Intelligence and its Assessment

PSYC3302: Psychological Measurement and Its Applications

Mark Hurlstone
Univeristy of Western Australia

Week 9

Learning Objectives

- What is intelligence?
- Theories of intelligence:
  - Factor-analytic theories
  - Information-processing theories
- The structure of human abilities:
  - First-order factors
  - Second-order factors
  - Third-order g factor
- Measuring intelligence:
  - Individual intelligence tests
  - Group intelligence tests

What is Intelligence?

- Intelligence is a multifaceted capacity
- In general, intelligence includes the abilities to:
  - acquire and apply knowledge
  - reason logically
  - make sound judgements and solve problems
  - infer perceptively
  - grasp and visualise concepts
- For psychologists, universal agreement as to how intelligence should be defined was initially elusive...

"Intelligence" is ...

Francis Galton (1822–1911)

"Intelligence" is. . .

Galton (1883) believed that the most intelligent persons were those equipped with the best sensory abilities. This position was intuitively appealing because, as Galton observed, "The only information that reaches us concerning outward events appears to pass through the avenues of our senses; and the more perceptive the senses are of difference, the larger is the field upon which our judgment and intelligence can act" (p. 27). Following this logic, tests of visual acuity or hearing ability are, in a sense, tests of intelligence. Galton attempted to measure this sort of intelligence in many of the sensorimotor and other perception-related tests he devised. Among his many other accomplishments, Sir Francis Galton is remembered as the first person to publish on the heritability of intelligence, thus anticipating later nature-nurture debates (McGue, 1997).

"Intelligence" is ...

Alfred Binet (1857–1911)

In papers critical of Galton's approach to intellectual assessment, Binet and a colleague called for more complex measurements of intellectual ability (Binet & Henri, 1895a, 1895b, 1895c). Galton had viewed intelligence as a number of distinct processes or abilities that could be assessed only by separate tests. In contrast, Binet argued that when one solves a particular problem, the abilities used cannot be separated because they interact to produce the solution. For example, memory and concentration interact when a subject is asked to repeat digits presented orally. When analyzing a testtaker's response to such a task, it is difficult to determine the relative contribution of memory and concentration to the successful solution. This difficulty in determining the relative contribution of distinct abilities is the reason Binet called for more complex measurements of intelligence. Although Binet never explicitly defined intelligence, he discussed its components in terms of reasoning, judgment, memory, and abstraction (Varon, 1936).

"Intelligence" is ...

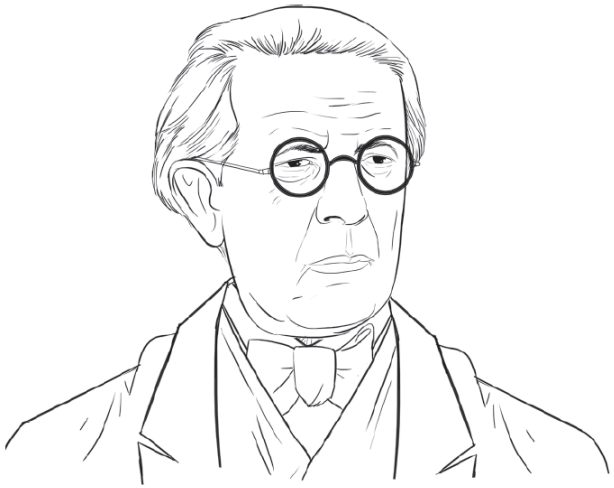
In Wechsler's (1958, p. 7) definition of intelligence, there is an explicit reference to an "aggregate" or "global" capacity:

> *Intelligence, operationally defined, is the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment. It is aggregate or global because it is composed of elements or abilities which, though not entirely independent, are qualitatively differentiable. By measurement of these abilities, we ultimately evaluate intelligence. But intelligence is not identical with the mere sum of these abilities, however inclusive. . . . The only way we can evaluate it quantitatively is by the measurement of the various aspects of these abilities.*

David Wechsler (1896–1981)

"Intelligence" is ...

For Piaget (1954, 1971), intelligence may be conceived of as a kind of evolving biological adaptation to the outside world. As cognitive skills are gained, adaptation (at a symbolic level) increases, and mental trial and error replaces physical trial and error. Yet, according to Piaget, the process of cognitive development occurs neither solely through maturation nor solely through learning. He believed that, as a consequence of interaction with the environment, psychological structures become reorganized. Piaget described four stages of cognitive development through which, he theorized, all of us pass during our lifetimes. Although individuals can move through these stages at different rates and ages, he believed that their order was unchangeable. Piaget viewed the unfolding of these stages of cognitive development as the result of the interaction of biological factors and learning.



Jean Piaget (1896–1980)

A Consensus Definition

- **Intelligence** may be defined, as did Charles Spearman (1904), as a "general reasoning ability"
- General because it is applicable to problems in many different fields
- This is not an idiosyncratic definition
- It is the one adopted by most of the leading psychometrists, for example, Cattell (1971), Jensen (1980), Carroll (1993), and Mackintosh (1998)
- **Abilities** may be defined as the cognitive (information processing) traits implicated in solving problems

Theories of Intelligence

- There are two classes of theories of intelligence:
  1. **Factor-analytic theories**
     - focus on identifying the ability or groups of abilities that constitute intelligence
  2. **Information-processing theories**
     - focus on identifying the specific mental processes that constitute intelligence

Theories of Intelligence

- There are two classes of theories of intelligence:
  1. **Factor-analytic theories**
     - focus on identifying the ability or groups of abilities that constitute intelligence
  2. **Information-processing theories**
     - focus on identifying the specific mental processes that constitute intelligence

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

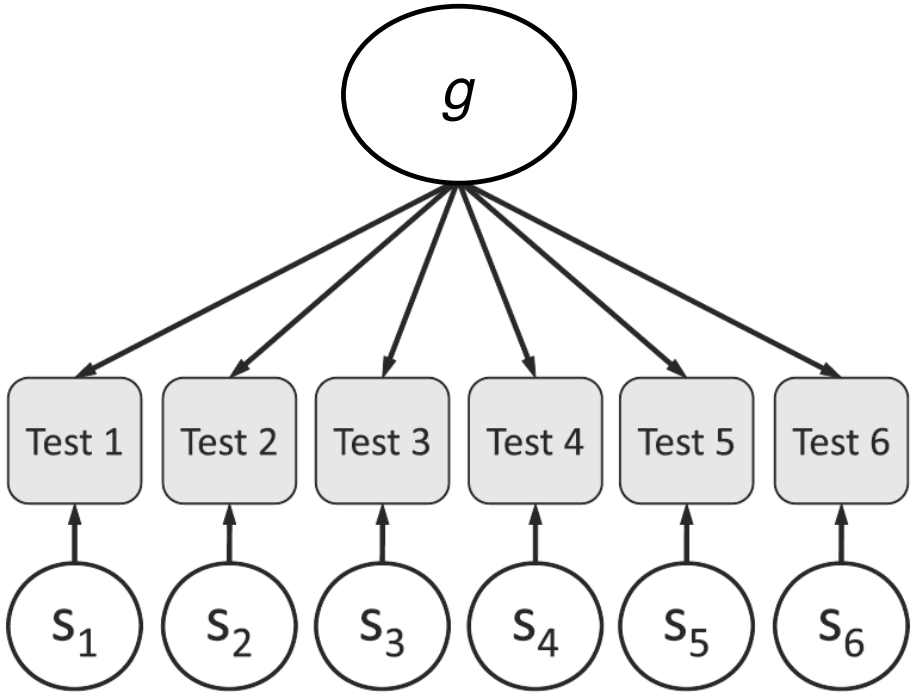
Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Spearman's Two-Factor Theory

- Charles Spearman found that measures of intelligence tended to correlate to various degrees with each other—known as the **positive manifold**
- Spearman (1927) proposed an influential theory of general intelligence that proposed the existence of a general intellectual ability factor (denoted as g) that is partially tapped by all other mental abilities
- Known as the **two-factor theory of intelligence**:
  - g represents the portion of variance that all intelligence tests have in common
  - the remaining portions of the variance are accounted for by specific abilities (denoted as s)

