural and strategic knowledge as apposed to primarily declarative knowledge. This allows researchers to examine the processes that participants are using within their mental models. In addition to these advantages, the concept mapping techniques employed in this study will provide additional information for both participants and researchers; however this issue will be revisited later in the paper. First, it is important to operationalize our definitions of teams and of mental models (knowledge structures, cognition, etc.). In 1992, Salas, Dickinson, Converse, and Tannenbaum defined a team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform and who have a limited life span of membership" (pp. 126-127). To this definition one adjustment is to be made in that a team can consist of two or more people *or groups of people* (i.e. teams of teams).

As can be imagined, the term mental model, which is a concept that has many names, also has many definitions. Harper et al (in press) defines the construct of structural knowledge (another term for mental model) as, "an internal representation and organization of information utilized by an individual" (p. 2). This internal representation is what is then brought out through knowledge elicitations such as concept mapping. The part of this definition that is most interesting is "information utilized". This statement makes no reference as to the "correctness" of this information or even the nature of its source. This is the grounds from which this idea to utilize concept mapping has advanced. Mental models, when elicited through concept mapping can be evaluated for correctness against an expert model, as well as for sharedness with other concept map elicitations. This quality allows for two distinctly different methods for which to evaluate team members' shared mental models, as they are correct with an expert model and as they are accurate regardless of correctness to a teammates mental model (i.e. sharedness). The premise behind this analysis is that teammates who have become more familiar with one another will be able to recognize errors in their teammates' mental models and thus be able to predict and compensate for these errors allowing for no significant drop in performance. This knowledge however will require more than just the standard of knowing one's teammates' tasks (cross training) but also knowing one's teammates' tendencies (familiarity).

Rentsch (in press) said, "Much of the literature on cognition in teams to date has neglected the idea that team effectiveness may be a function of not only the overlap of team members' cognitions, but also a function of other forms of cognitive similarity, such as teammates' awareness of their teammates' schemas." (p. 22). With this in mind, it is important to determine what factors are most important in the make up of effective team composition. Teams performance in this case could be compared on a simulation task as well as through concept mapping (that will include pictorial stimuli, a modality not previously explored in this research but proven to be significant in the work of Evans, Hoeft, Jentsch, Bowers, & Camizzi (2003)) versus both experts and their teammates. It is hypothesized that the teams showing the greatest amount of overlap with *both* the expert maps (correctness) and their teammates' maps (sharedness/familiarity) will have the highest levels of performance on the simulation task. Additionally, of the teams that either score high versus the expert *or* high versus their teammates on the concept mapping task, the group scoring high against their teammates will perform at a higher level in the simulation than those that only score high versus the expert map. This will provide support favoring the idea that familiarity of team members is a more important factor in team effectiveness than is team knowledge of the task.



2 Methodology

2.1 Apparatus

The data revealing how well teammates know one another could be collected using the TPL-KATS concept mapping program (see Figure 1), IHMC's CmapTools software, or one of many other concept mapping packages. These software packages have been found to be comparable to traditional manual concept mapping methods by Harper et al. (2002). Using TPL-KATS software, participants would execute the concept mapping program in much the same way as the solitaire game that is found on most PCs. Concepts can be 'dragged' by clicking on them and pulling them across the screen to the desired location. This software allows for the addition of multimedia (pictorial) stimuli to be attached to the concept terms (see Figure 2). For more information on the software please see Hoeft, et al. (2002).

