Kognitionspsychologie II: Session 2

What is intelligence?

Rui Mata, FS 2022

Learning Objectives for Session 2

- Recall the (consensual!) definition of intelligence and list a few empirical findings that demonstrate why intelligence (testing) matters
- Understand the psychometric approach to measuring intelligence and discuss past (and current) debates about the structure of intelligence
- Name a few intelligence batteries/tests, and identify their most important characteristics
- Compare and distinguish different neural models of intelligence
- Discuss potential overlap and conflict between psychometric and neural models of intelligence

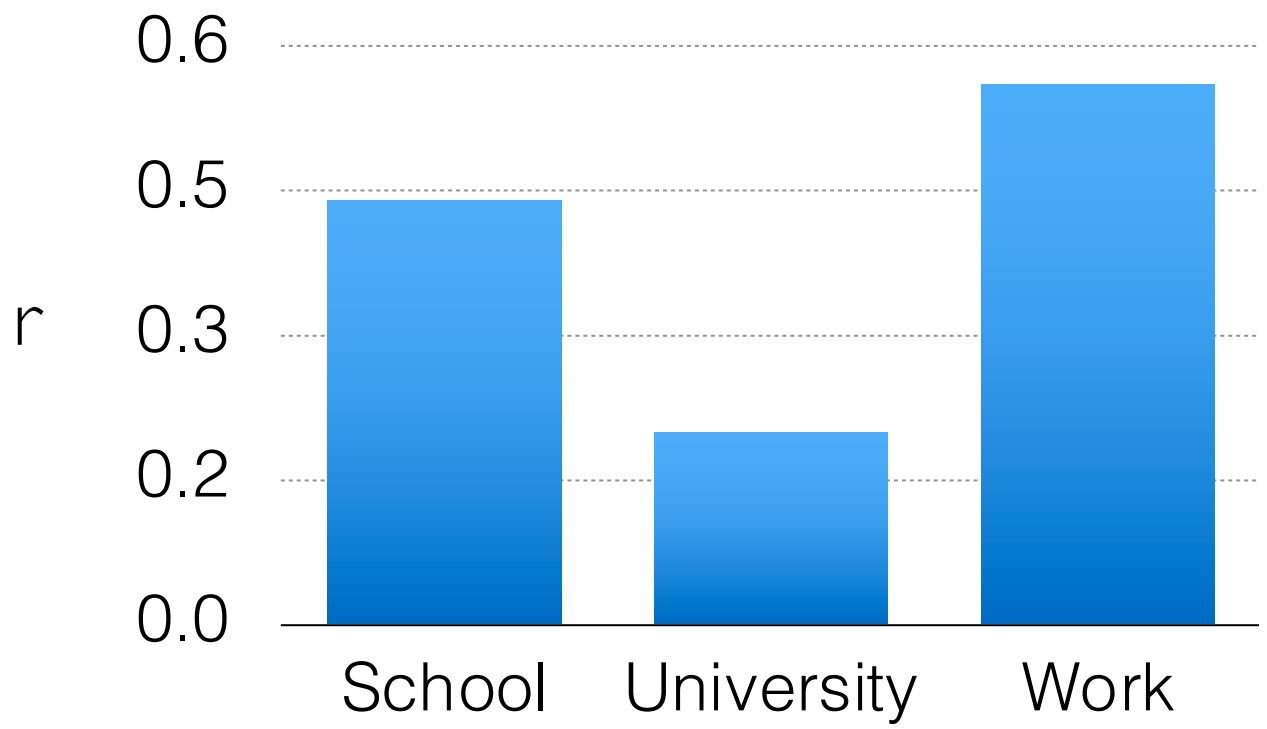
Consensus on Intelligence

"Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do. Intelligence, so defined, can be measured, and intelligence tests measure it well."

Gottfredson, L. S. (1997) Mainstream science on intelligence: An editorial with 52 signatories, history, and bibliography. Intelligence, 24, 13–23.

[cf. Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., & Turkheimer, E. (2012). Intelligence: New Findings and Theoretical Developments. *American Psychologist, 67*, 130-159]

Intelligence is a Predictor of Academic and Work Performance



Roth, B., Becker, N., Romeyke, S., Schäfer, S., Domnick, F., & Spinath, F. M. (2015). Intelligence and school grades: A meta-analysis. ***Intelligence***, ***53***(C), 118–137.

