Cyber Aptitude and the Science of Intellectual Assessment

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Problem

WHY ARE CYBER SELECTION (HIRING), PLACEMENT, & TRAINING CHALLENGING?

Survey of cyber course difficulty

Discovery Research: *Why is cyber security training challenging?*

- Developed protocol for in-depth, comprehensive interview:
  214 questions; 14 cognitive difficulty factors; 6 course aspects
- Interviewed 11 current & former students in USG cyber security training:
  30 hours; good, average, & poor students; 2013 & 2014
- Analyzed summary data and currently analyzing full dataset:
  75% complete

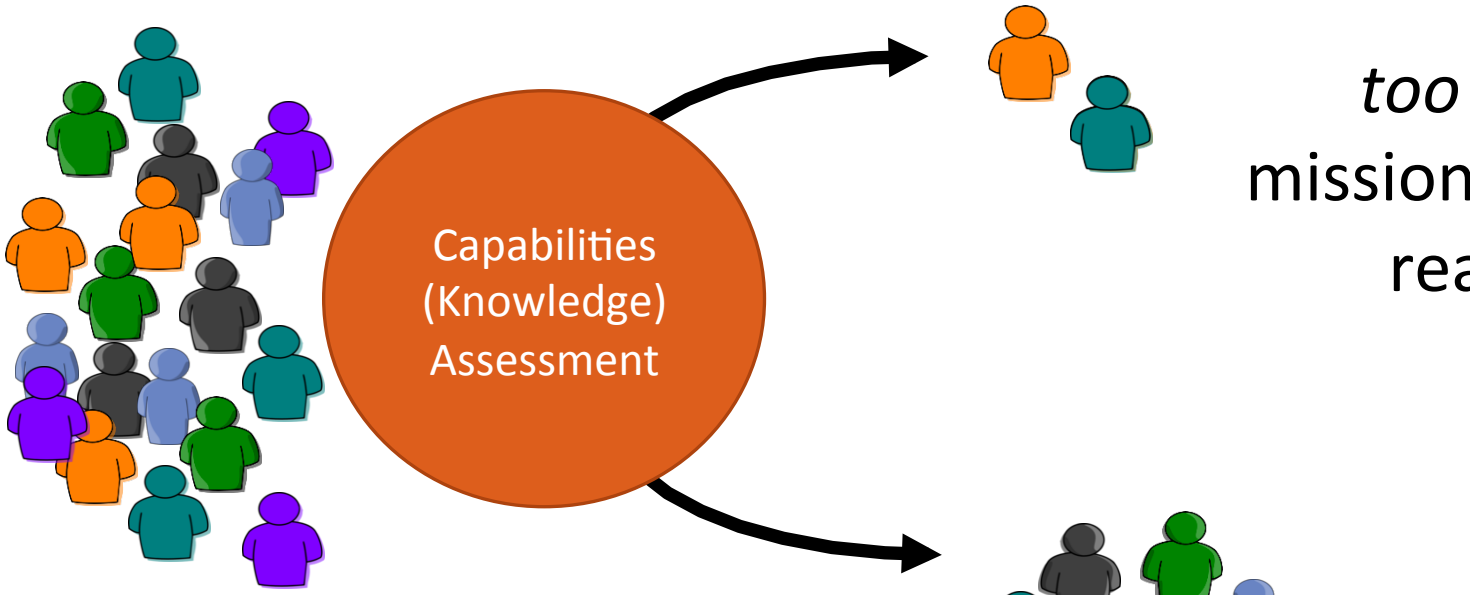
Findings-to-date

- Overly heterogeneous student population:
  tremendous variation in prior cyber-relevant course and job experience
- Cognitive overload, due to:
  high pace, amount, suboptimal teaching methods,
- Insufficient practice; not smart practice:
  limiting learning rate, generalization, and persistence
- Insufficient metacognitive awareness of need for real-time, flexible, adaptive responding
- Mismatch between actual course content and expected job-relevance

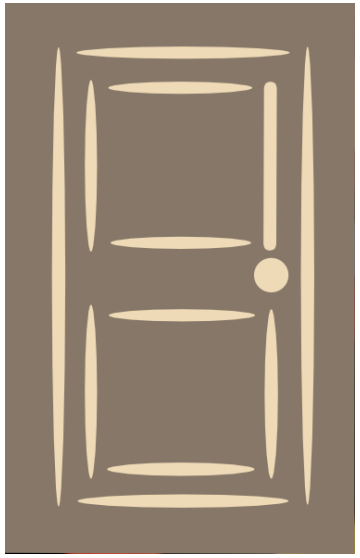
Problem (from discovery research):
"Overly heterogeneous student population & tremendous variation in prior cyber-relevant course and job experience."

Solution: Screen student population using CASL's *Cyber Aptitude & Talent Assessment*

Cyber Workforce Problems:
Finding, cultivating & certifying cyber talent



too few
mission- & job-ready



- Who has learning potential?
- Who is ready to learn?
- How best can we match people to pathways to success?

Goals

I.

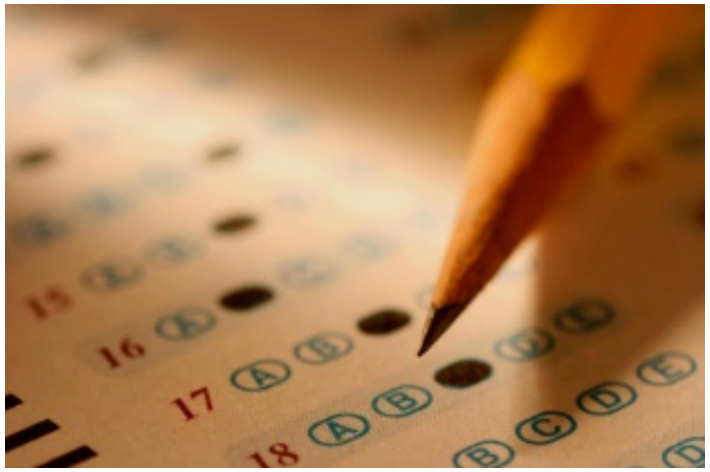
Define cyber

II.

Determine cognitive abilities, dispositions & skills that matter for cyber

III.

Test those abilities



How?

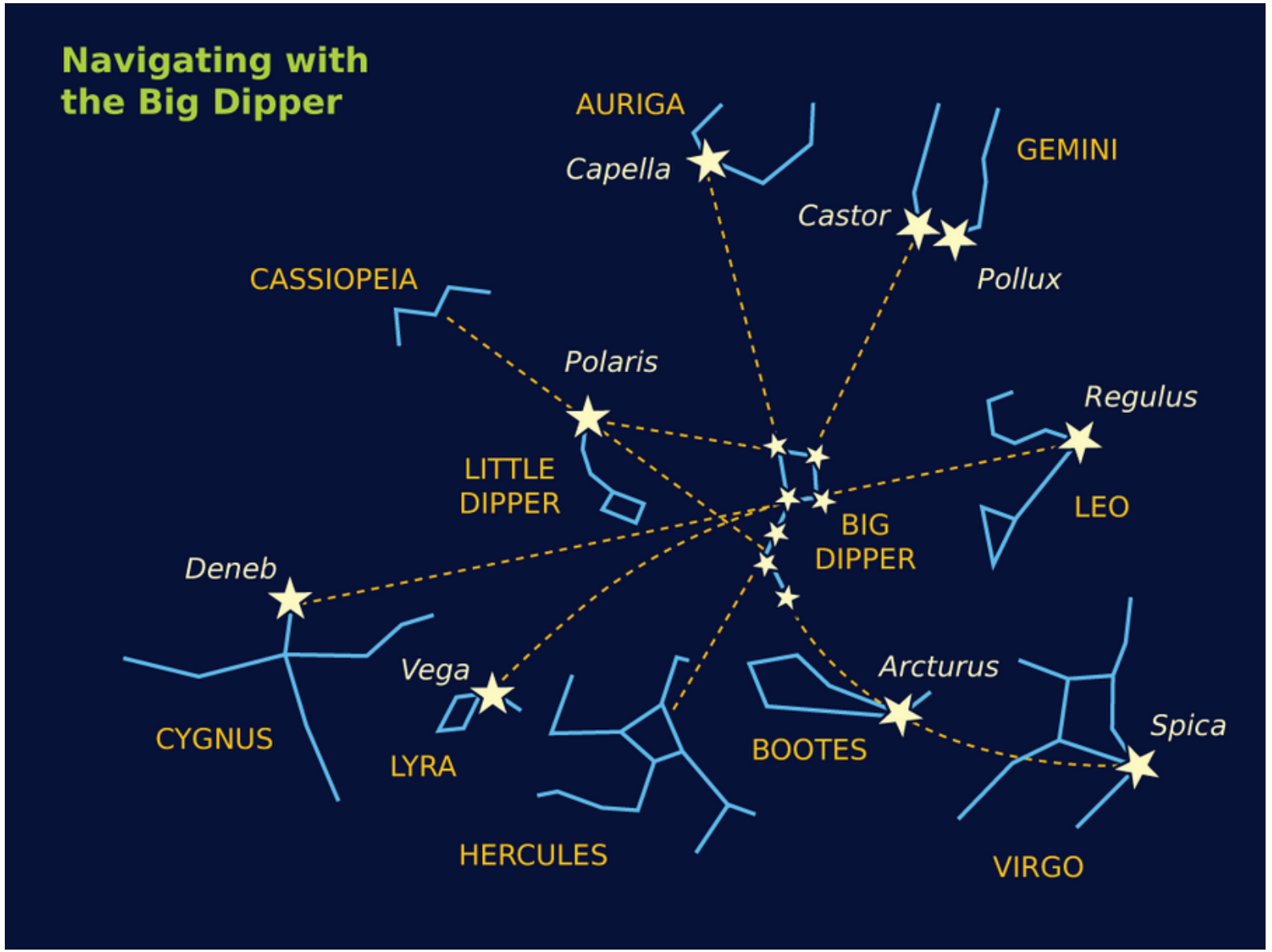
WHAT IS THE SCIENCE OF INTELLECTUAL ASSESSMENT

