Multi-Modal Measurement Approach to Team Cohesion

Camilla C. Knott, Alexandra Geyer, Jason Sidman, and Emily Wiese

Aptima, Inc., 12 Gill Street, Suite 1400, Woburn, MA 01801, USA
{ccnott,ageyer,sidman,wiese}@aptima.com

Abstract. Team performance is a function, in part, of team cohesion: a dynamic process that is reflected in the tendency of a group to remain united in the pursuit of its goals and objectives (Carron 1982). We propose that a multi-modal measurement approach that integrates data from a variety of sources is critical to forming a comprehensive understanding of the relationship between team cohesion and performance, and can afford measurement of the hard-to-assess social component of team cohesion. Moreover, the use of a multi-modal measurement technique can afford flexibility in measuring across a variety of environments and selecting the most relevant measurement tools to minimize the technical footprint required for the assessment of teams and individuals in an operational environment.

Keywords: Team cohesion, multi-modal measurement, team performance.

1 Introduction

In military environments, where consequences of poor team performance can be catastrophic, it is critical for commanders and leaders to be able to quickly assess team performance to ensure safety and mission success. That performance is a function, in part, of **team cohesion**: a dynamic process that is reflected in the tendency of a group to remain united in the pursuit of its goals and objectives (Carron 1982). Hence, team cohesion has been related to team performance and its associated components but not reliably (e.g., Bowers, Urban, & Morgan, 1992; also see Salas, Bowers, & Canon-Bowers, 1995 for a review). Meta-analyses of the team cohesion and performance literature points to a generally positive relationship between team cohesion and performance, but one that is complex and highly variable across tasks (Evans & Dion, 1991; Gully, Devine, & Whitney, 1995; Oliver, Harman, Hoover, Hayes & Pandhi, 1999; Salo & Siebold, 2005).

Part of the problem lies in the complexity of team cohesion itself. Team cohesion is commonly broken down into task and social cohesion components. Task cohesion is a dimension of team cohesion that reflects team's ability to work together as a group to complete tasks required to support a common goal, and social cohesion, reflects affinity among team members. However, even these components are still complex and dynamic. Another part of the problem may be attributable to the methods used to measure these components of team cohesion. Though conceptually very different – Task cohesion should reflect performance and cognitive processing and Social cohesion should reflect affective and social processes – both components

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are commonly measured using self-report questionnaires or surveys. Likewise, in some cases even performance variables (which vary across studies) have been measured through questionnaires or surveys (either self-report or observer-based). However, surveys can only offer a limited viewpoint about team cohesion and performance.

We argue that a single measurement method will be inadequate for an accurate and comprehensive assessment of the relationship between team cohesion and performance. In this paper, we will focus primarily on essential task work components and teamwork functions that must be present for effective performance (Salas, Dickinson, Converse & Tannenbaum, 1992), specifically, back-up behaviors, coordination, feedback, and, communication (Dickinson & McIntyre, 1997) as well as workload, which has been shown to reliably affect performance and may, likewise, have an impact on team cohesion. We propose that a multi-modal measurement approach integrating data from a variety of sources is not only critical for developing a comprehensive and accurate assessment of team cohesion, but it can also afford a potentially effective method for measuring the hard-to-assess social component of team cohesion. Moreover, the use of a multi-modal measurement technique can provide flexibility in measurement methods across a variety of environments and in selection of the most relevant measurement tools to minimize the technical footprint required for the assessment of teams and individuals in an operational environment.

2 Use Case

To frame the measurement problem, we have developed a scenario anti-piracy training scenario in which a Combined Task Force (CTF) is monitoring international waters for pirate activity. The CTF is composed of 2 US Navy (USN) ships, a Royal Navy (RN) ship, and a French Navy ship. Each ship has a selection of airborne assets (unmanned aerial vehicles (UAVs) and helicopters) it can employ to assist in the mission. Data link compatibility issues between the USN, RN, and French ships preclude real-time data exchange between the CTF assets, with the exception of UHF line-of-sight voice communications. Because the CTF is composed of ships from a variety of countries, each ship must be considered with multi-level security issues and must therefore monitor the content of their communications to others. The CTF's mission is to prevent acts of piracy against any commercial or private vessel operating in international waters. To that end, the rules of engagement (ROEs) state that CTF assets should be employed to deter and/or prevent pirate intercepts by show of force, primarily by positioning assets. Weapons engagement is permitted only in self-defense or to negate a hostile attack. The team of trainees has been training together for a period of two weeks.