Richardson, M., Abraham, C. & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. ***Psychological Bulletin, 138***, 353-387.

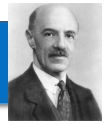
Schmidt, F. L., & Hunter, J. E. (1998). The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. ***Psychological Bulletin. 124***, 262-274.

The Psychometric Approach to Intelligence

Perspectives

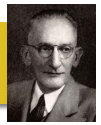
Intelligence as a general ability

Charles E. Spearman (1863-1945)



Intelligence as the product of specific faculties

Louis L. Thurstone (1887-1955)



1900 1925 1950 1975 2000

The Psychometric Approach to Intelligence

Spearman's correlation matrix for six measures of school performance. All the correlations are positive, a phenomenon referred as the *positive manifold*. The bottom row shows the *g* loadings of each performance measure.[5]

	Classics	French	English	Math	Pitch	Music
Classics	-					
French	.83	-				
English	.78	.67	-			
Math	.70	.67	.64	-		
Pitch discrimination	.66	.65	.54	.45	-	
Music	.63	.57	.51	.51	.40	-
g	.958	.882	.803	.750	.673	.646

http://setosa.io/ev/principal-component-analysis/

The Psychometric Approach to Intelligence

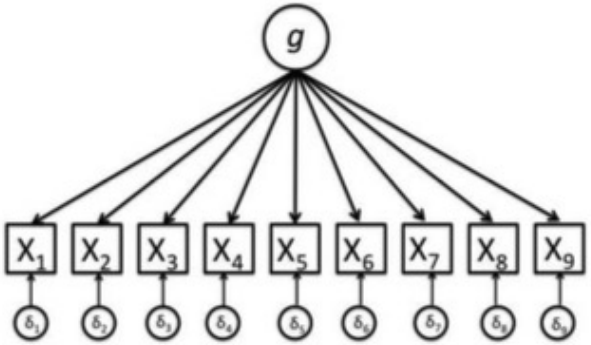


Figure 1. A model depicting Spearman's original conception of a single general factor.

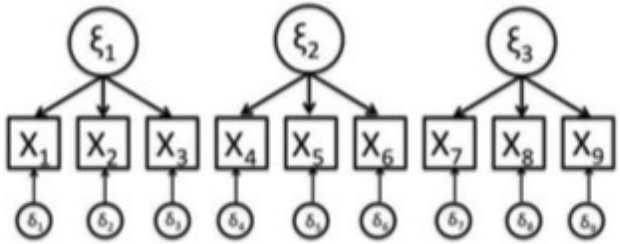


Figure 2. A model depicting Thurstone's original (but later revised) conception of orthogonal group factors.

Both models capture important aspects of intellectual functioning but also neglect others. Sperman's model captures the positive manifold but does not account for the result that some tests are more highly correlated than others. Thurstone's model does not capture the overall correlation between specific abilities.

Kovacs, K., & Conway, A. R. A. (2016). Process Overlap Theory: A unified account of the general factor of intelligence. ***Psychological Inquiry, 27***(3), 151–177. http://doi.org/10.1080/1047840X.2016.1153946

Markon, K. E. (2019). Bifactor and Hierarchical Models: Specification, Inference, and Interpretation. ***Annual Review of Clinical Psychology, 15***(1), 51–69. http://doi.org/10.1146/annurev-clinpsy-050718-095522

The Psychometric Approach to Intelligence

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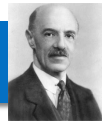

Intelligence as the product of specific faculties

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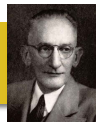


