Collective Intelligence in Human Groups

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Network Science meets Team Science

October 2013

The Collective . . .

- Ishani Aggarwal, *Georgia Tech*

- Christopher Chabris, *Union College*

- David Engel, *MIT*

- Nada Hashmi, *MIT*

- Lisa Jing, *MIT*

- Thomas Malone, *MIT*

Tepper School of Business • *William Larimer Mellon, Founder*

The Puzzle of Collective Intelligence

Ant Colony

Animal Herd

Flock of Birds

The Puzzle . . .

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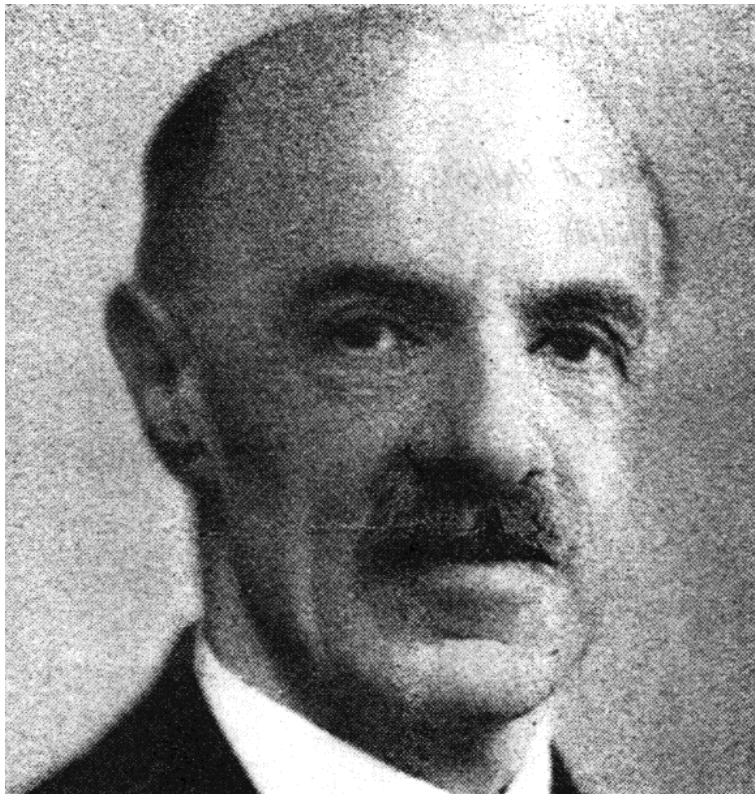
General Intelligence

- 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

Woolley, Chabris, Pentland, Hashmi & Malone, *Science,* 2010

Sampling Tasks
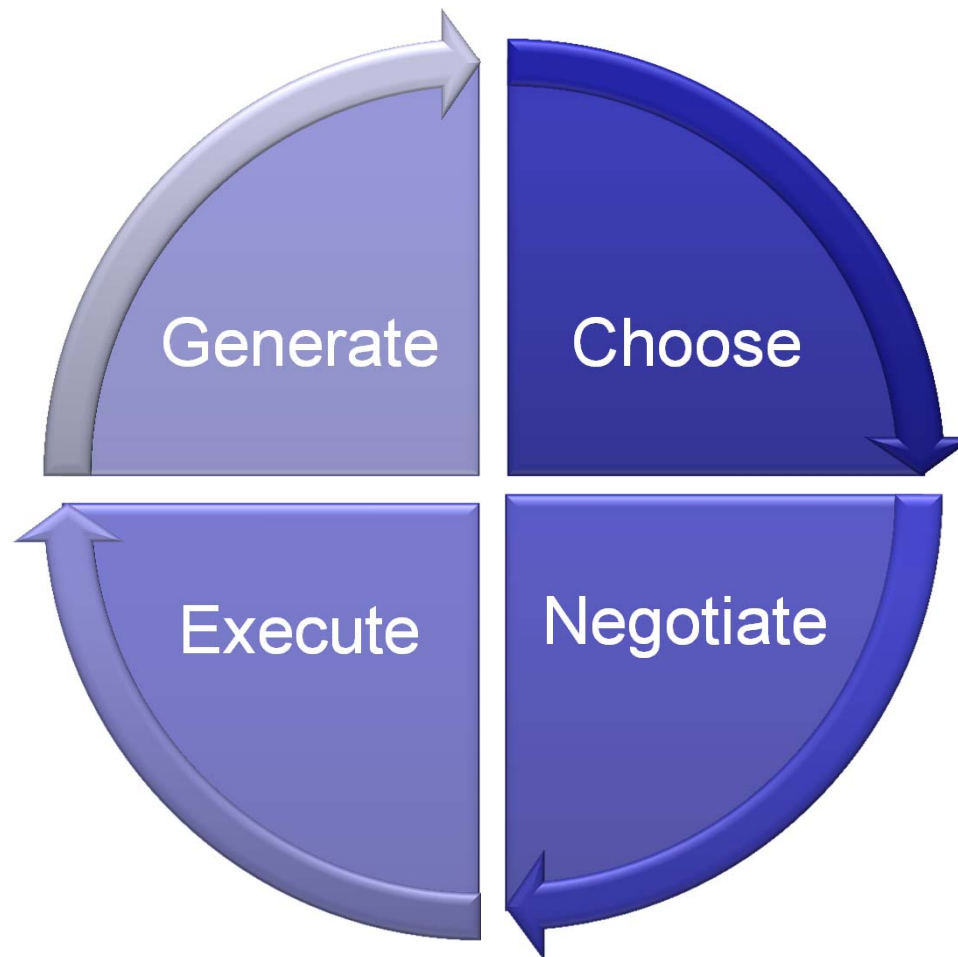
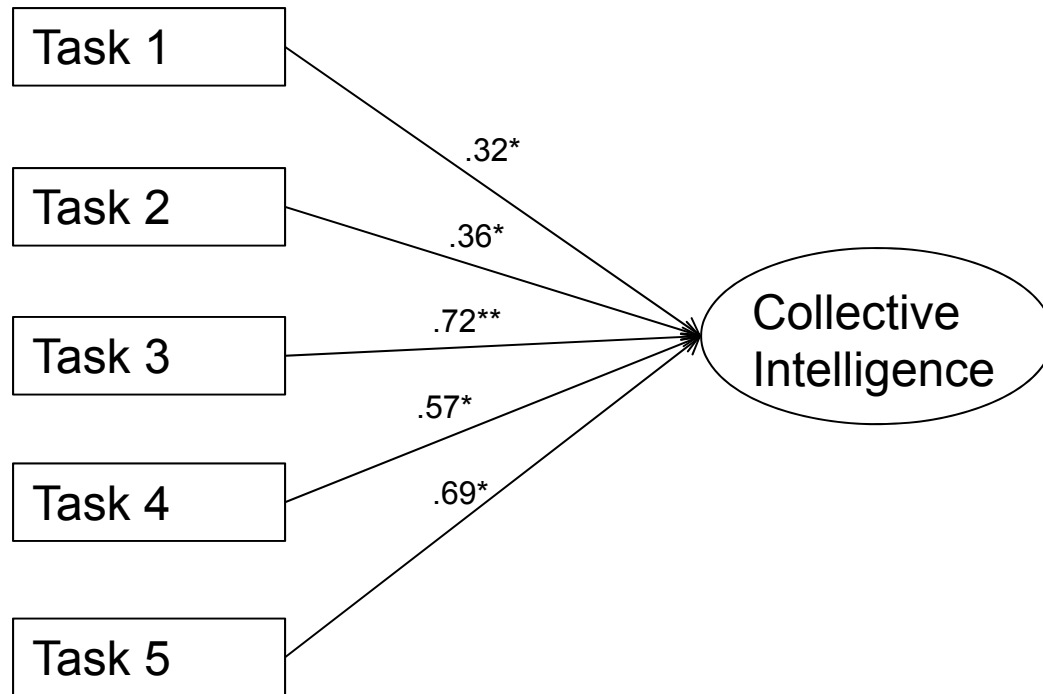Adapted from Larson, 2009; McGrath,1984