In this simplified training scenario, the trainees are the commanders of each ship. They are responsible for communicating with the other CTF members, coordinating activities with the other CTF members, and directing their own assets in appropriate intelligence, surveillance, reconnaissance, and targeting activities. The training objectives for this scenario include multiple aspects of Social and Task cohesion:

- Support inter-team collaboration/communication while adhering to multi-level security considerations.
- Manage the team members' task/workload.
- Identify and track all pirate vessels.
- Intercept/suppress pirate attacks while adhering to stated rules of engagement.
- Achieve mission objectives within fuel, weapons, etc. allotment.

The trainee performance in each of these areas is being assessed throughout the exercise using various measure types. Observer-based assessments are captured via an instructor, system-based measures are captured directly from the simulation data stream, trainees provide self-assessments during the scenario execution, and neurophysiological/physiological data is collected using various measurement tools which could include eye tracker, heart rate monitor, electroencephalography (EEG), respiration monitors, etc., depending on the availability and practicality. Table 1 below shows a mapping of each performance measurement source to each training objective.

Table 1. Summary of performance measurement source relevant for each training objective

Training Objectives	System-based	Observer-based	Self-Report	Neuro/physiological
Inter-team collaboration/communication	x	x	x	x
Task/Workload Management	x	x	x	x
Coordinate target tracking and identification	x	x		x
Coordinate intercept/suppress attacks	x	x		
Achieve mission objectives within fuel, weapons, etc. allotment	x	x	x	

As the training scenario unfolds, an unidentified track is detected and begins to close in on a known commercial vessel, the MV Sirius Star. The CTF must communicate with each other to determine which ship's assets should be used to investigate the track. Using their limited communication mechanisms (chat messages and voice communication), the CTF must determine which assets are in the vicinity of the track and have the resources (e.g., fuel, weapons, etc.) available to investigate the track. It is determined that a helicopter from a French Navy ship is the best choice to investigate the track, even though it is low on fuel and available weapons. From an assessment perspective, the inter-team collaboration/communication training objective is most relevant in this situation. The quantity and quality of communication can

becaptured using system-based measurement. Number of chat messages and voice communications that occur between the CTF members can be used to analyze communication quantity. Observer-based measurements add context to those automated measures by assessing the CTF's ability to coordinate effectively given the communication delays and multi-level security issues imposed. Quality of communication and coordination may be assessed by querying the trainees directly, through self-report measures. Likewise, analysis of key words or even tone can also provide some information about social cohesion. In addition, coordination could be assessed by querying the trainees directly, through self-report measures as well as by collecting neurophysiological and physiological data.

Task/workload management is another objective that would benefit from neurophysiological and physiological assessment because system-based, observer-based, and self-report measures often lack the sensitivity to detect increases in workload prior to the point at which it affects performance. Ideally, increases in workload should be detected before it can lead to performance degradations to allow interventions to be introduced at the right time to mitigate those performance degradations. Neurophysiological and physiological measures of workload allow for such early detection. Moreover, on-line measures of workload circumvent the problem of when to administer self-report questionnaires.

While investigating the unidentified track, the French helicopter determines that the track is a pirate vessel heading towards the MV Sirius Star. During its investigation, the helicopter comes under attack and defends itself. However, given the French helicopter's fuel and weapons status, a second helicopter must be deployed to defend the Sirius Star. The CTF attempts to coordinate this activity, but the communication delays, combined with the added stress of dealing with an armed pirate vessel, results in confusion. The result is that two replacement helicopters are deployed: one from the French ship and one from the US ship. They arrive at the pirate vessel before it reaches the Sirius Star, thereby preventing a pirate attack. Again, the quantity and quality of communications between the CTF ships can be captured via automated performance measures. In addition, the ability of the CTF to manage their assets' fuel and weapons load and determine the appropriate assets to deploy can be assessed automatically through system-based measures. Finally, the helicopters' ability to effectively engage the pirate vessel can also be assessed automatically (system-based) through timeliness and accuracy measures. Observer-based measurements can capture additional detail about the coordination issues experienced by the team, high-level assessments about the tactics employed to intercept and suppress the pirate attack, and the ability of the CTF to effectively manage its assets to achieve mission objectives. Self-report measures can be used to obtain an understanding of the trainee's view of workload during this situation and the coordination amongst the CTF members. As in the previous situation, for on-line measurement of workload, neurophysiological and physiological data can be collected. Additionally, eye tracking data can be used to provide more detailed information about the CTF communication by analyzing whether or not the ship commanders are "seeing" relevant chat messages and scan patterns can be analyzed to assess coordination of tracking activities. Throughout the exercise, neurophysiological and physiological measures can be collected to assess