The Psychometric Approach

"The science of: **measuring** stable mental capacities, skills, personality traits, beliefs, and knowledge + **discovering** relations + **making** predictions based on those relations."

...think finding patterns in BIG DATA

Kamphaus, 2001; Kaufman & Lichtenberger, 2002; McGrew & Flanagan, 1998


Navigating with the Big Dipper
AURIGA
Capella
GEMINI
Castor
Pollux
CASSIOPEIA
Polaris
Regulus
LITTLE DIPPER
LEO
BIG DIPPER
Deneb
Vega
Arcturus
Spica
CYGNUS
LYRA
BOOTES
HERCULES
VIRGO

The Psychometric Approach

- *Use data reduction and description methods (factor analysis, structural equation modeling, cluster analysis)*
- Discover relative differences in performance
- *Individual differences: Abilities, Skills, Traits, Beliefs, Knowledge*
  - *(Main focus)* ***Ability*** = Developed skill, competence, or power to do something, especially…existing capacity to perform some function, whether physical, mental, or a combination of the two, without further education or training

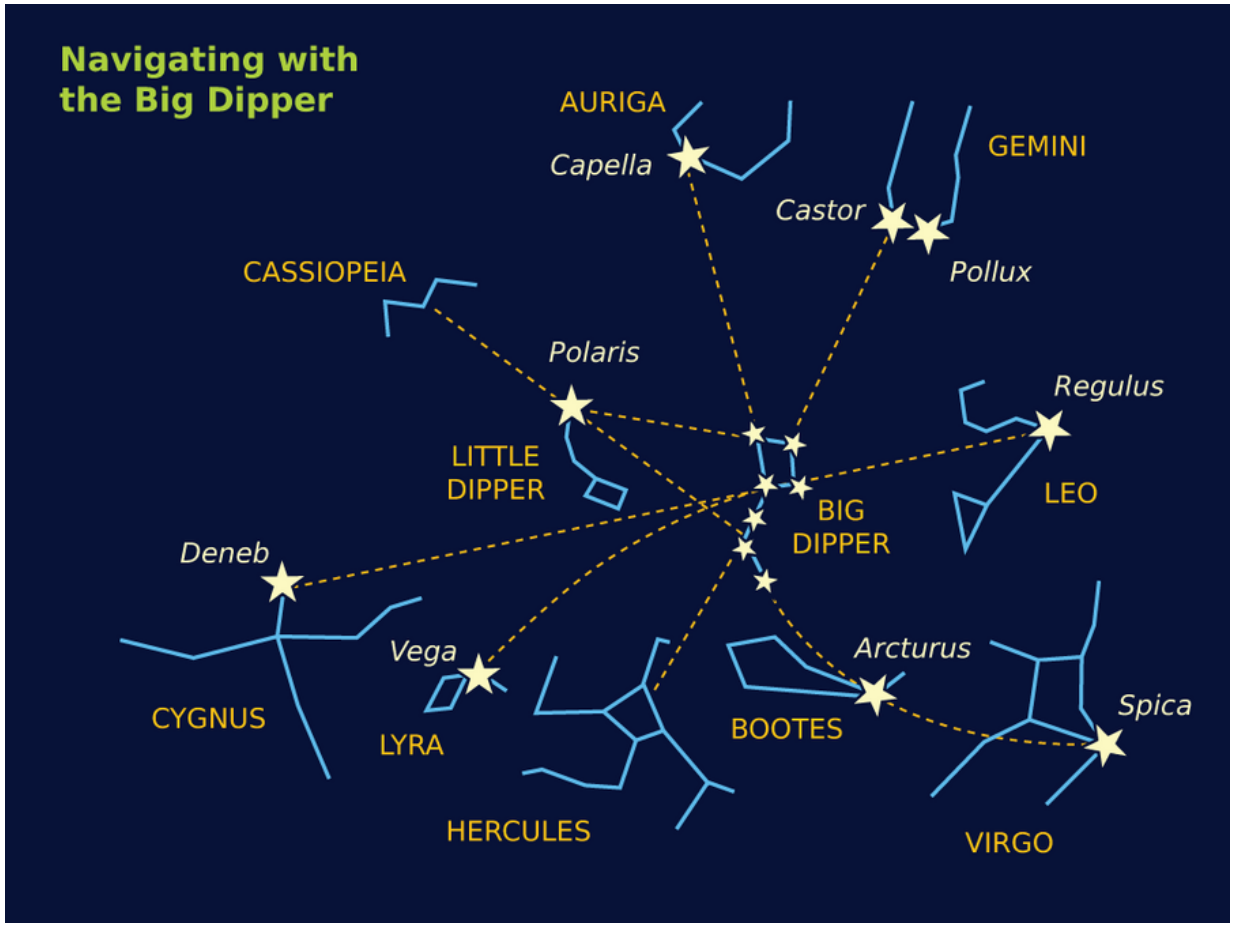
Colman, 2001

Psychometric Results

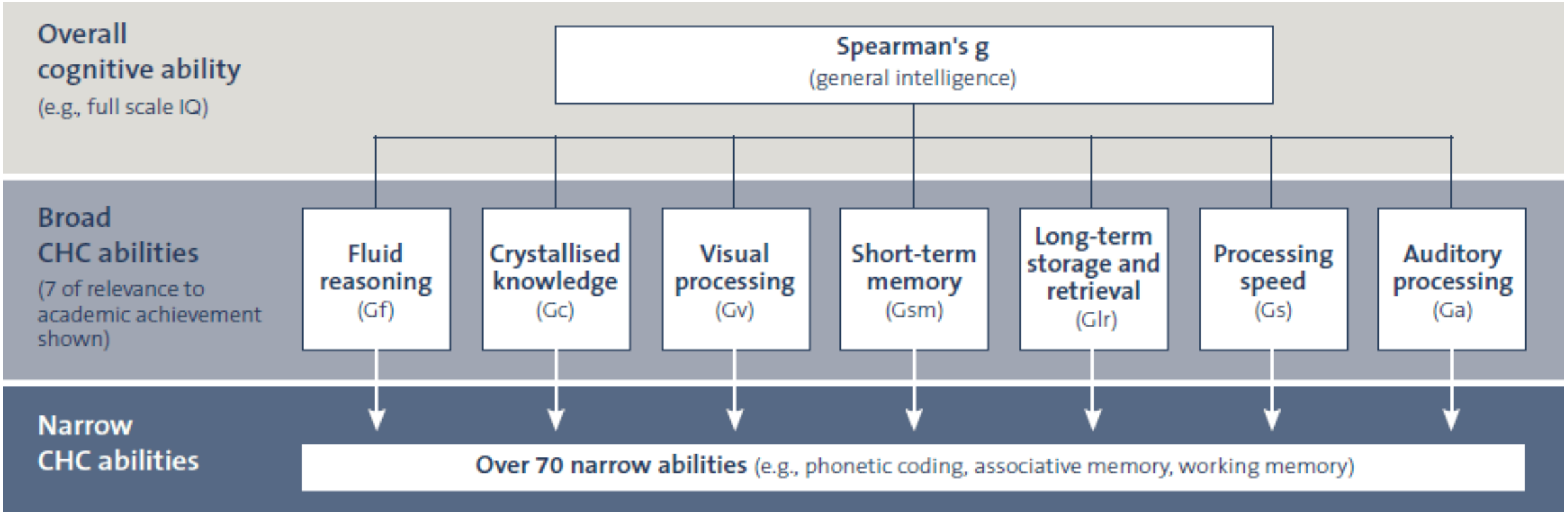
Predict

- Academic attainment
- Occupational status
- Social status
- Job performance
- Income

