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From Battle Plans to Football Plays: Extending Military Team Cognition to Football

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Abstract

One area of focus for the sport sciences is on the improvement of team process and performance. The analogies and similarities between military command-and-control and American football serve as a useful bridge in which human factors, military, and industrial/organizational psychologist can share their findings in team process and performance with the sports sciences. The Cognitive Engineering on Team Tasks Laboratory (CERTT) has approached this problem with the development of a synthetic test-bed replicating unmanned aerial vehicle command-and-control coordination in the lab. Results from the lab in the areas of performance, process, holistic vs. aggregative methods, training, and communication and skill retention are used to suggest future directions in improving team performance in football.

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In an April 2002 interview with a correspondent for a major U.S. sports magazine, National Security Advisor (now Secretary of State), Condoleeza Rice intimated that after her government obligations are over she would be seeking another opportunity: to become the next commissioner of the National Football League (Cassman & Lai, 2003). Unlikely as this may seem to some, the fact that a member of the current president's cabinet may wish to serve in a position pertaining to sports may not be as far fetched as it seems at first glance. Both positions are actually very similar. The National Security Advisor oversees the rules and regulations regarding the security of the nation and the operation of the nation's military forces throughout the world regarding that security. The NFL commissioner oversees the rules and regulations regarding the operation of the NFL, the conducting of games, ensuring the safety of players, and establishing and enforcing the rules of which the players must abide by while employed by the NFL (e.g., rules regarding drug use).

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The similarities between these two seemingly different domains do not stop there. Upon closer inspection, one finds that there are a multitude of analogies and similarities that exist between the broader contexts of coordination between military teams and team sports, namely that of American football. A football game is analogous to commanding officers in a centralized command structure directing troops in a battlefield setting but without the violence and bloodshed that follows real-world military operations. On the surface, one can immediately discern the most obvious of similarities between warfare and a game of football: the pursuit of gaining territory over the opposition. From the dawn of man, a major objective of war has always been the acquisition of territory from enemy forces in the pursuit of natural resources or political gain. Football is no different from this endeavor in the pursuit of obtaining a higher score as a result of gaining territory (e.g., more yardage) over the opposing team. While team sports such as football do not share the same import and hazards as the efforts of our military, they are subject to similar unexpected events and rapid changes. American football also serves as an excellent paradigm for the concept of centralized control and execution of which our military traditionally operates.

The analogy between military operations and football serves as a useful comparison for mapping our research and findings in the area of military command-and-control teams to research questions, hypotheses, and possible implications for football. In this paper, we will highlight the various similarities present in the game of American football and military operations to show that the analogy is actually more than superficial in nature. In fact, the military and football share many elements such as dynamic, fast paced environments, and coordination and communication among team members who hold interdependent roles. We will also show that our research findings serve as a starting point for future work in sports psychology, such that researchers in the field of team sports may be able to use them to derive testable techniques to improve the coordination and performance of athletes.

The Analogy between American Football and Military Warfare

American football brings with it a great number of similarities to modern warfare complete with power, speed, discipline, teamwork, and courage under fire (Cassman & Lai, 2003). As stated above, football also shares with warfare the overarching goal of gaining enemy territory. The offense has four downs in which it attempts to gain ground and score. If they are unable to score, the ball is punted or turned over, and the team must switch from an offensive paradigm, to a defensive one where an entirely new set of personnel take to the field.

The game, like the battlefield environment, is often dynamic and fast paced. There is often a possibility of unexpected events such as equipment failure, inclement weather, and even enemy counter-intelligence in the form of coaching staff attempting to predict the opposition's next move. In such an environment, even the best-laid plans are subject to rapid change. Therefore, soldiers and players alike must be ready to implement changes in plans or strategy to meet the oncoming threat. For example, inclement weather is a factor that affects both the military and a football game. Poor weather is commonplace during the later weeks of the football season. Visibility, ability to maintain physical balance, and catching the ball are all inhibited by inclement weather conditions. Weather conditions are also an important consideration to the military. Soldiers operating in the field can be adversely affected by poor visibility. Snow and ice on a battlefield can affect a soldier's footing and ability to complete their tasks. Inclement weather can also for example, negatively affect an unmanned aerial vehicle (UAV) team operating in a remote trailer, altering the platform's sensors and the UAV's ability to fly and maneuver. In fact, the weather is deemed so important that the military invests a great deal of time and manpower on predicting and tracking weather conditions during operations (Shope, DeJoode, Cooke, & Pedersen, 2004).

The dynamic nature of the battlefield does not stop with the soldier on the ground however. Nearly all aspects of military operations are subject to the dynamic and unexpected events described above whether it be a Navy warship captain who, in order to protect his ship and crew, must quickly decide on whether an unidentified aircraft has hostile intentions to the crew of a U.S. Air Force C-130 Hercules transport that, due to mechanical failure, must make an emergency landing. Football too, has its share of unexpected events such as pass interceptions and two-point conversion passes made by the kicker after a touchdown. These unexpected events can be potentially devastating to the opposing team and are akin to the interception of supplies or intelligence data (e.g. communications) by the enemy or attack where an enemy force is able to gain ground due to the element of surprise.

Both football and war have rules and accords which dictate to both sides what behaviors are allowed and which are not. In the war, militaries of the world are held accountable for fair and just treatment of prisoners of war (POWs), not harming civilians, and accepting surrender from enemy forces. Similar rules in football include penalties for unnecessary roughness, holding, and helmet-to-helmet contact. Such behaviors usually result in penalties issued to the player who violated the rule and take the form of loss of yardage or even ejection from the game in extreme circumstances (such as for fighting with another player, or even engaging in verbal/physical altercation with a referee). Like many other team sports, a penalization stemming from the actions of a single player typically has an effect on the entire team. For example, a call of unnecessary roughness on the quarterback results in a loss of 15 yards which is a great detriment to the entire team. In some cases, the penalties can be catastrophic such that the team is never able to recover resulting in turning over of the ball to the opposing team or even a safety. The same consequences hold true to real-life military operations and warfare.

The loss of a unit, such as a single ground troop, can have dire consequences for an entire operation. This is partially because many teams in military operations (e.g. Navy SEAL teams) are comprised of members that, much like in football, each have an individual and interdependent role (e.g. a sniper, demolitions expert, mission commander, etc.). Due to the specialization and interdependency of each member, if one member is lost the entire mission could be compromised. An interesting side note here is that the larger the unit is, the more dire the consequences. The loss of an F-14 Tomcat not only results in the loss of two lives, but also a loss of offensive capability that the operation in question would otherwise have. The unthinkable loss of an aircraft carrier not only compromises military operations in an entire region but also has the power to destabilize the political and military balance in the area. The loss of life is also very far reaching, affecting the families and loved ones of the crew in the country where the carrier was based.