Example Tasks

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

Study 1

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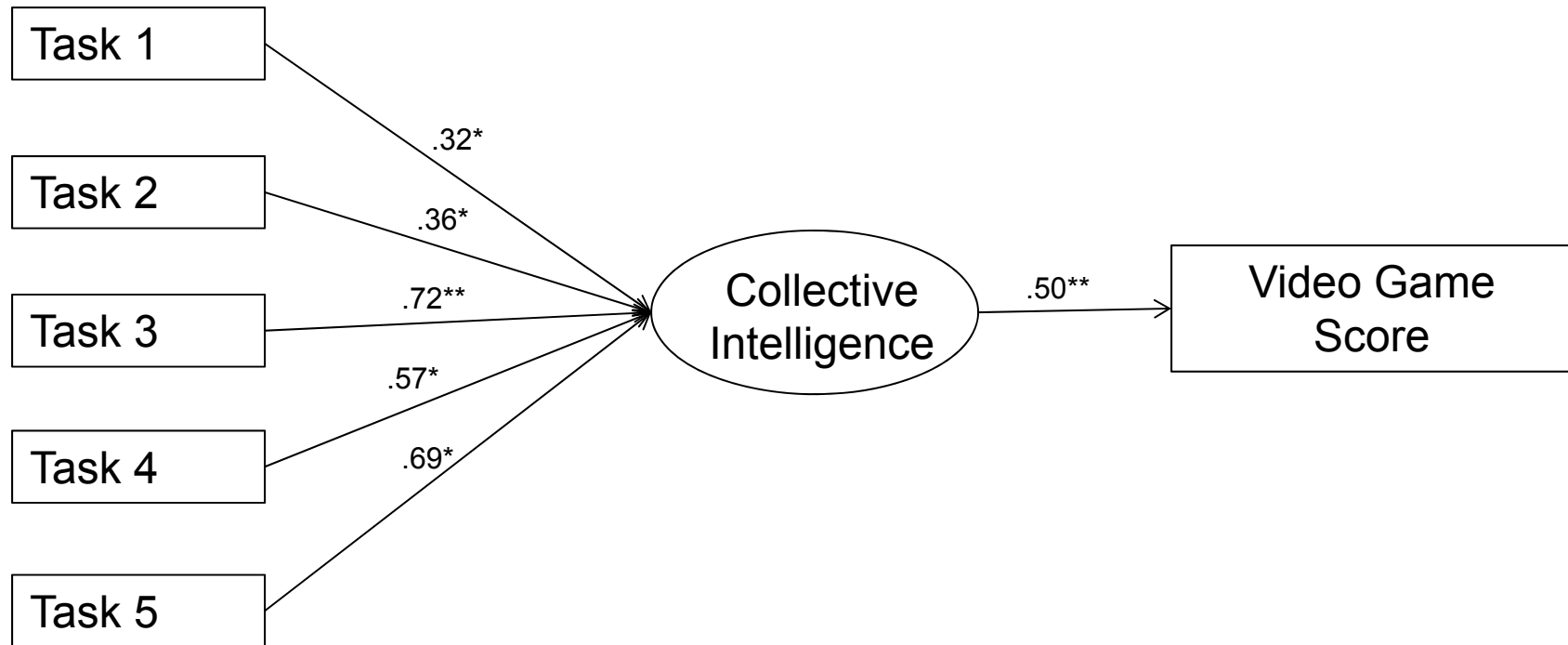- First principal component accounts for 43% of variance

Woolley, Chabris, Pentland, Hashmi & Malone, *Science,* 2010

Evidence for a *c*-factor

Task 1 — .32* → Collective Intelligence
Task 2 — .36*
Task 3 — .72**
Task 4 — .57*
Task 5 — .69*