Scales

Stanford-Binet

Army Alpha

Raven

Wechsler

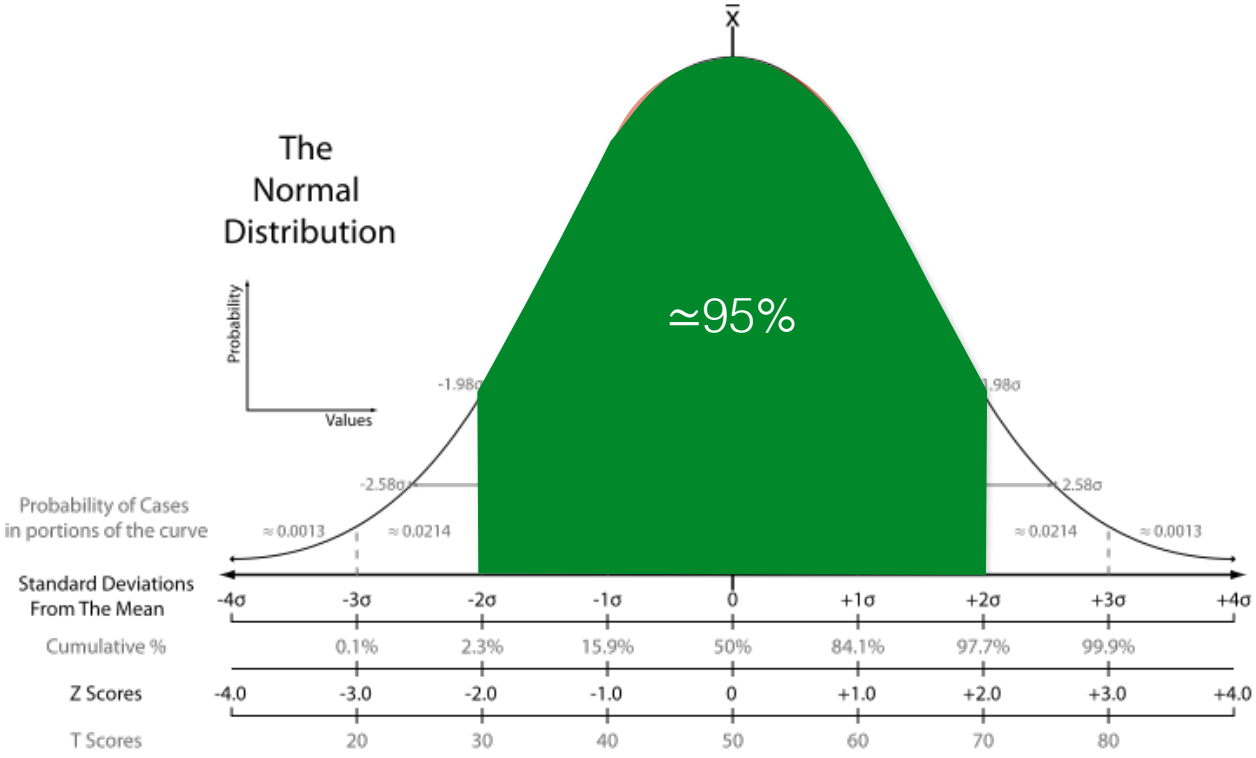
....

1900 1925 1950 1975 2000

The Psychometric Approach to Intelligence

Intelligence (as IQ) is a relative statement

"without variation in mental abilities there would be no latent variables—the last survivor of a meteor collision with Earth would still have cognitive abilities and mental limitations but would not have g." (Kovacs & Conway, 2016, p. 153)



The distribution of test results is standardized as having a mean of 100 and a standard deviation of 15. Consequently, about 2/3 of the population have an IQ between 85 and 115. The larger the distance from 100, the fewer individuals can be found with a given IQ.

http://de.wikipedia.org/wiki/Intelligenzquotient

$$IQ = 100 + 15 \times \frac{\text{Raw score - Mean}}{\text{Standard Deviation}}$$

The Psychometric Approach to Intelligence

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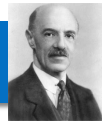

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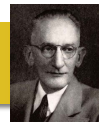
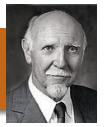


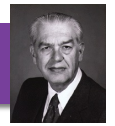
Synthesis: Cattell-Horn-Carroll Model

Raymond B. Cattell (1905-1998)



John L. Horn (1928-2006)

John B. Carroll (1916-2003)



Scales

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The Psychometric Approach to Intelligence

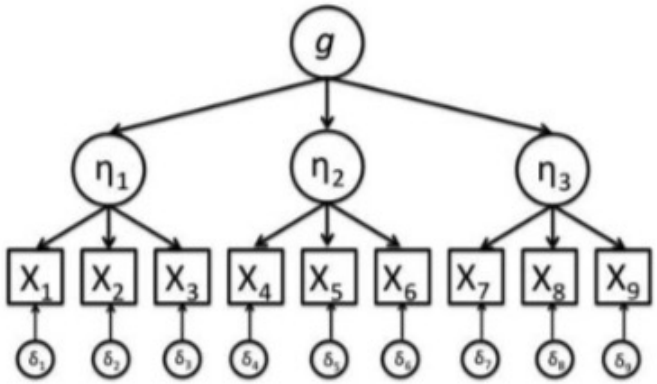

Figure 4. A hierarchical model of cognitive abilities.

