Collective Intelligence as a Central Characteristic of Small Groups

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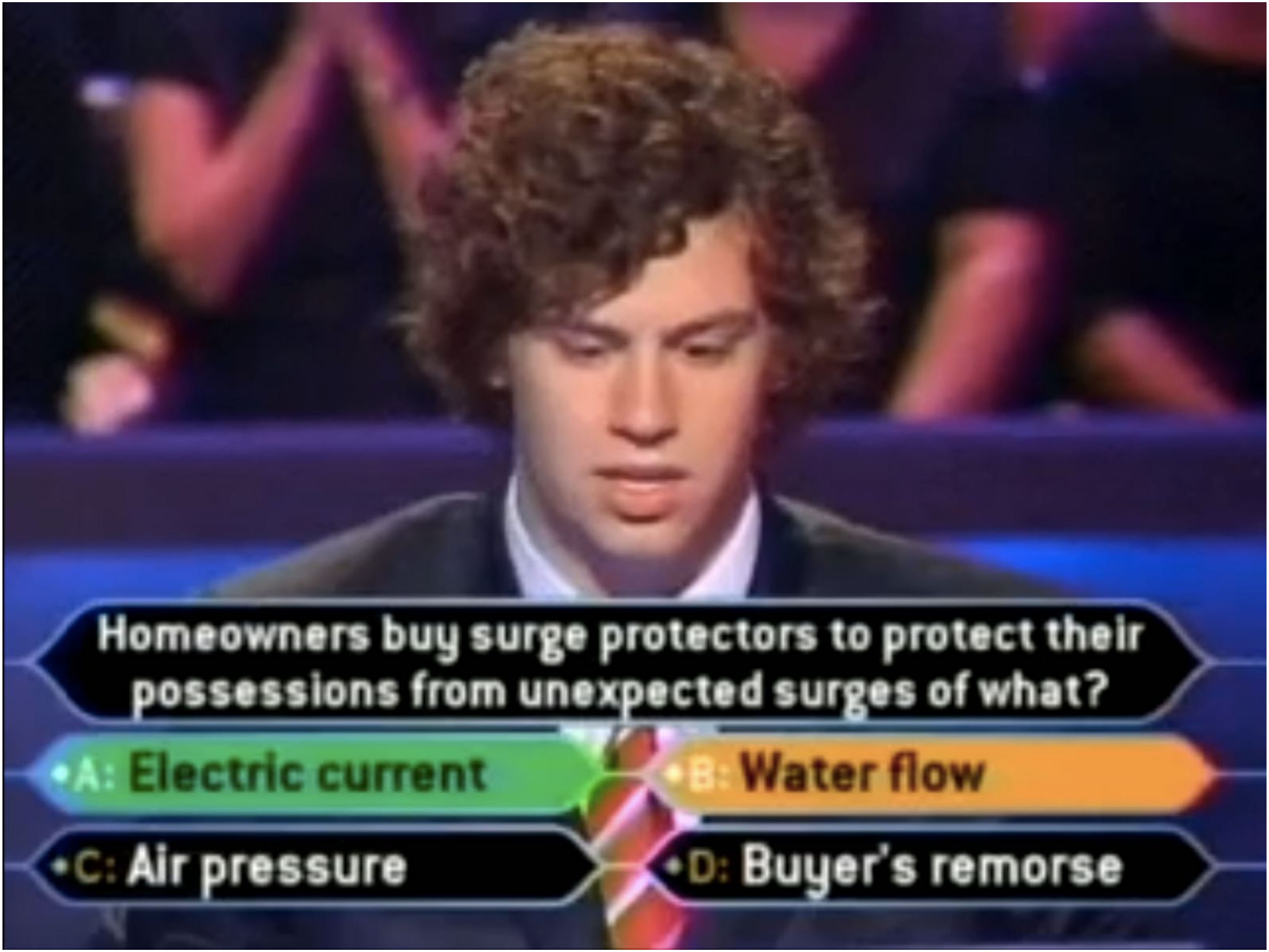
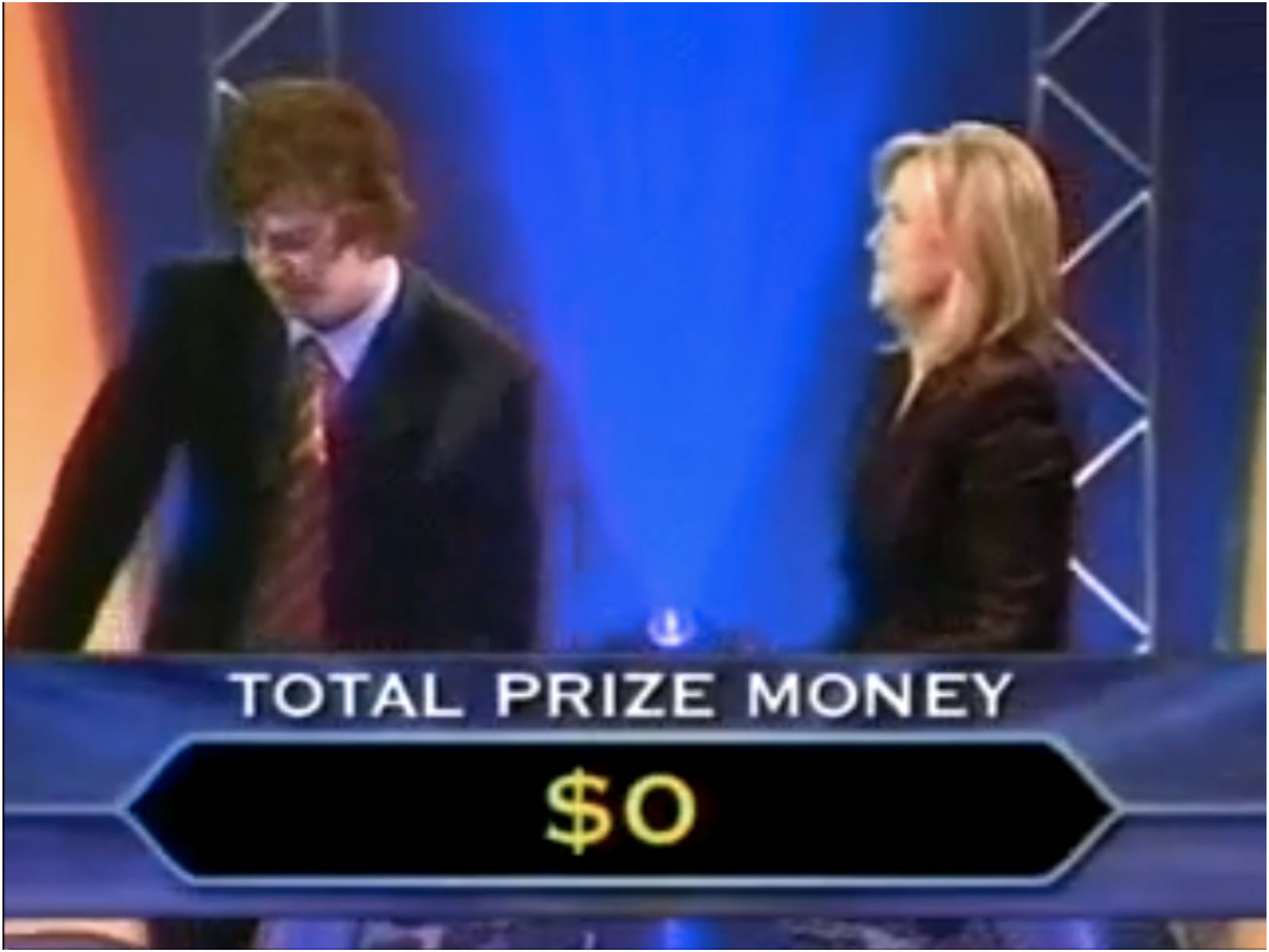

Homeowners buy surge protectors to protect their possessions from unexpected surges of what?
A: Electric current
B: Water flow
C: Air pressure
D: Buyer's remorse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ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF "JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD."

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

equipment, and to Dr. G. E. R. Deacon and the captain and officers of R.R.S. *Discovery II* for their part in making the observations.

[1] Young, F. B., Gerrard, H., and Jevons, W., *Phil. Mag.*, **40**, 149 (1920).
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[4] Ekman, V. W., *Arkiv. Mat. Astron. Fysik. (Stockholm)*, **2** (11) (1905).

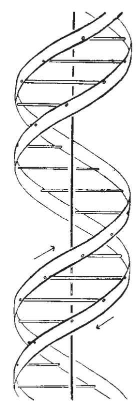
MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid

WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three inter-twined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe that the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces would hold the structure together, especially as the negatively charged phosphates near the axis will repel each other. (2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has also been suggested by Fraser (in the press). In his model the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rat...