Spearman's Two-Factor Theory



- Spearman's two-factor theory has a misleading name because there are not just two factors; there is one general factor and as many s factors as there are tests
- Thus, the two-factor theory is really a theory about two different kinds of factors: general and specific

Spearman's Two-Factor Theory

- Tests that exhibited high positive correlations with other intelligence tests were thought to be highly saturated with g
- Tests with low or moderate correlations with other intelligence tests were viewed as possible measures of specific factors (such as visual or motor ability)
- The greater the magnitude of g in a test of intelligence, the better the test was thought to predict overall intelligence

Spearman's Two-Factor Theory

- Spearman (1927) thought of the g factor as some type of electrochemical mental energy available for problem solving
- It was g rather than s that was assumed to afford the best prediction of overall intelligence
- Abstract reasoning problems were thought to be the best measure of g in formal tests
- Spearman also acknowledged the existence of an intermediate class of factors common to a group of activities but not to all
- These **group factors** are neither as general as g or as specific as s (for example, linguistic, mechanical, and arithmetical abilities)

Brief interlude: Does g exist?

- The question of whether g exists is one on which cognitive ability researchers are sharply divided:
  - for some, the notion of g brings to mind abuses of IQ tests and the Nazi Germany eugenics program
  - for others, the fight for g is about defending cognitive ability research from political intrusion
- Spearman did not think performance on a test was only affected by g
- He believed that g may be composed of more than one factor

g is not an ability itself ...

- ... it is the sum total of all forces that cause abilities within the same person to be more similar to each other than they would otherwise be

Brief interlude: Does g exist?

- The question of whether g exists is one on which cognitive ability researchers are sharply divided:
  - for some, the notion of g brings to mind abuses of IQ tests and the Nazi Germany eugenics program
  - for others, the fight for g is about defending cognitive ability research from political intrusion
- Spearman did not think performance on a test was only affected by g
- He believed that g may be composed of more than one factor

g is not an ability itself ...

- ... it is the sum total of all forces that cause abilities within the same person to be more similar to each other than they would otherwise be

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Thurstone's Primary Mental Abilities

- Thurstone (1938) argued that g was a statistical artefact arising from the mathematical procedures used to study it
- He proposed that intelligence is defined by seven, independent, primary mental abilities (PMAs):
  1. Verbal comprehension
  2. Reasoning
  3. Perceptual speed
  4. Numerical ability
  5. Word fluency
  6. Associative memory
  7. Spatial visualization
- Thurstone designed tests to measure these seven abilities

Thurstone's Primary Mental Abilities

- When Thurstone administered his tests to an intellectually homogenous group of children, he found that the primary mental abilities were entirely independent
- However, when he administered his tests to an intellectually heterogenous group of children, he failed to find that the seven primary mental abilities were entirely seperate
- Instead, the primary mental abilities were moderately correlated—providing evidence for the existence of g
- Thurstone (1947) became willing to accept the existence of g above his PMAs
- The key Spearman/Thurstone disagreement concerned the perceived difference in relative importance of the first-order PMAs and the second-order g factor

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

The Work of Guilford and Gardner

- Other multiple-factor models of intelligence have been proposed that have sought to deemphasise, if not eliminate, reference to g
- Guilford (1967) developed a **Structure of Intellect Model** which included 120 independent ability factors
- Gardner (1983, 1994) developed a **Theory of Multiple Intelligences**: logical-mathematical, bodily-kinesthetic, linguistic, musical, spatial, interpersonal, and intrapersonal
- As we shall see later, these theories are at odds with the results of the most careful and comprehensive factor analytic studies which support the existence of g

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Cattell-Horn Model

- This is a theory developed by Raymond B. Cattell (1941, 1971) that has been modified by John Horn (e.g., Cattell & Horn, 1978)
- Cattell proposed that the original g factor of Spearman actually breaks down into two major cognitive abilities:
  1. **Fluid intelligence (g_f)**
  2. **Crystallised intelligence (g_c)**
- The genius of this theory is not the idea that there was more than one factor, or that there were specifically two factors (both ideas had been previously suggested by Spearman)
- The astounding achievement is that Cattell was able to describe the nature of both factors, and how Spearman's g arose from g_f and g_c

Cattell-Horn Model

Cattell's (1943) first printed description of both factors is worth quoting:

> *Fluid ability has the character of a purely general ability to discriminate and perceive relations between any fundaments, new or old. It increases until adolescence and then slowly declines. It is associated with the action of the whole cortex. It is responsible for the intercorrelations, or general factor, found among children's tests and among the speeded or adaptation requiring tests of adults.*
>
> *Crystallized ability consists of discriminatory habits long established in a particular field, originally through the operation of fluid ability, but no longer requiring insightful perception for their successful operation. (p. 178)*

Cattell-Horn Model

- Cattell believed that differences in people's breadth and depth of knowledge—crystallised intelligence—are the joint function of two kinds of influences:
  1. low fluid intelligence limits the rate at which a person can acquire and retain new knowledge
  2. people with high fluid intelligence have far fewer constraints on their ability to learn
- The influence of fluid intelligence on crystallised intelligence is moderated by **investment**—time and effort spent on learning
- Differences in time and effort spent on learning can be due to societal, familial, and personal investments

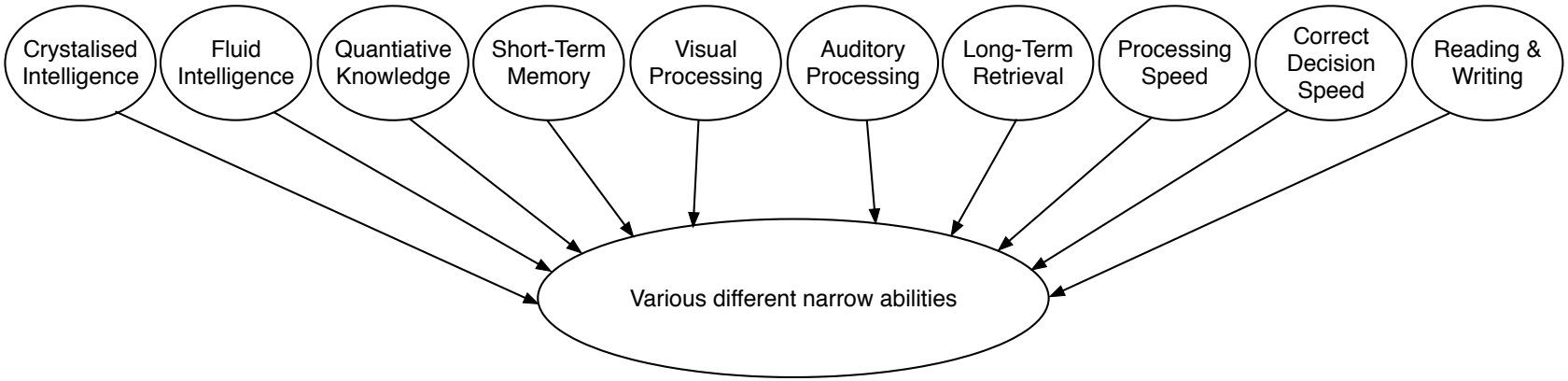
Cattell-Horn Model

- Catell's theory has an explanation for the positive manifold:
  - g_f and g_c are both general ability factors, and these factors are strongly correlated because g_f, in part, causes g_c via investment
  - however, for people low in g_f, investments pay smaller dividends than for people with high g_f
- this causes g_f and g_c to be highly correlated, and psychometric g emerges in the resulting positive manifold

Cattell-Horn Model

- Horn proposed the addition of several other broad ability factors:
  - Quantitative knowledge
  - Short-term memory
  - Visual processing
  - Auditory processing
  - Long-term retrieval
  - Processing speed
  - Correct decision speed
  - Reading/writing
- The broad ability factors subsume many different narrow ability factors