Other similarities include the use of similar vocabulary. Football vernacular is replete with militaristic terms such as 'offense,' 'defense,' 'interception,' 'bombs,' 'encroachment,' 'battles,' and 'blitzes' to name a few. In turn, the U.S. military has been known to adopt various football terms in its history such as "Operation Linebacker," a bombing action carried out by the U.S. Air Force in the Vietnam War (Phan, 2002), and "Operation Hail Mary," a plan utilized by General Schwarzkopf in the Gulf War ("Thunder and Lightning," 1997). The reach of the football culture has also permeated the military such that every year, there is a fierce rivalry between the football teams of the Army, Navy, and Air Force Academies. The U.S. Army also goes as far as to sponsor its 'Army All-American Bowl,' an all-star game for the highest ranking high school players in the United States.

The various similarities between American football and modern warfare discussed thus far have been superficial, spanning the use of similar vernacular, to the reliance on teamwork in dynamic environments. Table 1 summarizes the similarities between various military operations and football.

The similarities between military operations and football go deeper, however, to encompass the very essence of teamwork and coordination. This deeper similarity is explored below.

Table 1. Surface feature similarities of teams in military operations and football.

	Military Command and Control	American Football
Environment	Dynamic	Dynamic
Command Structure	Centralized	Centralized
Importance of Technology	High	Moderate
Reliance on Teamwork	High	High
Planning	High	High

Extending the Analogy to Team Cognition

Salas, Dickinson, Converse, and Tennenbaum (1992) define 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). Advances in technology have increased the complexity of today's tasks which frequently surpasses the cognitive (and physical) capabilities of individuals and therefore, necessitates a team approach. Teams operating in highly cognitive domains (e.g., aircraft cockpits, air traffic control, operating rooms) are required to plan, detect and interpret cues, make decisions, and perform as one coordinated unit. These collaborative cognitive activities that teams perform are referred to as *team cognition*. We hold that team cognition is more than the sum of the cognition of individual team members. Instead, it emerges from the interplay of the individual cognition of each team member and team process behaviors (Cooke & Gorman, in press). The widespread use of teams has spurred social scientists to explore their efficacy in a variety of settings. There is evidence that teams "think." That is, individuals possess knowledge that allows them to function effectively as a team even during periods of high workload (Orasanu, 1990). Team cognition is also linked to performance and is as important as skills and attitudes. The measurement of team cognition provides a window to factors underlying team acquisition and performance of complex skills and can be valuable in diagnosing team performance successes and failures. An understanding of team cognition can also lead to training and design interventions which can improve overall team performance. Given its similarities with the military, we believe that the study of team cognition can be extended to the game of American football.

The similarities between football and military teams go beyond the superficial, and extend to the factors important in measuring team cognition. In the military and football, teams are comprised of a collection of units, with each unit serving its own purpose and with each individual having a specific, equally important role. Football teams for example, are comprised of three separate units: the offense, defense, and special teams. Within each separate entity, each individual team member has their own specific interdependent role. This interdependency is a key concept in our view of team cognition and will be discussed in detail later. There are other deeper similarities that permeate both areas pertaining to strategy, coordination, and the teamwork involved in obtaining success in both endeavors. To the layperson, a football game may seem to be merely a chaotic jumble of bodies clashing over the rights to an oval-shaped ball. Warfare at first glance may also seem a confusing display of discord, but both military operations and football are very ordered and both endeavor to make full use of intelligence data. Every play, whether in the battlefield or the football field, is preceded by a plan. For example, the offense of a football team will huddle before every play. The quarterback, which is akin to a lieutenant in a battlefield, delineates the next play that the offense will attempt in order to maintain situational awareness of where the guards and tackles will be, where the receivers will run, and who the intended receiver will be. That every play has a plan, and every member of the team is aware of the plan, and what his fellow teammates will be doing is of paramount importance if the play is to succeed. The same can be said for military operations where every operation is preceded by a briefing. Even simple operations involve planning such as the specific route a patrol aircraft will fly and how long it will fly based on time and fuel considerations.

Briefings before operations are important to the success and safety of all personnel involved. Large-scale operations such as the recent 'Operation Iraqi Freedom' bring together different branches of the military, and involve many different personnel each with their own role and specialization to act as one entity toward a common goal. For an operation of such scale to be successful, all involved must be situationally aware of what the others are doing as well as be aware of what their own roles are. One of the factors that can be attributed to the success of large-scale military coordination is the use of technology and communications aids. Personnel are able to communicate, coordinate, and share information over great distances through the use of radio, internet, and satellites. Football has also used technology with success as coaches are able to communicate with each other via headsets. Coaches are also able to communicate with players such as the quarterback via the use of speakers mounted within players' helmets. Such communication and situation awareness behaviors are integral to the development of team cognition.

That football teams conduct briefings in the form of huddling before plays stems from the desire to catch the opposing team by surprise. In football as in warfare, the element of surprise is a strong tool that often dictates the outcome of many plays—teams that are caught off-guard are at a severe disadvantage by not being prepared (e.g., a defense that chooses man-to-man coverage in anticipation of a pass when the quarterback actually intends to hand-off the ball to a running back). In military operations, the element of surprise is something that everybody wants to have, and nobody wants to be caught off guard by. The U.S. military (as well as the militaries all over the world) goes to great lengths to gain intelligence over enemy threats and has been an important factor throughout the history of warfare from the deployment of forward scouts, to the use of UAVs for visual reconnaissance, interception of enemy communications, and even the use of spies. Like the military, players and coaches in football also desire to gain intelligence over the opposing team. This can be seen from the way that many head coaches will actually cover their mouths when discussing plays which suggests that the opposing team may have lip-readers placed in the crowd. This reflects the notion that shared knowledge of the oppositions' plans is important in having good, predictive situation awareness in order to be prepared for surprises. Although there is a great emphasis placed on gaining intelligence in both football and the military, surprises may still occur. In the military, this may take the form of an unforeseen group of enemies in the distance caught by the camera of a UAV or a sudden explosion from a hidden landmine or roadside bomb. In football, such surprises can take the form of a team on offense calling an audible in response to surveying the opposition's defense, or the interception of a well-planned pass.

As discussed above, there are a great number of similarities between operations in the military and the sport of American football. The various similarities are both superficial as well as deep, spanning from the use of similar vernacular, to the similarities found in cognitive coordination among personnel and teammates. Table 2 summarizes the similarities between various military operations and football with regards to team cognition.

