Modeling Processes of Enculturation in Team Training

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INTRODUCTION

Both military and civilian work is increasingly organized around small, dynamic teams rather than large bureaucratic frameworks. Such teams combine individuals with highly specific skill sets and extensive training to solve complex, non-standard problems, often under extreme pressure. Importantly, these teams are not typically composed of interchangeable members but are formed and trained *as expert teams* to function semi-autonomously. To accomplish mission objectives in the face of complex challenges, the United States military needs to develop teams that consistently exhibit high levels of taskwork and teamwork skills. Implementing principles of team training and maintaining team efficacy are critical in the armed forces, where teams are often widely dispersed and consequences for underperformance can be severe, though many civilian teams—such as hospital trauma teams or flight crews—face similar challenges. Establishing and maintaining high levels of team performance in these contexts requires the creation of practical and effective team development interventions, including team training, as well as systems for ongoing assessment of team function.

We argue that one critical component of training, monitoring, and maintaining high-functioning teams is the ability to *model team performance*.

Communication, cognition, coordination, collaboration, and coherence in teams are critical for predicting team performance. To improve our ability to enhance and maintain team performance, we need to develop a better understanding of these components. Specifically, we need to understand how the components of team dynamics influence team performance in complex problem-solving situations (Fiore et al., 2010; O'Neil, Chuang, & Baker, 2010; Paris, Salas, & Cannon-Bowers, 2000; Salas, Cooke, & Rosen, 2008). However, current tools and methods lack the capacity to assess these components of teamwork, to the dismay of stakeholders. This is true in the armed forces, industry, government, and civic organizations, and it has motivated national and international assessments of teamwork and collaborative problem solving as a 21st-century skill.

In what follows, we outline a program of research on the science of teamwork, based on a theoretical framework for analyzing the decision-making processes and effectiveness of teams. Drawing on our prior work developing critical constructs and mechanisms to measure team performance using multilevel network analysis, we argue that one critical advance in the science of teamwork is using these tools to build predictive models that consider teams as complex systems. To model team performance effectively, we need to understand teams as multilevel networks comprised of three main components: (a) the *social network* that structures team interactions; (b) the *conceptual networks* that guide the actions of individuals on the team; and (c) the *communication network* by which that action is accomplished. A critical step in creating a system to monitor and support team performance, then, is the development of multilevel network analysis techniques for assessing teamwork during complex problem solving.

HIGH-PERFORMANCE TEAMS IN MILITARY AND CIVILIAN WORK

Two factors have made analysis of the performance dynamics of small teams critically important to current and future U.S. military endeavors. First, the nature of armed conflict has shifted in the last 50 years from large-scale machine warfare organized around regiments of conventional forces, in which combat and intelligence gathering present relatively standard problems (*materiel domain*), to small-scale asymmetric warfare organized around small teams of special forces, in which counter-insurgency and other elements of unconventional combat present non-standard, highly complex problems (*human domain*). Second, budget cuts, the current geopolitical landscape, and changes in military priorities have led to reorganization of operations around small, dynamic teams engaged in counter-terrorism, cyberwarfare, drone operations, foreign internal defense, peacekeeping, and humanitarian aid (Knoke, 2013; Odierno, Amos, & McRaven, 2013; Ressler, 2006; Stewart, 2013; Thomas & Dougherty, 2013; Tucker & Lamb, 2007; Turnley, 2011).

Today's small military teams, such as four-member Navy Special Warfare squads or twelve-member Army Operational Detatchment-A teams (Feickert, 2010; McRaven, 1996), combine individuals with highly specific skill sets and extensive training to solve complex, non-standard problems under extreme pressure. Importantly, teams such as these are not composed of interchangeable soldiers embedded in rigid bureaucratic frameworks—as in the squads of conventional military organization. Rather, these teams are formed and trained *as expert teams* to function semi-autonomously (Thomas & Dougherty, 2013).