individual preferences/likeness (e.g., Doherty, et al., 2006) as well as frustrations (e.g., Abler, et al., 2005) without requiring explicit acknowledgement from team members. While possibly controversial, these measures could provide some insight into the social and affective components of team cohesion.

After the training exercise, the data collected can be used to gain a comprehensive understanding of team performance - not one type of data can provide a complete and accurate picture of team performance or cohesion. The system-based data frequently lack the context required for complete interpretation; observer-data do not capture detailed data (e.g., timing and accuracy); self-report data provide only the perspective of the trainees and could be subject to trainee biases; and similar to system-based data, neurophysiological/physiological data require additional context to put the fine grained individual analyses in the context of a team. By viewing these data in combination with one another, however, the benefits of each measurement source are realized and the costs associated with each can be minimized. Most importantly, each measurement type can assist in the interpretation of the team's performance at specific points throughout the exercise. For example, the lack of communication between CTF members (as assessed using system-based measures) can help make sense of observer and self-report ratings of poor performance that occurred shortly thereafter. Just like completing a puzzle, obtaining an objective view of team member workload during that time period through neurophysiological/physiological sources can provide the final piece in completing the picture of team performance (what went right/wrong and why) during that time period.

3 Future Directions

The value of the multi-modal approach to measurement we propose is the ability to construct a more comprehensive assessment of team cohesion, and indeed it requires a considerable effort to determine which constructs, measures, and combinations of measures should contribute to that assessment. We believe that there are additional questions to explore based on that foundational effort. In particular, we foresee a need for the ability to deduce meaningful assessments in impoverished research and operational conditions when the full set of measures is simply not available. While the use case described above assumes a full array of measurement equipment capabilities, in reality, and particularly as we progress to more operational settings rather than research ones, such an array is unlikely to be available. Following a program to develop a comprehensive multi-modal approach to team measurement, we believe an equally valuable exercise for this reason would be the decomposition of team cohesion measures to determine the minimum measures, or combinations of measures, required to assess team cohesion constructs.

A critical relationship to establish among the measures would be redundancies; different measures or combinations of measures that lead to the same conclusions about team cohesion. Redundancies can serve multiple purposes. First, they can be used to validate measures. For example, certain self-report measures about performance could be validated by physiological measures that detect the indicators of that same construct. Second, they could be used to identify "surrogates" or "proxies" when certain measures are unavailable. The key challenge when identifying

surrogates and proxies is distinguishing between measures that complement each other and measures that are redundant. Measures that complement each other produce a more comprehensive picture of a construct by addressing it from multiple angles (as described above). Measures that are redundant address the same part of the construct; they are interchangeable.

Mistaking complementarity for redundancy would produce major errors in assessing team cohesion. For example, knowing that people can feel uncomfortable discussing other team member's performance through self-report should cue researchers to explore the use of other potential sources of data that can provide complementary information. However, when measuring a construct that can be assessed in multiple ways, such as communication (see Table 1 above), one might not need physiological measures given other data sources that can provide redundant information that are less intrusive and cumbersome to collect. Or, it may be that three sources of data are more than what is needed to assess communication, and adequate assessments can be made based on only observer and system-based measures instead, thereby relieving participants of the burden of responding to questions.

As such, the challenge for multi-modal assessment is not simply to be all-encompassing, but to derive "just enough" assessment to make useful conclusions about team cohesion. Such a research program would involve not only building up the comprehensive set of measures and combinations of measures for assessing team cohesion, but pruning the measures down to the fewest that will yield the greatest assessment value.

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