This figure is purely diagrammatic. The two ribbons symbolize the two phosphate—sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis

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is a residue on each chain every 3·4 A. in the *z*-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical *z*-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows: purine position 1 to pyrimidine position 1; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are: adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine; similarly for guanine and cytosine. The sequence of bases on a single chain does not appear to be restricted in any way. However, if only specific pairs of bases can be formed, it follows that if the sequence of bases on one chain is given, then the sequence on the other chain is automatically determined.

King's College, London. One of us (J. D. W.) has been aided by a fellowship from the National Foundation for Infantile Paralysis.

J. D. WATSON
F. H. C. CRICK

Medical Research Council Unit for the Study of the Molecular Structure of Biological Systems, Cavendish Laboratory, Cambridge.
April 2.

[1] Pauling, L., and Corey, R. B., *Nature*, **171**, 346 (1953); *Proc. U.S. Nat. Acad. Sci.*, **39**, 84 (1953).
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[6] Wilkins, M. H. F., and Randall, J. T., *Biochim. et Biophys. Acta*, **10**, 192 (1953).

Initial sequencing and analysis of the human genome

International Human Genome Sequencing Consortium*

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Why we need to understand group performance

- As work becomes more complex, groups become more crucial:
  – Medicine is increasingly team-based
  – Over half of the articles produced in the natural and social sciences are authored by more than one person
  – The average size of teams producing patents and scientific articles nearly doubled between 1955 and 2000
- Many groups perform a wide variety of tasks rather than repeatedly do one particular thing
- BUT: smart people can choose horrible group processes!

  → The intelligence of a group as a whole—the group's *collective intelligence*—may not be determined just by the intelligence of its individual members

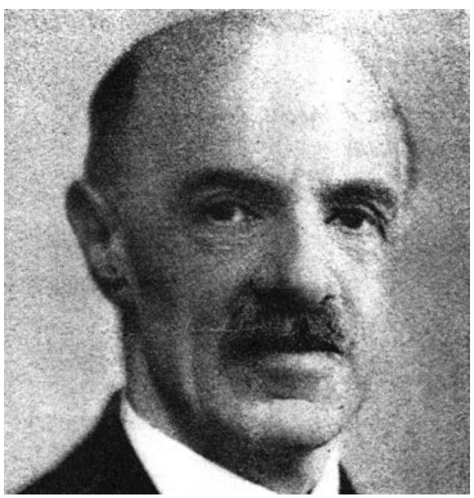
"For each individual among the many has a share of excellence and practical wisdom, and when they meet together, just as they become in a manner one man, who has many feet, and hands, and senses, so too with regard to their character and thought."

— Aristotle, *Politics,* c. 350 B.C.E.

The Law of General Intelligence (*g*)

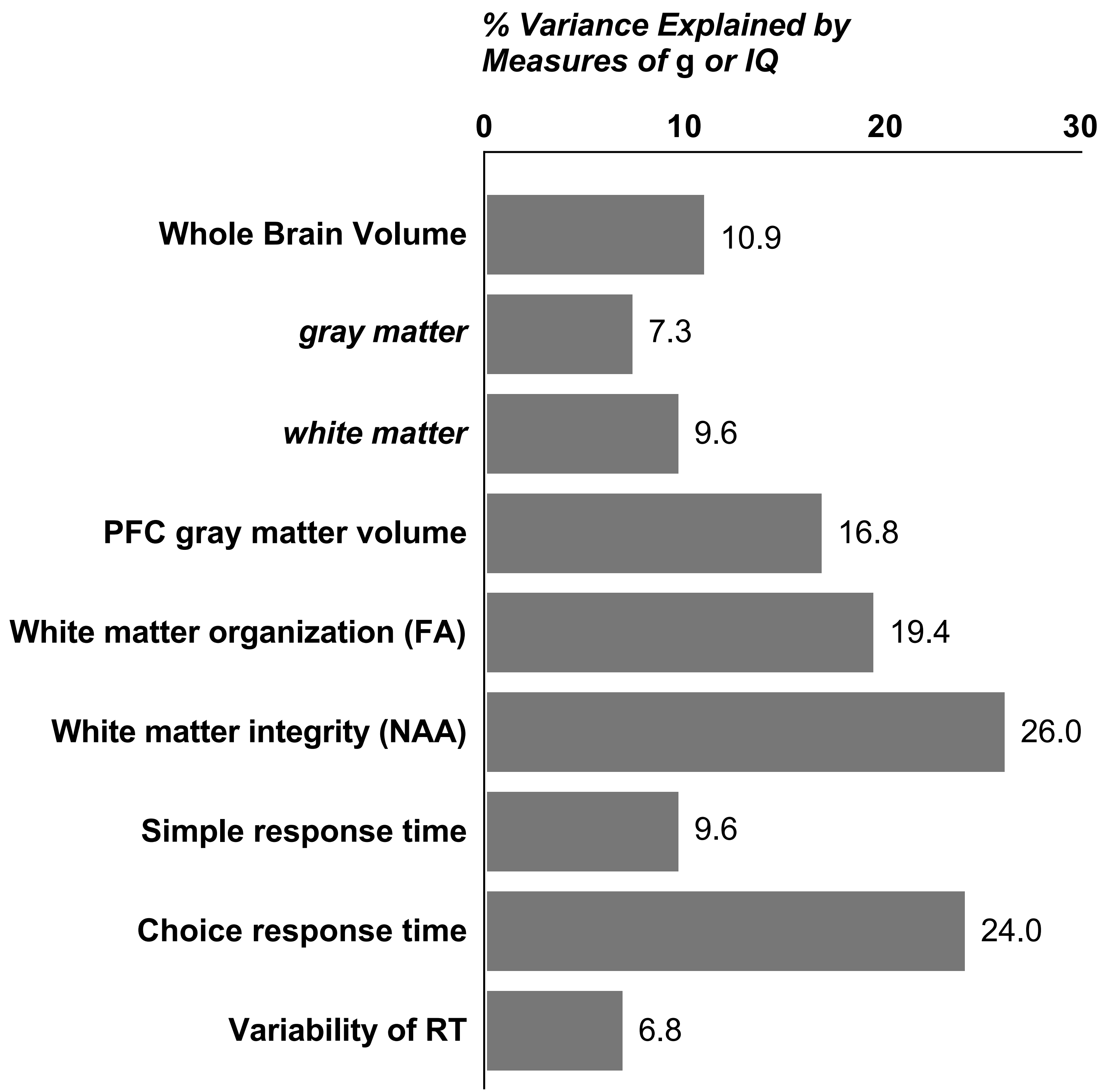
	RAPM	WM	VF	RT	MR	Coo	Cat	***g***
Raven's Advanced Progressive Matrices	—							.50
Working Memory	**.39**	—						.46
Verbal Fluency	**.36**	**.48**	—					.42
Response Time	**.41**	**.28**	**.41**	—				.39
Mental Rotation	**.41**	**.29**	.15	**.21**	—			.34
Coordinate Spatial Encoding	**.32**	**.30**	.07	–.02	.04	—		.25
Categorical Spatial Encoding	**.21**	.12	–.02	.13	.16	**.21**	—	.20

(N = 111, g = 36%)