Astronomers way of representing data

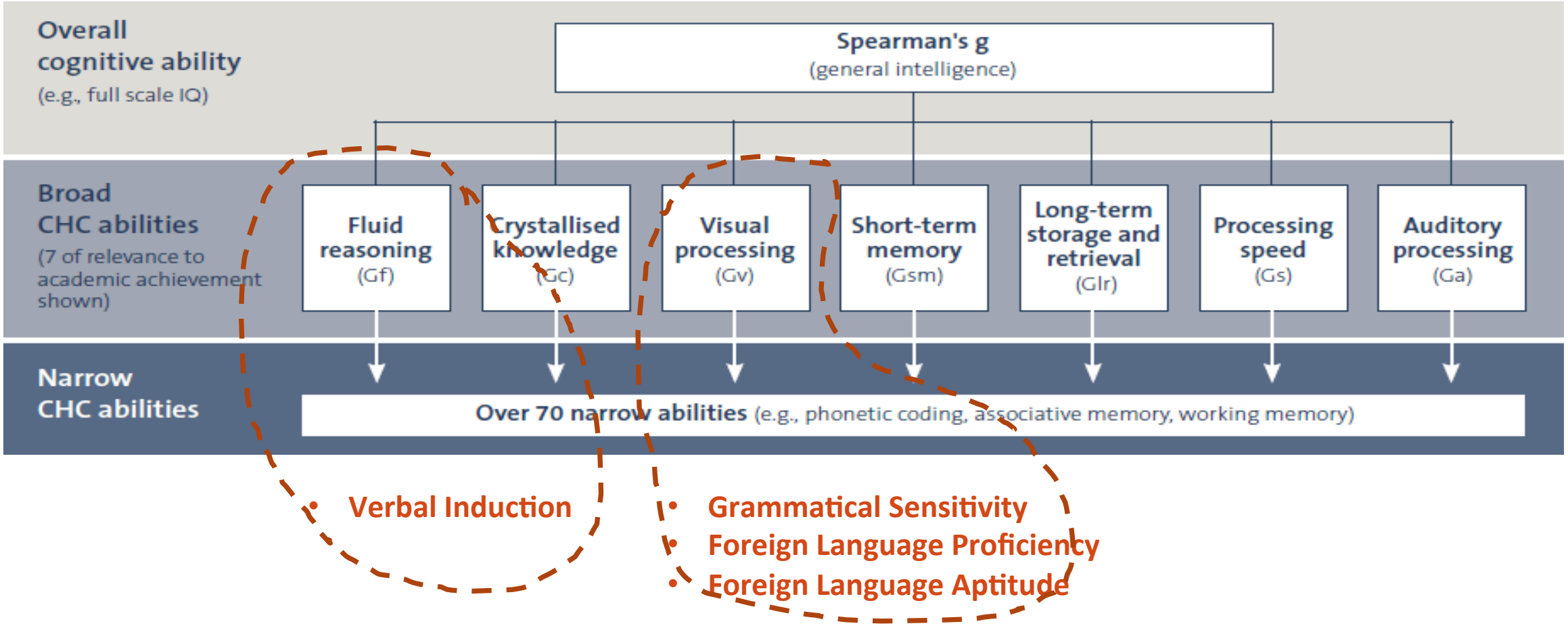


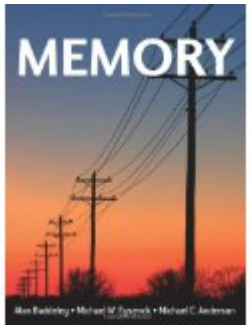
Psychometricians ways of representing data

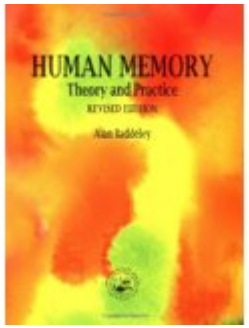


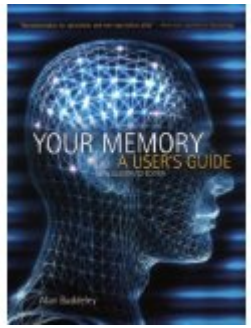
The Cattell-Horn-Carroll Model of Cognitive Abilities

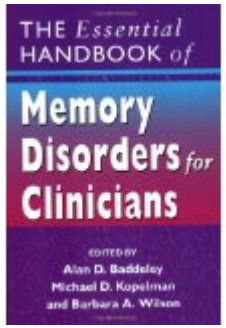
Defense Language Aptitude Battery

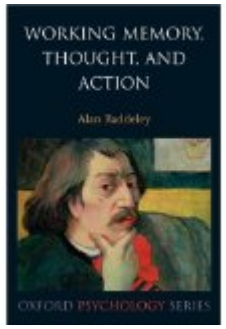


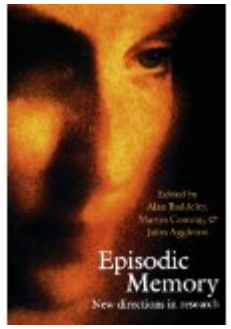


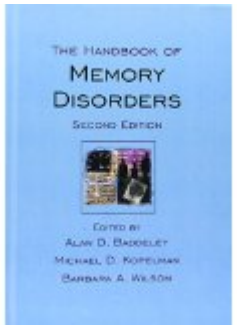


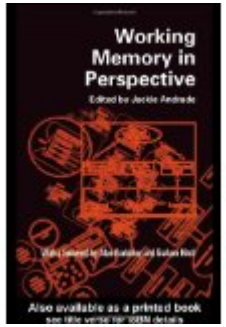


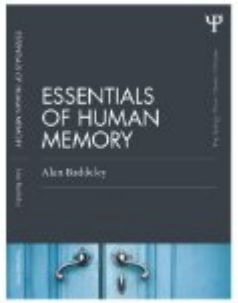


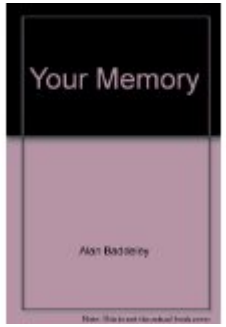












Dr. Alan Baddeley
Professor of Psychology
University of York

Citations 121,036
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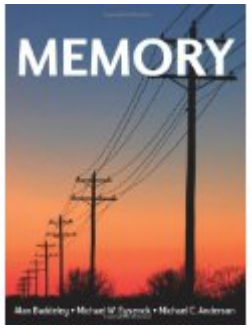
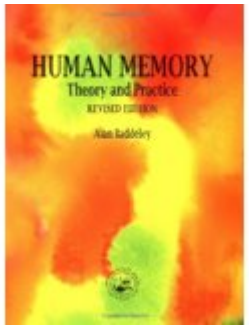
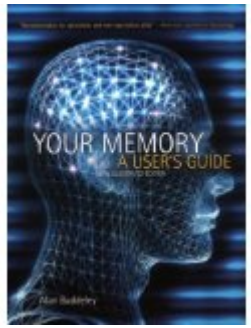
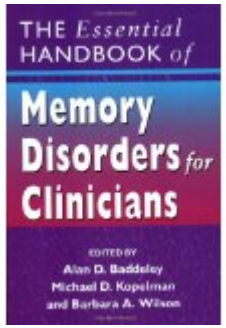
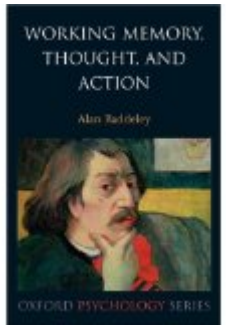


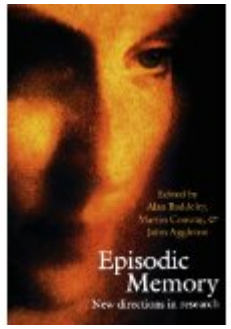


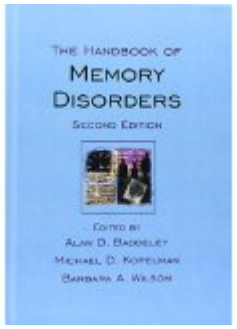




"Over the past 50 years, it could be argued that the greatest impact of psychology on society has come from psychometrics, the attempt to study and measure individual differences." ~Alan Baddeley, 1998

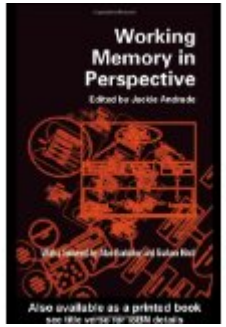


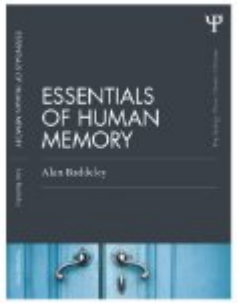


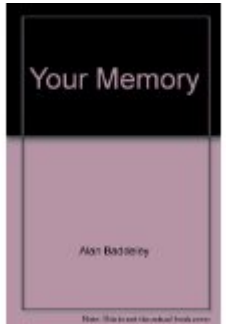


Accomplishments like:

- Shaping societal views on nature vs. nurture, intelligence, gender, and race differences
- Creating an international industry for the assessment and treatment of patients
- Creating the dominant model for secondary and higher education enrollment practices







"Yet, despite this impressive impact, psychometrics has had relatively little influence on…genuine theoretical progress." ~Alan Baddeley, 1998

Summary: The Psychometric Approach

Pros

- Useful for prediction purposes with large groups of people
- Has yielded *robust* and *reliable* measures of abilities that predict
  - Academic attainment
  - Occupational status
  - Social status
  - Job performance
  - Income

Cons

- Focus is on ranking individuals based on summaries of item-level performance (i.e., subtest or composite scores) but fails to explain ***why*** an individual has performed at a level above or below others in a comparison group
- Focus on breadth of factors and scores obscures an understanding of the particulars of cognitive performance, such as strategy use and the activation of specific mental operations

Floyd, 2005; Jensen, 1998

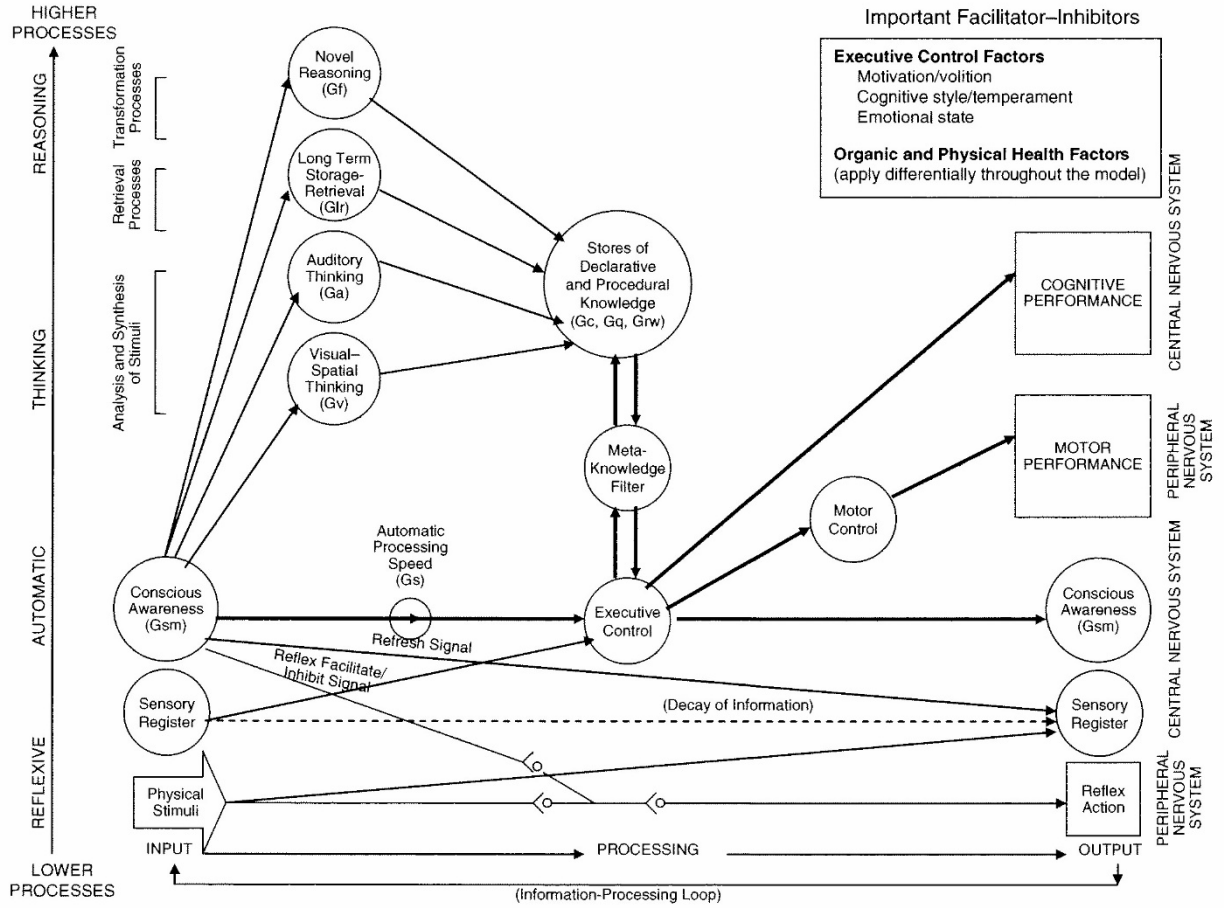
The Information Processing Approach

- *Information process* = A fundamental mental event in which information is operated on to produce a response
- *Information processing* = A sequence of mental operations and their products involved in performing a cognitive task
- Information processing models provide a description of the stages through which information is transformed from sensations to mental representations, analyzed within the cognitive system, and expressed via some response

Sternberg, 1981

tasco

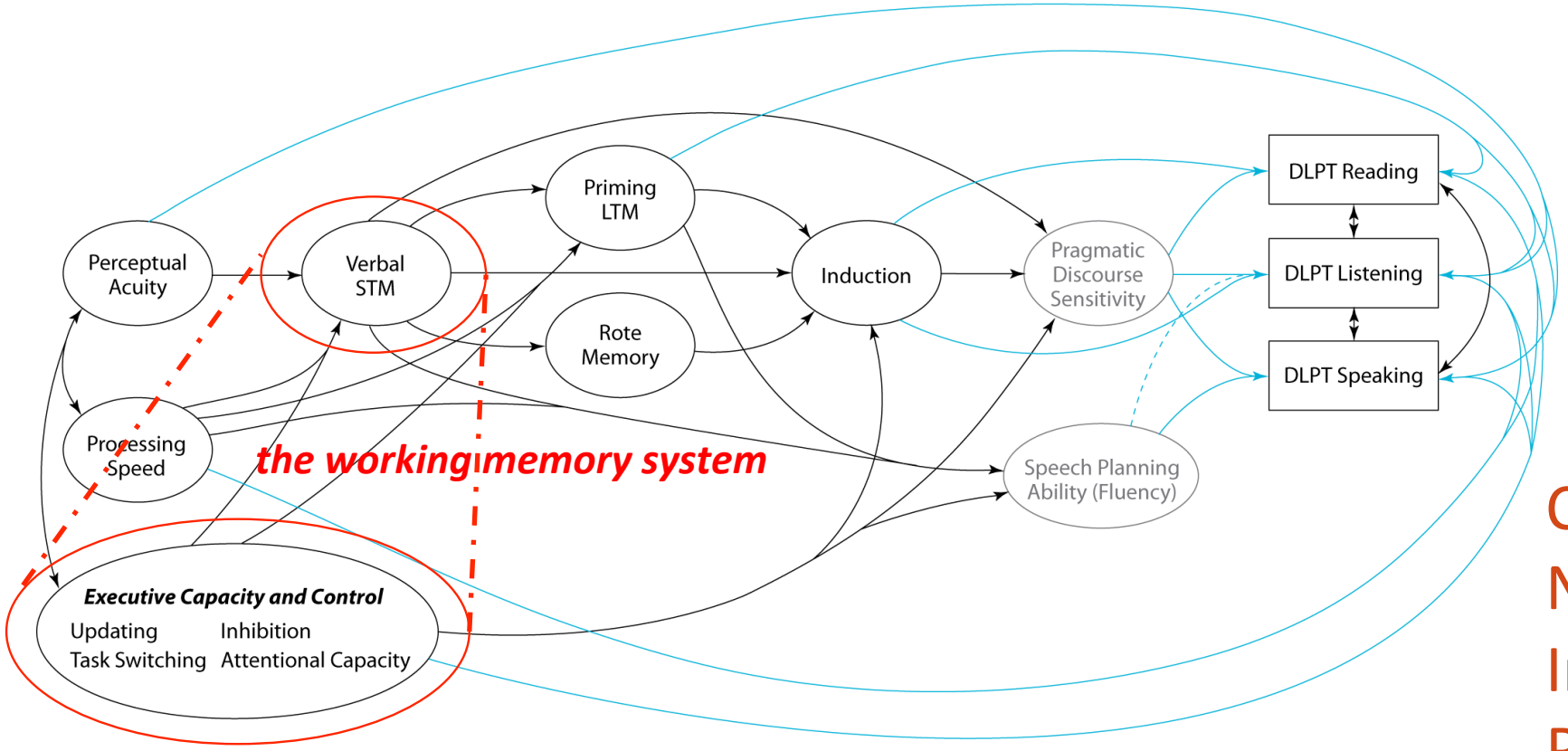
Theoretical Model of Information Processing