$\chi^2 = 1.66$, p = .89, NFI = .94, CFI = 1.00

Evidence for a *c*-factor

Task 1 —.32*→ Collective Intelligence

Task 2 —.36*→ Collective Intelligence

Task 3 —.72**→ Collective Intelligence

Task 4 —.57*→ Collective Intelligence

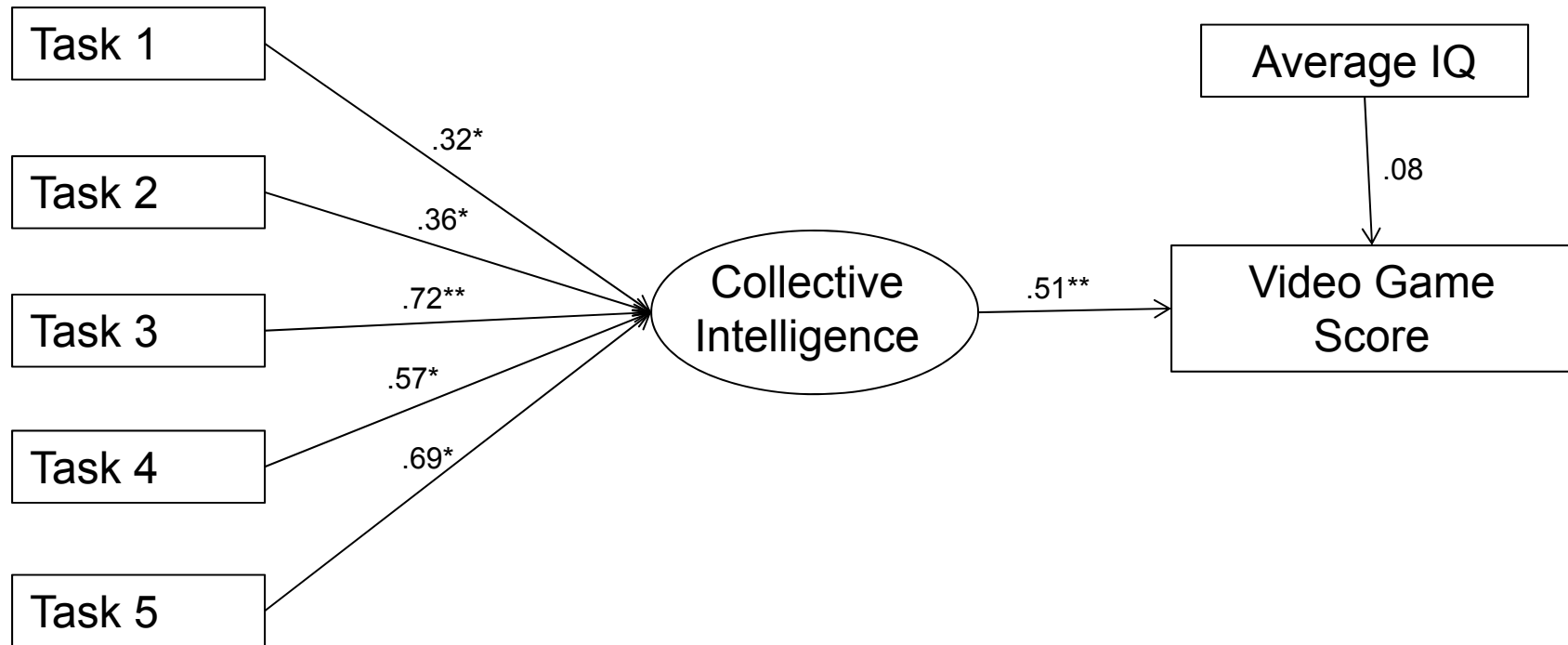Task 5 —.69*→ Collective Intelligence

Collective Intelligence —.50**→ Video Game Score

$\chi^2 = 3.30$, p= .95; NFI = .91, CFI = 1.00

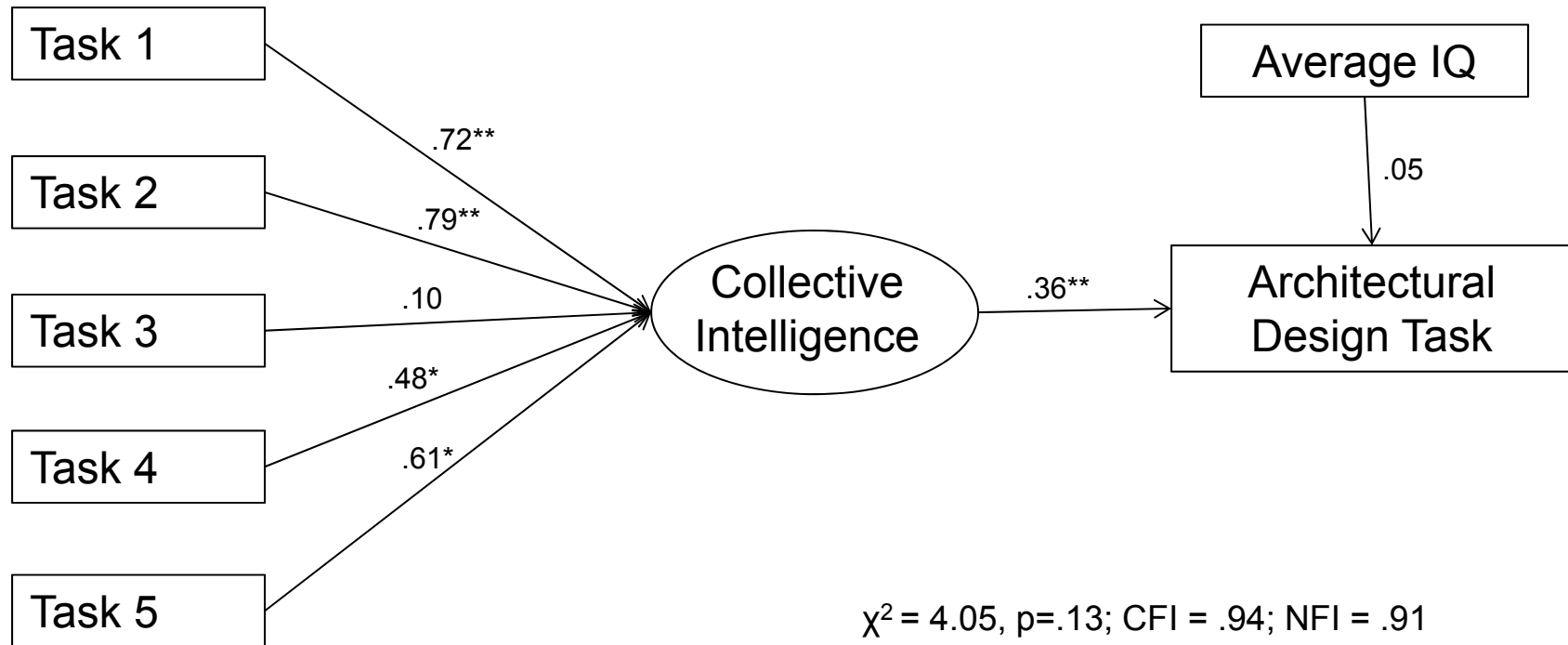Woolley, Chabris, Pentland, Hashmi & Malone, *Science,* 2010