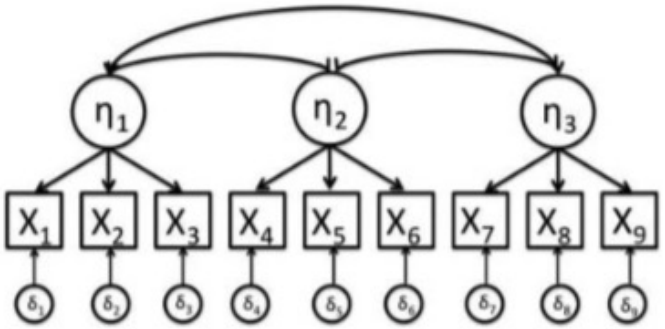

Figure 5. An oblique model of cognitive abilities.

although these models seem structurally different their fits (and predictions) are equivalent, making it difficult to obtain a definitive answer to the structure of mental functions!

Kovacs, K., & Conway, A. R. A. (2016). Process Overlap Theory: A Unified Account of the General Factor of Intelligence. ***Psychological Inquiry, 27***(3), 151–177. http://doi.org/10.1080/1047840X.2016.1153946

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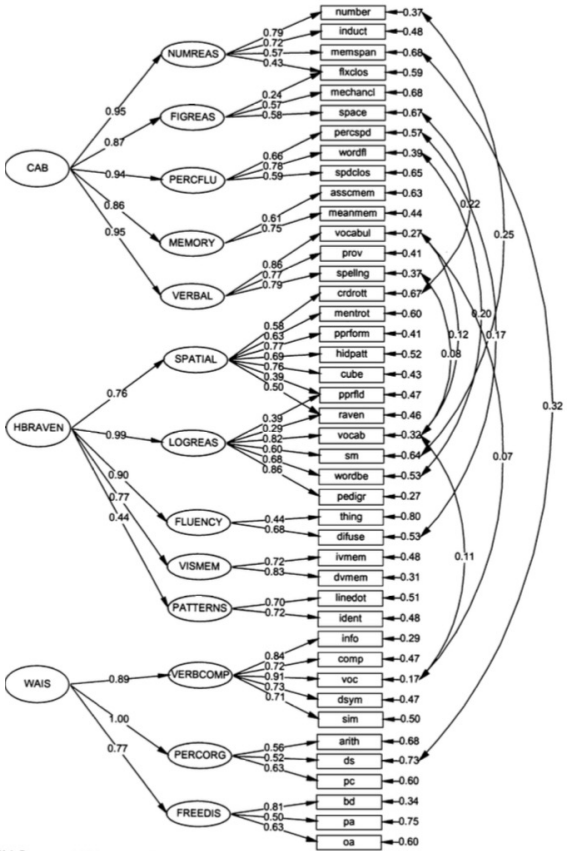
The Psychometric Approach to Intelligence

Convergent validity



"We addressed the extent to which this prediction was true using three mental ability batteries administered to a heterogeneous sample of 436 adults. Though the particular tasks used in the batteries reflected varying conceptions of the range of human intellectual performance, the g factors identified by the batteries were completely correlated (correlations were **.99**, **.99**, and **1.00**). This provides further evidence for the existence of a higher-level g factor and suggests that its measurement is not dependent on the use of specific mental ability tasks."

Johnson W, Bouchard TJ, Krueger RF, McGue M, Gottesman II. (2004). Just one g: Consistent results from three test batteries. Intelligence, 32, 95–107

Johnson, W., Nijenhuis, J. T., & Bouchard, T. J., Jr. (2008). Still just 1 g: Consistent results from five test batteries. Intelligence, 36(1), 81–95.

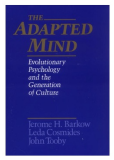
From armchair theorising to empirical estimation of modularity

"Our modern skulls house a stone age mind"

modularity: i.e., the degree to which a system's components may be separated and recombined; in cognitive science, the thesis of modularity of mind holds that the mind is composed of (at least some) independent, domain-specific processing modules.

strong modularity

Our cognitive architecture consists of a confederation of hundreds or thousands of domain-specific (function specific) modules designed to solve adaptive problems from our evolution as a species of hunter-gatherers.