The Dean-Woodcock Information Processing Model

Dean & Woodcock, 1999

Cognitive Model of Language Aptitude



Cognitive-Neuroscience Information Processing Model

Summary: The Information Processing Approach

Pros

- Reveals the micro-level cognitive processes that underlie cognitive abilities and that lead to individual differences
- Explains ***why*** an individual has performed at a level above or below others in a comparison group

Cons

- Measurement issues, including frequent disregard for reliability and internal consistency
- Experimental methods and instruments that are incompatible with mass testing

Carroll, 1993; Posner & McLeod, 1982; Sternberg, 1981

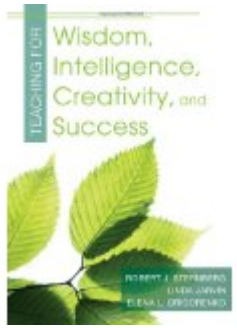
Methods of Discovery

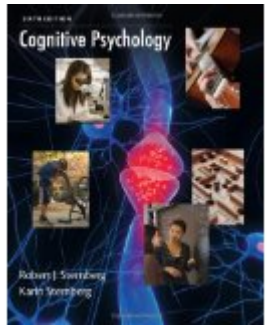
Classic psychometric (testing) approach: Use statistical techniques to synthesize *who* performs at desired levels

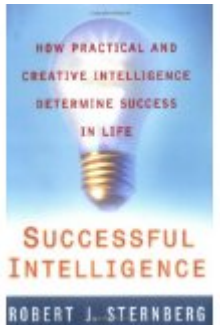
- Pros: Highly valid & reliable; legally defensible
- Cons: Protracted costly development & huge samples (ok for big military, universities)

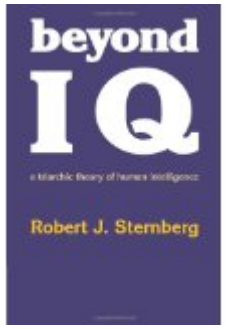
Cognitive neuroscience approach: Use dissociations to analyze *why* people differ

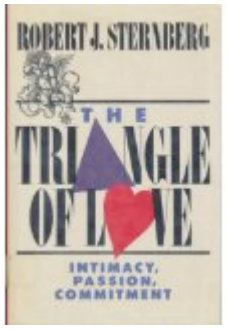
- Pros: Causal theoretical models of cognitive processes underlying ability and individual differences; ok for small samples (e.g., USG civilians)
- Cons: Experimental methods & instruments incompatible with mass testing

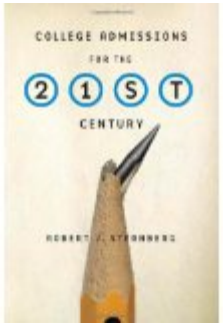


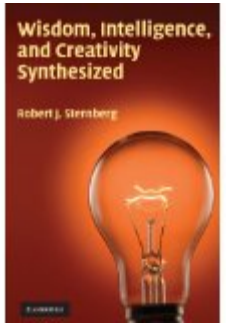


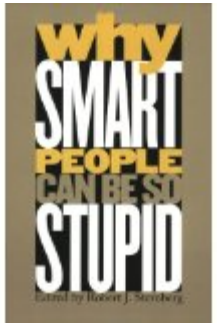


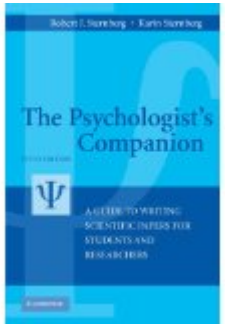


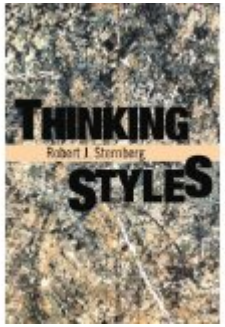


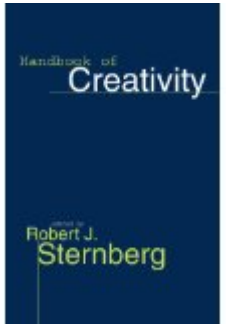


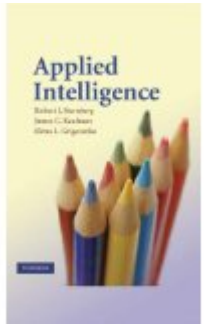












Dr. Robert Sternberg
Professor of Human Development
Cornell University

Citations 85,795
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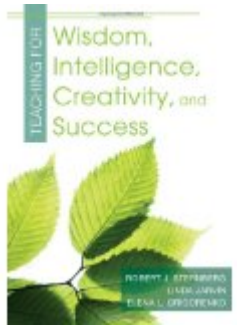
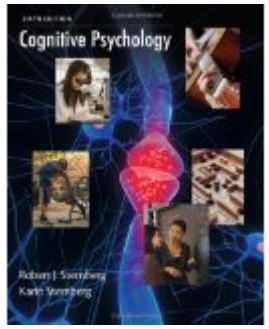
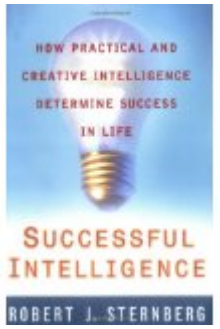
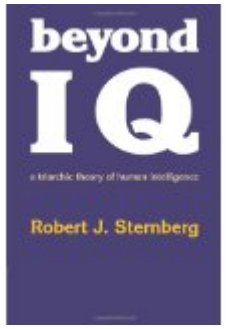
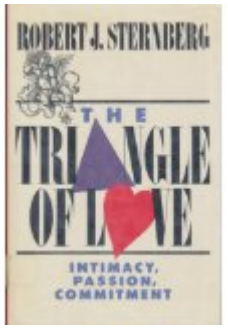
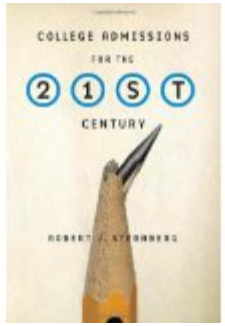


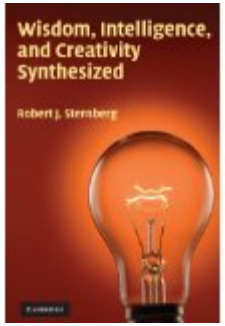


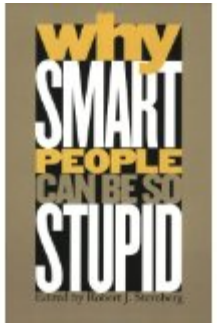


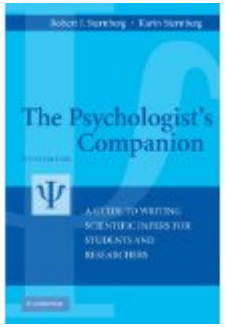


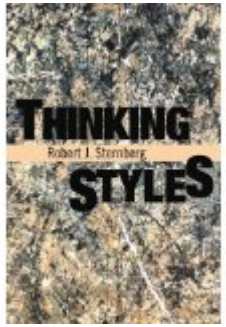


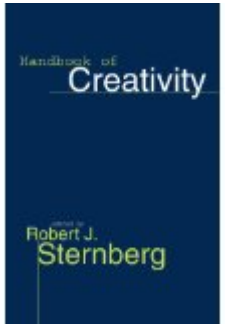


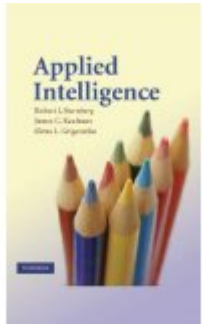








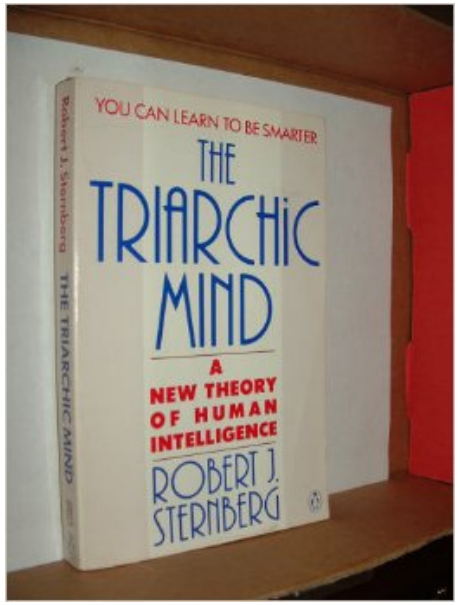




"The systems approach attempts to combine some of the best elements of [these] approaches." ~Robert Sternberg