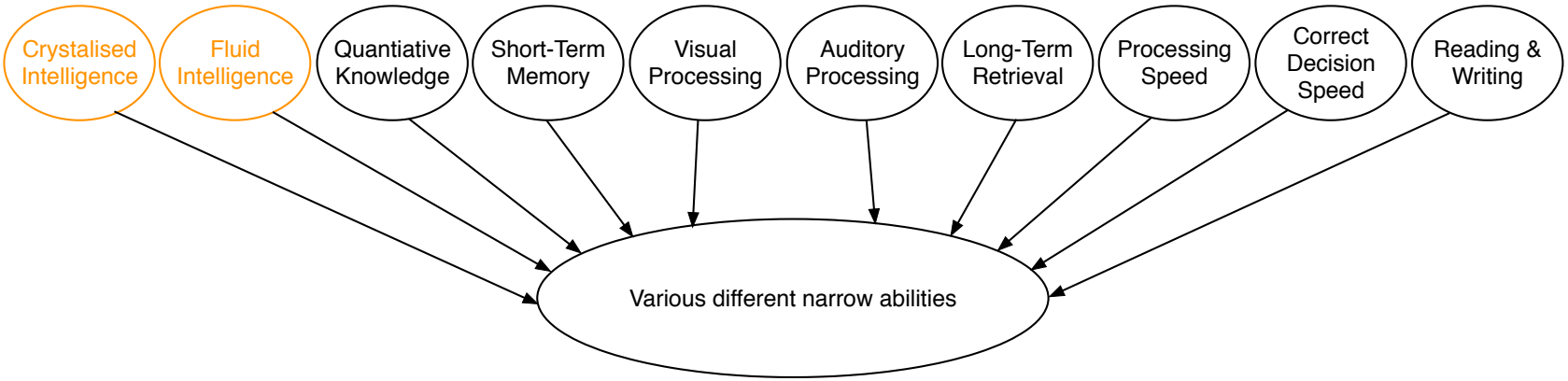
Cattell-Horn Model



Cattell-Horn Model

There is **no** general factor *g* in the Cattell-Horn Model

g is instead split into two components: **Cyrstallised Intelligence** and **Fluid Intelligence**



Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

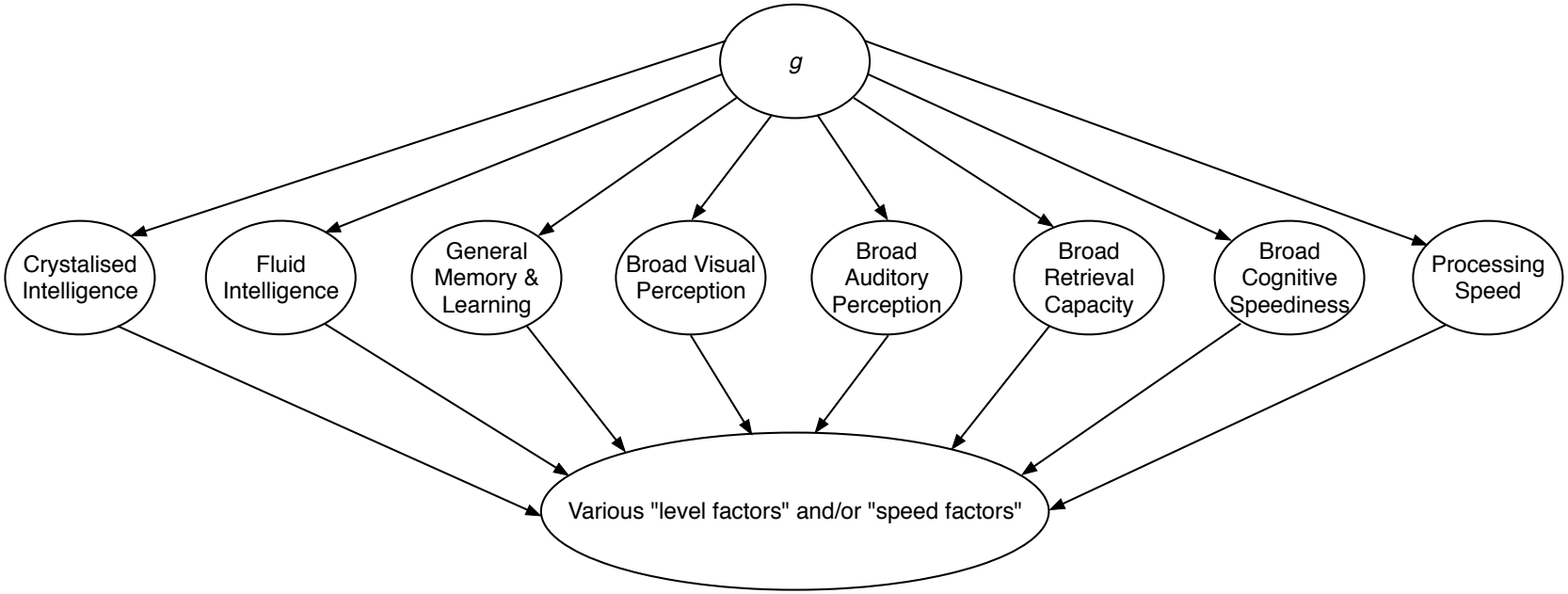
Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

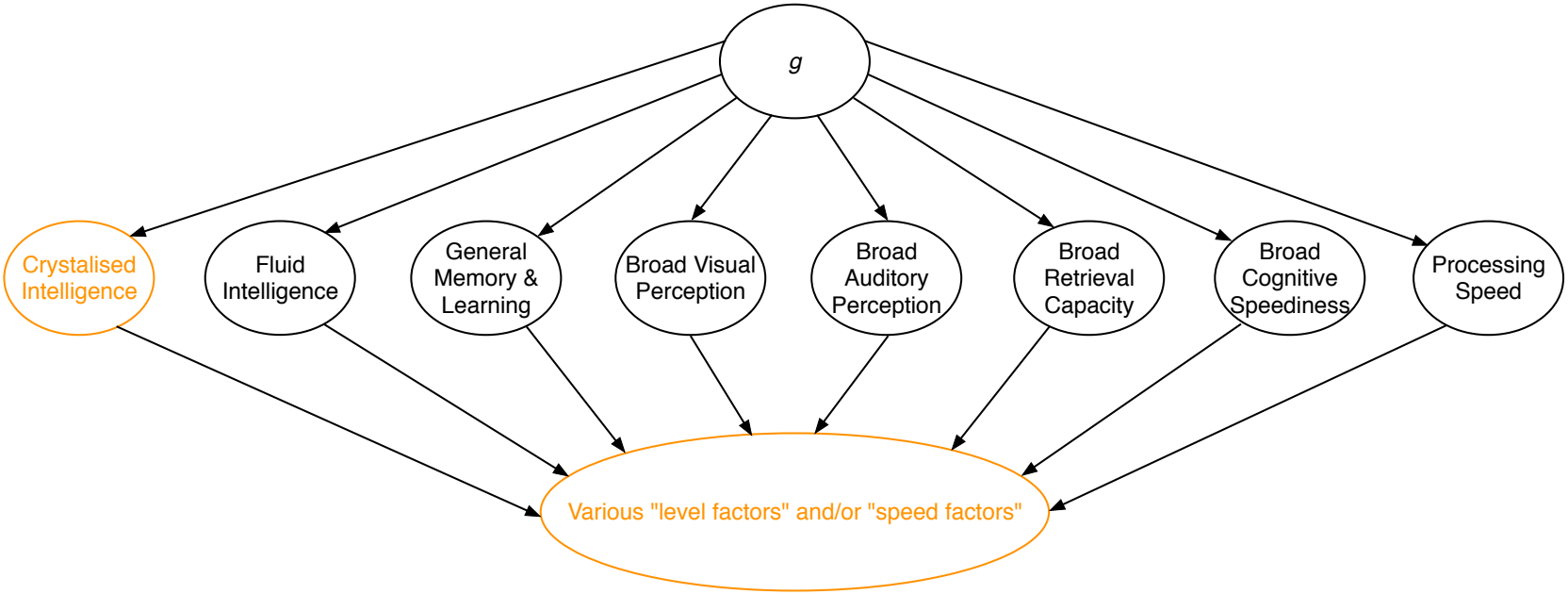
Carroll Model

- Another influential multiple-intelligences model is the **three-stratum theory of cognitive abilities** (Carroll, 1997)
- This is a hierarchical model with three levels, or strata:
- Top stratum (general ability):
  - general factor (g)—a unitary construct responsible for the positive manifold
- Second stratum (broad abilities):
  - fluid intelligence and crystallised intelligence
  - plus several additional abilities and processes: general memory and learning, broad visual perception, broad auditory perception, broad retrieval capacity, broad cognitive speediness, processing/decision speed
- Third stratum (narrow abilities):
  - various "level factors" and/or "speed factors"