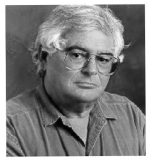


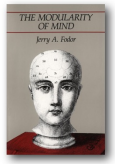
John Tooby (1952-)
Leda Cosmides (1957-)

1992

weak modularity

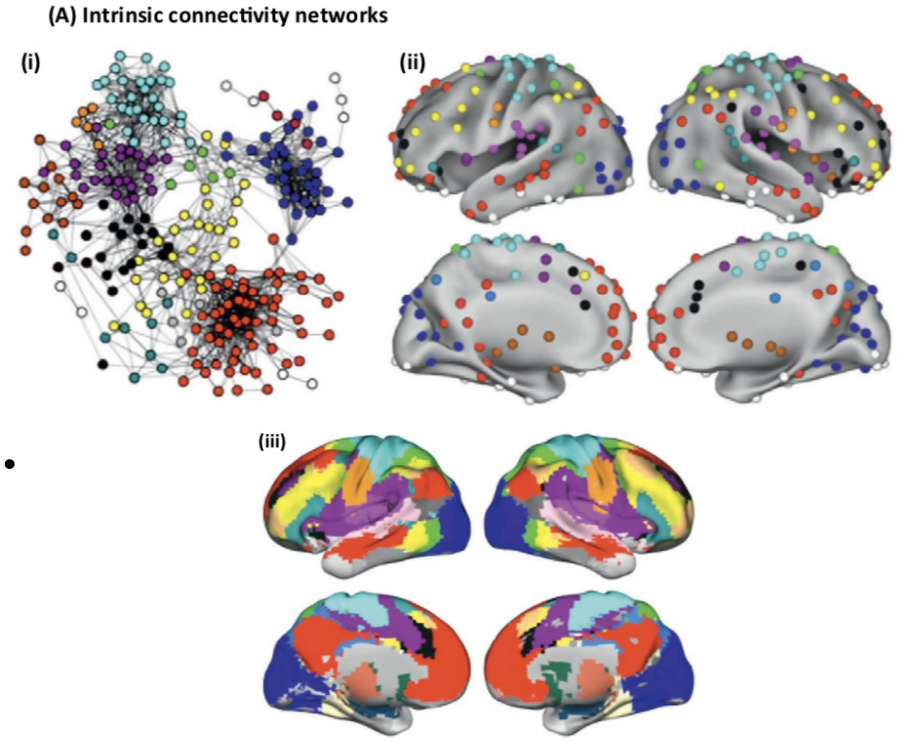
Modularity is only applied to perceptual modules, which are informationally encapsulated and provide input to higher-order systems.





Jerry Fodor (1935-2017)

24



vs.

Barbey, A. K. (2018). Network Neuroscience Theory of Human Intelligence. ***Trends in Cognitive Sciences***, ***22***(1), 8–20.

Neural Theories of Intelligence

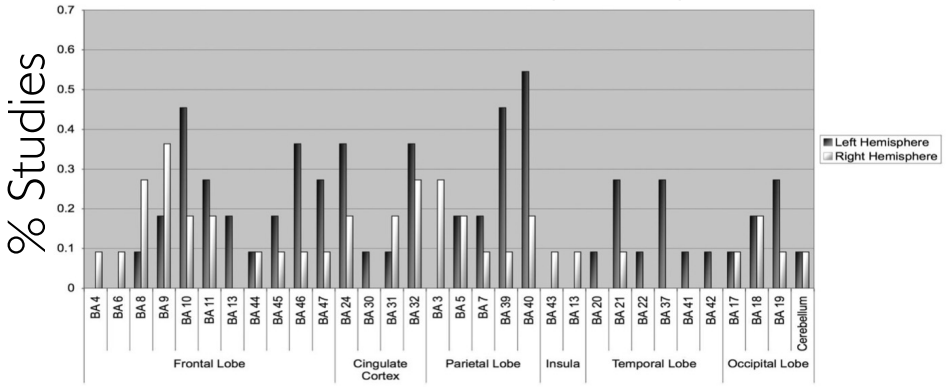
Table I. Summary of Cognitive Neuroscience Theories of Human Intelligence

	Functional localization			System-wide topology and dynamics		
	Primary region	Primary network	Multiple networks	Small-world topology	Network flexibility	Network dynamics
Lateral PFC Theory [103]	✔	x	x	x	x	x
P-FIT Theory [75]	x	✔	x	x	x	x
MD Theory [82]	x	✔	x	x	x	x
Process Overlap Theory [83]	x	x	✔	x	x	x
Network Neuroscience Theory	x	x	✔	✔	✔	✔