Examples of the systems approach:

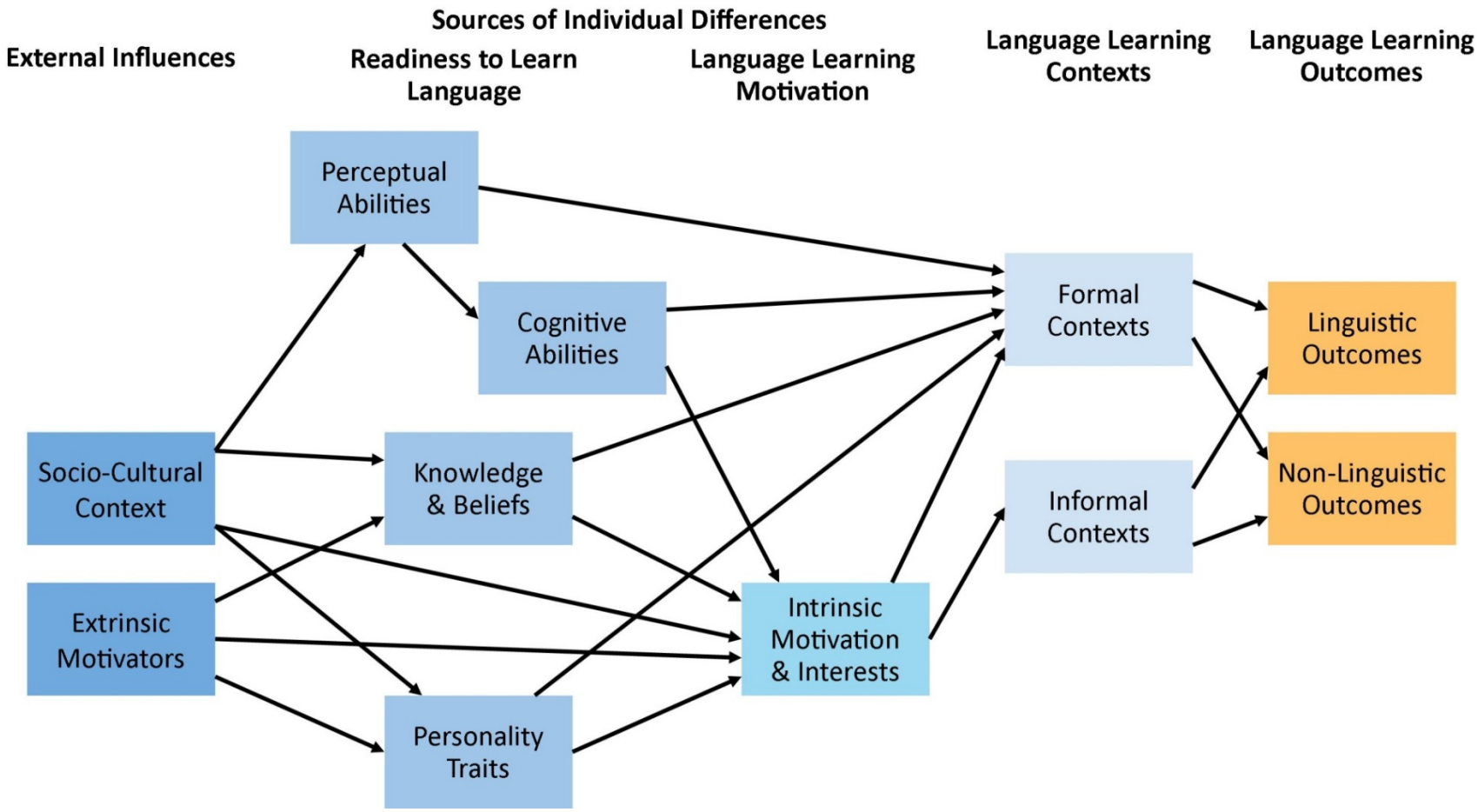
- Gardner's (1983) theory of multiple intelligences
- Sternberg's (1985) triarchic theory intelligence



"While the experimenter is interested only in the variation he himself creates, the correlator finds his interest in the already existing variation between individuals, social groups, and species…A united discipline will study both of these, but it will also be concerned with the otherwise neglected interactions between organismic and treatment variables."

~ L. J. Cronbach, 1957 address to the American Psychological Association.

Systems Model: Abilities, Beliefs, Traits & Circumstances of Language Aptitude



Goals

I.

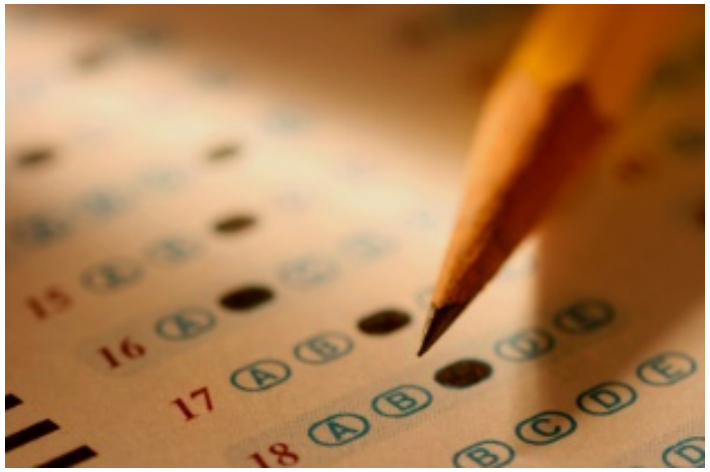
Define cyber

II.

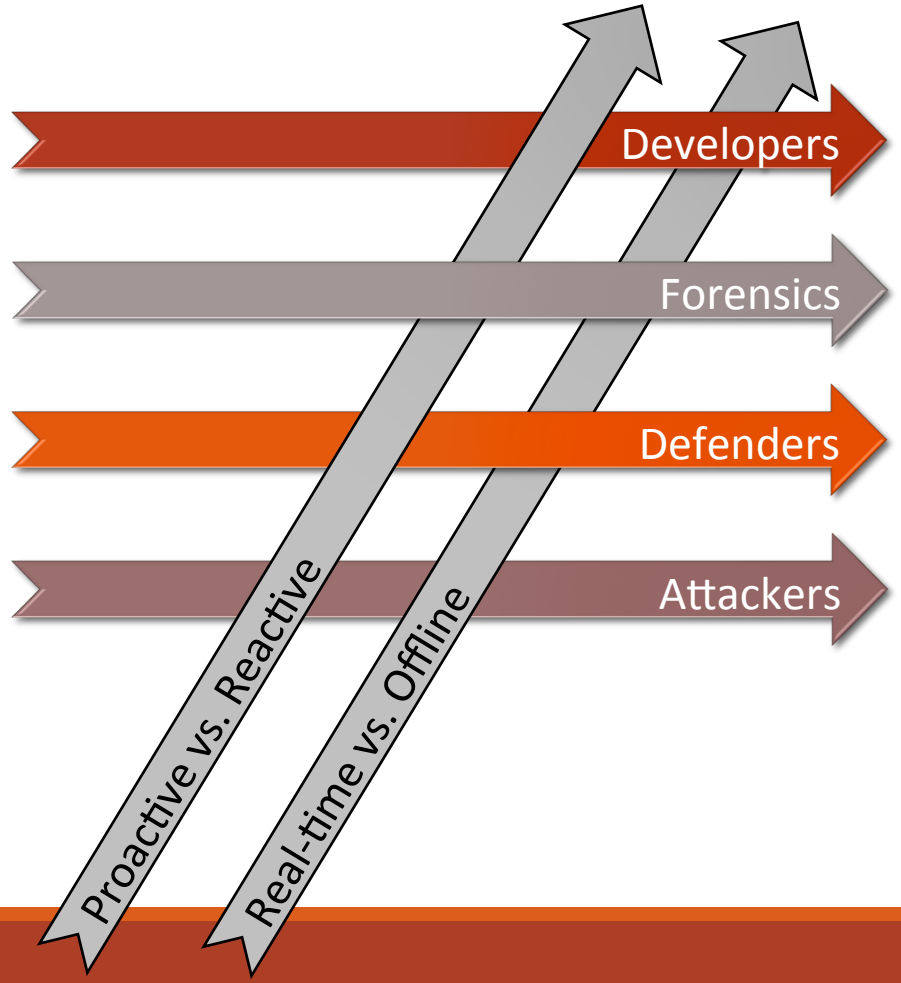
Determine cognitive abilities, dispositions & skills that matter for cyber

III.