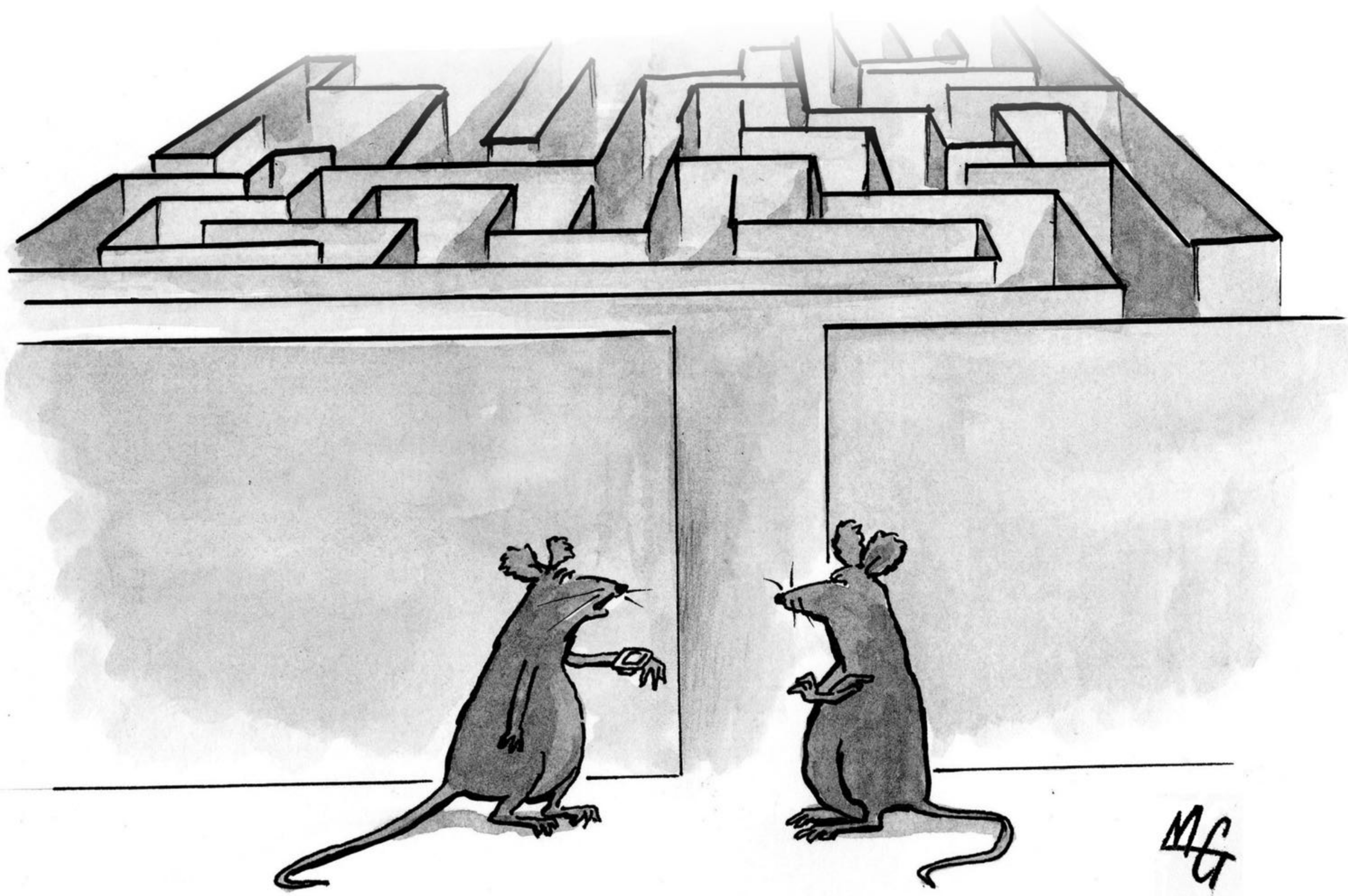


Measurements of cognitive ability tend to correlate positively across individuals (Spearman)

Chabris (2007)



Chabris (2007)



"This GPS eliminates the guesswork."

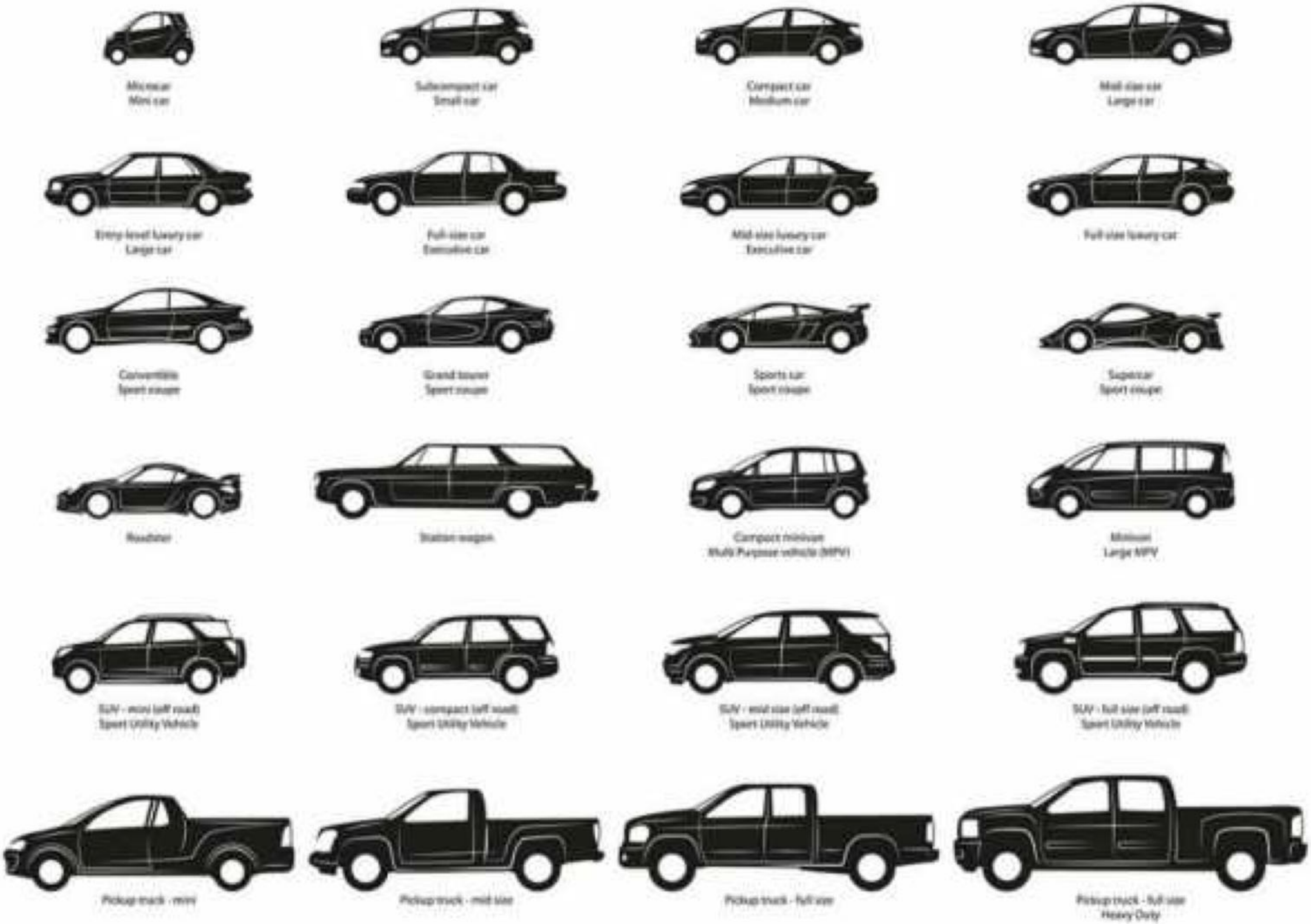
General intelligence in mice

	BP	HW(l)	PP	HW(e)	MWM	TM	***g***
Burrowing Puzzle	—						.66
Hebb-Williams Maze (latency)	.21	—					.65
Plug Puzzle	**.52**	**.30**	—				.62
Hebb-Williams Maze (errors)	.12	**.32**	.13	—			.60
Morris Water Maze	**.25**	**.39**	.05	.18	—		.56
T Maze	.32	**.22**	.06	.17	.14	—	.40

(N = 84, g = 35%)

Galsworthy et al. (*Behavior Genetics*, 2005); Chabris (2007)


Banerjee, Chabris, et al. (*PLOS One,* 2010)


Microcar
Mini car
Subcompact car
Small car
Compact car
Medium car
Mid size car
Large car
Entry level luxury car
Large car
Full-size car
Executive car
Mid-size luxury car
Executive car
Full size luxury car
Convertible
Sport coupe
Grand tourer
Sport coupe
Sports car
Sport coupe
Supercar
Sport coupe
Roadster
Station wagon
Compact minivan
Multi Purpose vehicle (MPV)
Minivan
Large MPV
SUV - mini (off road)
Sport Utility Vehicle
SUV - compact (off road)
Sport Utility Vehicle
SUV - mid size (off road)
Sport Utility Vehicle
SUV - full size (off road)
Sport Utility Vehicle
Pickup truck - mini
Pickup truck - mid size
Pickup truck - full size
Pickup truck - full size
Heavy Duty

12.9-in. iPad Pro	10.5-in. iPad Pro	iPad	iPad mini 4
			
12.9″	**10.5″**	**9.7″**	**7.9″**
Retina display ProMotion technology and True Tone display	Retina display ProMotion technology and True Tone display	Retina display	Retina display
A10X	A10X	A10	A8
A10X Fusion chip	A10X Fusion chip	A10 Fusion chip	A8 chip
12MP	**12MP**	**8MP**	**8MP**
photos and 4K HD video recording	photos and 4K HD video recording	photos and 1080p HD video recording	photos and 1080p HD video recording

Discovering the *c*-factor: Study 1 design

- 40 teams of 3 people each
- 51% of subjects male; average age 32 (range 18–66)
- Each subject completed individual IQ test
- Groups worked together, face-to-face, on 5-task battery:
  – Brainstorming
  – Group matrix reasoning
  – Group moral reasoning
  – Plan shopping trip
  – Group typing
- Groups completed a more complex task (“video game” = playing checkers vs. computer)