Table 2. Features of team cognition in military operations and football

- Reliance on teams of teams
- Heterogeneous team roles
- Interdependence among team members
- Importance of training
- Importance of planning
- Importance of team situation awareness
- Importance of briefings and debriefings
- Importance of communication
- Importance of coordination

Sports researchers have been interested in the investigation of team performance, process, and coordination and although the analogy between the military and football may not be entirely new, there may be much to be gained in bridging the gap between the two areas. That is, the findings from research on team cognition and coordination in military settings may actually be extendable in interesting ways to team sports such as football. Such inter-disciplinary integration can also lead to new research questions for sports researcher to explore not only football, but other team sports as well. Additionally, research on team cognition in the military may gain new insights from research and training strategies coming from the domain of football and other team sports. Before describing the specific findings on team cognition in our lab and how they may relate to teamwork in football, we discuss prior team coordination research in the context of sports.

Review of Coordination Research in on Team Sports

Sport researchers have concentrated heavily on the improvement of performance in sports teams. In examining this issue, researchers in the sports domain have emphasized different factors that are essential for amplifying team performance. Among such factors, special attention has been given to the effects of social norms, group cohesion, conflict, social loafing, and athletes' motivation (Widmeyer, Carron & Brawley, 1993; Harwood, 2002; Robbins, 2004); the effects of coaching on team performance (Hodges & Franks, 2002; Bloom, Stevens & Wickwire, 2003); the effects of stress and anxiety on team performance (Pensgaard & Duda, 2002; Smith, Bellamy, Collins & Newell, 2001), as well as skill excellence and expertise pertaining to a specific task (Button, MacLeod, Sanders & Coleman, 2003).

Coordination in sports teams and its effect on performance has been explored to much lesser degrees. For example, McGarry, Anderson, Wallace, Hughes and Franks (2002) considered sport competition as a dynamical system where dyadic (e.g., squash) and team (e.g., soccer) coordination may be represented as coupling and de-coupling of many accelerators (e.g., players). Ferarro, Sforza, Dugnani, Michielon, and Mauro (1999) proposed a quantification of team coordination based on analyzing soccer players' positions during a game. Grehaigne, Bouthier and David (1997) believe that success of soccer teams depends on how its players coordinate position, speed, and movement of their own teammates and opponents' teammates in changing environments. Although, this research examines team coordination, it does not address coordination of team-level cognitive processes. This limitation may be due to difficulties in eliciting and measuring cognitive processes that arise during a dynamic and complex task such as sports. Moreover, the measurement challenge is exacerbated when cognitive processes at the team level (such as coordination), rather than individual processes are studied (Eccles & Tenenbaum, 2004). Attempts to elicit individual cognitive processes, such as decision making, planning, information processing, situation awareness, and workload, and then aggregating these data to generalize to the team level have been made in sports research (Sullivan & Feltz, 2003; Magyar, Feltz & Simpson, 2004). The approaches discussed above, however, do not account for the emergence of team cognition and coordination. According to Eccles and Tenenbaum (2004), new team cognitive properties emerge from the interaction of players in the team, and these new properties which emerge on the team level are not the same as the simple aggregation of individual cognitive properties.

Our Laboratory Setting for the Study of Team Cognition

One of the primary goals of the Cognitive Engineering Research on Team Tasks Laboratory (CERTT) is to aid in the design of team training programs and other team interventions through the understanding of team cognition. This goal rests on an ability to measure team cognition. Why measure team cognition? Team cognition contributes to team performance now more than ever in today's increasingly cognitive tasks. Many organizations (military and business alike) hold the belief that teams are the solution to many problems. It is perceived that teams are better able to handle stress, are more adaptable and flexible in dynamic environments, make better decisions, and are more productive than individuals working alone. Research on understanding team cognition and effective team performance has long been an area of intense focus for human factors, military, social, cognitive, and industrial/organizational psychologists (Levine & Moreland, 1990; Guzzo & Shea, 1992; Cooke, Salas, Kiekel, & Bell, 2004). Therefore other goals of the CERTT Laboratory include the identification of issues and needs in the measurement of team cognition, the development and evaluation of new measures and the application of new measures and methods in which to better understand and evaluate team cognition.

The heart of the CERTT Laboratory is a flexible synthetic task environment (STE) that is designed to study many different synthetic tasks for teams working on complex environments. STEs provide an ideal environment for study of team cognition in complex settings by providing a middle-ground between the highly artificial tasks commonly found in laboratories and the often uncontrollable conditions found in the field. We are currently studying team cognition in the context of a UAV-STE controlled by a three-person team whose mission it is to take reconnaissance photographs (Cooke & Shope, 2004). The current set-up is based on a cognitive task analysis of the ground control station of the Predator UAV operated by the U.S. Air Force (Gugerty, DeBoom, Walker, & Burns, 1999). The UAV-STE emphasizes many team aspects of tasks found in football such as planning, re-planning, decision-making, and coordination.

The three team members in the UAV-STE are provided with distinct, though overlapping training and each member has a unique, yet interdependent role with individual responsibilities. The team members involved in this task are the Air Vehicle Operator (AVO) who flies the UAV by controlling the heading, altitude, and airspeed, the Payload Operator (PLO) who controls camera settings and takes reconnaissance photos, and the Data Exploitation, Mission Planning and Communications Operator (DEMPC) who plans the mission and acts as the navigator. To successfully complete missions, the team members need to share information with one another in a coordinated fashion. Most communication is done via microphones and headsets, although there is also some computer messaging involved. Measures taken include audio and video records, digital information flow data, embedded performance measures, team process behavior measures, situation awareness measures, and a variety of individual and team knowledge measures. More information on the CERTT Laboratory can be found in other publications (Cooke, Rivera, Shope, & Caukwell, 1999; Cooke & Shope, 2004; Gugerty, DeBoom, Walker, & Burns, 1999). The CERTT Laboratory has completed a total of five experiments which are discussed throughout this article. Table 3 summarizes the experiments and serves as an overall reference point.

Table 3. Summary of five completed experiments in the CERTT Laboratory

	AF1	AF2	AF3	AF4	AF5
Number of Missions	10	5	7	5	5
Workload	Constant	Constant	Missions 1-4: Low Missions 5-7 High	Missions 1-4: Low Mission 5: High	Missions 1-4: Low Mission 5: High
Number of Knowledge Sessions	4	3	2	1	1
Place of Knowledge Sessions	1-after mission 1 2-after mission 4 3-after mission 7 4-after mission 9	1-after training 2-aftermission 2 3-after all missions	1-after training 2-after all missions	1-after mission 3	1-after mission 3
Mission Time	40 min	40 min	40 min	40 min	40 min
Number of Teams	11	18	20	20	5
Number of Sessions	3	2	2	1	1
Manipulations	None-Acquisition Task	Shared vs. Non-shared Knowledge	Co-located vs. Distributed High vs. Low Workload	Co-located vs. Distributed Low vs. High Workload	Low vs. High Workload All Expert Teams
Participants	AF ROTC Cadets	AF ROTC Cadets	Campus Organizations	Male Students	Male Expert Teams
Compensation	$6/hr to organization plus $50 bonus to best team	$6/hr to organization plus $50 bonus to best team	$6/hr to organization plus $50 bonus to best team	$6/hr to individual plus $50 bonus to best team	$6/hr to individual plus $50 bonus to best team

Experiments typically involve an initial training period in which team members train individually on their respective tasks. This is followed by several (five to ten) 40-minute missions in which the team works together in the UAV-STE. These are sometimes interrupted by knowledge sessions in which taskwork and teamwork knowledge are measured. Other primary dependent measures include team performance (outcome-based), team process behavior, and team situation awareness. Manipulations have included the ability of the team to share knowledge, distributed versus co-located mission environments, and workload. The lab is currently conducting a study on the acquisition and retention of team coordination in which retention interval and team member familiarity is manipulated.