Of course, this approach is not limited to military organizations. Civilian work, too, is increasingly structured around small, high-performance teams (Buchholz, Roth, & Hess, 1987; Katzenbach, 1993; Lehman & DuFrene, 2010). Hospital trauma teams, emergency response teams, flight crews, design teams, and research teams, among others, are core organizational units in many contexts. While civilian teams may not face the same pressures as military teams, performance is often equally dependent on the extent to which the members function *as a team*.

TEAMS AS MULTILEVEL NETWORKS

A central challenge in understanding team performance is to integrate understanding of *how* a team collaborates with information about *what* they are collaborating on. For example, high-functioning teams "communicate clearly", but in order to assess whether a team is performing well, we need to know more than just *that* they are communicating well. We also need to know that they are communicating effectively about *particular aspects of the specific problem* they are working on, and that their approach to the problem is *appropriate for the specific circumstances* in which they are working.

That is, to measure team performance, we need a technique that can measure critical aspects of team performance, including those articulated in the PISA 2015 Collaborative Problem Solving Framework (Greiff, 2012; Organization for Economic Co-operation and Development, 2013) and various frameworks of 21^{st}-century skills (Griffin, 2012; Koenig, 2011; Kozma, 2009; Trilling & Fadel, 2012). These aspects include (a) how well a team collaborates in terms of social and cognitive alignment; (b) how well a team functions in a problem-solving context, including alignment with organizational factors and team outcomes; (c) how well each individual contributes to creating cognitive, social, and organizational alignment and team outcomes; and (d) the relationships among and integration of these factors.

Put another way, we need to understand, simultaneously, the social network of the team, the conceptual networks that guide the actions of the individuals on the team, and the communication network by which those actions are accomplished. Thus, we argue that a critical step in creating a system to monitor and support team performance is the development of network analysis techniques for assessing teamwork during complex problem solving. Specifically, we suggest that the science of teamwork needs research into methods for constructing *multilevel network models* of high-volume *discourse* data (Frank, 1998, 2011; Penuel, Riel, Krause, & Frank, 2009; Wang, Robins, Pattison, & Lazega, 2013). By "discourse", we refer to spoken interactions, but also more broadly to any actions or interactions of team members and others in the problem-solving context (Gee, 1999). Our goal is to develop network analysis techniques that *account simultaneously for the cognitive, social, and communications networks* that comprise team activity and within which a team functions.

NETWORK MODELS OF TEAMWORK

Our approach is to start with *epistemic network analysis* (ENA), a technique that we have developed to analyze records of individual and team problem solving (Shaffer, 2017; Shaffer, Collier, & Ruis, 2016; Shaffer & Ruis, 2017). A fundamental claim in this work is that *it is essential to consider the semantic and conceptual content of what gets said during social interactions in addition to tracing the patterns of who talks to whom in a social network*. Social network models devoid of content are doomed to fail because team interactions are never "content neutral" (Maroulis & Gomez, 2008). It is impossible to evaluate the quality of team interactions by examining who is talking to whom without knowing what they are talking about. This work is thus unique in combining deep analyses of both content and social network processes.

Specifically, ENA models team activity by identifying categories of action, communication, cognition, and other relevant features and characterizing them with appropriate coding schemes into smaller sets of domain-relevant nodes. The weights of the connections among network nodes (i.e., the association structure of key elements in the domain) are then computed and visualized. Critically, ENA models team actions and interactions in such a way that it is possible to *extract information about each team member's contributions to team performance*. ENA uses statistical and visualization techniques to enable comparison of the salient properties of different networks, including networks generated by different teams or by teams at different points in time, teams in different spatial locations, or teams engaged in different activities. These salient properties are modeled not just in terms of the general structure of the networks, as is often revealed by other network analysis techniques (changes in density or betweenness centrality, for example), but ENA also extracts properties relevant to the actual content of the network.

In other words, ENA can analyze what teams are doing, how they are thinking about what they are doing, what role individuals are playing in team performance, and how teams compare to one another in the context of real problem solving. Using ENA, we have been able to identify critical patterns of interaction in expert and novice teams, as well as successful and unsuccessful teams and individuals (Andrist, Collier, Gleicher, Mutlu, & Shaffer, 2015; Arastoopour, Shaffer, Swiecki, Ruis, & Chesler, 2016; Chesler et al., 2015; Quardokus Fisher, Hirshfield, Siebert-Evenstone, Arastoopour, & Koretsky, 2016; Shaffer, 2017; Sullivan et al., in press).