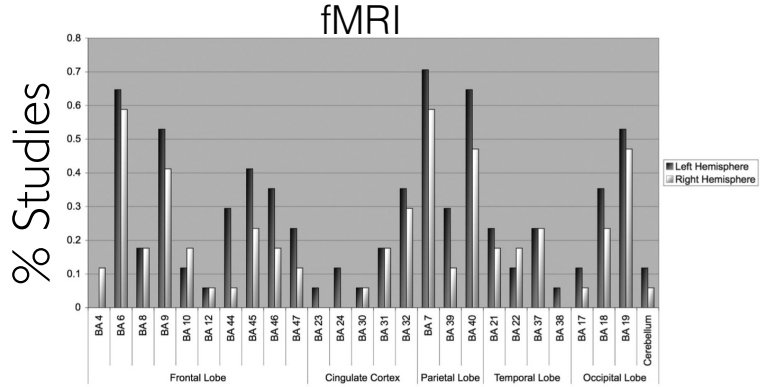
Barbey, A. K. (2018). Network Neuroscience Theory of Human Intelligence. ***Trends in Cognitive Sciences***, *22*(1), 8–20. http://doi.org/10.1016/j.tics.2017.10.001

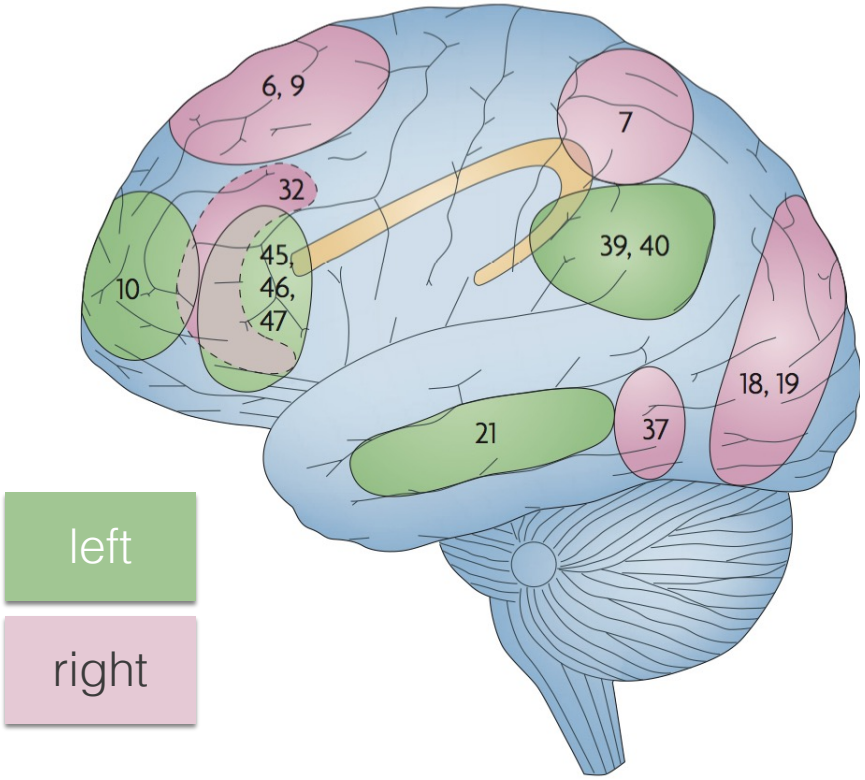
Parieto-Frontal Integration Theory of Intelligence

DTI (diffusion tensor imaging);
VBM (Voxel-based Morphometry)