Data collected thus far in the lab have provided valuable insights into the acquisition of team skills, knowledge development and sharing, and the effects of workload, training strategy, and distributed vs. co-located environments on team cognition and performance. This work has been reported in detail in technical reports, book chapters, journals, and conference presentations (Cooke, Salas, Kiekel, & Bell, 2004; Cooke, Kiekel, Bell, & Salas, 2002; Cooke, Kiekel, & Helm, 2001a; Cooke, Kiekel, & Helm, 2001b; Cooke, Shope, & Kiekel, 2001).

Extending Command-and-Control CERTT Research to Football

The operational environment of today's military forces is heavily dependent on command-and-control tasks that are increasingly cognitively demanding, information-centric, and sensor-dependent in settings that are dynamic, uncertain, and of high tempo. Operators in these settings work together in teams that are often geographically distributed, heterogeneous in regard to skills and backgrounds, and, therefore, must rely on the development of team cognition to be successful. The research and theories surrounding military command-and-control parallels many civilian tasks including emergency operations centers, telemedicine, and air traffic control. Given the similarities between military command-and-control and football discussed earlier, it is apparent that such theories can be extended to team sports as well.

Now more than ever, issues of assessing team performance, training teams, and designing technological aids for effective team command-and-control performance are critical, yet highly challenging. How can team performance be measured? How can we characterize and assess cognitive skill at the team level? Can assessment occur without disruption of operational performance and can it occur in time for intervention? How is team cognition and performance impacted by training, technology, and team composition? Is team cognition different than the sum of the cognition of individual team members? What are effective training regimes or decision tools for these team members?

Our research program in the CERTT Laboratory is focused on these and other questions pertaining to team performance and cognition. Team coordination is characterized by timely and adaptive information exchange among team members. More specifically, command-and-control tasks in both military and civilian domains can be characterized as challenging from the perspective of the command-and-control team for a number of reasons including the 1) unanticipated nature of the situation, 2) *ad hoc* formation of team structure, 3) lack of familiarity among team members, and 4) extended intervals with little or no team training. Items 3 and 4 are particularly relevant to military and civilian command-and control communities because there can be fairly long periods when command-and-control teams are not able to train and practice together, yet are expected to be competent as soon as they are deployed. We view team coordination as central to team skill in command-and-control. In addition, for teams that stay together in a natural, operational setting (e.g., UAV teams) it is difficult to control the amount of exposure teams get to the operational tasks between laboratory sessions.

The command-and-control concepts described above closely mirror the command-and-control issues found in team sports such as football which has developed other the decades since its inception. While maintaining its dynamically high tempo during plays, football has become more information-centric and sensor dependent. For example, offensive coordinators will often times be seen observing the game in a higher, geographically distributed location in order to better view the overall situation. The same coordinator will communicate with players and other coaches via headset. Another example can be seen with the way the head coaches will often cover their mouths when speaking to hide their intentions from possible 'spies' from the opposing team. As discussed in the first section, there are also other parallels such as unanticipated events (e.g. pass interceptions, 2-point conversions after touchdown), ad hoc formation of teams (e.g. trades, signing free agents), lack of familiarity among new teammates and long periods of time with no team training (e.g. the off-season).

From the task parallels drawn in the discussion above, it is reasonable that the CERTT UAV-STE findings may have implications for football and may suggest research questions and hypotheses for sports researchers to test in the domain of football. Those findings may then lead the way to enhanced coordination in football teams and team sports in general. In the next sections, we discuss the various findings of the UAV-STE and how they may have implications for the sport of football.

Our Research Findings

Performance vs. process. Are team process measures able to predict performance in football and can process measures be developed for sports teams such that they are diagnostic of team weaknesses and strengths and therefore instrumental in improving team effectiveness? Team performance or team effectiveness is the "bottom-line" in most applications—whether it is on the battlefield or the football field. We use performance data as the criterion against which other measures can be evaluated. For instance, if one of our cognitive measures fails to predict performance differences, then it is not as useful as one that does. All interventions, personnel selection rules, manipulations, technological innovations, decision aids, or training strategies are of little importance if they have no impact on this bottom line. As a result, much of the team literature has focused on measures of team performance or effectiveness and findings that impact team performance or effectiveness (e.g., Swezey & Salas, 1992).

The measurement of performance, whether individual or team-oriented, is not a trivial problem. For some types of teams, such as surgical teams, air traffic controllers, and emergency responders, indices of performance are not obvious. Sometimes it is just a matter of better understanding the teams' goals. Other times, there are no standards for optimal, or even effective, team performance.

In other domains, however, there are outcome measures that are well integrated with the task. In the UAV domain there are also obvious outcome measures. One that is frequently used is mishap rate; however, this is at such a molar level of granularity that it is only informative at a very high level to the human or team contributions to the system. A better measure in this domain is a more specific index of team-level mission performance such as the number of targets successfully photographed. Again, these outcome measures can be broken down by time (e.g., targets per minute) and by other dimensions (*ad hoc* targets vs. planned targets photographed; number of airspace violations, etc.). In our UAV simulation we rely on a composite measure of team performance that includes number of targets photographed per minute and amount of time spent in alarms and warnings.

In football for instance, we can rely on the final score. There are also often standard ways to decompose this score along various dimensions. For instance, the score can be broken down along the dimension of time and we examine the score at each quarter. Also, there are ways to break this down by other dimensions (e.g., number of yards run, number of pass completions, and the amount of time each team has possession of the ball).

Despite the fact that these measures of UAV and football team effectiveness are obvious and perhaps easy to record, we need to ask the question about whether they best reflect team effectiveness and reflect it in a way that speaks to interventions to improve team effectiveness. For instance, mishap rate in the UAV domain is probably not as sensitive a measure of team effectiveness as number of targets photographed, but is the latter the best that we can do?

But why consider measures other than performance or "bottom-line" measures? Researchers in the team arena have learned that performance measures can only go so far. They are not diagnostic. Outcome-based performance measures tell you about bottom line or how effective the team was, but they do not tell why the team was effective or ineffective. They also do not suggest interventions to improve performance. Thus, in the team arena there has been an emphasis on explanatory mechanisms such as team process behaviors and team cognition (e.g., Cannon-Bowers & Salas, 2001) that provide an understanding of the factors underlying team performance.