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

Discovering the *c*-factor: Study 1 results

	1	2	3	4	5	6	7	8
1 Collective intelligence (*c*)								
2 Brainstorming	0.38*							
3 Group matrix reasoning	0.86**	0.30*						
4 Group moral reasoning	0.42*	0.12	0.27					
5 Plan shopping trip	0.66**	0.21	0.38*	0.18				
6 Group typing	0.80**	0.13	0.50**	0.25*	0.43*			
7 Avg member intelligence	0.19	0.11	0.19	0.12	−0.06	0.22		
8 Max member intelligence	0.27	0.09	0.33*	0.05	−0.04	0.28	0.73**	
9 Video game	0.52*	0.17	0.38*	0.37*	0.39*	0.44*	0.18	0.13

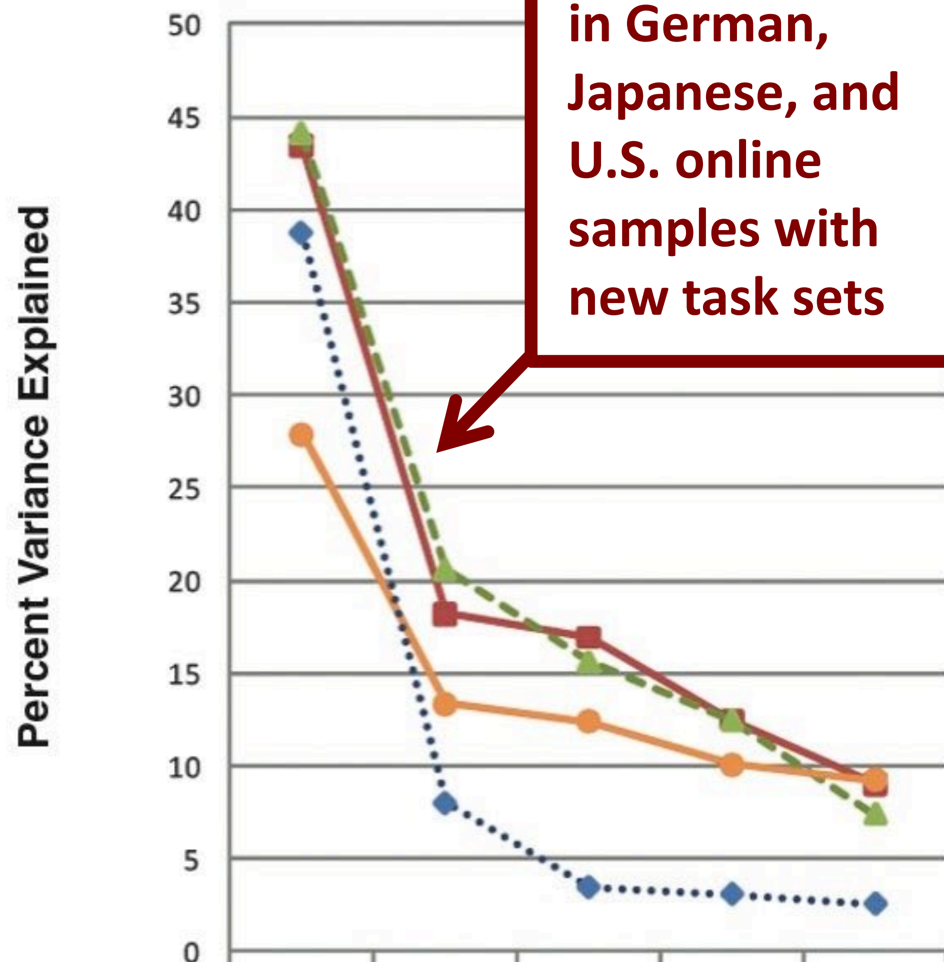
***c*-factor = 43%**

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

Replicating the *c*-factor: Study 2

- 579 subjects @ two sites
- 152 teams of 2–5 people
- Additional individual measures (personality traits, social intelligence) + different IQ test (WPT instead of RAPM)
- Individuals rated satisfaction, motivation, psychological safety, and group's cohesiveness
- Sociometric badges recorded turn-taking during discussions

replicated again in German, Japanese, and U.S. online samples with new task sets



	1	2	3	4	5
Study 1	43.39	18.18	16.93	12.46	9.04
Study 2 (five tasks)	44.07	20.54	15.57	12.44	7.39
Study 2 (ten tasks)	27.86	13.35	12.40	10.08	9.24
Indiv Intelligence Test	38.77	8.01	3.47	3.11	2.58

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

Meta-analysis (17 studies, 985 teams, 3777 individuals)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Brainstorm Object (1)							
Brainstorm Words (2)	0.24**						
Matrix Reasoning (3)	0.24***	0.16**					
Unscramble Words (4)	0.21***	0.33***	0.19***				
Memory Picture (5)	0.11	0.13***	0.27**	0.17***			
Sudoku (6)	0.19***	0.26***	0.25***	0.30***	0.19**		
Typing Numbers (7)	0.17***	0.05	0.28***	0.15*	0.13***	0.16*	
Typing Text (8)	0.19***	−0.02	0.27***	0.13**	0.16***	0.10*	0.36***

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Woolley et al., *Collective Intelligence 2017*

ELSEVIER
Contents lists available at ScienceDirect
Intelligence

Smart groups of smart people: Evidence for IQ as the origin of collective intelligence in the performance of human groups

CrossMark

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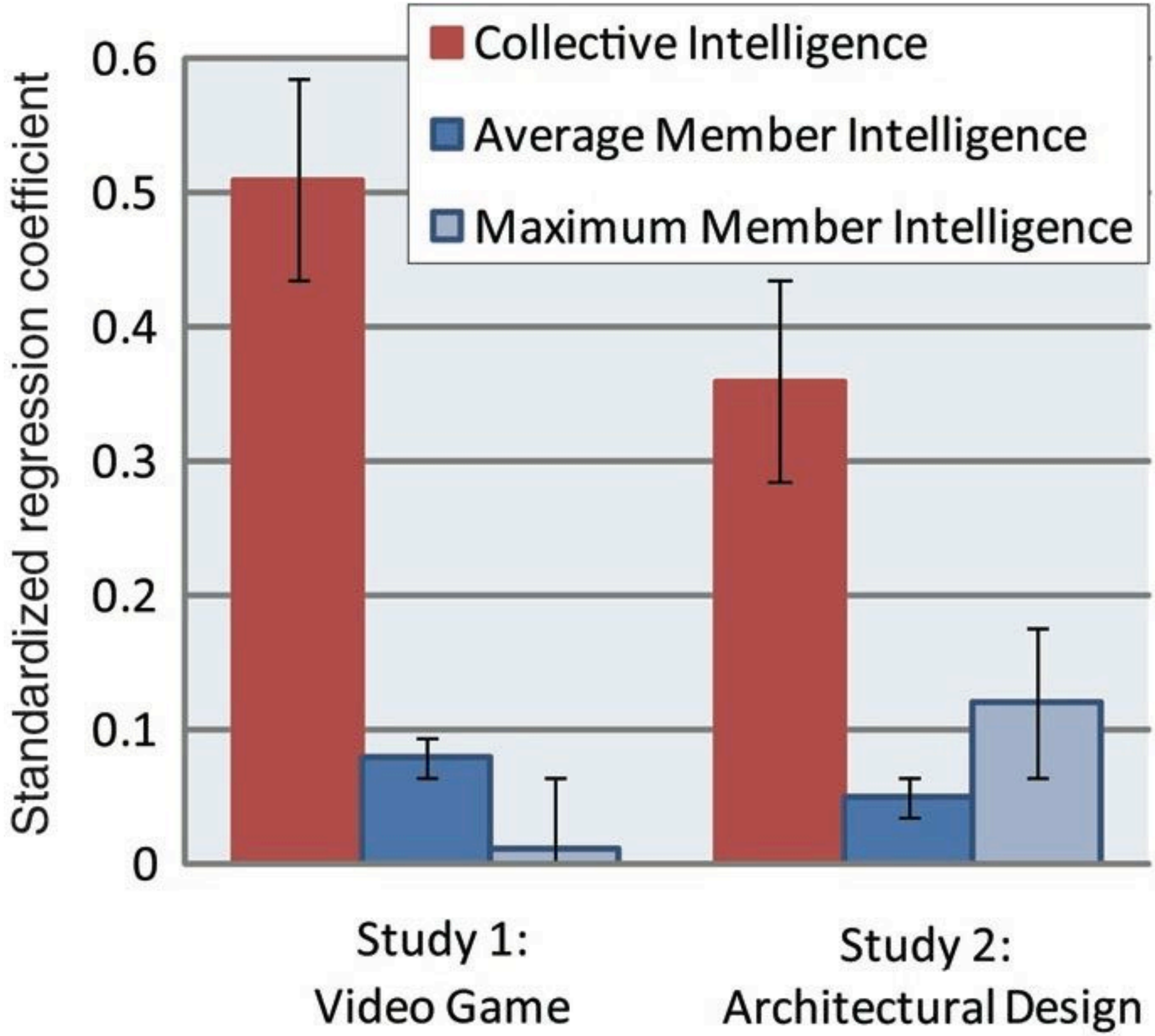
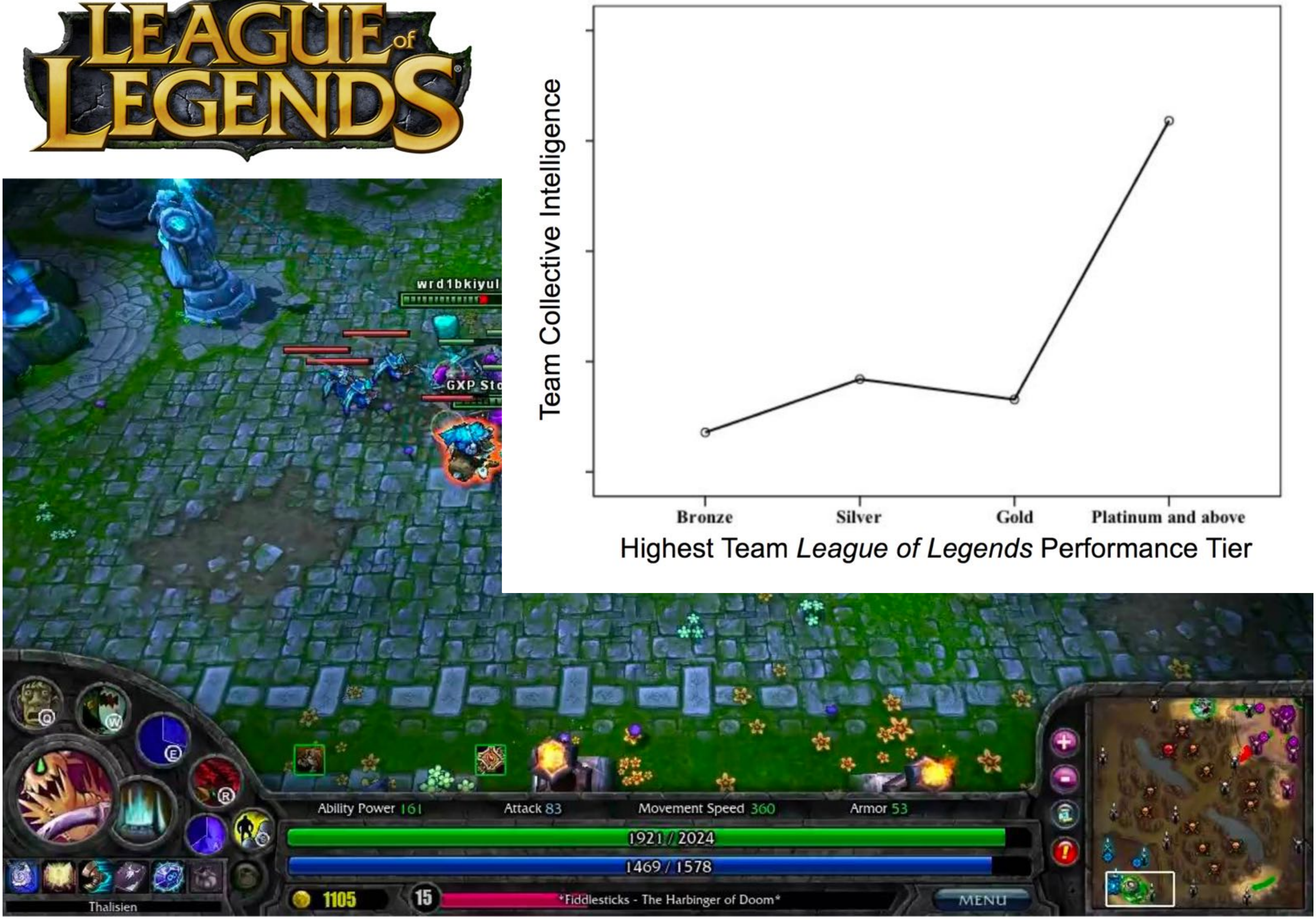
Not As Smart As We Think: A Study of Collective Intelligence in Virtual Groups