fMRI



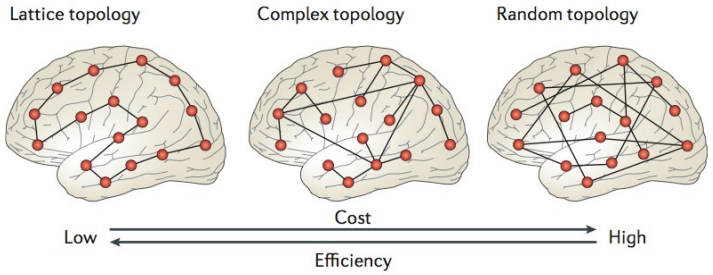


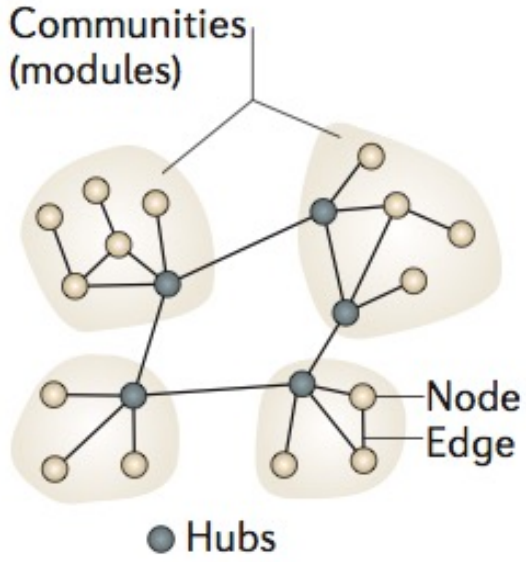
The loci of intelligence differences: Based on a review of all the structural and functional neuroimaging literature that was available, Jung and Haier proposed the parieto-frontal integration theory of intelligence (P-FIT), which is a very general description of how intelligence is distributed in the brain. The figure shows Brodmann Areas (BAs) involved in intelligence, as well as the arcuate fasciculus (shown in yellow) as a promising candidate for a white matter tract that connects the involved brain regions. BAs shown in green indicate predominantly left-hemispheric correlations and BAs shown in pink indicate predominantly right-hemispheric correlations with intelligence.

Deary, I. J., Penke, L. & Johnson, W. (2010). The neuroscience of human intelligence differences. ***Nature Reviews Neuroscience, 11***, 201-211.

Jung, R. E. & Haier, R. J. (2007). The Parieto-Frontal Integration Theory (P-FIT) of intelligence: Converging neuroimaging evidence. ***Behavioral and Brain Sciences, 30***, 135–154.

Brain network organization





Advantages of modular organization:

- helps conserve wiring costs and improving the local efficiency of specialized neural computations
- modules offer resilience against dynamic perturbations and small variations in structural connectivity;

Disadvantages of modular organization:

- functional integration between modules requires the addition of high-cost or long-distance axonal projections to interconnect spatially remote brain regions, which gives rise to connector hubs
- Hubs have a high participation index and can serve as a 'bottleneck' in the network.

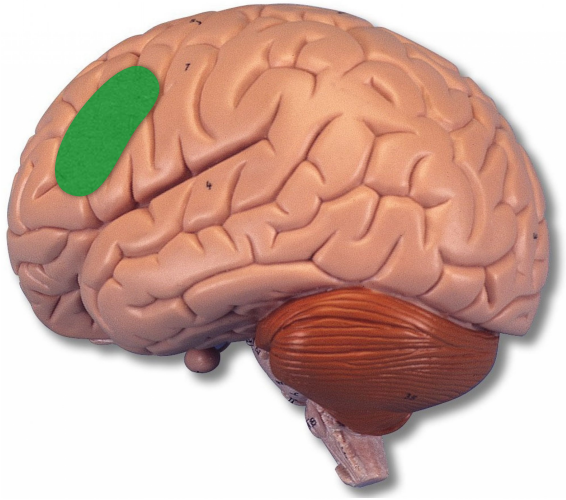
Bullmore, E. & Sporns, O. (2012). The economy of brain network organization. ***Nature Reviews Neuroscience, 13***(5), 336-349.

Neural Theories of Intelligence

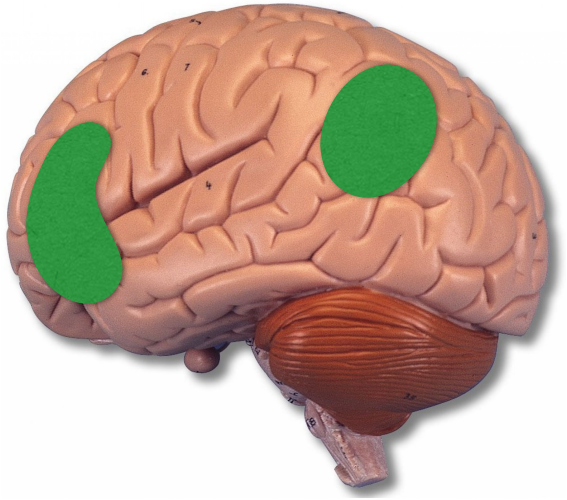
Table I. Summary of Cognitive Neuroscience Theories of Human Intelligence