Evidence for a *c*-factor

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

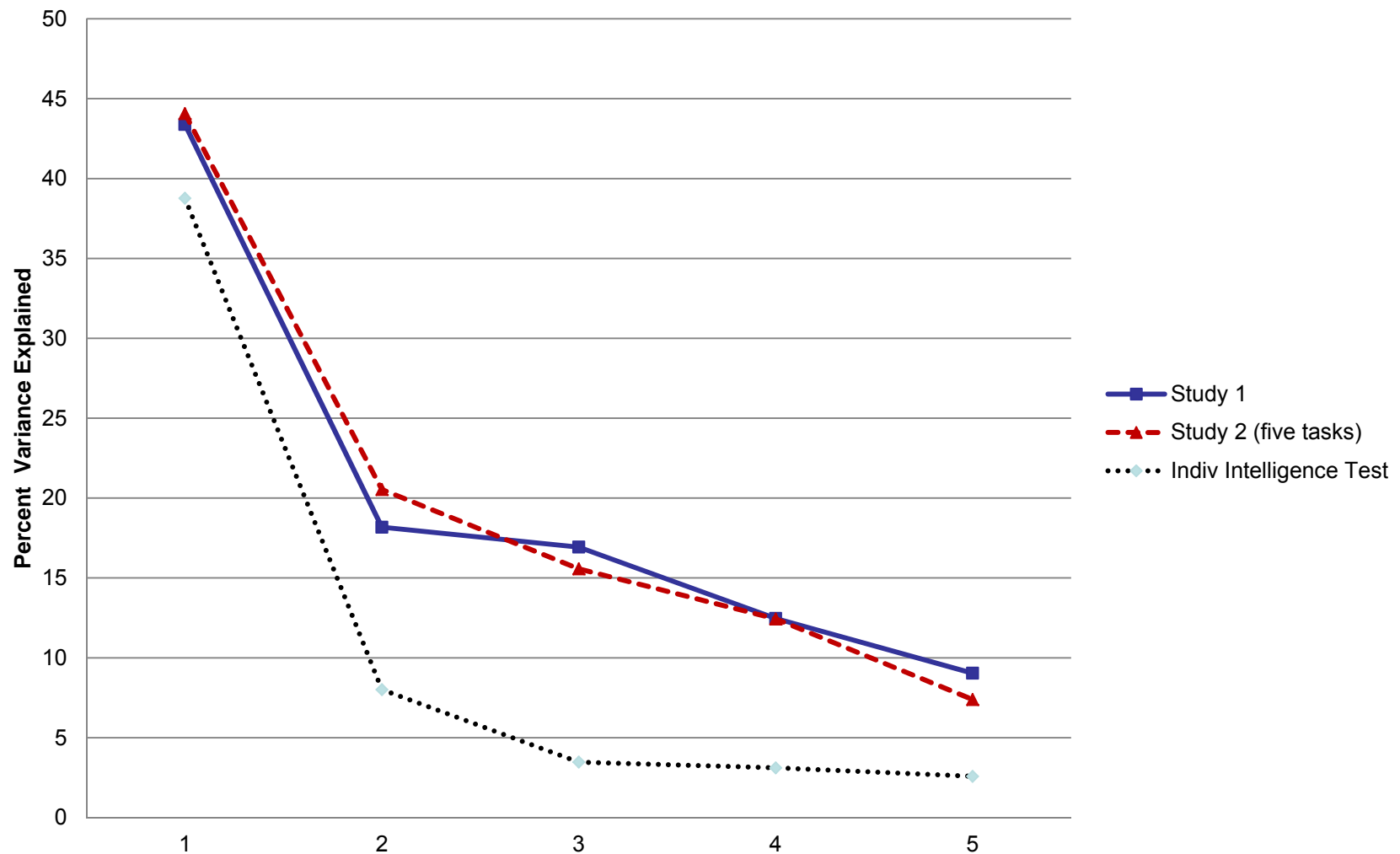Woolley, Chabris, Pentland, Hashmi & Malone, *Science,* 2010

Study 2

Task 1

Task 2

Task 3

Task 4

Task 5

.72**

.79**

.10

.48*

.61*

Collective Intelligence

.36**

Average IQ

.05

Architectural Design Task

$\chi^2 = 4.05$, p=.13; CFI = .94; NFI = .91
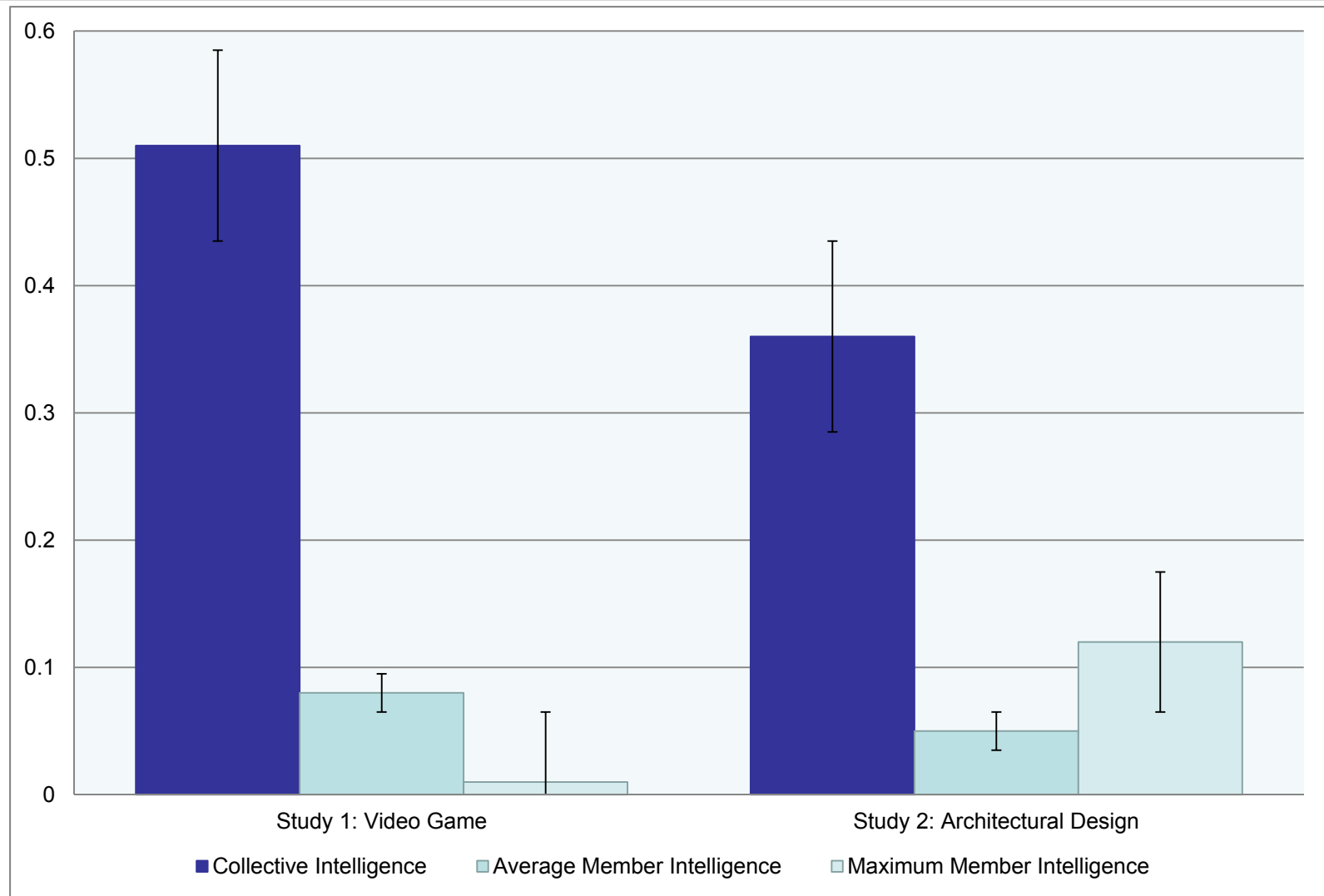
107 groups of sizes 2, 3, 4, and 5

Woolley, Chabris, Pentland, Hashmi & Malone, *Science,* 2010

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=.30, p=.01)
  - Change Pro Organizational Simulation 3 weeks later (r=.39, p=.005)