Jordan B. Barlow & Alan R. Dennis

c predicts complex task performance



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



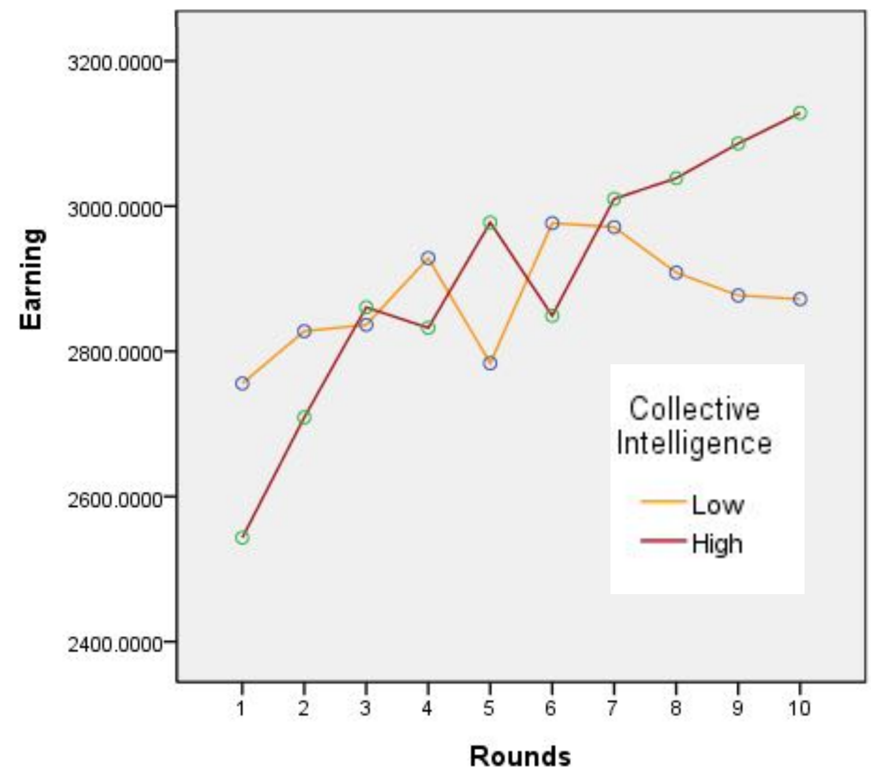
Kim et al., *Proceedings of CSCW 2017*

High-*c* groups earn more in tacit coordination game

- 98 teams did our collective intelligence test and played a 10-round "tacit coordination" game for real stakes (up to $10 per person)
- *c* did not predict earnings in initial round
- *c* → rate of increase in earnings: $r = .33$, $p < .01$
- *c* → 6% incremental variance after controlling for average IQ