	Functional localization			System-wide topology and dynamics		
	Primary region	Primary network	Multiple networks	Small-world topology	Network flexibility	Network dynamics
Lateral PFC Theory [103]	✓	x	x	x	x	x
P-FIT Theory [75]	x	✓	x	x	x	x
MD Theory [82]	x	✓	x	x	x	x
Process Overlap Theory [83]	x	x	✓	x	x	x
Network Neuroscience Theory	x	x	✓	✓	✓	✓

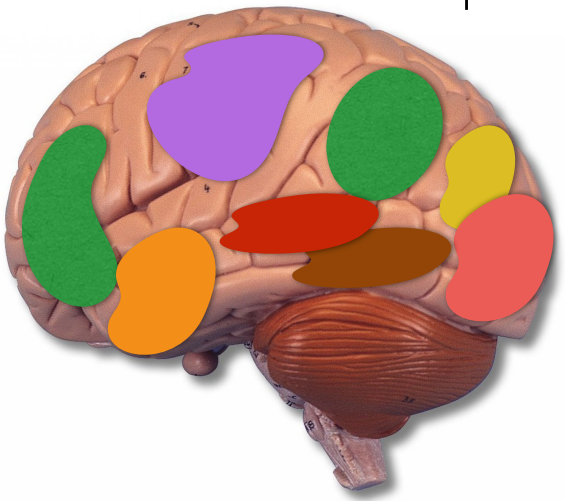
Lateral PFC



P-FIT/MD



Process Overlap

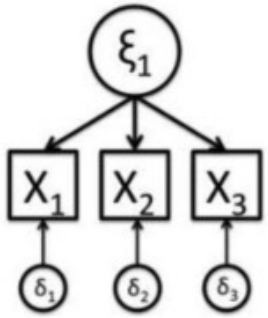


Network Neuroscience theory (NNT), like process overlap theory, assumes there are multiple networks relevant to intelligence but NNT emphasises system-wide topology (structure) and dynamics (function) that ensure the capacity to flexibly transition between network states

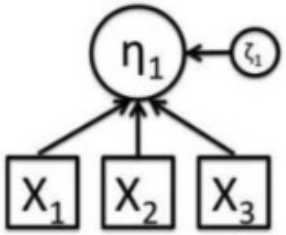
Barbey, A. K. (2018). Network Neuroscience Theory of Human Intelligence. ***Trends in Cognitive Sciences***, *22*(1), 8–20. http://doi.org/10.1016/j.tics.2017.10.001

What is g?

reflective



formative



the two models are formally equivalent but conceptually distinct; **g** is a central psychological construct (and statistical device) developed to account for the empirical findings of a positive manifold; yet, it is still controversial whether to think of it as cause or consequence of how the mind works…

g as general capacity

- **g** captures a general capacity, mental energy, or brain process that is necessary for the functioning of other more specific abilities.

g as process overlap

- no measure captures a single capacity purely, correlations between measures arise from each tapping to some extent into similar abilities (and, potentially, some being more often needed than others).

g as a consequence of development

- g as the result of a transactional process: People with certain abilities tend to select and be selected into environments that will lead to development in several abilities.

Summary

- **Intelligence and why it matters:** consensual yet perhaps unsatisfying definition as "ability to reason, plan, solve problems"; intelligence (IQ) matters because it has criterion/predictive validity concerning important life outcomes (e.g., health, academic and work performance) and can be used as criterion for interventions (e.g., education)
- **Mental testing**: multiple tests and batteries (Raven's Progressive Matrices, WAIS), norms and scoring, robust empirical findings (positive manifold, high convergent validity of batteries).
- **Psychometric approach:** ***differential*** (relative; non-mechanistic) perspective on intellectual function - focus on modeling of inter-individual differences; different formulations of the relation between measures leads to different "structures" of intelligence
- **Neural basis of intelligence:** different models emphasize primary regions (frontal cortex), primary networks (parieto-frontal network), or coordination of networks potentially distributed across the brain (process overlap theory, network theory)
- ***g***: central (statistical) construct to account for positive manifold; controversial status as cause or consequence of specific cognitive/neural mechanisms (reflective vs. formative models of intelligence) – psychology is still working on a *mechanistic* model of *g…*