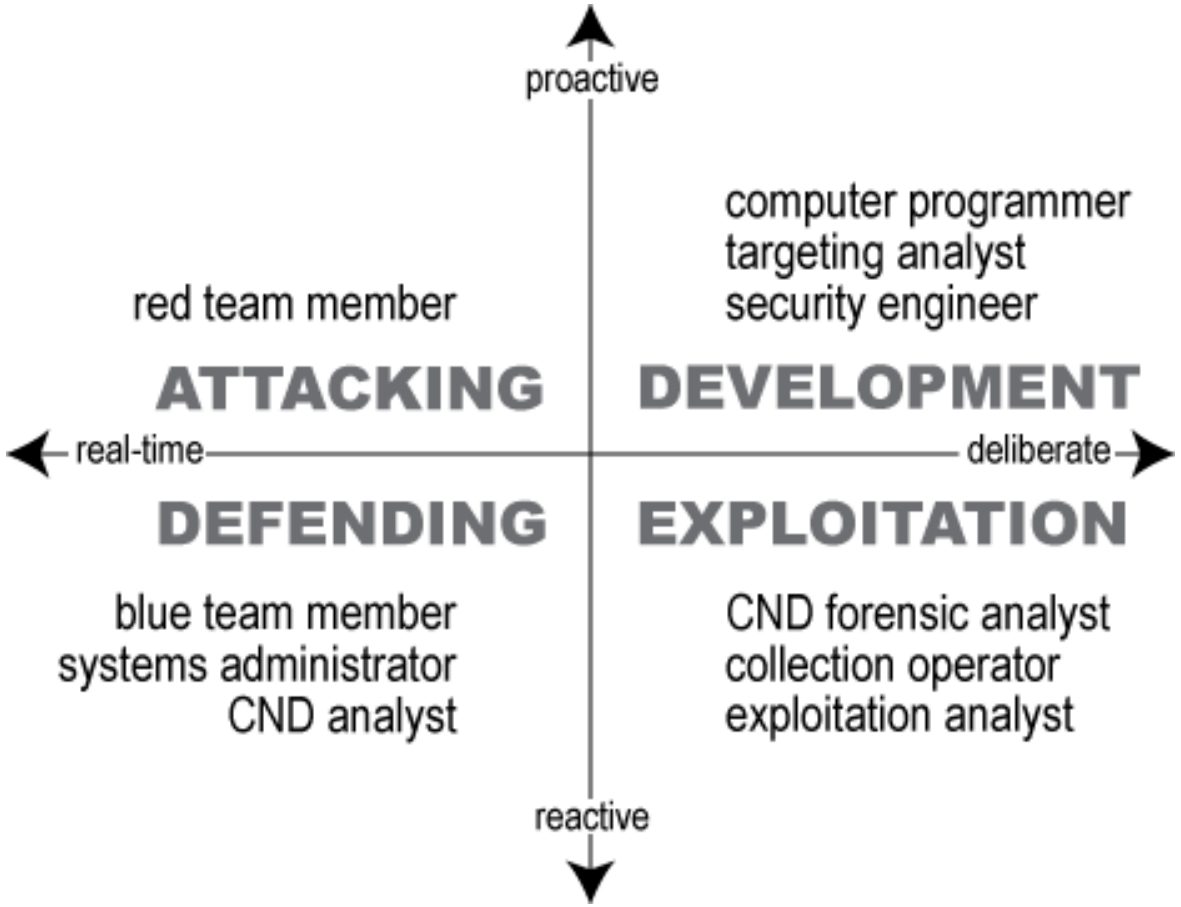
Test those abilities



Define Cyber



Cyber Job Model



Schematic of dimensions on which example cyber careers differ. The quadrant names correspond to a major task that has the characteristics described on its axes (for instance, “defending” requires real-time reaction, while “development” requires proactive deliberation).

Goals

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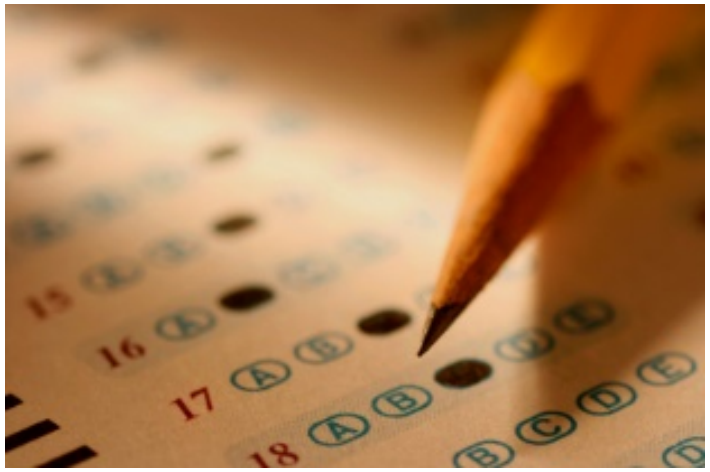
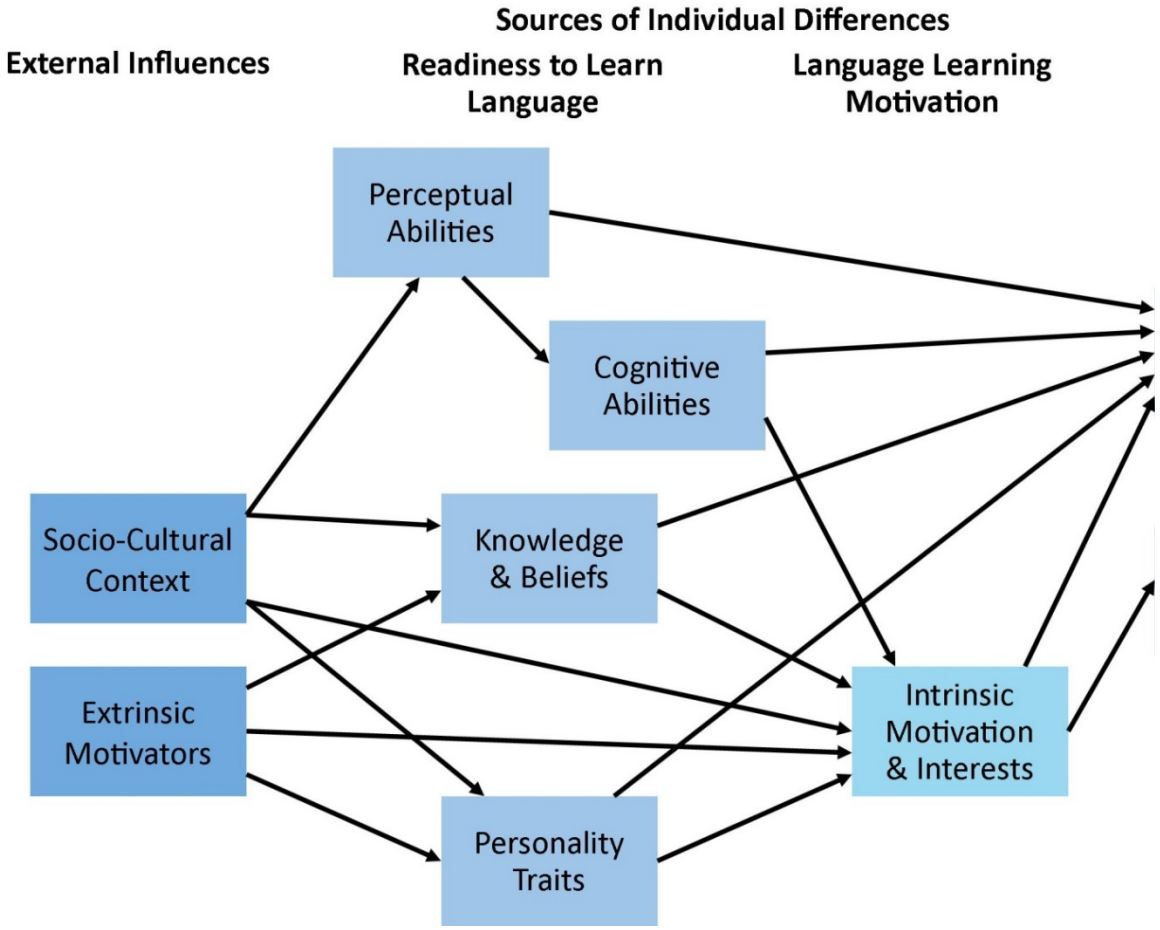
Test those abilities



Systems Model: Abilities, Beliefs, Traits & Circumstances for Cyber



Hypotheses for Cyber Aptitude

Ability	Measurement	Job(s)
Critical thinking	• General intelligence	All
Attention	• Vigilance for rare event • Capacity • Staying on task	Real-time mission
Speeded thought	• Quick decisions • Perceptual speed	Real-time mission
Rule learning Rule application	• Formal reasoning	Developer
Deliberate & intuitive thinking	• Complex problem solving	Operator & developer