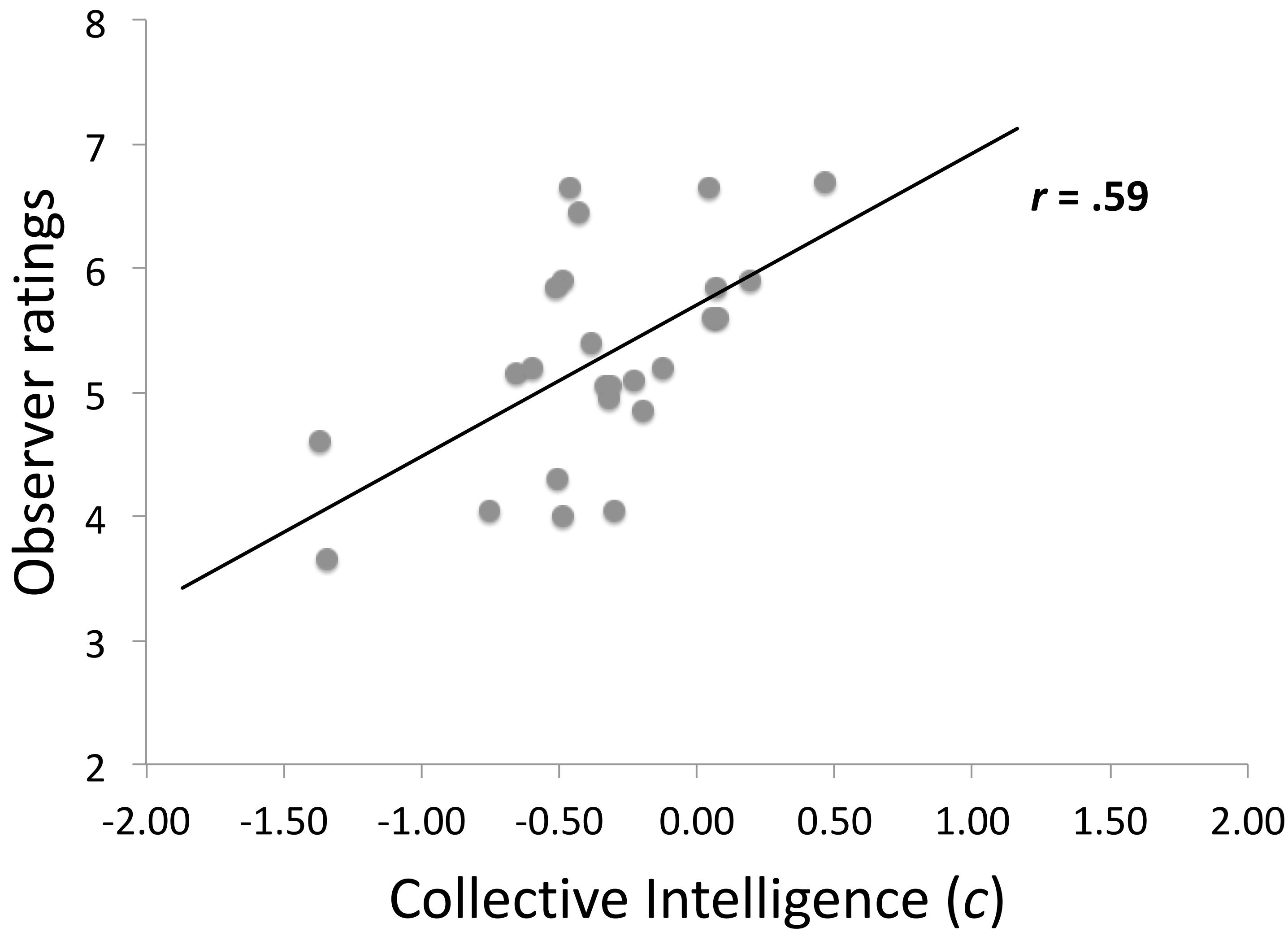
Minimum of Group Member Choices

Individual's Choice	0	10	20	30	40
0	2400				
10	2200	2800			
20	1600	2600	3200		
30	600	2000	3000	3600	
40	–800	1000	2400	3400	4000

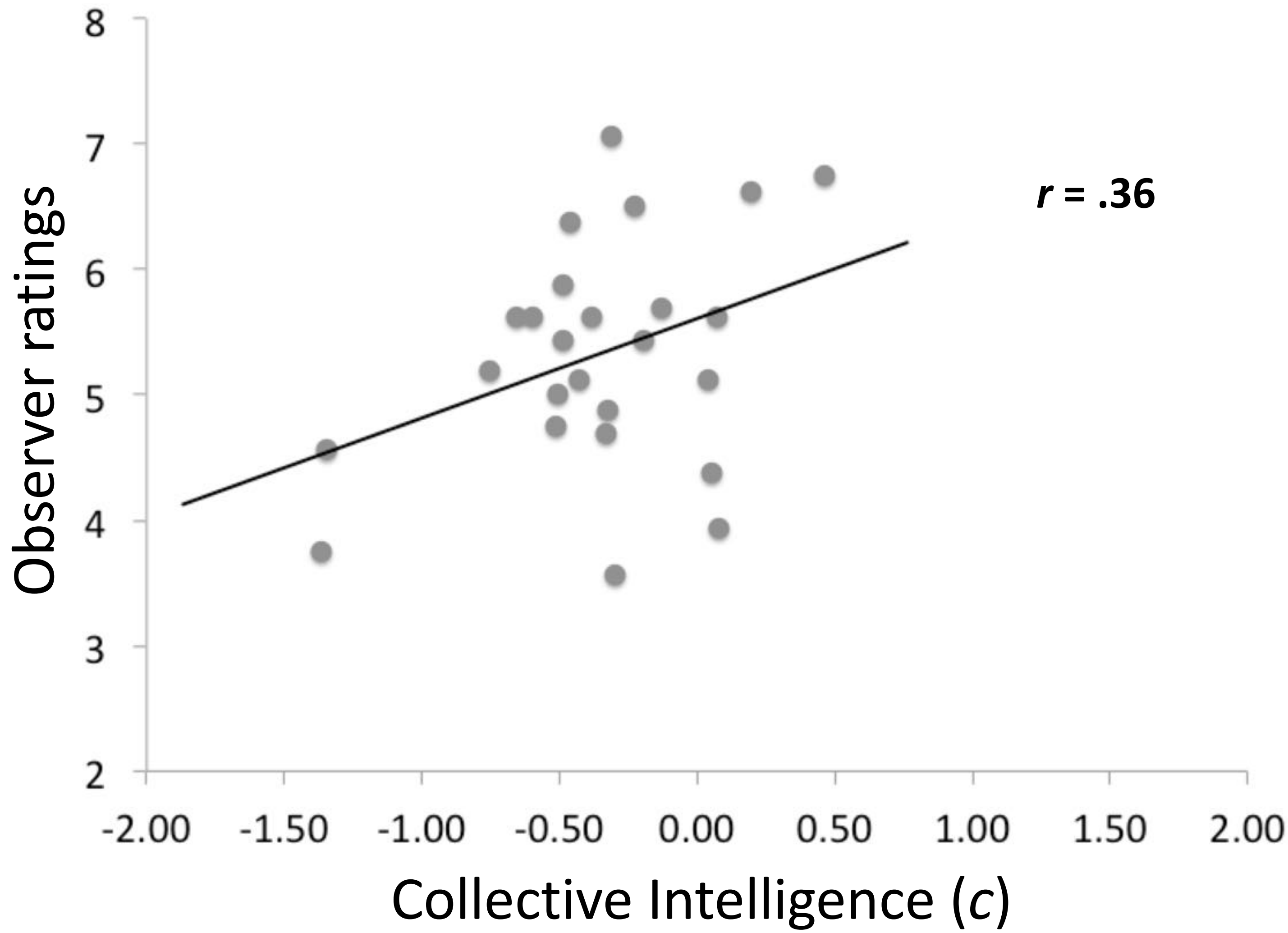


Aggarwal et al., *Collective Intelligence 2015*

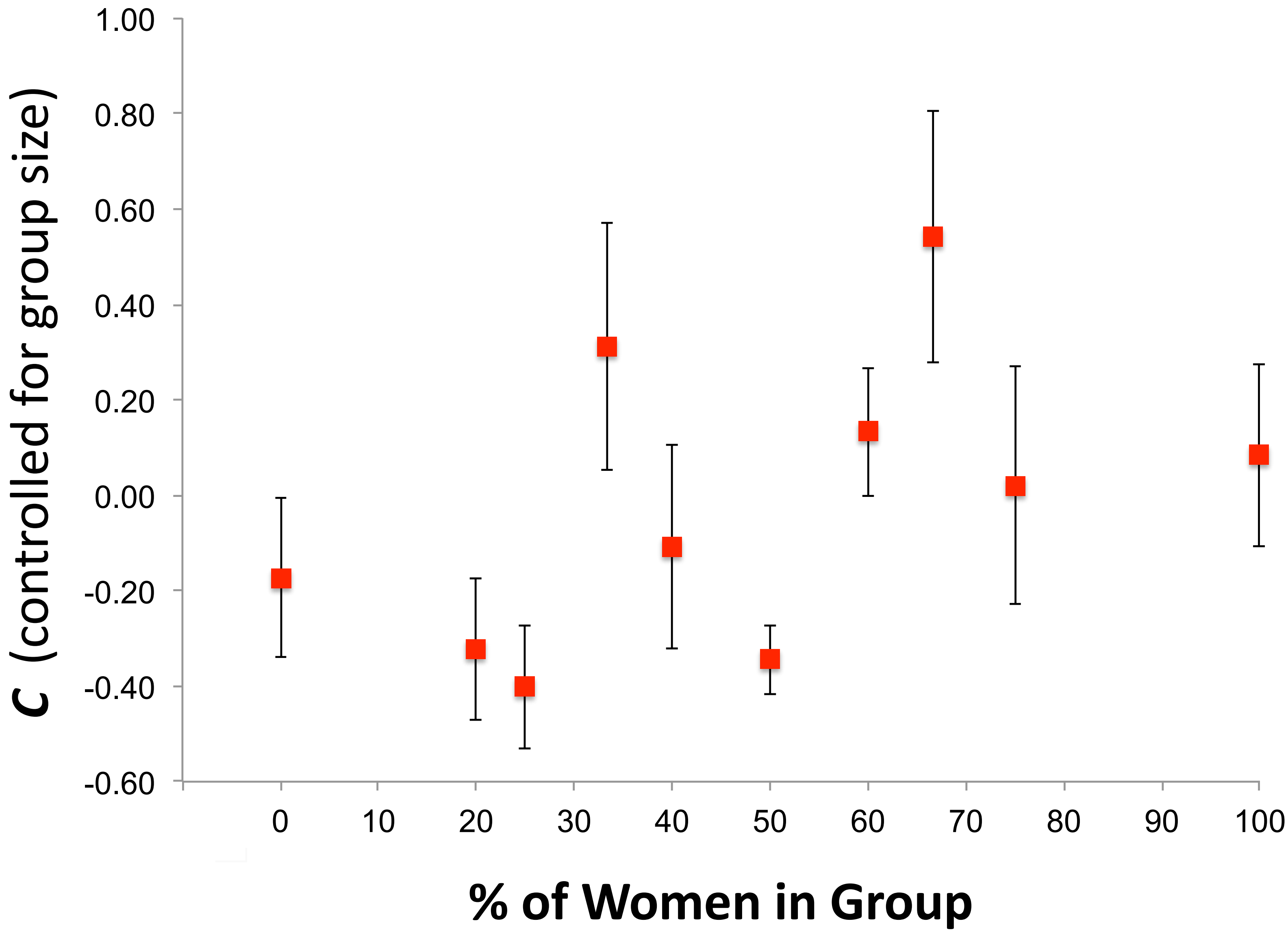
Recognizing *c* – Group Matrix Reasoning Task



Recognizing *c* – Group Moral Reasoning Task



% of women and collective intelligence



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

What explains collective intelligence?