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

A critical next step in developing a science of teamwork is to extend ENA from modeling team interactions in a single modality (communication among team members) to account for the different layers of activity that influence a team's work. Factors we believe can and should be modeled include: (a) cognitive and psychological factors of team members and of the problem being solved; (b) modes of communication, including synchronous and asynchronous interactions; (c) the organization and structure of the team, as well as the influence of role and hierarchy within the team; (d) social relationships and interactions among team members; and (e) organizational and other external influences on the team's activities.

To accomplish this, we hypothesize that we will need to make three significant advances in the network science of teams. First, we will need to extend our existing natural language processing coding algorithms for text dialog. That is, we will need to develop machine learning and other techniques to quickly and reliably develop, calibrate, and implement coding schemes for a wide array of discourse data, including both text and spoken dialogue. Building on existing computational linguistics technologies, such as Coh-Metrix (Graesser et al., 2014; Graesser, McNamara, & Kulikowich, 2011) and LIWC (Pennebaker, Booth, & Francis, 2007), we will augment the existing natural language processing capabilities of ENA to develop a version of the tool that can code diverse data streams for multilevel analyses.

Second, we will need to examine how we can most appropriately model the social, cognitive, and communicative processes by which connections in those networks are constructed. That is, we will need to develop a more robust scientific understanding of how to identify and model the links between ideas and between people that individuals make during team problem solving (Dillenbourg, 1999).

Third, we will need to develop multilevel ENA (mENA) network models. We conceptualize these mENA models as the network science analog of hierarchical linear modeling, where the effects of each layer of the model are analyzed, but critically, those analyses account for the interactions between the different layers of the model. For example, prior work has looked at integrating hierarchical linear modeling and social network analysis to examine how social factors influence students' school achievement (Frank, 1998). Similarly, mENA would be able to model the network of cognitive relations for each member of the team, but also account for the nesting of these individual cognitive models in the team setting. mENA would also be able to model the impact of individuals' cognitive and affective states on social interactions and relations among team members.

As part of this work, we will also explore ways to integrate mENA into systems for team training and development, such as training modules developed with GIFT, the Generalized Intelligent Framework for Tutoring (Sottilare, Brawner, Goldberg, & Holden, 2012). For example, mENA could be used to model expert teamwork and behavior based on observations gathered across an array of high-performing teams. In these instances, aggregating relevant mENA features across problem-solving scenarios can produce rich network models that will organize the actions, communications, and contextualized decision points that need to be explicitly defined within GIFT's domain module. Designating relationships between information, communication, and action across roles within a team provides rich inputs for structuring and configuring an associated Domain Knowledge File that manages assessment and pedagogical requests during a GIFT-managed scenario event. Through these techniques, one can determine whether high-performing teams execute tasks in similar ways (i.e., they have similar mENA networks), which could warrant more general claims about team performance, or whether there are unique differences across different teams or different teamwork scenarios. The same techniques can be applied to novice and low-performing teams to identify common challenges.

Following the development of an mENA expert model, mENA could be used to assess specific team activities in comparison with the expert model. This will enable functional evaluations of teams that are in training against representations of ideal behavior; as discussed above, mENA is particularly well suited to make such comparisons, both statistically and visually. Differences in mENA models that reflect critical cognitive, communicative, or enactive behaviors could thus assist in establishing granular assessment methods that can inform coaching decisions. With respect to GIFT, this involves making strategy selections that associate with directed feedback delivered in real-time, scenario adaptations that focus on adjustments in difficulty and complexity, and post-event scenario selections to target specified skill sets that require additional training or practice.

Ultimately, our goal is to produce a system for training and maintaining high-performance teams that (a) enables easy creation of training modules that (b) provide teams with realistic simulations of problem-solving scenarios and (c) generate mENA models that give team members and coaches actionable feedback.

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