- 114 groups of German Computer Science students
  - CI predicts peer-rated performance on final project two months later (r=.21, p< .05)
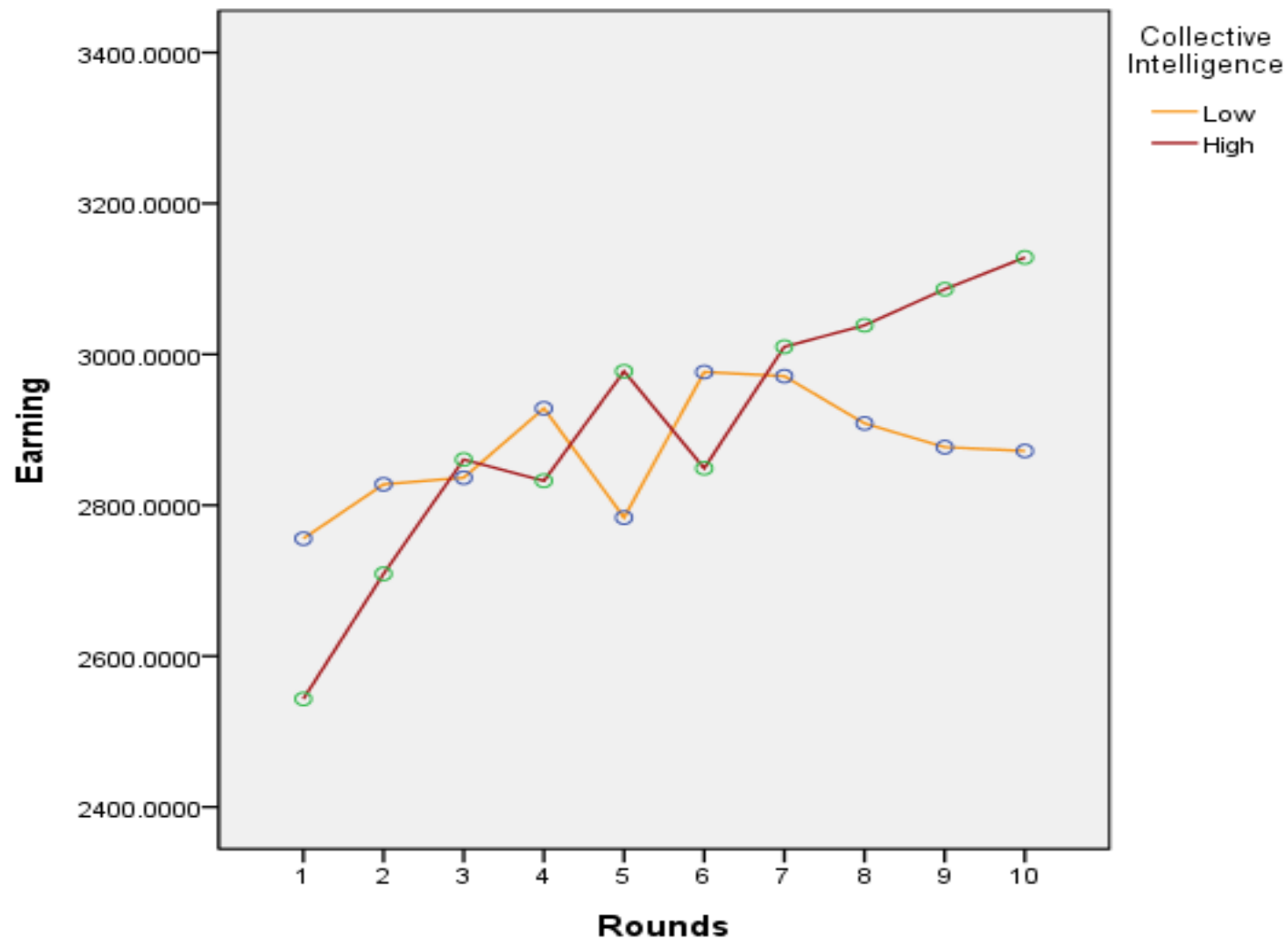
Learning & Collective Intelligence

- 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

		Minimum of the group's choice				
		0	10	20	30	40
Member choice	0	2400				
	10	2200	2800			
	20	1600	2600	3200		
	30	600	2000	3000	3600	
	40	-800	1000	2400	3400	4000

