Team Knowledge:
Origin, Emergence and Measurement

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ONR Command Decision Making
6.1-6.2 Program Review

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Objective

• Teams fail to share all relevant information for decision making (DM) => Sub-optimal decisions

• Research program is designed to develop:
  – Generalizable metrics to track acquisition, knowledge sharing, & emergence of team knowledge
  – Metrics diagnostic for team learning and info sharing
  – Research-based instructional principles, tools, & aids to improve team learning, knowledge sharing, & DM

• Theory driven, research based, application relevant
Technical Approach

Scientific Foundation
- Macrocognition (MC)
  - Fiore et al. (2010)
- Multilevel Theory (MLT)
  - Kozlowski & Klein (2000)
Embedded Training Design
  - Kozlowski et al. (2001)

Objectives/Products
- Measurement Model
  - Generalizable Metrics
- Team Diagnostics
- Computer Simulation
  - Validation of Metrics
  - Intervention Points
Research (CRONUS)
  - Design Principles:
  - Simulation Design
  - Embedded Training
  - Autonomous Entities
Team Learning & Knowledge Formation are Emergent – *Bottom up*

“A phenomenon is emergent when it originates in the cognition, affect, behaviors, or other characteristics of individuals, is amplified by their interactions, and manifests as a higher-level, collective phenomenon” (Kozlowski & Klein, 2000, p. 55).

The Emergence of Collective Behavior: BOIDS (Reynolds, 1986)

Computational Agent Rules:

1. Separation: Avoid collisions
2. Cohesion: Move toward average position of neighbor boids
3. Alignment: Fly in average direction of flock
4. View: Move sideways from any boid that is blocking view (Flake, “V” formation)

[Dynamic Illustration]
Emergence, Team Knowledge, & BOIDS

• The point of the BOIDS illustration is to show how *complex collective behavior emerges from the dynamic interaction of individuals*

• Applied to team learning processes, challenge is to capture dynamics of emergence across levels
  – Individuals, dyads, team ... over time

• Metrics - Team Knowledge Typology (TKT)
  – Generalizable metrics, team diagnostics
  – Captures knowledge emergence dynamically
  – Can drive embedded, tailored interventions
## Team Knowledge Typology (TKT)

<table>
<thead>
<tr>
<th>TKT type:</th>
<th>Knowledge Metrics</th>
<th>Brief Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Individual Knowledge</td>
<td>The proportion of the total pool of possible knowledge possessed by each team member separately</td>
<td>![Diagram 1] (The amount of knowledge individuals i, j, and k each possess within the problem space)</td>
</tr>
<tr>
<td>Type 2</td>
<td>Knowledge Pool</td>
<td>The proportion of the total pool of possible knowledge possessed by the team collectively</td>
<td>![Diagram 2] (The proportion of the total knowledge among individual team members not accounting for overlap)</td>
</tr>
<tr>
<td>Type 3 (internalized)</td>
<td>Knowledge Configuration</td>
<td>The proportion of the total pool shared in common by team members and the pattern of unique knowledge held across individuals</td>
<td>![Diagram 3] (Understanding what is common and what is unique knowledge among team members)</td>
</tr>
<tr>
<td>Type 4 (externalized)</td>
<td>Knowledge Acquisition</td>
<td>The rate of knowledge compiled by each team member over time</td>
<td>![Diagram 4] (How fast an individual learns (expands a circle in above venn diagrams))</td>
</tr>
<tr>
<td>Type 5</td>
<td>Knowledge Acquisition</td>
<td>Within team variance in the rates of knowledge acquisition</td>
<td>![Diagram 5] (Different rates of knowledge acquisition can affect a team’s learning)</td>
</tr>
<tr>
<td>Type 6</td>
<td>Knowledge Variability</td>
<td>The rates of growth for Knowledge Pool and Knowledge Configuration</td>
<td>![Diagram 6] (Changes over time across teams)</td>
</tr>
<tr>
<td>Type 7</td>
<td>Knowledge Emergence</td>
<td>Comparing growth rates for Knowledge Variability, Knowledge Pool, and Knowledge Configuration</td>
<td>![Diagram 7] (Comparing growth rates for knowledge across teams)</td>
</tr>
<tr>
<td>Type 8</td>
<td>Knowledge Emergence</td>
<td>To be defined</td>
<td>![Diagram 8] (To be defined)</td>
</tr>
</tbody>
</table>
Validating the TKT

• TKT is a conceptual measurement model for capturing emergence of team learning

• Validating the TKT necessitates wide variation on learning & knowledge sharing => large $n$

• A simulation process model (based on MC, MLT) links to the TKT measurement model

• Developed & implemented a computer simulation to validate the measurement model

• Computational agents, similar to the BOIDS
Human-Task Simulation: CRONUS

[Designed, Developed, Pilot Data]

• Design links to theoretical foundation (MC & MLT)
  – Iterative knowledge acquisition, individual to team knowledge emergence => DM effectiveness

• Task simulation also linked to
  – Simulation process model
  – TKT Metrics

• Distinct roles, assets, must combine knowledge

• Designed, software developed, pilot data
  – Describe task, illustrate TKT metrics, highlight experimental research plan
CRONUS Architecture

**Summary:** Group planning & decision-making task that requires members to acquire knowledge & integrate distributed expertise into a single problem solution

- **Performance:** Group decision based on *individual* learning & sharing and *team* integration of distributed knowledge
  - Optimal solutions require the relevant knowledge of all members to be leveraged
  - Deviations from optimality occur when relevant knowledge is not incorporated into the team decision

- **Design:** Multiple, self-contained scenarios requiring a series of unique decisions within the context of a larger mission
  - Allows longitudinal examination of individual and team knowledge building processes, knowledge emergence, & products as defined by the TKT, as well as performance trajectories across the mission space
Purpose of CRONUS

• When natural disasters such as earthquakes, tsunamis, and hurricanes strike, teams of specialists from the Navy and similar agencies are often tasked as “first responders” to spearhead crisis relief efforts.

