Collective Intelligence in Human Groups

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Network Science meets Team Science
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The Collective . . .

- Ishani Aggarwal, Georgia Tech
- Christopher Chabris, Union College
- David Engel, MIT
- Nada Hashmi, MIT
- Lisa Jing, MIT
- Thomas Malone, MIT

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The Puzzle of Collective Intelligence

Ant Colony

Flock of Birds

Animal Herd
The Puzzle . . .

- Does general collective intelligence exist in human groups?
General Intelligence

- General intelligence is the inference one makes from the observation that people who do well on one task tend to do well on other tasks.
  - In addition to separate, non-correlated abilities associated with each task, there is a more general ability that influences all tasks.

Source: Deary, 2000
Individual Intelligence

• Spearman’s $g$

Charles Spearman (1904)
Collective Intelligence: Questions

• Is there evidence of a general collective intelligence in groups?
• Can we isolate a small set of tasks that is predictive of group performance on a broader range of more complex tasks?
• Does $c$ have predictive validity beyond individual intelligence of group members?
• How can we use this information to build a better science of collective performance?
Study 1

- 40 groups spend five hours together in the laboratory
- Work together on a diverse range of tasks, plus a criterion computer game task
- Also measured individual intelligence

Sampling Tasks

- Generate
- Choose
- Execute
- Negotiate

Adapted from Larson, 2009; McGrath, 1984
## Example Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate</td>
<td>Brainstorming. Come up with as many uses for a brick as possible.</td>
<td>Scored on quantity and quality of ideas.</td>
</tr>
<tr>
<td>Choose</td>
<td>Intellective. Members answer a set of Raven’s Matrices questions as a group.</td>
<td>Scored on correctness.</td>
</tr>
<tr>
<td>Negotiate</td>
<td>Devise a shopping trip using a shared car so that all members can get as many of their items at the best places possible.</td>
<td>Cumulative score of all group members.</td>
</tr>
<tr>
<td>Execute</td>
<td>Typing task. Members must collectively type difficult text into a shared online document.</td>
<td>Scored on number of words typed minus errors and skipped words in limited time period.</td>
</tr>
</tbody>
</table>
Study 1

- Average inter-item correlation = .28
- First principal component accounts for 43% of variance

Evidence for a c-factor

\[ \chi^2 = 1.66, \ p = .89, \ NFI = .94, \ CFI = 1.00 \]
Evidence for a c-factor

χ² = 3.30, p = .95; NFI = .91, CFI = 1.00

Evidence for a c-factor

\[ \chi^2 = 13.92 \, p = .45; \, NFI = .70, \, CFI = .99 \]

Study 2

Task 1
Task 2
Task 3
Task 4
Task 5

Collective Intelligence

Average IQ
Architectural Design Task

χ² = 4.05, p=.13; CFI = .94; NFI = .91

107 groups of sizes 2, 3, 4, and 5

Evidence for a c-factor

Woolley, Chabris, Pentland, Hashmi & Malone, 2010
Predictive value of c and g factors

Woolley, Chabris, Pentland, Hashmi & Malone, 2010
CI and Student Project Performance

- 49 MBA student teams at CMU, CI predicts:
  - Desert Survival Simulation 1 week later ($r=0.30$, $p=0.01$)
  - Change Pro Organizational Simulation 3 weeks later ($r=0.39$, $p=0.005$)

- 114 groups of German Computer Science students
  - CI predicts peer-rated performance on final project two months later ($r=0.21$, $p<0.05$)
Learning & Collective Intelligence

- 98 teams
- CI measured at beginning of session
- Minimum-effort tacit coordination game (Van Huyck et al., 1990).
  - Multiple rounds of individual decision making
  - Collective gains or loses money as a result of the decisions made by team members without communication.
  - Provides a behavioral measure of learning across multiple trials

Aggarwal, Woolley, Chabris, & Malone, under review
## Tacit Coordination Task

<table>
<thead>
<tr>
<th>Member choice</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2200</td>
<td>2800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1600</td>
<td>2600</td>
<td>3200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>600</td>
<td>2000</td>
<td>3000</td>
<td>3600</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>-800</td>
<td>1000</td>
<td>2400</td>
<td>3400</td>
<td>4000</td>
</tr>
</tbody>
</table>
CI and Learning

Aggarwal, Woolley, Chabris, & Malone, under review
## CI and Learning

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Rate of Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Team Size</td>
<td>-.003</td>
</tr>
<tr>
<td>Initial performance</td>
<td>-.04*</td>
</tr>
<tr>
<td>Individual Intelligence</td>
<td>.02*</td>
</tr>
<tr>
<td>Collective Intelligence</td>
<td></td>
</tr>
</tbody>
</table>

| $R^2$                    | .26             | .32  | .38  |
CI and Learning in the Classroom

- 60 MBA student teams of 4-5 students each
- Class conducted using Team-Based Learning approach (Michaelson & Sweet, 2011)
  - Individual students complete a “Readiness Assurance Test” at the beginning of each unit
  - Teams complete same assessment immediately following
- All teams completed the CI battery at the beginning of the term.
CI in Classroom Teams

Aggarwal, Woolley, Chabris, & Malone, in prep

Test Score

High CI Teams
Low CI Teams
Max Indiv/High CI Teams
Max Indiv/Low CI Teams

Exam 1 Exam 2 Exam 3
What Predicts \( c \)??