We measure process behavior in our UAV task through experimenter observations and ratings. Experimenters monitor behaviors such as communication, coordination, and leadership behaviors and rate them on a scale that indicates the observed quality of these behaviors. Also behavior is observed and rated at critical event junctures in the simulation. Most recently we are exploring ways of doing this unobtrusively and more objectively through communication data. Overall, we find that process data can provide information where performance data do not. In some cases we find that outcome

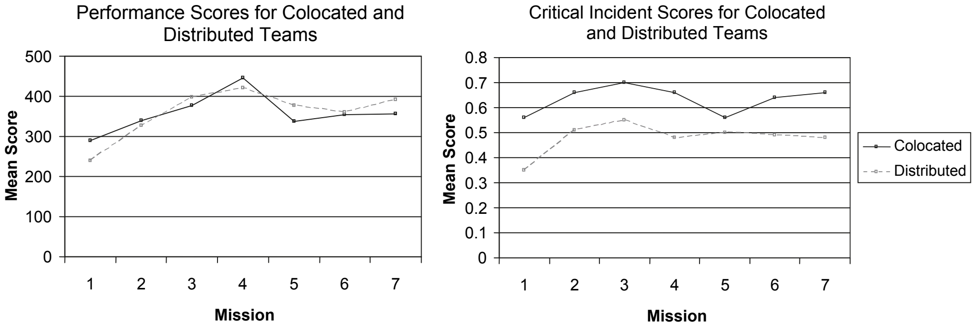

Figure 1. Performance (left graph) and process (right graph) for co-located and distributed teams in one of our CERTT experiments.

or the bottom line does not differ, but process does, providing some insight into the teams' adaptive behaviors (Figure 1). For example, in one of our UAV experiments we found that co-located and distributed teams behaved differently, but managed to obtain similar performance scores (Cooke, DeJoode, Pedersen, Gorman, Connor, & Kiekel, 2004). Without process data we might assume that there is no impact of distributed or co-located settings, but in conjunction with process data (and communication data) we now understand that team interactions are adaptive for their own environment and the adaptation of the best teams may provide insight for training or design interventions.

Although in this case, process and outcome told a different story about the impact of the manipulation, in most cases we find a close correspondence between process behavior and outcome with team process predicting team outcome. However, an additional benefit of examining process behavior is that, like performance, it can be decomposed into components, but these components are more diagnostic than a quarter-by-quarter score. For example, the team process behavior scores can be broken down into components as well such as coordination, conflict management, and leadership behaviors. By examining team process as well as performance we can have a better idea about what specific behaviors underlie the performance data which can better enable us to intervene through training, selection, or design to improve team performance.

The message here is that though measuring team performance is crucial, it is equally important to capture measures of the behavior that underlies that performance. In football this could be communication behaviors during time-outs, and before plays, passing style, situation awareness during plays, and leadership behaviors of the coaching staff and players on the field. It is also important to note that the measurements of behaviors that underlie team performance in the UAV simulation are based on theories of team cognition. As such, theories of team cognition in sports teams also need to be similarly developed to aid in the measurement team performance and its underlying behaviors.

Holistic vs. collective measures. Can holistic measures of team performance and cognition beyond the outcome-level score be identified and would such measures be more informative in regard to enhancing team performance compared to aggregate measures? In the CERTT Laboratory we have developed and evaluated holistic measures of team performance and cognition. That is, we have developed measures that elicit and assess team state at the team level as opposed to measuring at the individual level and aggregating. The football score is a holistic measure, but team statistics such as total offensive yards and total number of first downs, are examples of collective scores which are aggregated across team members to reflect performance of the team as a whole.

We believe that holistic metrics for measuring team processes are more accurate than aggregative approaches, such that the whole is more than sum of its parts. For example, a team of experts does not necessarily make an expert team such as was seen with the men's basketball team during the 2004 Summer Olympic Games in Athens, Greece. Surprisingly, the team, which was composed of the best basketball players in the National Basketball Association, was highly unsuccessful. Each player was an expert in performing his own task, and thus we may anticipate that based on the team-as-a-collection-of-individuals perspective we might assume that the team would also excel. Yet for all of the skill contained in the team, the lack of training together to coordinate as a team led to their poor performance.

In this light, we have developed a framework that helps to better define team knowledge, and especially, to distinguish team knowledge as it has been traditionally measured (e.g., collectively) from team knowledge as it may best be measured (e.g., holistically). Traditional collective measurement involves eliciting knowledge from individuals on the team and then aggregating the individual results to generate a representation of the collective knowledge of a team. Although we believe that knowledge measured collectively should be predictive of team performance, it is also an oversimplification, devoid of the influences of team process behaviors (e.g., communication, coordination, situation awareness). These process behaviors are analogous to individual cognitive processes in that they transform the collection of team member knowledge into effective knowledge that is associated with actions and, ultimately, with team performance in a dynamic environment. One of our research goals is to identify ways to measure effective team knowledge using team-level or holistic metrics. Furthermore, it is questionable whether simple aggregation of individual team member knowledge is appropriate for a team of individuals who have different roles and consequently, different knowledge bases.

To demonstrate that collective and holistic approaches measure different aspects of team state we can examine results when each metric was used to measure the same team outcome. For this purpose, we compared teams' performance data, which was obtained via two metrics, holistic and collective. The holistic team performance metric was a composite score based on team-level outcomes (e.g., number of targets photographed, time in warning and alarm states of all team members) and the collective team performance metric was the average of standardized individual scores also based on outcome but pertaining only to the individual (e.g., route deviations and fuel used for the AVO). Performance scores that were obtained during low and high workload conditions in

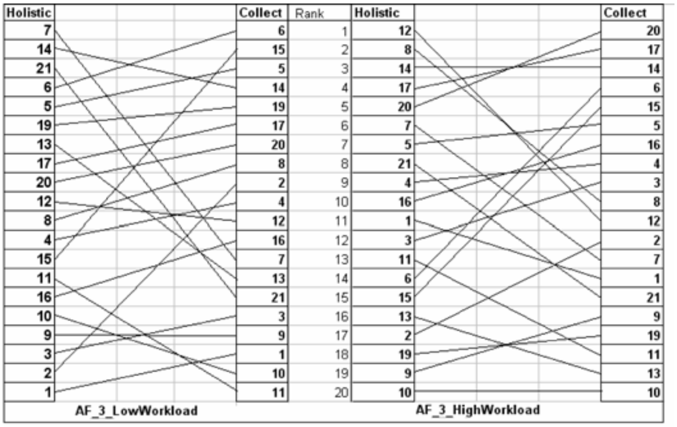

Figure 2. Team's Rank Order According to their Holistic vs. Collective Performance during Low and High Workload Conditions (Experiment 3), Rankings: 1 = the highest and 20 is the lowest.