CI and Learning

Aggarwal, Woolley, Chabris, & Malone, under review

CI and Learning

Dependent Variable	Rate of Learning		
	(1)	(2)	(3)
Team Size	-.003	-.003	-.01
Initial performance	-.04*	-.04*	-.04*
Individual Intelligence		.02*	.01
Collective Intelligence			.02*
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.
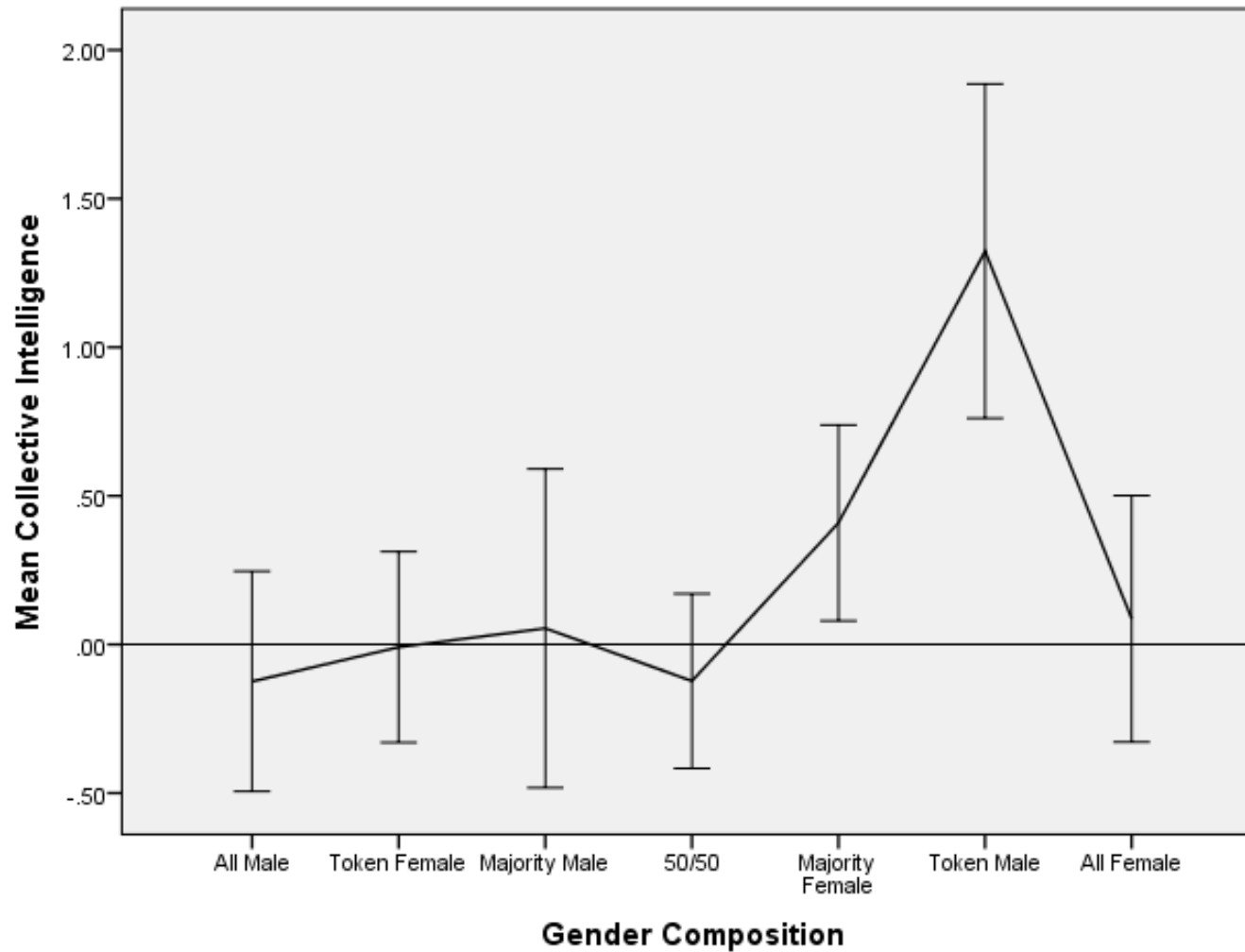
CI in Classroom Teams
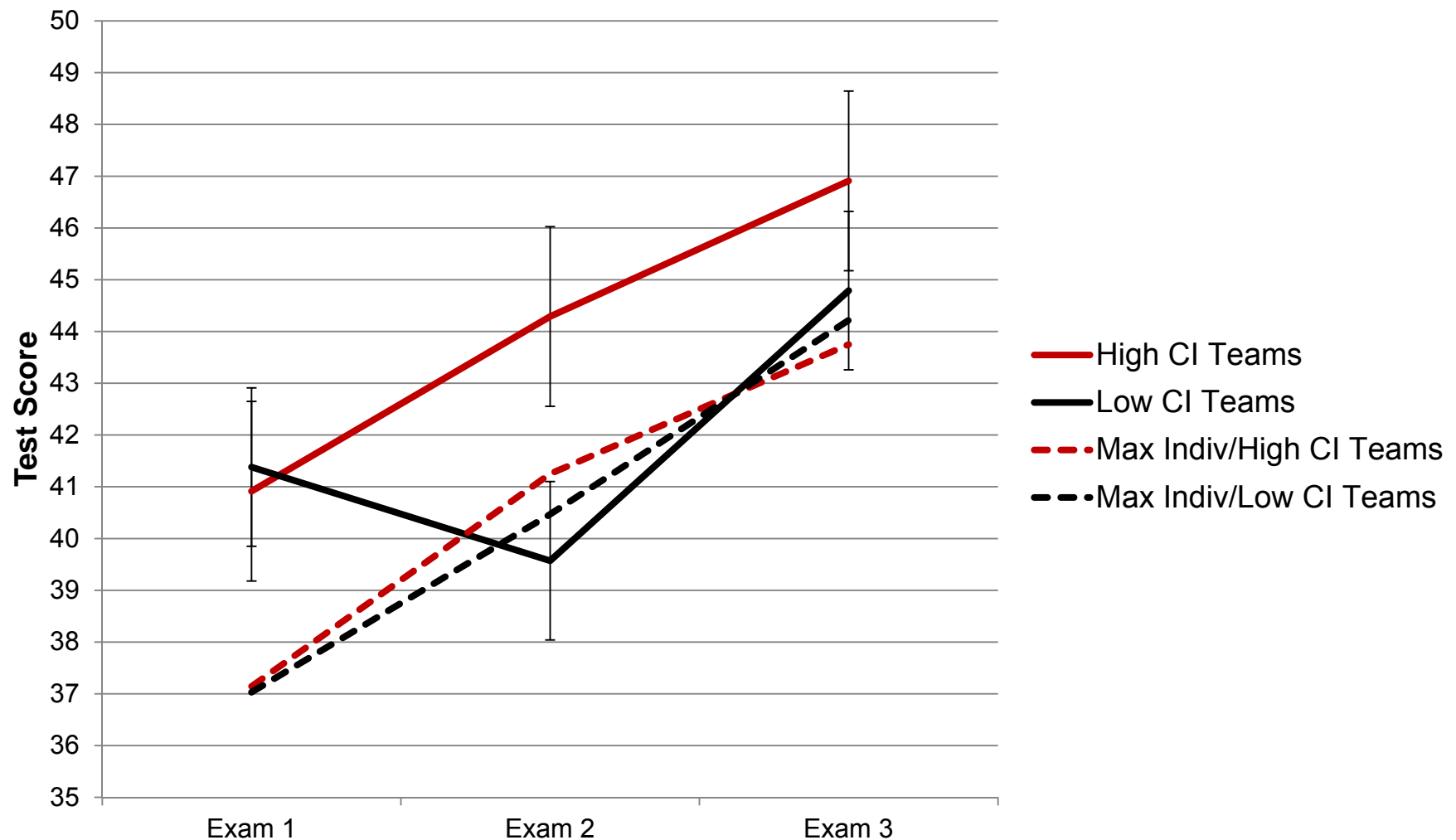
Aggarwal, Woolley, Chabris, & Malone, in prep

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

Error bars: 95% CI

Engel, Woolley, Aggarwal, Chabris & Malone, in prep

Social Perceptiveness

Playful   Comforting   Irritated   Bored

"Reading the Mind in the Eyes" Baron-Cohen et al., 2001

CI and Communication

Sociometric Badge

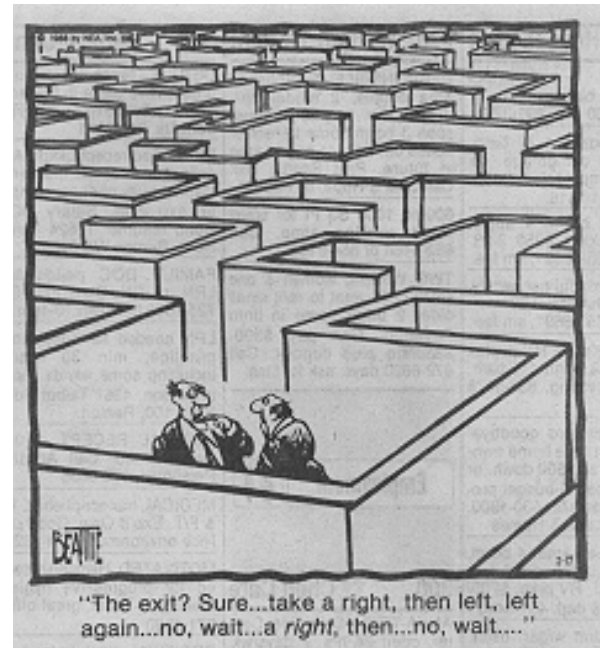- Uneven distribution in speaking turns negatively predicts c (Woolley et al., 2010)