Carroll Model



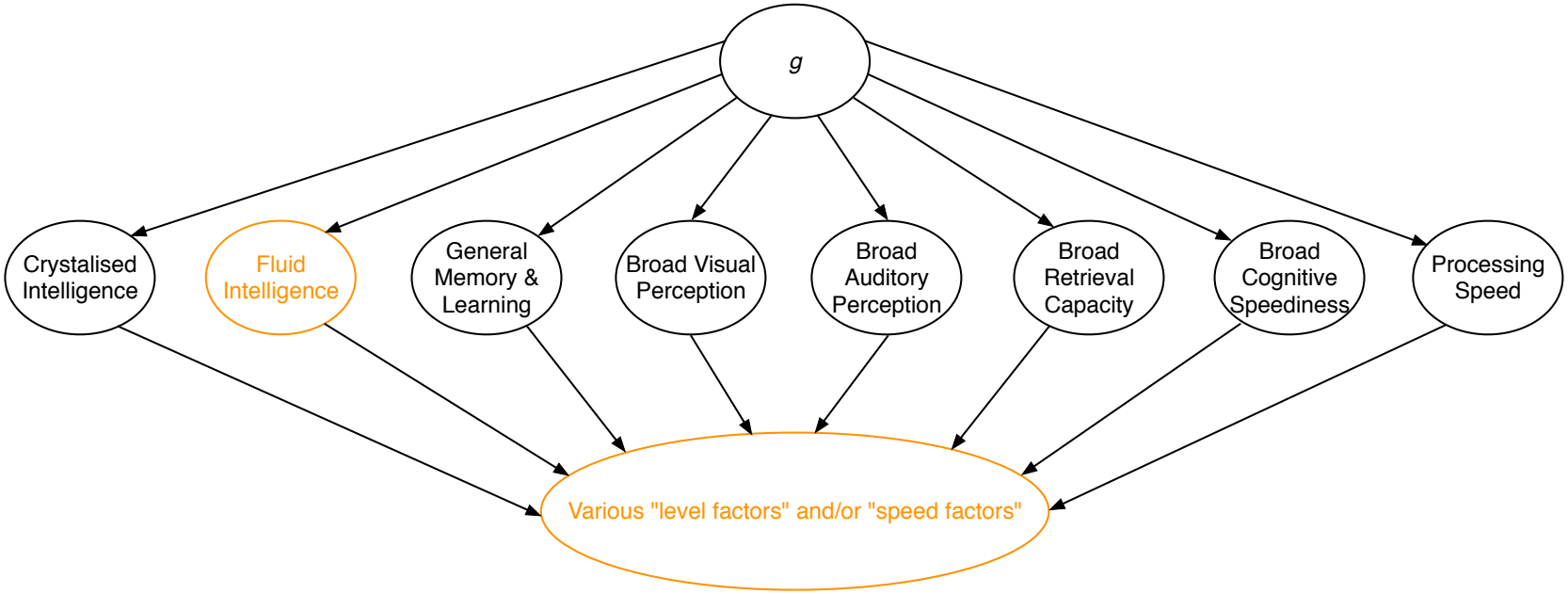
Carroll Model



Level factors
General reasoning, quantitative reasoning, and *Piagetian reasoning*

Speed factors
Speed of reasoning

Carroll Model



Level factors
Language development, comprehension, spelling ability, and *communication ability*

Speed factors
Oral fluency and writing ability

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Factor-Analytic Theories

- Factor analysis has been the primary methodological engine that has driven the psychometric study of intelligence for over 100 years
- The general approach which has been used is to administer a battery of tests covering the spectrum of abilities and to submit the correlations to factor analysis
- Over the years there have been many different factorial accounts of human abilities:
  1. Spearman's two-factor theory
  2. Thurstone's primary mental abilities
  3. The work of Guildford and Gardner
  4. Cattell-Horn Model
  5. Carroll Model
  6. Cattell-Horn-Carroll Model

Cattell-Horn-Carroll Model

- The **Cattell-Horn-Carroll (CHC) model** is a blending of the Cattell-Horn theory with Carroll's three-stratum theory
- These models are similar in several respects, particularly the correspondence between the broad abilities (second-stratum level in Carroll's theory)
- The key differences are:
  1. the presence (Carroll) or absence (Cattell-Horn) of a general intelligence (g) factor at the top stratum
  2. the inclusion (Cattell-Horn) or exclusion (Carroll) of a quantitative knowledge domain and reading and writing abilities at the second stratum
  3. the separation (Cattell-Horn) or integration (Carroll) of short-term memory and longer-term storage and retrieval

Cattell-Horn-Carroll Model

- The **Cattell-Horn-Carroll (CHC) model** is a blending of the Cattell-Horn theory with Carroll's three-stratum theory
- These models are similar in several respects, particularly the correspondence between the broad abilities (second-stratum level in Carroll's theory)
- The key differences are:
  1. the presence (Carroll) or absence (Cattell-Horn) of a general intelligence (g) factor at the top stratum
  2. the inclusion (Cattell-Horn) or exclusion (Carroll) of a quantitative knowledge domain and reading and writing abilities at the second stratum
  3. the separation (Cattell-Horn) or integration (Carroll) of short-term memory and longer-term storage and retrieval

Cattell-Horn-Carroll Model

- The **Cattell-Horn-Carroll (CHC) model** is a blending of the Cattell-Horn theory with Carroll's three-stratum theory
- These models are similar in several respects, particularly the correspondence between the broad abilities (second-stratum level in Carroll's theory)
- The key differences are:
  1. the presence (Carroll) or absence (Cattell-Horn) of a general intelligence (g) factor at the top stratum
  2. the inclusion (Cattell-Horn) or exclusion (Carroll) of a quantitative knowledge domain and reading and writing abilities at the second stratum
  3. the separation (Cattell-Horn) or integration (Carroll) of short-term memory and longer-term storage and retrieval