- *Not* group satisfaction \((r = -.07)\) cohesion \((r = -.12)\), or motivation \((r = -.01)\)
- Not personality
- Proportion of females in group
CI and Proportion of Women

Engel, Woolley, Aggarwal, Chabris & Malone, in prep
# Social Perceptiveness

<table>
<thead>
<tr>
<th>Playful</th>
<th>Comforting</th>
<th>Irritated</th>
<th>Bored</th>
</tr>
</thead>
</table>

“Reading the Mind in the Eyes” Baron-Cohen et al., 2001
CI and Communication

- Uneven distribution in speaking turns negatively predicts $c$ (Woolley et al., 2010)
Effects of Cognitive Diversity

Verbal Reasoning

Large : Big
Triumph: ___________ (1) Small (2) Success (3) Lose

Visual Reasoning

Kozhevnikov, Kosslyn & Shephard, 2005; Kozhevnikov & Blazhenkova, 2013; Woolley et al. 2008
Cognitive Diversity & c

Aggarwal, Woolley, Chabris, & Malone, in prep
Given the reaction when we displayed this graph at the MCI meeting last week, I wonder if we want to show this?

teeper, 2010-07-20
Our new online CI Battery

- Online
- 60 minutes
- Collaborative interface
- Adaptable for studies
- Task groups: Typing, Matrix Problem Solving, Brainstorm, Unscramble, Sudoku
Testing the new CI Battery

- 68 groups of four people in two conditions
- Both conditions in the lab
Are the results comparable?

<table>
<thead>
<tr>
<th>Factor #</th>
<th>Face to Face</th>
<th>Online</th>
<th>Previous Study 1</th>
<th>Previous Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.3</td>
<td>41.4</td>
<td>43.4</td>
<td>44.1</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>13.8</td>
<td>18.2</td>
<td>20.5</td>
</tr>
<tr>
<td>3</td>
<td>11.5</td>
<td>11.9</td>
<td>16.9</td>
<td>15.6</td>
</tr>
<tr>
<td>4</td>
<td>8.4</td>
<td>11.5</td>
<td>12.5</td>
<td>12.4</td>
</tr>
<tr>
<td>5</td>
<td>5.7</td>
<td>9.3</td>
<td>9.1</td>
<td>7.4</td>
</tr>
</tbody>
</table>
Communication

- Better groups chat more
- Better groups participate more equally
% Women and CI Online and F2F

Online

Face-to-Face

% Women
Social Perceptiveness

Equally important in online and face-to-face groups
(r=.57 and r=.55, p<.001)
## CI in Online vs. Face-to-Face Groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>Face-to-face</th>
<th>Online</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. score on RME test for group members</td>
<td>0.57***</td>
<td>0.55***</td>
</tr>
<tr>
<td>% women in group</td>
<td>0.20</td>
<td>0.41*</td>
</tr>
<tr>
<td>Amt. of communication</td>
<td>0.51**</td>
<td>0.47**</td>
</tr>
<tr>
<td>Std. deviation of communication among individuals</td>
<td>-0.29 *</td>
<td>-0.41*</td>
</tr>
<tr>
<td>Std. deviation of individual contributions to task solutions</td>
<td>-0.47**</td>
<td>-0.42*</td>
</tr>
</tbody>
</table>

(* = p<.05, ** = p<0.01 and *** = p < 0.001)
General Conclusions

- Our studies supply strong evidence of a “c-factor” underlying collective performance that predicts future performance and group learning.
- Factors that facilitate the transfer of information seem to facilitate CI:
  - Equality of contribution
  - Social perception
  - Low or moderate cognitive diversity
Collective Intelligence and Network Science

- Can networks be designed to produce a consistent level of performance across domains?
- What are the qualities of networks that yield a high level of collective intelligence?
- What is the relative contribution of individual capability versus network capability to the collective intelligence of networks?
Future Directions

- Further explore what predicts CI
- Use the CI battery to predict team performance in other contexts
  - Larger groups online
  - Teams in organizational settings
- Experiment with tools that enhance the processes known to enhance CI
Thanks!

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