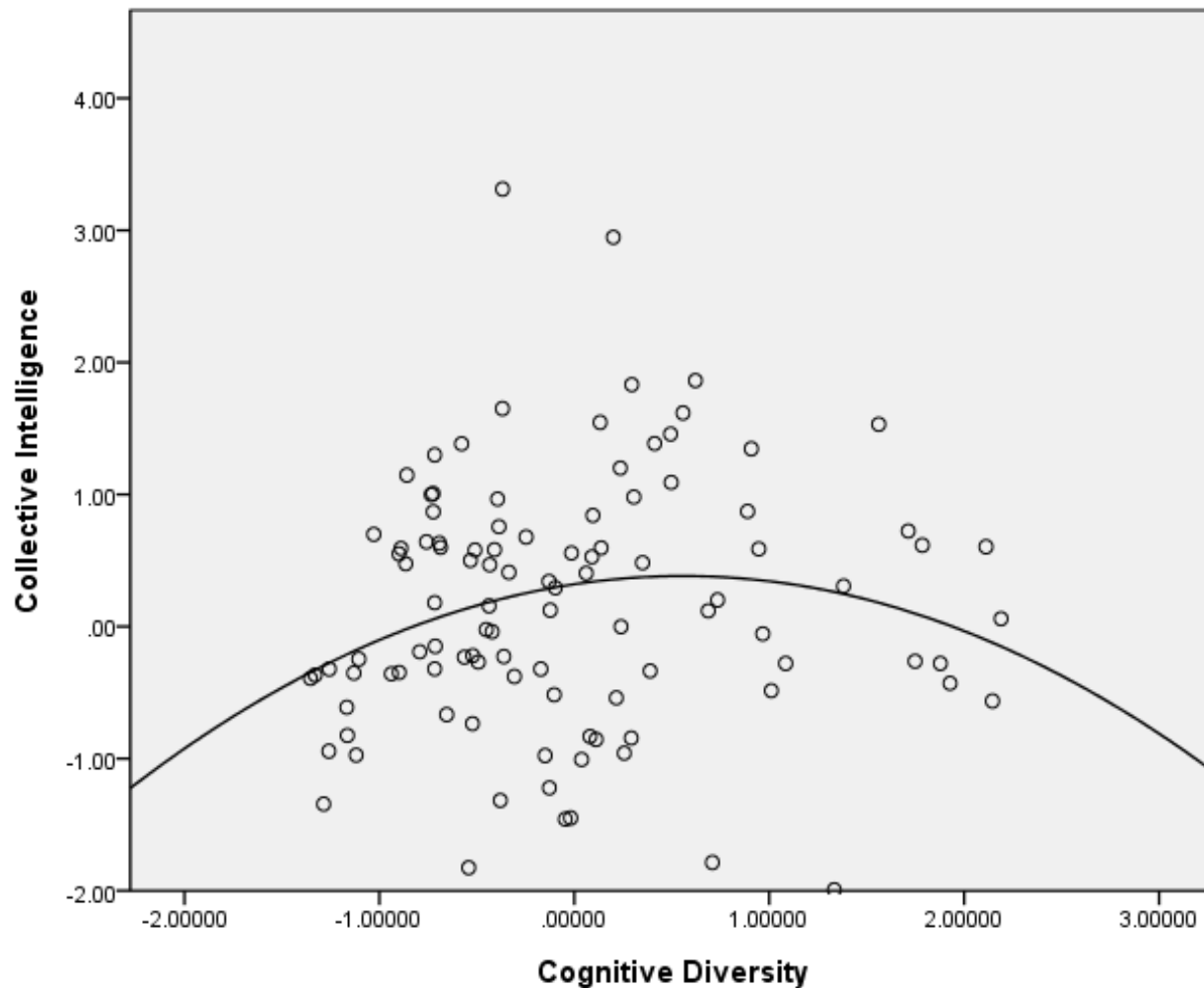# Effects of Cognitive Diversity

Verbal Reasoning

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

Visual Reasoning

"The exit? Sure...take a right, then left, left
again...no, wait...a *right*, then...no, wait...."

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

Cognitive Diversity & c

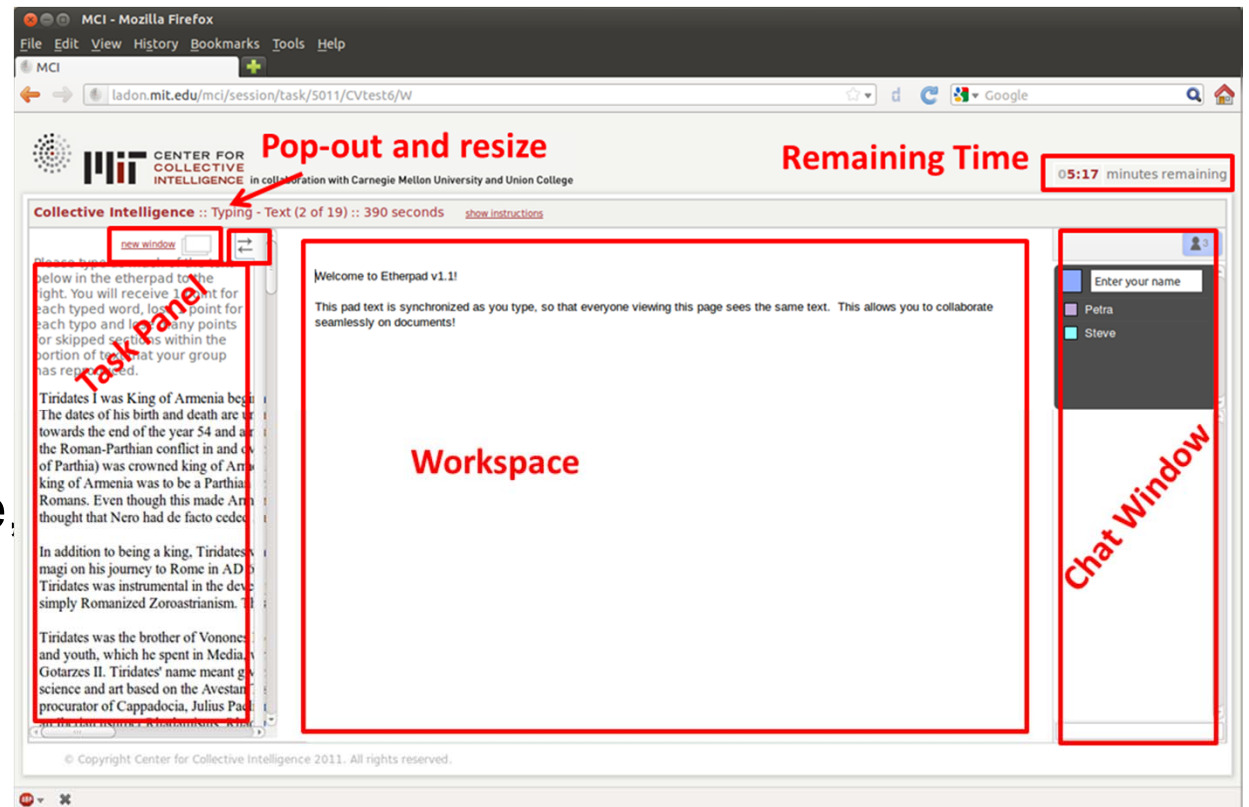Aggarwal, Woolley, Chabris, & Malone, in prep