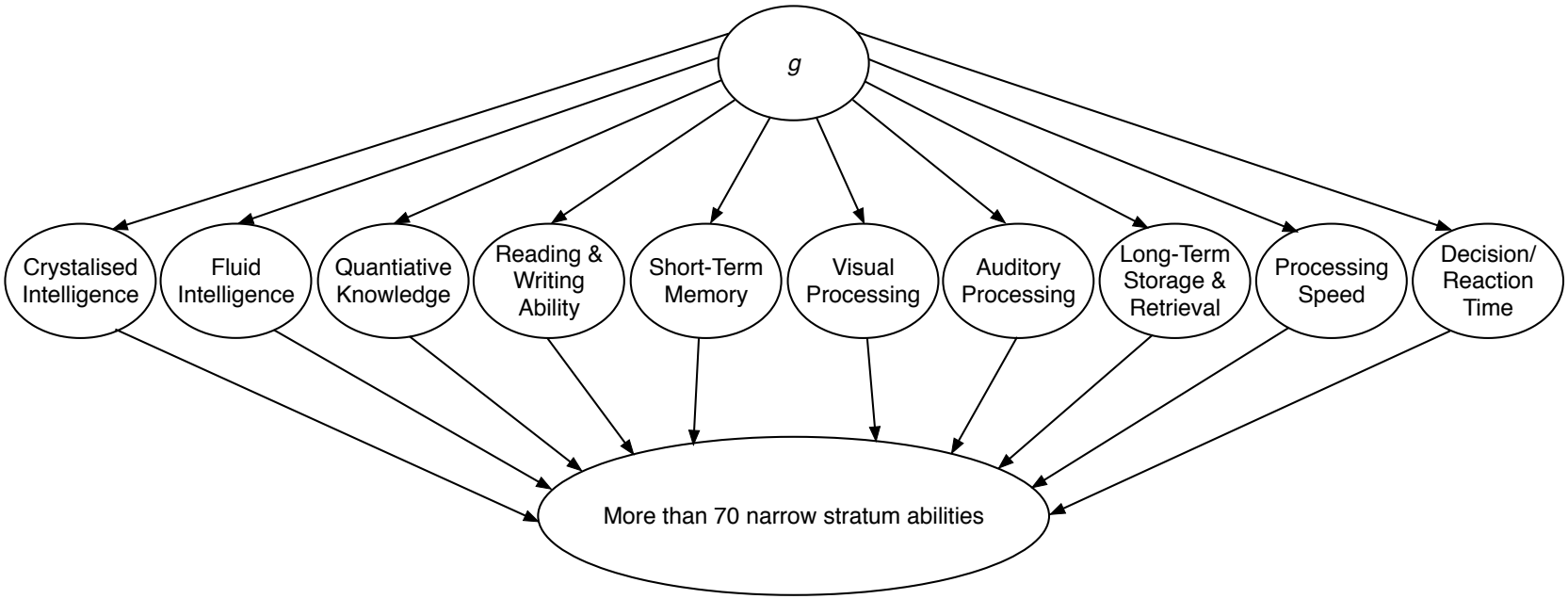
Cattell-Horn-Carroll Model

- The **Cattell-Horn-Carroll (CHC) model** is a blending of the Cattell-Horn theory with Carroll's three-stratum theory
- These models are similar in several respects, particularly the correspondence between the broad abilities (second-stratum level in Carroll's theory)
- The key differences are:
  1. the presence (Carroll) or absence (Cattell-Horn) of a general intelligence (g) factor at the top stratum
  2. the inclusion (Cattell-Horn) or exclusion (Carroll) of a quantitative knowledge domain and reading and writing abilities at the second stratum
  3. the separation (Cattell-Horn) or integration (Carroll) of short-term memory and longer-term storage and retrieval

Cattell-Horn-Carroll Model

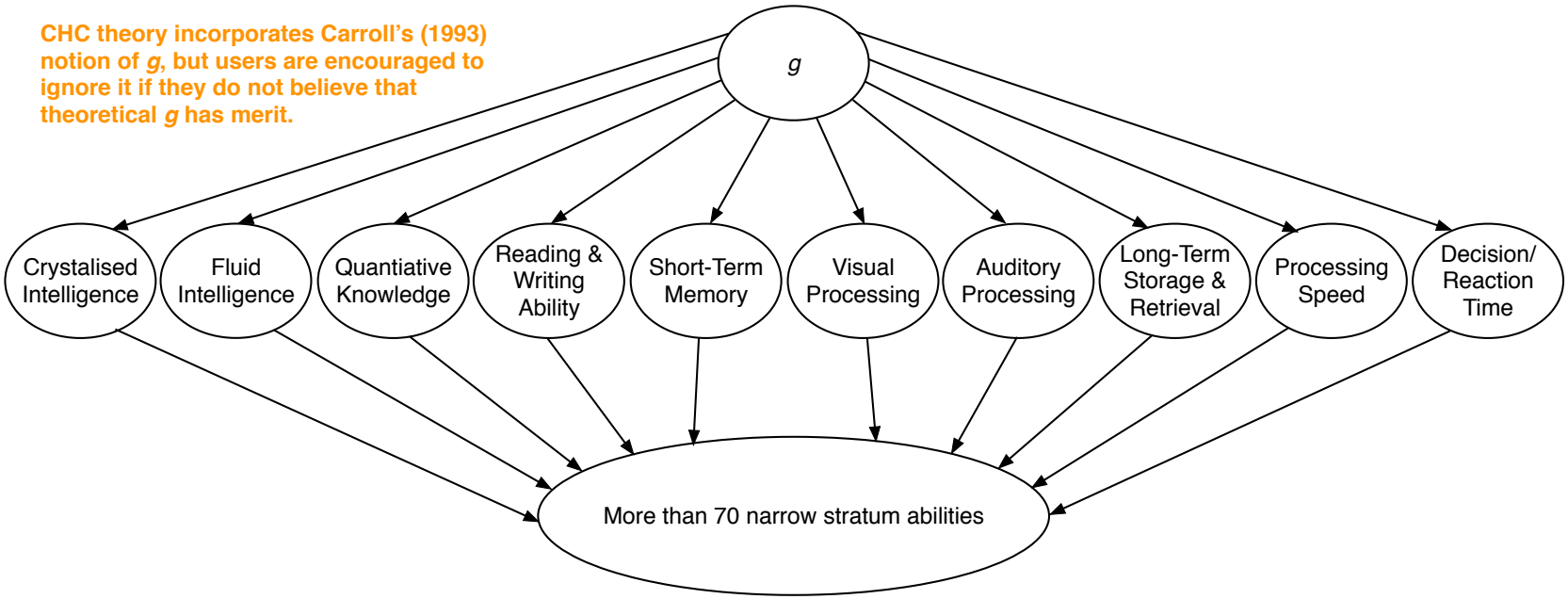
- CHC model contains a general factor (top stratum), ten "broad-stratum" abilities (second stratum), and over seventy "narrow-stratum" abilities (third stratum)
- The broad abilities of "quantitative knowledge" and "reading/writing ability" in the Cattell-Horn model are retained in the second stratum of the CHC model
  - factor analytic studies determined that these are best conceived as broad abilities (as envisaged by Cattell-Horn), rather than narrow abilities (as envisaged by Carroll)
- McGrew (2009) called on intelligence researchers to adopt CHC as a *consensus model*, thus allowing for a common theoretical framework

Cattell-Horn-Carroll Model



Cattell-Horn-Carroll Model

CHC theory incorporates Carroll's (1993) notion of *g*, but users are encouraged to ignore it if they do not believe that theoretical *g* has merit.



Theories of Intelligence

- There are two classes of theories of intelligence:
  1. **Factor-analytic theories**
     - focus on identifying the ability or groups of abilities that constitute intelligence
  2. **Information-processing theories**
     - focus on identifying the specific mental processes that constitute intelligence

Theories of Intelligence

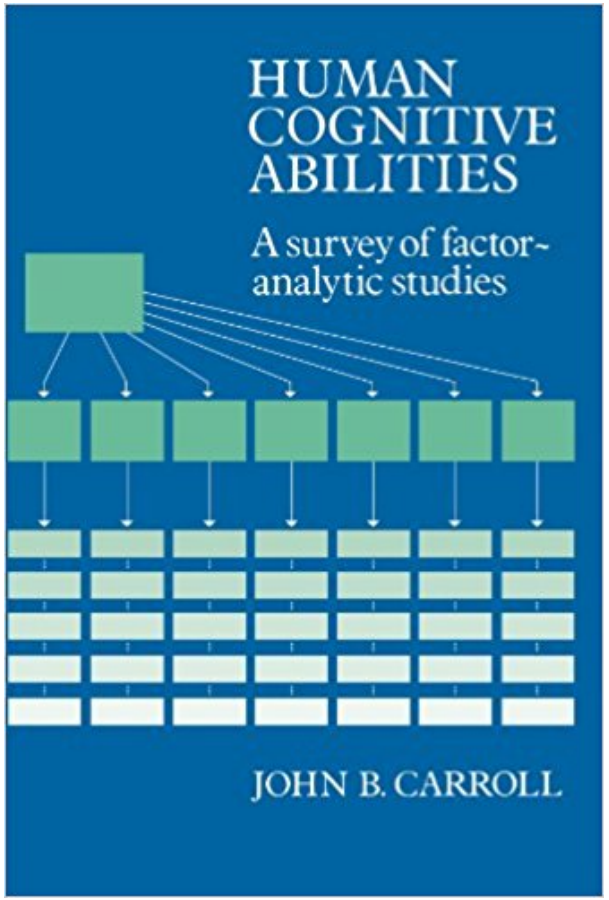
- There are two classes of theories of intelligence:
  1. **Factor-analytic theories**
     - focus on identifying the ability or groups of abilities that constitute intelligence
  2. **Information-processing theories**
     - focus on identifying the specific mental processes that constitute intelligence