Experiment 3 were compared using Spearman rank order correlations. First, the Spearman rank correlation coefficient *(rho)* was calculated by converting holistic and collective team performance scores to team ranks which were then correlated. The Spearman rank-order correlation coefficients for low and high workload conditions were: *rho* = .50, $p < .05$ and *rho* = 0.56, $p < .01$, respectively. Although the results were significant, a closer examination of the arrangement of teams revealed that the best and the worst performing teams were different depending on the metric applied. For example, Figure 2 shows that during the low workload condition the best performing team was Team 7 (based on the holistic measure). However, this team was ranked 13th when collective performance measures were applied. Similarly, the same situation occurred under high workload conditions; the best performing, according to holistic measure, Team 12 moved to 11th place with the collective measure.

Holistic and collective performance measures were further correlated with two CERTT team process measures: the critical incident process score and team process ratings (variables that were obtained using experimenters' judgments on specific team' behavior, such as coordination, communication, situational awareness) for low and high workload conditions.

As discussed above, our teams seem to be more than a sum of parts and thus the metrics should be holistically oriented. For example, in football the score is a holistic score, but other metrics, such as total rushing yards, total passing yards, and defensive sacks, which are simply aggregated, are not holistic in nature. Our research findings suggest that there is a difference between holistic and collective measures of team processes, and thus, this difference should be considered in assessing team state (e.g., process, performance, cognition) in football. To summarize, although it is clear that outcome measures such as "winning" are truly important, in regards to diagnosing process and performance, they may not be as diagnostic as desired.

Acquisition of team skill. What is the performance benefit obtained by training as a whole team versus training as sub-teams or individuals? Can team coordination skill be improved or the acquisition hastened by practice on transfer tasks (e.g., coordination demanding video games)? What is the role of team member familiarity and how much does turn-over or player trading impact team performance? Acquisition of learned skills has been a subject of study in fields ranging from academia to the military. One of the most relevant issues in the acquisition literature is the establishment of the optimal length of time allowed for training (Lane, 1987; Adams, Webb, Angel & Bryant, 2003). Too little training leads to higher rates of forgetting, while too much training wastes time and resources. While it is beyond the scope of this article to discuss the various findings of acquisition research in the literature, there are a number of variables (e.g., distribution of practice, transfer, and individual difference in motor learning) that have been shown to affect skill acquisition (see Adams, 1987 for a review).

Despite the military's interest in increasing the effectiveness of skill acquisition, there is still an emphasis on training (which deals with task-oriented goals and objectives to achieve desired outcomes) vs. education (which conveys a background in general skills and knowledge). While military training in general tends to involve some classroom type education, it is more task-specific (Lane 1987), and does not tend to emphasize the importance of coordination and teamwork.

The first experiment run in the CERTT Laboratory examined the acquisition of team performance in the UAV-STE context with eleven 3-person teams performing ten 40-minute missions. Of particular interest was the finding that individual team members are able to quickly acquire the skills that are required to perform their individual roles (1.5 hours). Also of interest is the finding that early attempts to "force-feed" teamwork and coordination information prior to the development of taskwork knowledge was not successful suggesting a sequential dependency in knowledge development (taskwork must precede teamwork). Team performance as measured by a composite score made up of components relevant to the rate of performance (e.g., number of targets successfully photographed in each mission) reached asymptotic levels over four 40-minute missions after individual training (see Figure 3).

This pattern of skill acquisition has been replicated across all experiments that have been conducted in the lab. Because individuals have attained a criterion level of performance prior to the first mission as a team, it is theorized that team skill is what develops over the first four missions. In particular, we theorize that the team members are learning how to coordinate and share information with the right person at the appropriate time.

The implications of these findings for football teams are twofold. First, football training camps closely approximate the training conditions often found in the military such that skills training is emphasized over education in team skills such as coordination and the development of team cognition. Special teams, offense, and defense often train task skills separately (although they do so on the same field), only to scrimmage against

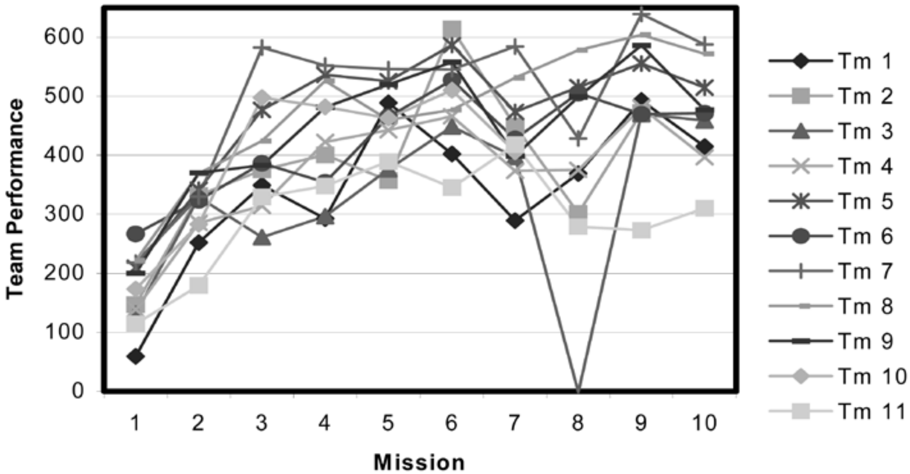

Figure 3. Team performance of 11 teams over 10 missions. A long break occurred between Missions 7-8.

each other later. Our findings indicate that team skill is acquired only by teams working together, and that such training should be maximized as much as possible. In addition, attempts to force-feed coordination and teamwork knowledge in our UAV-STE have been unsuccessful, suggesting that task knowledge must be learned before teamwork knowledge. Unlike participants in the UAV-STE however, individuals in professional sports teams often start with the necessary skills and knowledge needed to perform their individual roles and, therefore, may not require any additional role knowledge instruction.