t2   Given the reaction when we displayed this graph at the MCI meeting last week, I wonder if we want to show this?
tepper, 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
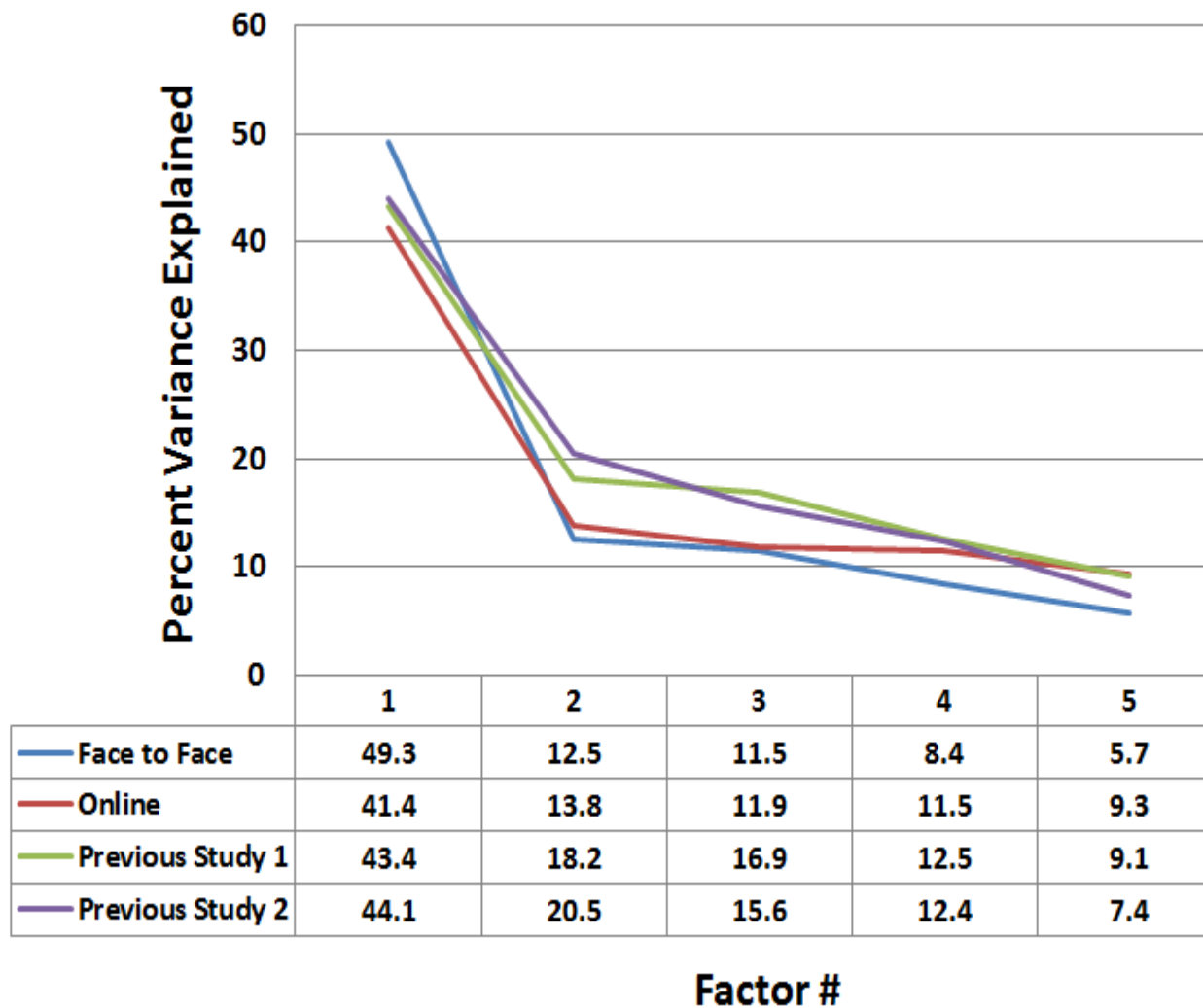
Testing the new CI Battery

vs.

- 68 groups of four people in two conditions
- Both conditions in the lab

Are the results comparable?

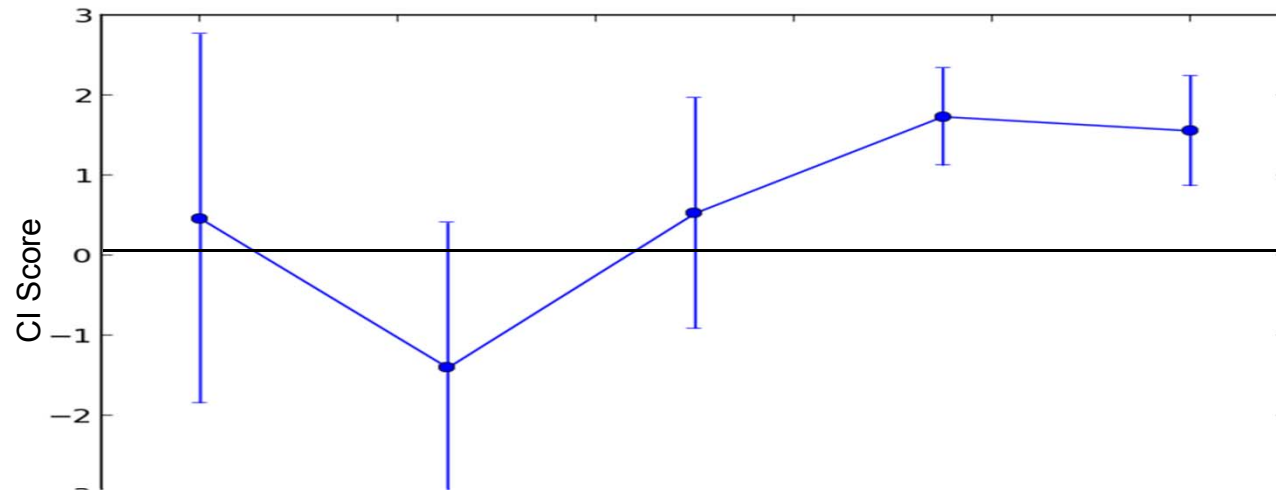| Factor #	1	2	3	4	5
Face to Face	49.3	12.5	11.5	8.4	5.7
Online	41.4	13.8	11.9	11.5	9.3
Previous Study 1	43.4	18.2	16.9	12.5	9.1
Previous Study 2	44.1	20.5	15.6	12.4	7.4

Communication

- Better groups chat more

- Better groups participate more equally

% Women and CI Online and F2F

Online

Face-to-Face

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

	Face-to-face	Online
Avg. score on RME test for group members	0.57***	0.55***
% women in group	0.20	0.41*
Amt. of communication	0.51**	0.47**
Std. deviation of communication among individuals	-0.29 *	-0.41*
Std. deviation of individual contributions to task solutions	-0.47**	-0.42*

(* = p<.0.05, ** = 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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