Information Processing Theories

- This approach focuses on the mechanisms by which information is processed—*how* information is processed, rather than *what* is processed
- We will not be covering these theories as part of this lecture, you just need to be aware of the existence of this second class of theories
- If you want to know more about the information processing approach, read about the PASS model of intellectual functioning developed by Das et al. (1975), which is an influential model in this class of theories

Carroll's (1993) Principia: Structure of Human Cognitive Abilities

- In a seminal work, Carroll (1993) presented a comprehensive account of human cognitive abilities
- He reported the results of his systematic exploratory factor analysis of over 460 human cognitive ability datasets
- He used the best factor analytic procedures on these datasets, and his resulting list of factors may be regarded as definitive
- These factors will form the basis of this section on the structure of human cognitive abilities



Primary Ability (First-Order) Factors

- Primary ability, or **first-order factors**, are the factors that emerge when the correlations between a battery of tests covering the spectrum of abilities are subjected to factor analysis
- The factors in the table on the next slide represent the main primary ability factors extracted in the analyses by Carroll (1993)

The Main Primary Ability (First-Order) Factors

V	**verbal ability:** understanding words and ideas.
N	**numerical factor:** facility in the manipulation of numbers.
S	**spatial ability:** ability to recognise figures in different orientations.
P	**perceptual speed/accuracy:** rapidly assessing differences between stimuli.
C_s	**speed of closure:** ability to complete a pattern with a part missing.
I	**inductive reasoning.**
M_a	**rote memory:** memorising unlinked stimuli.
M_k	**mechanical ability.**
C_f	**flexibility of closure:** ability to find stimuli among distractors.
M_s	**memory span:** ability to recall immediately lists of letters or digits.
S_p	**spelling.**
E	**aesthetic judgement:** ability to detect basic principles of good art.
M_m	**meaningful memory**
O_1	**ideational flexibility:** ability to generate many different and original ideas.
F_1	**ideational fluency:** ability rapidly to develop many ideas on a topic.
W	**word fluency:** rapid production of words according to letter requirements.
O_2	**originality:** ability to combine two objects into one functional object.
A	**aiming:** hand-eye coordination.
R_d	**representational drawing ability.**
A_u	**auditory ability:** ability to differentiate/remember a sequence of tones.

The Main Primary Ability (First-Order) Factors

- These factors account for most of the variance in the main tests of ability
- As Carroll (1993) has shown, they are the factors which reliably appear when all studies are subjected to appropriate factor analytic techniques
- There are too many to be able to make a coherent picture of human ability
- Fortunately, these factors are correlated, meaning that the table of factors can be simplified by:
  - factor analysis of the correlations between the factors (**second-order factors**)
  - factor analysis of the correlations between the second orders (**third-order factors**)

The Main Higher-Order Ability Factors

- These are the main higher-order ability factors extracted from Carroll's (1993) analyses

1	g (third order). Extracted from around 150 of the data sets by Carroll (1993).
2	Fluid intelligence (second order).
3	Crystallised intelligence (second order).
4	Visual perception (second order).
5	Auditory perception (second order).
6	Cognitive speed (second order).
7	Retrieval ability (second order).
8	Memory ability (second order).

Second-Order Factors: Fluid and Crystallised Intelligence

- As Cattell (1971) demonstrated, the original g factor of Spearman actually breaks down into two correlated intelligence factors:
  1. Fluid intelligence
  2. Crystallised intelligence
- It is therefore strictly incorrect to talk of intelligence—intelligence is actually comprised of two factors
- Intelligence, as measured by many intelligence tests, is a mixture of these two factors
- In any battery of cognitive tests, these two factors account for most of the variance

Other Second-Order Factors

- The other second order factors account for less variance in human abilities than the two intelligence factors
- **Visual perception**: the ability to visualise, which is important in the solution of some kinds of problems
- **Cognitive speed**: this can be seen in activities like writing and mental arithmetic
- **Retrieval capacity**: this is a fluency factor, reflecting the ability to retrieve material quickly from memory
- **The memory factor**: involved in any task in which memorising plays a role
- **Auditory perception**: involved in all tasks requiring auditory discrimination

Conclusions Regarding Second-Order Factors

- There are two large second-order factors, fluid and crystallised intelligence, that dominate the performance of most tasks
- Retrieval capacity is important with regards fluency (e.g., in conversational speech)
- Cognitive speed and visual perception are also important in certain problems, as are auditory perception and various memory factors
- The first two factors, the split of the old g factor, are fundamental to problem solving

The Third-Order g Factor

- Third-order factors are, in principle, derived from the correlations between second order factors
- However, it is possible, and usually more informative, to examine the loadings of primary factors onto the third orders
- The third order g factor, in the work of Carroll (1993), when submitted to this form of analysis has informative loadings
- The main ones are inductive reasoning, visualisation, quantitative reasoning, and verbal ability
- Suggests this factor is "truly general"—it loads all those components we would regard as typical of intelligence

The Third-Order g Factor

- The existence of the g factor confers support for the notion of a general reasoning ability
- Further evidence for a general reasoning ability comes from the correlated factors of fluid and crystallised intelligence

Conclusions Concerning The Structure of Human Abilities

- The factor analytic findings are extremely clear
- Two general reasoning factors account for much of the variance in human ability:
  1. Fluid intelligence
  2. Crystallised intelligence
- There are other substantial factors:
  1. Visual perception
  2. Cognitive speed
  3. Retrieval capacity

Conclusions Concerning The Structure of Human Abilities

- The importance of the general factors does not deny the influence in some individuals of more specific abilities
- For example, musical ability in a musician or high visualisation in a chess player
- The most important finding—replicated in over 10,000 studies—is the pervasive influence of general ability
- This is evinced through the consistently high proportion of variance in human ability explained by fluid and crystallised intelligence

Conclusions Concerning The Structure of Human Abilities

- In terms of the factor-analytic theories presented at the outset, the results favour hierarchical models of intelligence:
  - Carroll's three-stratum theory
  - CHC model
- The results are clearly at variance with theories that deemphasise or eliminate the role of g:
  - Thurstone's (1938) Primary Mental Abilities
  - Guildford's (1967) Structure of Intellect Model
  - Gardner's (1983, 1994) Theory of Multiple Intelligences

Measuring Intelligence

- Intelligence tests fall into two groups:
  1. those designed to test participants individually
  2. those which can be used with groups of participants
- **Individual tests** are used in educational psychology where it is useful to observe how a child actually solves problems
  - however, they take a long time to administer and require specialised training
- **Group tests** require far less skill to administer
  - these are generally used where large numbers of participants need to be tested

Individual Tests

- The two most well-known individual tests of intelligence are two of the oldest, although they have been extensively modified and developed over the years
- They are regarded as benchmark measures of intelligence, although they were developed before the structure of abilities was defined
- They measure a mixture of crystalised and fluid intelligence
- These are the Stanford-Binet test and the tests devised by David Wechsler—the Wechsler scales for adults and children

Stanford-Binet (SB5) Test

- Designed for administration to assess individuals as young as 2 and as old as 85
- The test yields a number of composite scores, including a Full Scale IQ derived from the administration of ten subtests
- Other composite scores are:
  - an Abbreviated Battery IQ score
  - a Verbal IQ score, and a
  - Nonverbal IQ score
- The test yields five Factor Index (IQ) Scores corresponding to each of the five factors that the test is presumed to measure
- The SB5 is based on the CHC theory of intellectual abilities