The second implication is that such skills should be trained to asymptote which further implies that such a ceiling needs be established. Determination of the asymptote will serve as an indicator to coaching staff as to how much coordination training is required. This will, in turn, save time and resources while minimizing the effects of forgetting. Coaching staff should also take into account the distinctions between team generic/specific and task generic/specific skills (Cannon-Bowers, Tannenbaum, Salas & Volpe, 1995). For example, sports teams often experience high turnover rates. Individuals with differentiated and specific task expertise are expected to function well but may only play together for a single season. Because of this, players may benefit from additional training on generic teamwork skills such as general planning and communication that will carry over across teams. In addition, coaching staffers should be aware that individual training may lead to individual experts but not foster team expertise as seen in the U.S.2004 Olympic Men's Basketball team. Training as a team is needed for team expertise to emerge. Evidence for this was found in a recent study in the UAV-STE that used "expert teams" (e.g., flight instructors that have flown together) such that participants in a team knew each other and had experience coordinating before participating. Results showed that "expert" teams reached asymptotic levels of performance after only the first mission as opposed to the majority of teams which require four missions. The best performing team in the study were three males who knew each other very well and played an online video game together (which required headsets to communicate over the internet) for several hours a day for the past year. The team's familiarity with each other, as well as their experience in coordinating, apparently sped up their acquisition of performance. The implications of this finding are that team familiarity and experience, and prior coordination/communication experience are valuable such that the experience can transfer from one task to another--in this case, an online "capture the flag" game to our UAV-STE. This finding also suggests that online video games that require coordination and communication may be useful tools in training football teams off the field. However, it is also important to note that we have not yet separated out the contribution of team member familiarity from practice in environments requiring coordination to the rapid acquisition team skill. This is a focus in a current study being conducted in the UAV-STE.

Retention of team skill. To what degree does a lag without practice (e.g., off season) impact the team cognition and coordination of the team? Closely related to the concept of skill acquisition is the problem of retaining what has been learned. This concept has especially been of great interest to the military in its need and desire to minimize forgetting and maintain combat readiness while keeping training costs as low as possible (Hagman & Rose, 1983). Wisher, Sabol, and Ellis (1999) describe three skills/subtasks which are present in all military tasks and are subject to forgetting: retrieval of facts from memory, ability to combine and evaluate incoming information, and execution of the chosen actions or procedural steps. However, with the cognitive complexity and reliance on teams in today's military tasks, there may be one skill/subtask that has been overlooked: the ability to coordinate as a team. We are currently exploring the effects of retention intervals on a teams' ability to maintain team coordination. The impetus for the current study developed from a finding in the very first experiment run in the UAV-STE.

Referring back to the first experiment conducted in the UAV-STE, teams experienced a lengthy break between the second and third sessions of the experiment. The length of this break differed across teams. The first and second sessions were separated by one to two days, whereas the second and third sessions (Missions 8-10) were separated by anywhere from four weeks to 11 weeks. As a pilot test to a study currently running in the UAV-STE, the retention data from the 11 teams were examined. In order to observe the effects of the "accidental" retention interval on performance during Session 3, the teams were split into two groups based on the median number of weeks between Sessions 2 and 3. The groups can be seen in Table 4.

Table 4. Descriptive statistics on retention interval length for each group

Retention Interval Group	Mean (# of weeks)	Min	Max	N
Short (4-7 weeks)	5.86	4.71	6.57	4
Long (8-11 weeks)	9.63	8.71	10.86	5

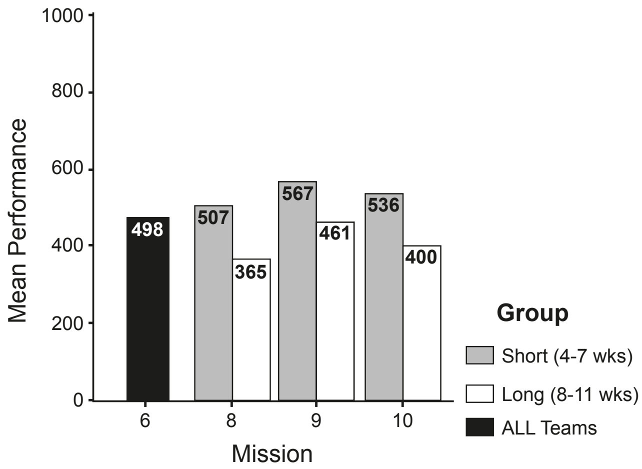

Figure 4. Mean team performance for all teams at Mission 6 (baseline performance) and for the short (n=4) interval and long (n=5) interval groups at Missions 8 through 10.

Mission 6 was used as a baseline measure of performance for both groups and did not differ significantly $t(7) = .96$, $p = .37$. As Figure 4 suggests, Mission 8 performance was significantly lower than baseline for the long interval group $t(4) = -3.48$, $p = .03$, but not for the short interval group $t(3) = .28$, $p = .80$.

Thus, these preliminary results suggest that team performance acquired in this task declines after eight weeks. However, another possibility is that the decline was specific to individuals' knowledge of the task and not team level skills such as coordination. This distinction is being examined however, in a current study being run in the lab.

The implication of this finding for team sports such as football is that team coordination skills acquired in training, as well as individual task skills, are likely to decline in the off-season, leading to a decrement in overall team performance. Possible methods to combat such skill degradation include mental rehearsal of coordination (e.g. of key plays) during the off-season (Wright, 1973; Farr, 1986). Rehearsal of coordination can also come in the form of playing video games over the internet that require players to coordinate and communicate so that coordination skills can be refreshed on an ongoing basis. Increasing the initial amount of training, also known as overlearning (Wisher, Sabol & Ellis, 1999), and the use of better and more detailed feedback through after-action reviews to help the player understand what they are doing incorrectly and to correct those errors may also prove useful.

Team situation awareness. Can we assess team situation awareness on a football team and to what degree does coordination-focused training improve team SA? Situation awareness at the individual level involves an individual's assessment of the cues in the dynamic environment, the meaningful interpretation of these cues including projection of future states of the situation, and execution of the appropriate action (Endsley, 1995). At the team level some have opined (Endsley & Jones, 1997) that team situation awareness is the extent to which team members each have the situation awareness that they need to do their job. According to this perspective, if the AVO, PLO, and DEMPC each have adequate situation awareness, then team situation awareness should also be adequate. Initially, for our UAV study, we measured team situation awareness along these lines. Individuals were queried about aspects of the ongoing and forthcoming scenario. The accuracy of the individual responses and their similarity to one another was measured. Team situation awareness measured in this way was predictive of team performance, but we suspect for the wrong reason (Cooke et al., 2004). In particular, individuals seemed to learn how to answer repeated queries or even the aspects of the task that might be queried. For example, with increasing experience, team members learned in response to "how many targets will you get?" that there are nine targets in these scenarios and with experience it is very likely that "we will get them all." Though we were measuring the participants' awareness of the experimental situation, we were not satisfied that this was getting at the core of team situation awareness.

One specific problem with this view of team situation awareness is that it stresses the thoughts that individuals have, rather than the interactions that teams display. The former is more of a collective perspective, and the latter holistic. We now view team situation awareness as the coordinated assessment and action of a team in response to a changing environment. We have developed a Coordinated Awareness of Situations by Teams (CAST) framework to provide theoretical backing to this concept of team situation awareness (Gorman, Cooke, & Winner, submitted). It gives a central role to coordination rather than what goes on inside the heads of individuals. It also prescribes a measurement approach that focuses on team interaction and coordination, rather than response to single queries.