Goals

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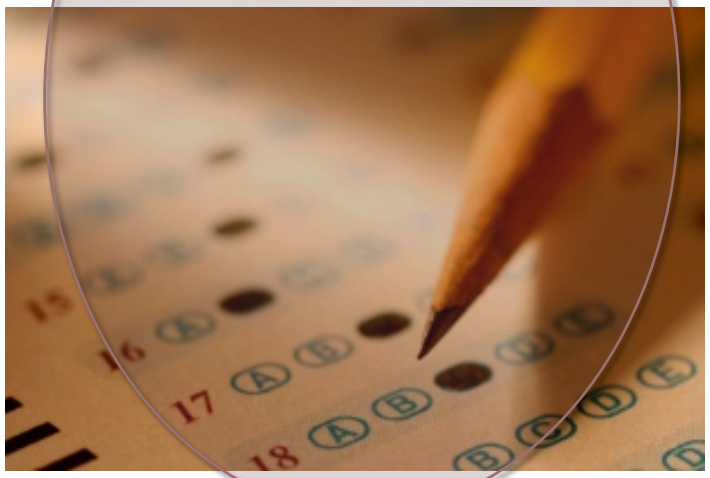
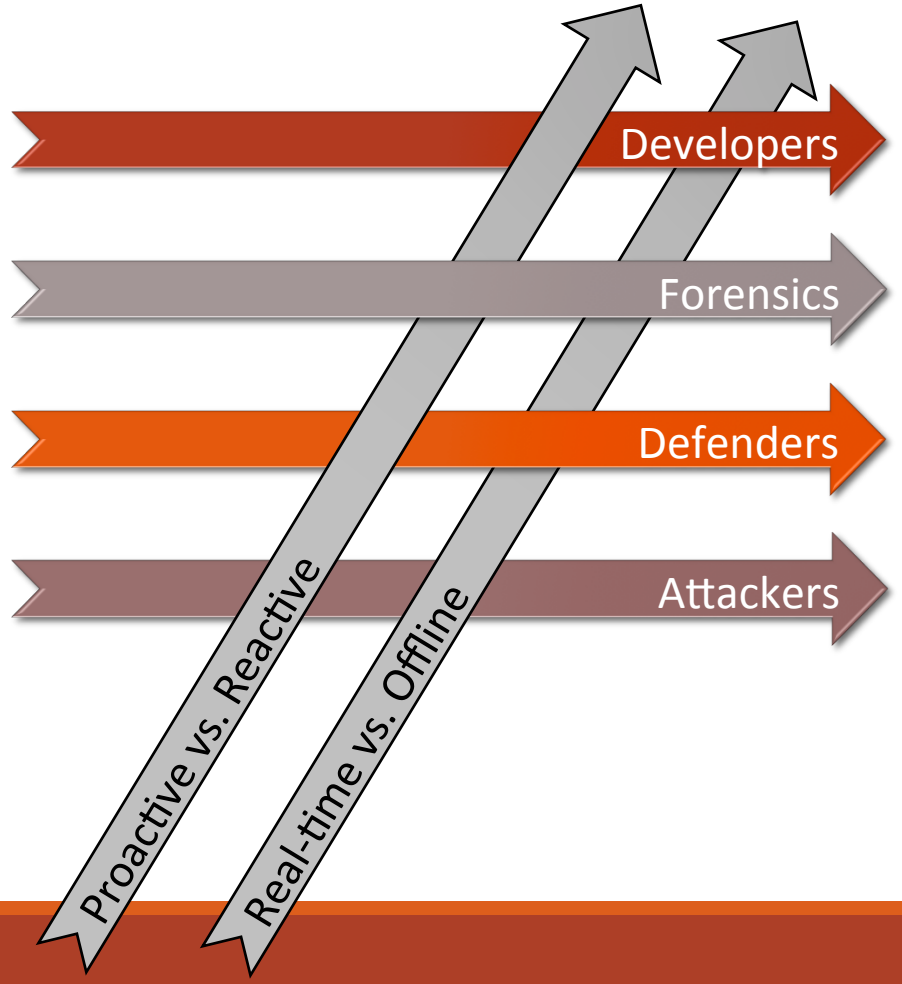


Cyber Aptitude & Talent Assessment (CATA)

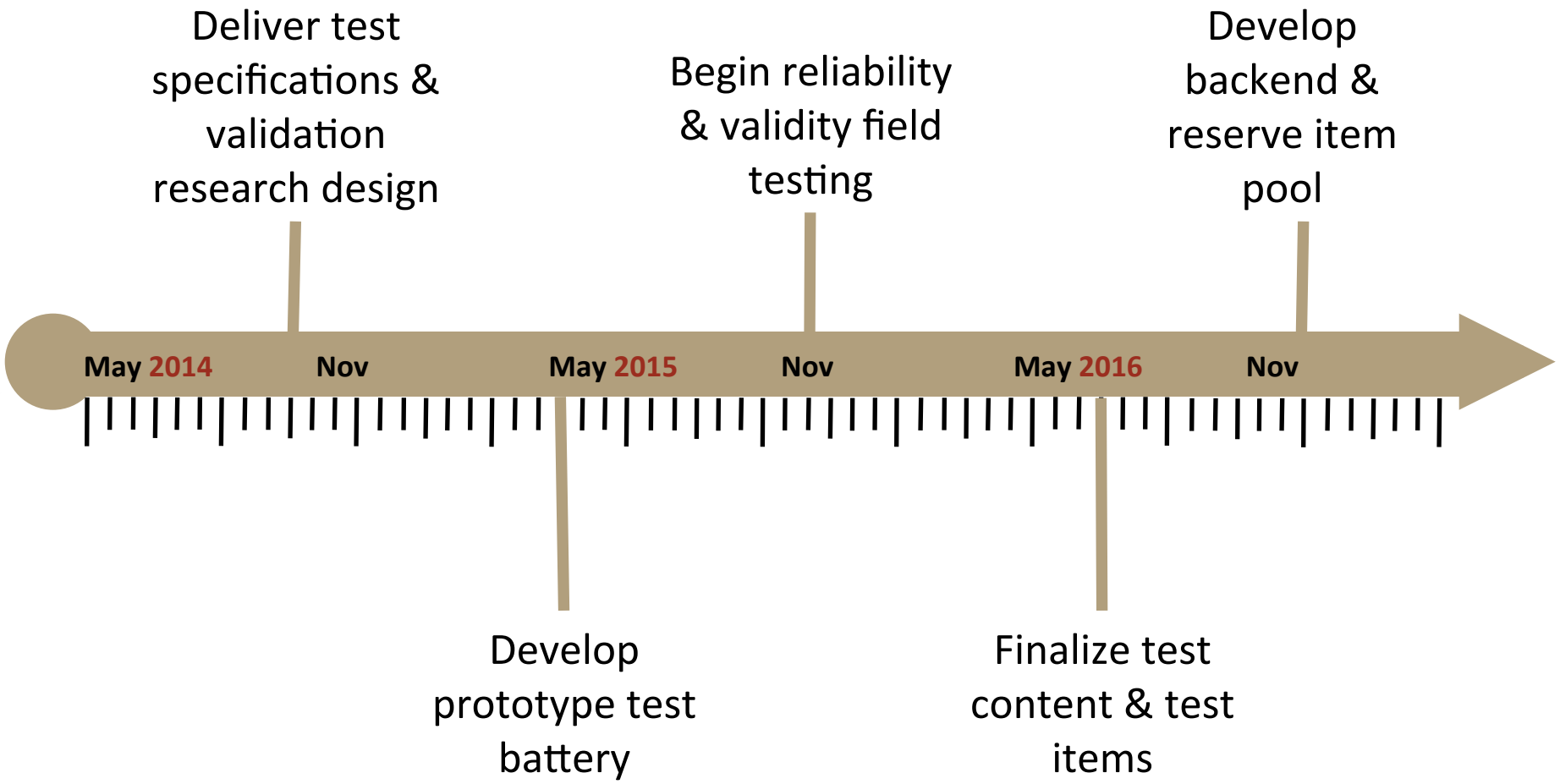
Critical Thinking Subtest: Most general predictor of all job performance (Delivered 2013)

Subtests (In progress)

- Deliberate Decision Making
- Real-Time Performance
- Proactive Thinking
- Reaction Thinking



CATA development timeline



How is Aptitude Info Useful?

A practical and theoretical aptitude battery – based on a systems model – can diagnose strengths and weaknesses

- Cognition
- Disposition
- Motivation & Persistence

Useful for:

- Selection and placement decisions (like any psychometric test)
- (Unlike ordinary correlational tests) make aptitude-by-treatment decisions
  - Identify people needing training or other interventions for success
  - Identify people who will benefit from tailored instruction
  - Informs training

Future (your help is welcome)

- Refine the job model from general to specific
- Test large and diverse populations
- Improve selection, placement, and instruction

Co-authors and collaborators

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