Stanford-Binet (SB5) Test

- This test is designed to measure five different factors
  1. Fluid Reasoning
  2. Knowledge
  3. Quantitative Reasoning
  4. Visual-Spatial Processing
  5. Working Memory
- These five factors are measured using different types of tasks and subtests
- Some tasks require facility with language, whereas other tasks minimise demands on facility with language
- The latter subtests use pictorial rather than verbal items

Stanford-Binet (SB5) Test

CHC and Corresponding SB5 Factors

CHC Factor Name	SB5 Factor Name	Brief Definition	Sample SB5 Subtest
Fluid Intelligence (*Gf*)	Fluid Reasoning (FR)	Novel problem solving; understanding of relationships that are not culturally bound	Object Series/Matrices (nonverbal) Verbal Analogies (verbal)
Crystallized Knowledge (*Gc*)	Knowledge (KN)	Skills and knowledge acquired by formal and informal education	Picture Absurdities (nonverbal) Vocabulary (verbal)
Quantitative Knowledge (*Gq*)	Quantitative Reasoning (QR)	Knowledge of mathematical thinking including number concepts, estimation, problem solving, and measurement	Verbal Quantitative Reasoning (verbal) Nonverbal Quantitative Reasoning (nonverbal)
Visual Processing (*Gv*)	Visual-Spatial Processing (VS)	Ability to see patterns and relationships and spatial orientation as well as the gestalt among diverse visual stimuli	Position and Direction (verbal) Form Board (nonverbal)
Short-Term Memory (*Gsm*)	Working Memory (WM)	Cognitive process of temporarily storing and then transforming or sorting information in memory	Memory for Sentences (verbal) Delayed Response (nonverbal)

- The SB5 measure five CHC factors by different types of tasks and subtests at different levels

Stanford-Binet (SB5) Test

CHC and Corresponding SB5 Factors

CHC Factor Name	SB5 Factor Name	Brief Definition	Sample SB5 Subtest
Fluid Intelligence (*Gf*)	Fluid Reasoning (FR)	Novel problem solving; understanding of relationships that are not culturally bound	Object Series/Matrices (nonverbal) Verbal Analogies (verbal)
Crystallized Knowledge (*Gc*)	Knowledge (KN)	Skills and knowledge acquired by formal and informal education	Picture Absurdities (nonverbal) Vocabulary (verbal)
Quantitative Knowledge (*Gq*)	Quantitative Reasoning (QR)	Knowledge of mathematical thinking including number concepts, estimation, problem solving, and measurement	Verbal Quantitative Reasoning (verbal) Nonverbal Quantitative Reasoning (nonverbal)
Visual Processing (*Gv*)	Visual-Spatial Processing (VS)	Ability to see patterns and relationships and spatial orientation as well as the gestalt among diverse visual stimuli	Position and Direction (verbal) Form Board (nonverbal)
Short-Term Memory (*Gsm*)	Working Memory (WM)	Cognitive process of temporarily storing and then transforming or sorting information in memory	Memory for Sentences (verbal) Delayed Response (nonverbal)

- The SB5 measure five CHC factors by different types of tasks and subtests at different levels

Stanford-Binet (SB5) Test

- SB5 Full Scale IQ internal consistency reliability is very high (.97 to .98)
- Test-retest reliability coefficients are also high (high .7's to low .9's)
- Criterion-related validity provided in the form of concurrent and predictive data:
  - SB5 is correlated with other measures of intelligence, notably the WAIS (see next)
  - SB5 correlated with measures of achievement, such as the Wechsler Individual Achievement Test
- Factor-analytic support for the construct validity of the SB5
  - but some questions about this structure with clinical populations

Wechsler Adult Intelligence Scale (WAIS-IV)

- The WAIS-IV is the current Wechsler Adult Intelligence Scale
- It is made up of subtests designated either as *core* or *supplemental*
- **Core subtest:**
  - administered to obtain a composite score
- **Supplemental subtest:**
  - administered to provide additional clinical information, or extend the number of abilities/processes sampled
- Sometimes a supplemental subtest might be used in place of a core subtest
  - for example, if an examiner incorrectly administered a core subtest

Wechsler Adult Intelligence Scale (WAIS-IV)

- The WAIS-IV contains ten core subtests and five supplemental subtests

WAIS-IV Subtests Grouped According to Indexes

Verbal Comprehension Scale	Perceptual Reasoning Scale	Working Memory Scale	Processing Speed Scale
Similarities[a]	Block Design[a]	Digit Span[a]	Symbol Search[a]
Vocabulary[a]	Matrix Reasoning[a]	Arithmetic[a]	Coding[a]
Information[a]	Visual Puzzles[a]	Letter-Number Sequencing (ages 16–69)[b]	Cancellation (ages 16–69)[b]
Comprehension[b]	Picture Completion[b]		
	Figure Weights (ages 16–69)[b]		

[a]Core subtest.
[b]Supplemental subtest.

- The WAIS-IV subtests load on four factors:
  1. Verbal Comprehension
  2. Perceptual Reasoning
  3. Working Memory
  4. Processing Speed

Sample Items Used To Measure Intelligence

Subtest	Description
Information	*In what continent is Brazil?* Questions such as these, which are wide-ranging and tap general knowledge, learning, and memory, are asked. Interests, education, cultural background, and reading skills are some influencing factors in the score achieved.
Comprehension	In general, these questions tap social comprehension, the ability to organize and apply knowledge, and what is colloquially referred to as "common sense." An illustrative question is *Why should children be cautious in speaking to strangers?*
Similarities	*How are a pen and a pencil alike?* This is the general type of question that appears in this subtest. Pairs of words are presented to the examinee, and the task is to determine how they are alike. The ability to analyze relationships and engage in logical, abstract thinking are two cognitive abilities tapped by this type of test.
Arithmetic	Arithmetic problems are presented and solved verbally. At lower levels, the task may involve simple counting. Learning of arithmetic, alertness and concentration, and short-term auditory memory are some of the intellectual abilities tapped by this test.
Vocabulary	The task is to define words. This test is thought to be a good measure of general intelligence, although education and cultural opportunity clearly contribute to success on it.
Receptive Vocabulary	The task is to select from four pictures what the examiner has said aloud. This tests taps auditory discrimination and processing, auditory memory, and the integration of visual perception and auditory input.
Picture Naming	The task is to name a picture displayed in a book of stimulus pictures. This test taps expressive language and word retrieval ability.
Digit Span	The examiner verbally presents a series of numbers, and the examinee's task is to repeat the numbers in the same sequence or backward. This subtest taps auditory short-term memory, encoding, and attention.
Letter-Number Sequencing	Letters and numbers are orally presented in a mixed-up order. The task is to repeat the list with numbers in ascending order and letters in alphabetical order. Success on this subtest requires attention, sequencing ability, mental manipulation, and processing speed.
Picture Completion	The subject's task here is to identify what important part is missing from a picture. For example, the testtaker might be shown a picture of a chair with one leg missing. This subtest draws on visual perception abilities, alertness, memory, concentration, attention to detail, and ability to differentiate essential from nonessential detail. Because respondents may point to the missing part, this test provides a good nonverbal estimate of intelligence. However, successful performance on a test such as this still tends to be highly influenced by cultural factors.