- ***Turn-taking* in the group**

  – measured by MIT Media Lab sociometric badges

  – the more even the distribution of # of speaking turns among the members, the smarter the group (r = .41, p = .01)

- **Proportion of *women* in the group** (r = .23, p = .007)

- **Average *social intelligence* of group members** (r = .26, p = .002)

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

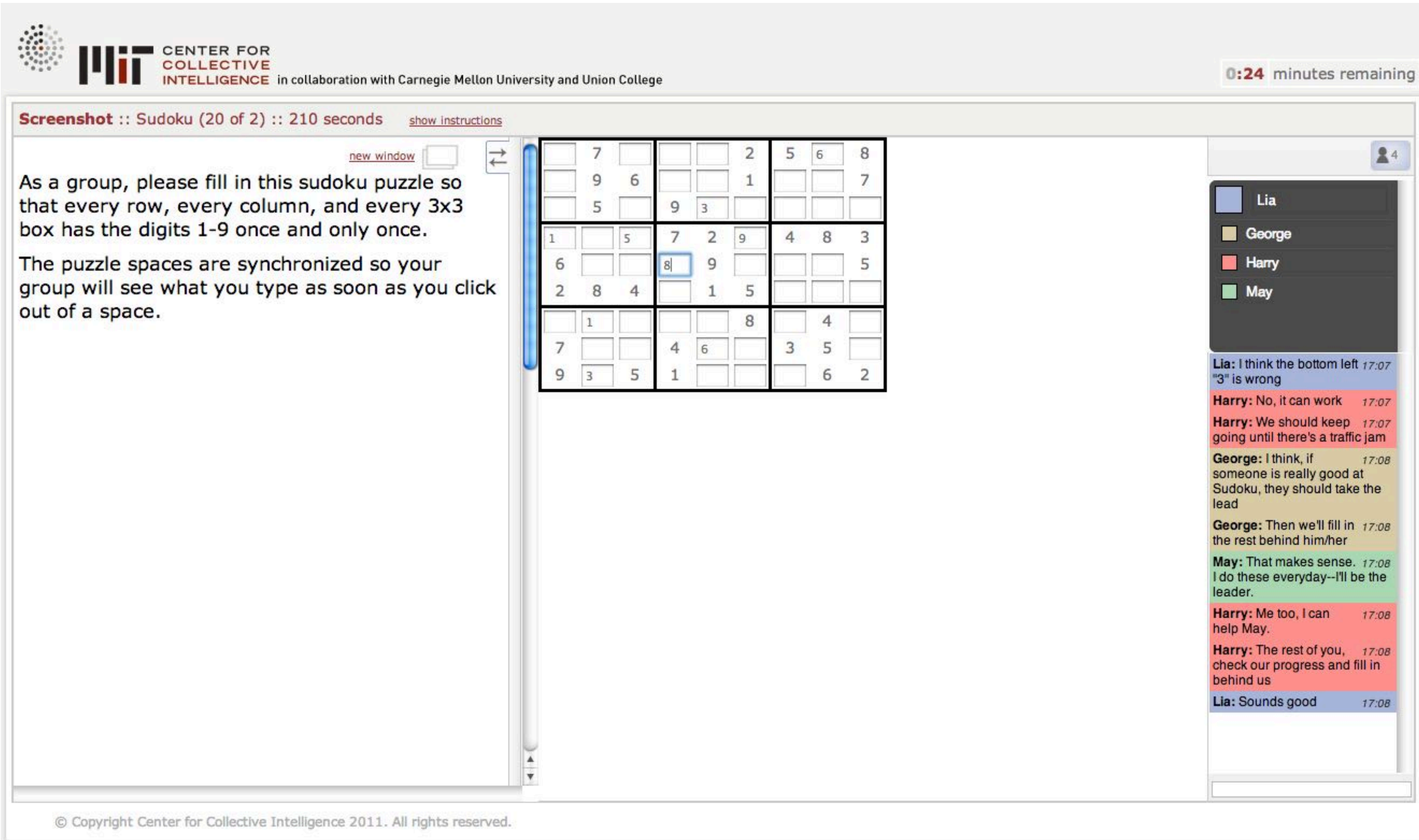
Social intelligence explains collective intelligence

- Measured by *Reading the Mind in the Eyes* (RME) test:
  – Example: terrified, upset, arrogant, or annoyed?

  – Example: playful, comforting, irritated, or bored?

- How do we know this is social intelligence and not just facial expression processing?