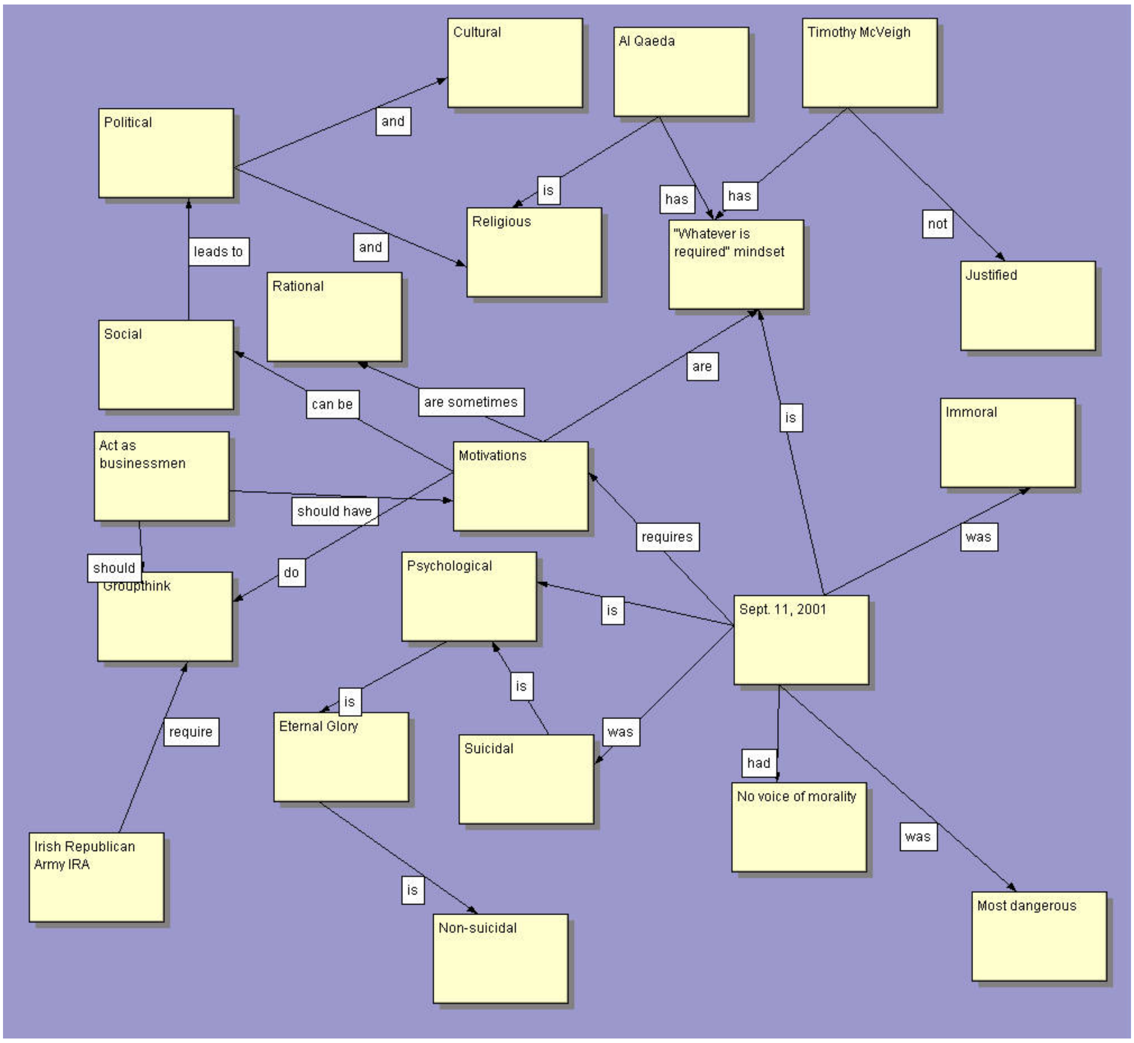


Figure 1. Example of completed concept map using TPL-KATS

Figure 2. Example of multimedia stimuli using TPL-KATS

2.2 Scoring

Often an area of debate, the relationships would be rated using a simple scoring method. A score of "1" means the concepts had a direct connection, via an arrow and proposition term and a score of "0" means the concepts did not have a direct connection, via an arrow and a proposition term. This means of 'scoring' a concept map has recently been found to have no significant difference from more complicated and time intensive methods (Harper et al, manuscript).

3 Results

Using this data coupled with the other biographical data there will then be an opportunity for a regression analysis to be performed. The data yielded from such an analysis could provide valuable information as to what factors can help to most accurately predict the make up of a successful teams' members.

4 Application

If the hypotheses in these theories are supported, new light would be shed on the world of shared mental models. Data would recommend that rather than devote increasing amounts of time to cross training (though cross training is still important) that instead we focus more on training teams to be familiar with their members. This means that one should know his teammates attitudes, abilities, tendencies, fears, etc. In addition, this data would provide another step in a more expansive form of shared mental models, which is shared mental models of teams of teams. Advanced research in this area could provide for increased proficiency in the global arena of military operations affording commanders the knowledge of not only what there colleagues and counter parts should be doing procedurally both also what they will most likely be doing strategically.

As well, if regression analysis shows significant results, this research could play a significant role in the formation of new selection criteria with which teams will be constructed. A new base model could be formulated from this data, providing for a new set of characteristics that contribute to the identification of a 'good' team member.

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