Sample Items Used To Measure Intelligence

Picture Arrangement	In the genre of a comic-strip panel, this subtest requires the testtaker to re-sort a scrambled set of cards with pictures on them into a story that makes sense. Because the testtaker must understand the whole story before a successful re-sorting will occur, this subtest is thought to tap the ability to comprehend or "size up" a situation. Additionally, attention, concentration, and ability to see temporal and cause-and-effect relationships are tapped.
Block Design	A design with colored blocks is illustrated either with blocks themselves or with a picture of the finished design, and the examinee's task is to reproduce the design. This test draws on perceptual-motor skills, psychomotor speed, and the ability to analyze and synthesize. Factors that may influence performance on this test include the examinee's color vision, frustration tolerance, and flexibility or rigidity in problem solving.
Object Assembly	The task here is to assemble, as quickly as possible, a cut-up picture of a familiar object. Some of the abilities called on here include pattern recognition, assembly skills, and psychomotor speed. Useful qualitative information pertinent to the examinee's work habits may also be obtained here by careful observation of the approach to the task. For example, does the examinee give up easily or persist in the face of difficulty?
Coding	If you were given the dot-and-dash equivalents of several letters in Morse code and then had to write out letters in Morse code as quickly as you could, you would be completing a coding task. The Wechsler coding task involves using a code from a printed key. The test is thought to draw on factors such as attention, learning ability, psychomotor speed, and concentration ability.
Symbol Search	The task is to visually scan two groups of symbols, one search group and one target group, and determine whether the target symbol appears in the search group. The test is presumed to tap cognitive processing speed.
Matrix Reasoning	A nonverbal analogy-like task involving an incomplete matrix designed to tap perceptual organizing abilities and reasoning.
Word Reasoning	The task is to identify the common concept being described with a series of clues. This test taps verbal abstraction ability and the ability to generate alternative concepts.
Picture Concepts	The task is to select one picture from two or three rows of pictures to form a group with a common characteristic. It is designed to tap the ability to abstract as well as categorical reasoning ability.
Cancellation	The task is to scan either a structured or an unstructured arrangement of visual stimuli and mark targeted images within a specified time limit. This subtest taps visual selective attention and related abilities.

Wechsler Adult Intelligence Scale (WAIS-IV)

- Scoring of subtests yields four factor index scores:
  1. Verbal Comprehension Index
  2. Perceptual Reasoning Index
  3. Working Memory Index
  4. Processing Speed Index
- There is also a General Ability Index (GAI)—a composite of indexes 1 and 2
- Additionally, there is a Cognitive Proficiency Index (CPI)—a composite of indexes 3 and 4
- The GAI and CPI can be used as aids to better understand and identify various learning disabilities

Wechsler Adult Intelligence Scale (WAIS-IV)

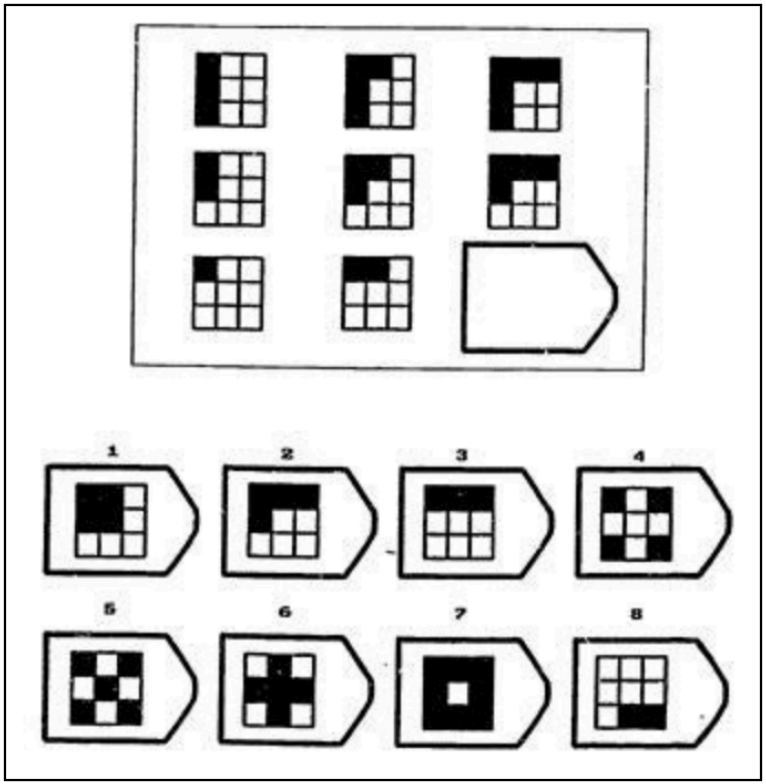
- Data from several studies suggest the WAIS-IV is psychometrically sound (Coalson & Raiford, 2008):
  - all of the subtest and composite scores have high internal consistency reliability estimates (>.90)
  - the validity of the WAIS-IV has been verified through concurrent validity studies, and convergent and discriminant validity studies

Group Tests

- There are a large number of group tests of intelligence
- The most valid measures are:
  1. Raven's Matrices
  2. The Mill-Hill and Crichton Scales
  3. The Culture-Fair Test

Raven's Matrices

- These were developed by Raven in the late 1930s and there have been various updated versions
- Incomplete sequences of diagrams are presented to subjects for completion
- Requires the relationships between the diagrams to be worked out and the rule to be applied to select the correct answer



Raven's Matrices

- Raven's Matrices was designed to measure:
  - the ability to make sense of complexity and
  - the ability to store and reproduce information
- It is considered to be a very good measure of fluid intelligence
- In factor analytic studies, the matrices are the best loading test for fluid intelligence (Carroll, 1993)

The Mill-Hill and Crichton Scales

- These are two vocabulary tests designed to use alongside Raven's matrices
- Vocabulary is the single best measure of crystallised intelligence
- Thus, the combination of one of these vocabulary tests and the Raven's matrices yields an excellent assessment of the two intelligence factors

The Culture-Fair Test

- This test is designed to measure fluid intelligence
- It differs from Raven's in that there is a variety of items, in addition to matrices, to overcome problems of specific variance
- All items are nonverbal consisting of:
  1. Mazes
  2. Figure matrices
  3. Classifications
  4. Series
- The test was designed to include only those tasks that seem to reflect experiences, knowledge, and skills common to different cultures

The Culture-Fair Test

Mazes

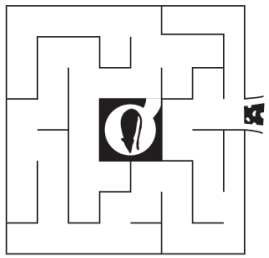
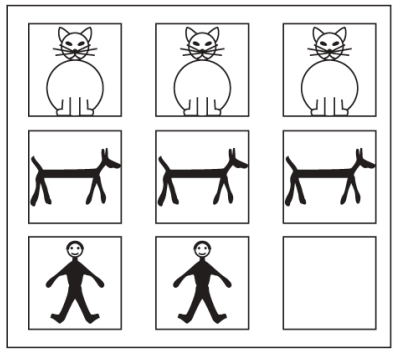


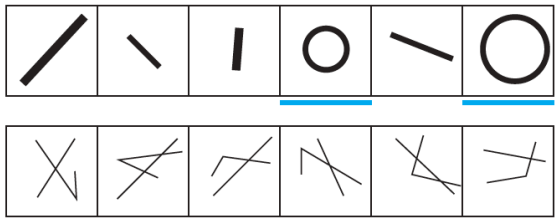
Figure Matrices

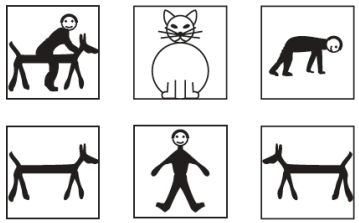
Choose from among the six alternatives the one that most logically completes the matrix pattern above it.



Classification

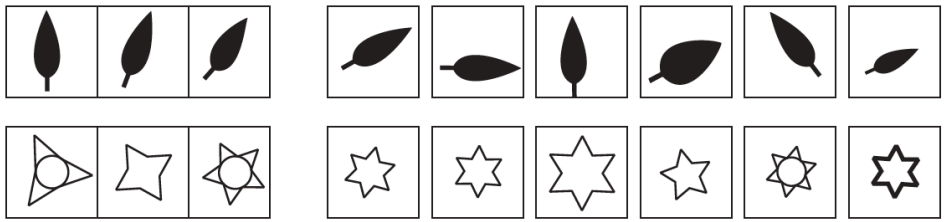
Pick out the two odd items in each row of figures.





Series

Choose one figure from the six on the right that logically continues the series of three figures at the left.



Next Week ...

- ... Personality and its Assessment