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



CENTER FOR COLLECTIVE INTELLIGENCE in collaboration with Carnegie Mellon University and Union College
0:24 minutes remaining
Screenshot :: Sudoku (20 of 2) :: 210 seconds
show instructions
new window
As a group, please fill in this sudoku puzzle so that every row, every column, and every 3x3 box has the digits 1-9 once and only once.
The puzzle spaces are synchronized so your group will see what you type as soon as you click out of a space.
7 2 5 6 8
9 6 1 7
5 9 3
1 5 7 2 9 4 8 3
6 8 9 5
2 8 4 1 5
1 8 4
7 4 6 3 5
9 3 5 1 6 2
4
Lia
George
Harry
May
Lia: I think the bottom left "3" is wrong 17:07
Harry: No, it can work 17:07
Harry: We should keep going until there's a traffic jam 17:07
George: I think, if someone is really good at Sudoku, they should take the lead 17:08
George: Then we'll fill in the rest behind him/her 17:08
May: That makes sense. I do these everyday--I'll be the leader. 17:08
Harry: Me too, I can help May. 17:08
Harry: The rest of you, check our progress and fill in behind us 17:08
Lia: Sounds good 17:08
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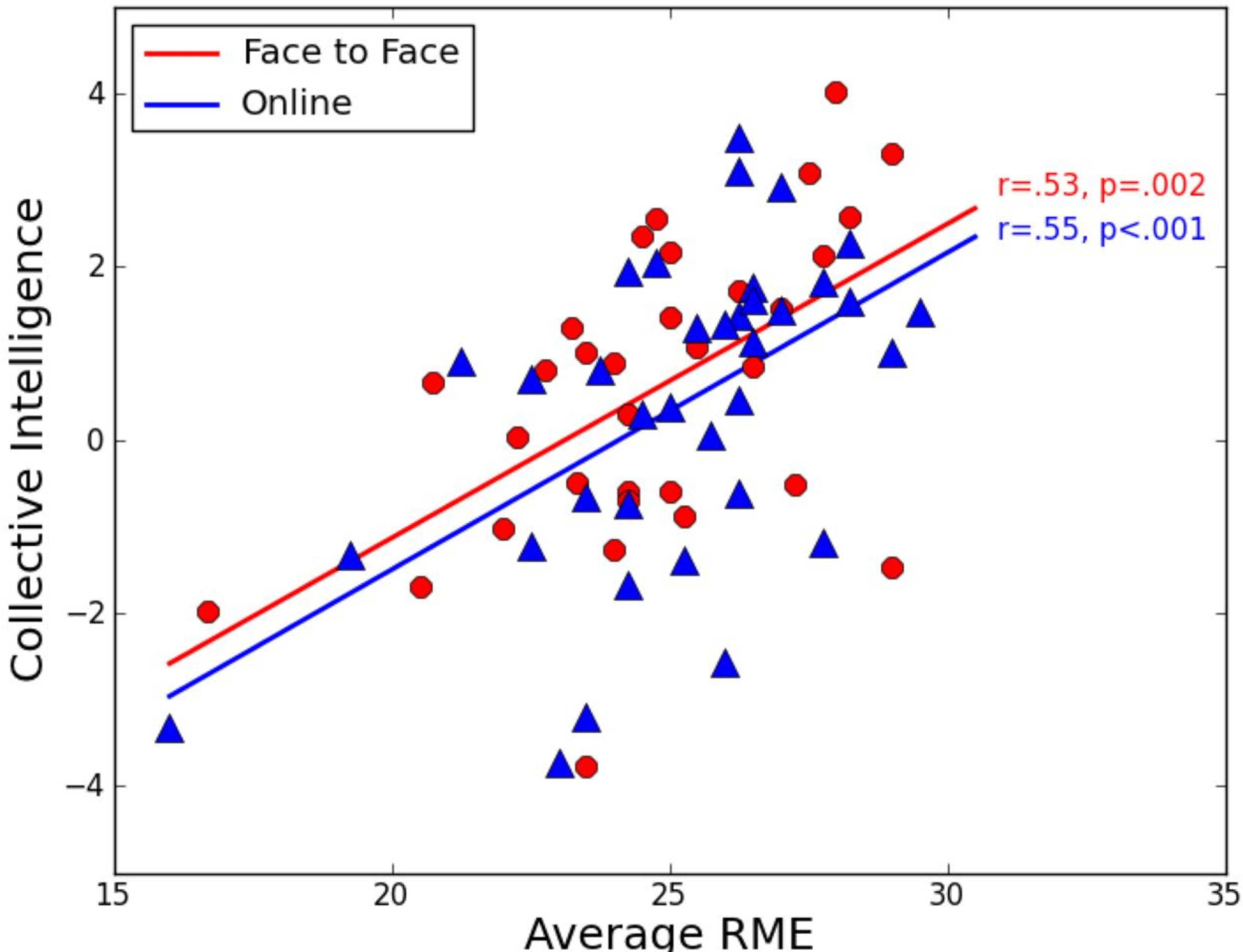
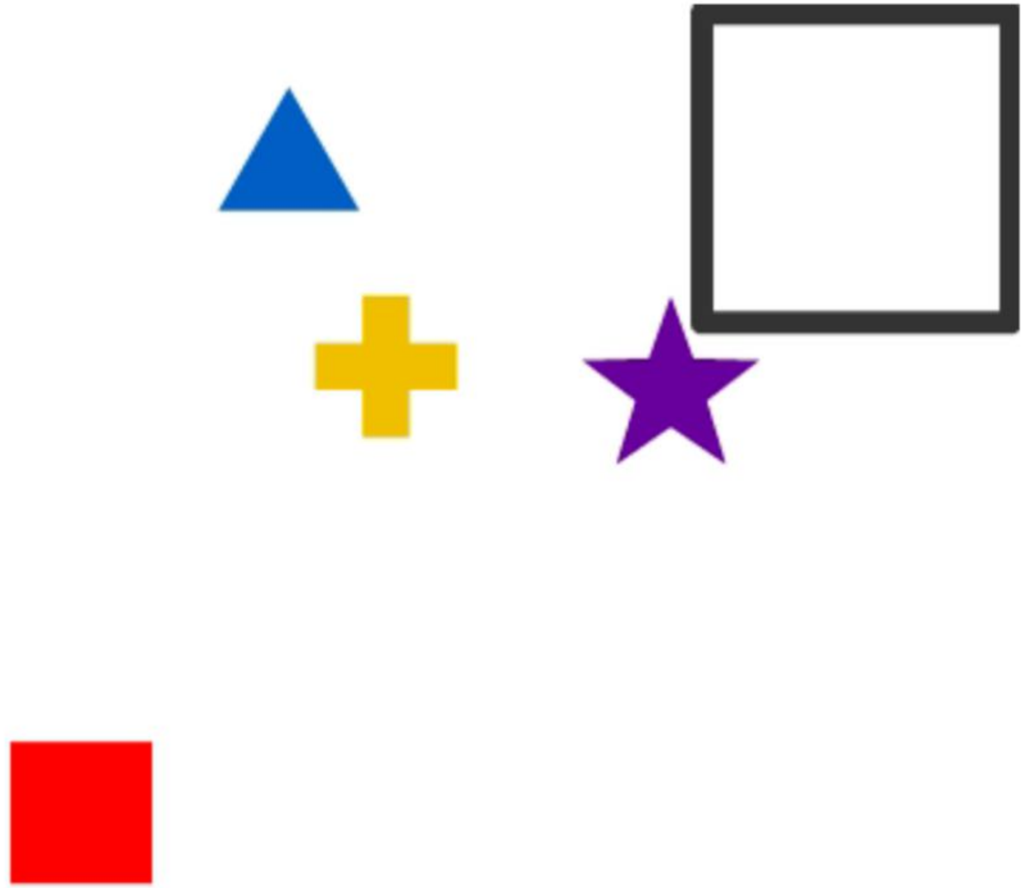
Reading the Mind in the Eyes test predicts *c* equally online or face to face



Engel et al. (*PLoS One,* 2014)



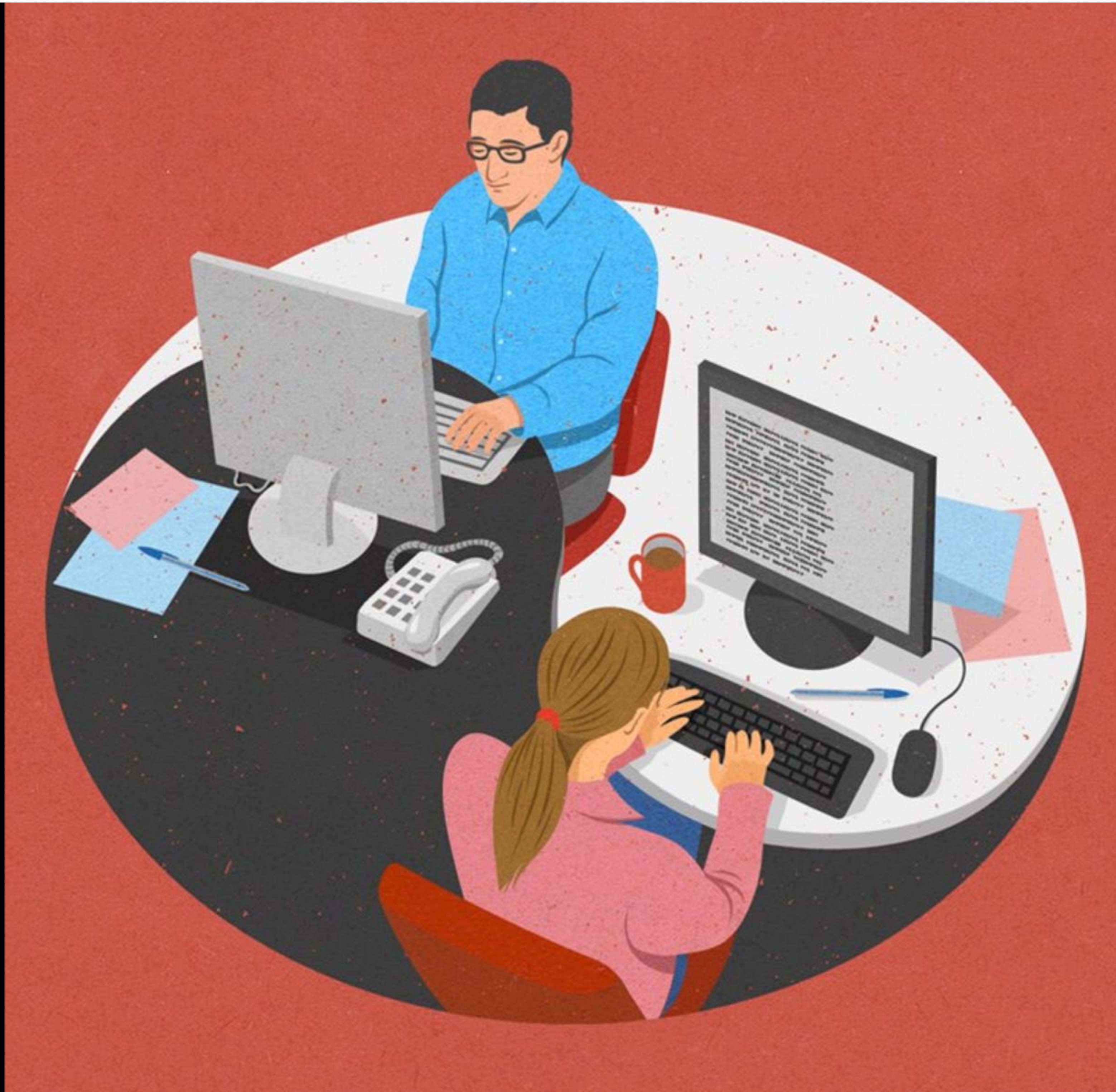
Who is being rude?

(a) yellow + (b) purple ☆

(c) red ▢ (d) blue △

Implications of collective intelligence

- Measurability of *c* provides foundation for a new approach to the science of group performance
  - an important factor to control for or consider
  - a way to link individual and group levels in cognition
- Better understanding of collective intelligence can help to improve individual decision-making
- Enhancing collective intelligence could be a strategic aim for organizations
- Collective intelligence may be easier to enhance than individual *g*
  - change composition of team
  - change interaction processes and support mechanisms
  - add computers, AI, machine learning to human teams



SUMMING UP

Thank you!

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