Hypothesis Testing of Edge Organizations: Empirically Calibrating an Organizational Model for Experimentation

Doug MacKinnon, Marc Ramsey, Dr. Ray Levitt, and Dr. Mark Nissen

http://crgp.stanford.edu

Acknowledgements: OASD-NII/CCRP and Center for Edge Power
Agenda

- Motivation
- Research Questions
- Points of Departure
  - Previous hypothesis testing
  - Cognitive Science: Learning and forgetting rates
- Conceptual Model
  - POW-ER 3.2 extensions
- Calibration
  - AROUSAL Exercise
- Validation
  - ELICIT Exercise
    - Edge vs. Hierarchy
- C2 Application
- Theoretical Contributions
- Next Steps
Motivation

- **Edge Organization definition**
  - No headquarters to rely upon
  - Requires: shared awareness / self synchronization

- **Knowledge flow is especially critical for Edge Organizations**
  - High levels of strategic & operational knowledge needed at nodes
  - Enables “agility” in an uncertain environment
  - Understanding knowledge growth & decay in Edge organizations - critical for optimizing performance
Research Questions

- How can we model and simulate Edge vs. Hierarchy organizational forms engaged in similar project-oriented tasks, taking account of the impacts of individual learning and forgetting on performance outcomes for the two structures?
  - How can individual skill acquisition and decay be computationally modeled, calibrated, and validated?
  - How are Edge vs. Hierarchy organizations and projects effected by the sum of individual participants’ skill growth and decay?
Points of Departure

- **Hypothesis Testing of Edge Organizations**
  - Nissen, 10th ICCRTS, 2005
  - Orr and Nissen, 11th ICCRTS, 2006

- **Cognitive Science**
  - Learning and Forgetting rates
    - Anderson, 2005
    - Sikstrom and Jaber, 2004 and 2002
  - Skill Classification
    - Dar-EI et al, 1995
Theoretical Point of Departure
Skill Context (Dar-EI et al., 1995)

- Different skill types seem to have different learning curves
  - Ranging from highly cognitive to highly motor skills

Modeling High Cog to High Motor

![Graph showing learning curves for different skill types.](image-url)
Conceptual Model
Individual Skill Acquisition and Decay

- Extensions to POW-ER computational modeling
- Develop fine-grained agent knowledge metric
  - Provide for dynamic, continuous knowledge over time
- Focus on individual knowledge
  - Inflows through OJT
  - Outflows through decay
AROUSAL Model

POW-ER 3.2
Empirical Validation of Learning Rates
Arousal Exercise

Dar-EI Learning Curves *Plotted Against*
Observed Individual & Group Learning Rates

![Graph showing learning curves](image-url)

- Hi Cog
- More Cog
- More Motor
- Hi Motor
Empirical Validation of Learning Rates
Arousal Exercise

Dar-El Learning Curves *Plotted Against* Observed Individual & Group Learning Rates

- Qtr’s 2-5
- Qtr’s 5-8
- Interruption

Time (normalized)
Empirical Validation of Learning Rates
Arousal Exercise

Dar-El Learning Curves *Plotted Against*
Observed Individual & Group Learning Rates

![Graph showing Dar-El Learning Curves plotted against observed individual & group learning rates. The graph includes lines for Hi Cog, More Cog, More Motor, Hi Motor, and Individual Time. The x-axis represents time (normalized), and the y-axis represents time (normalized). The graph is labeled with Qtr’s 2-4, Interruption, and Qtr’s 5-8.]
Empirical Validation of Learning Rates
Arousal Exercise

Dar-EI Learning Curves *Plotted Against*
Observed Individual & Group Learning Rates

![Graph showing learning curves over time](image)
Empirical Validation of Learning Rates
Arousal Exercise

Dar-El Learning Curves *Plotted Against*
Observed Individual & Group Learning Rates

Time (normalized)
Empirical Validation of Learning Rates
Arousal Exercise

Dar-El Learning Curves *Plotted Against*
Observed Individual & Group Learning Rates

![Graph](image-url)
POW-ER Validation

Empirical vs. Predicted Individual Performance

![Bar graph showing individual duration for each AROUSAL quarter with bars for AROUSAL and POW-ER 3.2]
POW-ER Validation
Empirical vs. Predicted **Group** Performance

![Bar chart showing empirical vs. predicted group performance by AROUSAL Quarter from Q2 to Q8. The chart compares AROUSAL and POW-ER 3.2 performance metrics.]
### Organizational Level POW-ER Models

Empirical findings from AROUSAL learning and forgetting

<table>
<thead>
<tr>
<th>Metric</th>
<th>Individual Data</th>
<th>Group Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Empirical</td>
<td>POW-ER 3.2</td>
</tr>
<tr>
<td>Summed individual durations (based on initial period, without subsequent learning)</td>
<td>161 minutes</td>
<td>161 minutes</td>
</tr>
<tr>
<td>Duration (with learning)</td>
<td>106 minutes</td>
<td>103 minutes</td>
</tr>
<tr>
<td>Percent Savings from Learning</td>
<td>34.2%</td>
<td>36.0%</td>
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</tbody>
</table>
ELICIT Exercise

- Anti-terrorist, intelligence (knowledge) sharing game
- 17 players
- Either Edge or Hierarchy organizations
  - All players may share information with each other
  - Hierarchy is limited to viewing own team’s website
  - No talking
- Each player required to identify target
  - Who, what, when, where
- Allowed approximately 60 minutes
POW-ER Model Validation

ELICIT Exercise

Hierarchy

Edge
ELICIT Exercise

Correct Responses in 10-minute Intervals
For Different Organizational Forms

Correct Answers

10-Minute Intervals (non-cumulative)

Hierarchy (2 game avg)
Edge
POW-ER Experimental Results
3 Exercise Rounds: 3 day delay after 2\textsuperscript{nd} round

<table>
<thead>
<tr>
<th>Metric</th>
<th>Hierarchy (3 Rounds) Mean (Std. deviation)</th>
<th>Edge (3 Rounds) Mean (Std. deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>No learning</td>
<td>With learning and forgetting</td>
</tr>
<tr>
<td></td>
<td>No learning</td>
<td>With learning and forgetting</td>
</tr>
<tr>
<td>Duration (minutes)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination (minutes)*</td>
<td></td>
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<tr>
<td>Rework (minutes)</td>
<td></td>
<td></td>
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<tr>
<td>Functional Exception</td>
<td></td>
<td></td>
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<tr>
<td>Work (minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Work (minutes)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Quality Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost ($K)*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)
POW-ER External Validity
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POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)
POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)

(p = .018)
POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)
POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)
POW-ER External Validity
Using ELICIT Observations (Leweling & Nissen, 2007)
C2 Application

- Example: Crew training (deployment preparation)
  - Consider improvement in command’s performance through adoption of edge-like organizational qualities
- Leverage experimental results to develop and test new command models
  - To predict project lengths for a single project
  - To consider impacts of other agent-based knowledge interventions
    - e.g., training and mentoring
Theoretical Contributions

- Produced quantitative analysis of how micro-behaviors (learning and forgetting) affect organizational performance, extending our understanding of organizational learning.

- Calibrated and validated tool to develop and test individual knowledge flow impacts on Edge and other organizational forms.
Next Steps

- Develop and validate further via future ELICIT experiments, so that we can
  - Improve our predictions of project lengths for a single project
  - Model the effects of other knowledge interventions
    - Training, mentoring
    - Obsolescence, interference
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