Most importantly for this paper, the two views of team situation awareness have different implications for improving team situation awareness. Under the collective view of team situation awareness one might focus training resources on the individual, instructing them on how to attend to and interpret environmental cues. Or perhaps some technology could be devised to aid each individual in situation assessment. Alternatively, the CAST view suggests that training and design should instead focus on improving team interaction and coordination—how does the right information get to the right person at the right time. We suggested previously that team practice at some internet video games might improve team interaction. In addition, we have speculated that a human expert or intelligent agent could be inserted into a team (at training, warm-up, for instance) and serve the role of forcing the pattern of coordination back into the pattern most effective for optimal performance. So in football, instead of focusing on improving the situation assessment of individual players, one might focus on improving team coordination through additional off-season practice (e.g., internet video games) and coordination experts which might possibly take the form of seasoned veterans serving as examples of how to coordinate during practice and pre-game warm-ups.

Team communication. Can communication patterns be used as a barometer to measure and quantify coordination in football teams and can the measurement occur in real-time? Team communication is central in command-and-control tasks. Communication is also a critical mode by which coordination occurs, though it is possible to communicate in a variety of different ways (e.g., oral, gestural, computer messaging) and it is possible to coordinate implicitly without communication. In our UAV experiments we have found that communication patterns (both the content of what is said and the flow from person to person) are associated with team performance (Kiekel, Cooke, Foltz & Shope, 2001; Kiekel, Gorman & Cooke, 2004). Effective teams are generally more consistent in their communication patterns than ineffective teams. Other factors such as geographic distribution, experience, and workload can also influence communication patterns. Why are we interested in communication? It is not so much to train teams in ways to better communicate, thereby enhancing coordination, though that would be one approach. Rather we view communication as a readily available source of information on team cognition. Again, because we view team cognition as an emergent property of teams and believe that cognitive processing at the team level takes place in the interactions among team members, we see communication as a direct reflection of the team cognition. Like team cognition, the communication-based measures should predict team performance, but should also provide additional diagnostic information. After having identified patterns associated with ineffective and effective teams, we are now exploring finer distinctions among teams in regard to team knowledge and team situation awareness that can be ascertained through analysis of communication data. We are also identifying ways to automate this process with the ultimate goal of embedded and on-line communication analysis leading to a diagnosis of a team's cognitive state.

For our UAV teams, the goal is to use communication data as a barometer for team coordination and more specifically, to provide specific information about the state of team cognition. How could this be used in football? Communication patterns could similarly serve as a source of diagnostic information in an "after action" or "post-game" review. While instances of verbal communication between players and coaching staff may not be as numerous and/or complex as those seen in the UAV-STE, an even more interesting idea is to monitor and analyze communication patterns during the course of the game in order to flag critical or problematic interactions that may signal impending break down in coordination.

Research Questions

The findings in the previous section pertain to a military command-and-control task. However, given the similarities highlighted between military command-and-control and American football in terms of team tasks and cognitive team tasks, the findings in one domain suggest research questions in the other. Table 5 lists some of the research questions raised in the previous section in regard to team cognition of American football.

Table 5. Research questions associated with team cognition in football

- Are team process measures able to predict performance in football and can process measures be developed for sports teams such that they are diagnostic of team weaknesses and strengths and therefore instrumental in improving team effectiveness?
- Can holistic measures of team performance and cognition beyond the outcome-level score be identified and would such measures be more informative in regard to enhancing team performance compared to aggregate measures?
- What is the performance benefit obtained by training as a whole team versus training as sub-teams or individuals?
- What is the role of team member familiarity and how much does turn-over or player trading impact team performance?
- Can team coordination skill be improved or the acquisition hastened by practice on transfer tasks (e.g., coordination demanding video games)?
- To what degree does a lag without practice (e.g., off season) impact the team cognition and coordination of the team?
- Can we assess team situation awareness on a football team and to what degree does coordination-focused training improve team SA?
- Can communication patterns be used as a barometer to measure and quantify coordination in football teams and can the measurement occur in real-time?

Conclusions

The analogy between military command-and-control and American football is a highly useful tool for which to map the exploration of team cognition in team sports. We have shown that the similarities between the two areas are more than superficial, extending to the deeper concepts of training, team performance, communication, coordination, and team cognition. The similarities, in essence, provide a starting point for future work in the sport sciences. Care must be exercised, however, when applying the analogy as the U.S. military is currently undergoing a shift from the traditionally centralized, to "network-centric," decentralized command and control schemes (Gorman et. al., 2005). The migration towards a decentralized command structure is less like American football, and more similar to soccer where there is constant movement, individuals are highly mobile and dispersed, and personnel must act in both defensive and offensive roles simultaneously (Cassman & Lai, 2003). Therefore, care must be taken by sport researchers when extending and interpreting their results in the context of different team sports.

Given the similarities between military command-and-control and team sports, the findings from the CERTT UAV-STE are highly applicable to the team sport of football. In the same manner that UAV teams benefit from the insights provided by our research, so may football teams benefit. We feel that the study of team cognition in football teams through the use of process measures and holistic measures will show great promise in improving team performance. In addition, the exploration of team familiarity, training of coordination skill (e.g., through internet video gaming), retention of coordination skill, situation awareness and communication behaviors will also be successful in improving the performance of football teams. However, sport researchers must be aware that the methods and metrics described in this paper follow a specific theoretical view of team cognition and that other views exist. Related approaches to the study of team cognition such as dynamical systems also exist, and should be taken into account (Cooke, Salas, Cannon-Bowers & Stout, 2000). However a broad view of team cognition may aid in the development of metrics and training techniques that will serve to improve performance in football teams.

Future directions for sport researchers include directly exploring the research questions pertaining to team familiarity discussed in the sections above. These include the testing of the benefits of different training techniques (e.g., whole team vs. sub-team training and coordination focused training to improve situation awareness), the effects of team member familiarity and retention intervals on coordination, and the coordination benefits of transfer tasks such as internet video games. Other directions involve the development and empirical validation of team process measures to identify strengths and weaknesses to improve performance, as well as holistic measures that will further aid in the enhancement of team performance compared to aggregative measures. Lastly, the examination of patterns in communication may lead to promising advances in the measurement and quantification of coordination that will aid team performance.

The research and findings gathered from the CERTT UAV-STE hold far reaching values in extending what is known about team cognition in the military to the sport of American football. The similarities between the sport and many aspects of military operations coupled with the desire of the sport sciences to investigate team performance and process warrants the melding of the two fields. The various techniques and measures from the UAV-STE serve as a starting point for which the sport sciences may adapt for use in team sports such as football. With the many similarities between the two areas, we believe that the measurement of team cognition in football teams using similar techniques will also improve overall performance by enhancement of coordination and communication behaviors, as well as aid in the development of training regimens.

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