• In order to be effective, first response units must quickly gather information about a situation and make rapid, well-informed decisions—often with serious consequences.

• CRONUS was designed to simulate a crisis relief scenario in order to study and improve how teams from Naval and other first responder agencies learn about and engage with their environment in order to make effective and efficient decisions.
Introduction to CRONUS

• In CRONUS, you will be asked to complete a series of missions in a team consisting of three members

• You and each member of your team fills a specific role that contributes unique assets and expertise needed to complete the missions

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<tr>
<th>Transport</th>
<th>Intel</th>
<th>Engineer</th>
</tr>
</thead>
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<tr>
<td><strong>Expertise</strong></td>
<td>Avoiding/dealing with hostile and local military forces</td>
<td>Bypassing terrain conditions that impede travel</td>
</tr>
<tr>
<td>Road conditions relevant to traveling between locations</td>
<td>Navigators for handling terrain/hazardous obstacles</td>
<td>Engineers that provide structures and fortifications</td>
</tr>
<tr>
<td><strong>Assets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicles and protection from hazardous obstacles</td>
<td>Engineers that provide structures and fortifications</td>
<td></td>
</tr>
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ACAV | MTVR | Combat | Construction | Military | Local
Introduction to CRONUS

- In order to satisfy the objectives of a mission, your team is presented with a map displaying three possible routes that can be used to move your units between a Starting and Destination point.
Introduction to CRONUS

- Each route contains a number of obstacles that appear as distinct icons on the map. Your units will encounter these obstacles as they travel along a route.
Introduction to CRONUS

• For each mission, your team must **decide which route to follow and which assets to bring that will most effectively and efficiently enable your team to overcome the obstacles encountered when traversing the route**
Introduction to CRONUS

- The overall goal of the task is to thus utilize your own expertise/assets as well as those of your team members in order to maximize:

- **Effectiveness** of your individual performance
- **Effectiveness** of your team’s decision
- **Efficiency** of your team’s collaborative efforts

Transport
- Expertise
- Assets

Intel
- Expertise
- Assets

Engineer
- Expertise
- Assets
Conclusions

• TKT metrics capture knowledge emergence

• TKT metrics, conceptual foundation validated

• Computational results, pilot human data exhibit similar configurations of knowledge emergence
  – Computational simulation can be used to identify leverage points to improve knowledge emergence

• TKT metrics exhibit diagnostic value

• TKT metrics => drive embedded interventions
Steve W. J. Kozlowski, Ph.D. is a Professor of Organizational Psychology at Michigan State University. His theory and research are focused on the design of active learning, simulation, and “synthetic experience” to develop adaptive skills; systems for enhancing team learning and team effectiveness; and the role of team leaders in shaping team development. The goal of his programmatic research is to generate actionable theory, research-based principles, and deployable tools to facilitate the development of adaptive individuals, teams, and organizations. Current research is supported by NASA (Team Cohesion) and the Office of Naval Research (Team Collaborative Decision Making). Previous research has been supported by the Air Force Office of Scientific Research (AFOSR), the Army Research Institute for the Behavioral and Social Sciences (ARI), and the Naval Air Warfare Center Training Systems Division (NWCTSD), among others. As an advisor, he is a former member of the National Academy of Sciences Board on Human Systems Integration and the National Academy of Sciences Committee on Behavioral and Social Science Research to Improve Intelligence Analysis for National Security. Dr. Kozlowski is the Editor (and a former Associate Editor) for the Journal of Applied Psychology. He has served on the Editorial Boards of the Academy of Management Journal, Human Factors, the Journal of Applied Psychology, and Organizational Behavior and Human Decision Processes. He is also the Editor of the Handbook of Industrial and Organizational Psychology, a volume in the Library of Psychology to be published by the Oxford University Press, and Series Editor for companion handbooks. He is a Fellow of the American Psychological Association, the Association for Psychological Science, the International Association for Applied Psychology, and the Society for Industrial and Organizational Psychology. Dr. Kozlowski received his B.A. in psychology from the University of Rhode Island, and his M.S. and Ph.D. degrees in organizational psychology from The Pennsylvania State University.
Georgia T. Chao, Ph.D. is Associate Professor of Management at the Eli Broad College of Business at Michigan State University. Her primary research interests lie in the areas of cultural influences on organizational behavior, the emergence of knowledge in teams, team effectiveness, organizational socialization, mentoring, and career development. An underlying theme in her research programs is work adjustment: how individuals adjust to new work environments and how team members can adjust to one another in order to maximize team effectiveness. Dr. Chao’s research on cultural influences on organizational behavior includes networks of social identities that can facilitate or inhibit interpersonal relationships. This work links some of her current research: examining the emergence and measurement of team knowledge, team processes in emergency medical teams, and work adjustment issues for the current generation of young adults. Dr. Chao’s research has been supported by grants from the US Army Research Office, the Asia Pacific Economic Cooperation, US Agency for International Development, and US Information Agency. She has been an invited speaker in over a dozen countries around the world. She is a Fellow of the American Psychological Association (APA) and the Society for Industrial and Organizational Psychology (SIOP) and currently serves on four editorial boards. Dr. Chao was elected and served on APA Council and on executive committees in the Academy of Management and SIOP. She has a B.S. in psychology from the University of Maryland and M.S. and Ph.D. in industrial/organizational psychology from The Pennsylvania State University.