Fluid and Crystallized Intelligence

Subjects: Others
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The concepts of fluid intelligence (gf) and crystallized intelligence (gc) were introduced in 1963 by the psychologist Raymond Cattell. According to Cattell's psychometrically-based theory, general intelligence (g) is subdivided into gf and gc. Fluid intelligence is the ability to solve novel reasoning problems and is correlated with a number of important skills such as comprehension, problem solving, and learning. Crystallized intelligence, on the other hand, involves the ability to deduce secondary relational abstractions by applying previously learned primary relational abstractions.

Keywords: fluid intelligence ; general intelligence ; crystallized

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1. History

Fluid and crystallized intelligence are constructs originally conceptualized by Raymond Cattell.[1] The concepts of fluid and crystallized intelligence were further developed by Cattell and his former student John L. Horn.[2][3][4]

2. Fluid Versus Crystallized Intelligence

Fluid intelligence (g_f) refers to basic processes of reasoning and other mental activities that depend only minimally on prior learning (such as formal and informal education) and acculturation. Horn notes that it is formless, and can "flow into" a wide variety of cognitive activities [5] Tasks measuring fluid reasoning require the ability to solve abstract reasoning problems. Examples of tasks that measure fluid intelligence include figure classifications, figural analyses, number and letter series, matrices, and paired associates.[3]

Crystallized intelligence (g_c) refers learned procedures and knowledge. It reflects the effects of experience and acculturation. Horn notes that crystallized ability is a "precipitate out of experience," resulting from the prior application of fluid ability that has been combined with the intelligence of culture."[5] Examples of tasks that measure crystallized intelligence are vocabulary, general information, abstract word analogies, and mechanics of language.[3]

An example of the application of fluid and crystallized abilities to problem-solving

Horn[5] provided an example of crystallized and fluid approaches to solving a problem. Here is the problem he described:

"There are 100 patients in a hospital. Some (an even number) are one-legged, but wearing shoes. One-half of the remainder are barefooted. How many shoes are being worn?"

The crystallized approach to solving the problem would involve the application of the algebra we learned in high school. Algebra is an acculturational product.

x + 1/2(100-x)*2 = the number of shoes worn, where x = the number of one-legged men. 100 - x = the number of two-legged men. The solution boils down to 100 shoes.

Horn also provided an example of a fluid approach to solving the problem that does not depend on the learning of algebra in high school. Horn invented a boy who is too young to attend secondary school but could solve the problem through the application of fluid abiltiy: "He may reason that, if half the two-legged people are without shoes, and all the rest (an even number) are one-legged, then the shoes must average one per person, and the answer is 100."

3. Relationship to Piaget's Theory of Cognitive Development

Researchers have linked the theory of fluid and crystallized abilities to Piaget's theory of cognitive development.[6][7] Fluid ability and Piaget's operative intelligence both concern logical thinking and the "eduction of relations" (an expression Cattell used to refer to the inferring of relationships). Crystallized ability and Piaget's treatment of everyday learning reflect the impress of experience. Like fluid ability's relation to crystallized intelligence, Piaget's operativity is considered to be prior to, and ultimately provides the foundation for, everyday learning.[7]

4. Measurement of Fluid Intelligence

Various measures have been used to assess fluid intelligence.

4.1. Raven's Progressive Matrices

The Raven's Progressive Matrices (RPM)[8] is one of the most commonly used measures of fluid ability. It is a non-verbal multiple choice test. Participants have to complete a series of drawings by identifying relevant features based on the spatial organization of an array of objects, and choosing one object that matches one or more of the identified features.[9] This task assesses the ability to consider one or more relationships between mental representations or *relational reasoning. Propositional analogies* and semantic decision tasks are also used to assess relational reasoning.[10][11]

4.2. Woodcock-Johnson Tests of Cognitive Abilities, Third Edition

In the Woodcock-Johnson Tests of Cognitive Abilities, Third Edition, (WJ-III) g_f was assessed by two tests: Concept Formation and Analysis Synthesis.[12] On Concept Formation tasks, the individual had to use categorical thinking while Analysis Synthesis tasks required general sequential reasoning.[13]

WJ-III Concept Formation

Individuals had to apply concepts by inferring the underlying "rules" for solving visual puzzles that are presented in increasing levels of difficulty. As the level of difficulty increased, individuals had to identify a key difference (or the "rule") for solving puzzles involving one to one comparisons. For more difficult items, individuals needed to understand the concept of "and" (e.g., a solution must have some of this and some of that) and the concept of "or" (e.g., to be inside a box, the item must be either this or that). The most difficult items required fluid transformations and cognitive shifting between the various types of concept puzzles that the examinee had worked with previously.[13]

WJ-III Analysis-Synthesis

In the Analysis-Synthesis test, the individual had to learn and orally state the solutions to incomplete logic puzzles that mimic a miniature mathematics system. The test also contained some of the features involved in using symbolic formulations in other fields such as chemistry and logic. The individual was presented with a set of logic rules, a "key" that is used to solve the puzzles. The individual had to determine the missing colors within each of the puzzles using the key. Complex items presented puzzles that required two or more sequential mental manipulations of the key to derive a final solution. Increasingly difficult items involved a mix of puzzles that required fluid shifts in deduction, logic, and inference.[12]

4.3. Wechsler Intelligence Scales for Children, Fourth Edition

In the Wechsler Intelligence Scales for Children, Fourth Edition (WISC-IV),[14] the Perceptual Reasoning Index contains two subtests that assessed g_f: Matrix Reasoning, which involves induction and deduction, and Picture Concepts, which involves induction.[15]

WISC-IV Picture Concepts

In the Picture Concepts task, children were presented a series of pictures on two or three rows and asked which pictures (one from each row) belong together based on some common characteristic. This task assessed the child's ability to discover the underlying characteristic (e.g., rule, concept, trend, class membership) that governs a set of materials.[15]

WISC-IV Matrix Reasoning

Matrix Reasoning also tested this ability as well as the ability to start with stated rules, premises, or conditions and to engage in one or more steps to reach a solution to a novel problem (deduction). In the Matrix Reasoning test, children were presented a series or sequence of pictures with one picture missing. Their task was to choose the picture that fits the series or sequence from an array of five options. Since Matrix Reasoning and Picture Concepts involved the use of visual stimuli and did not require expressive language, they were considered to be non-verbal tests of g_f.[15]

4.4. In the Workplace

Within the corporate environment, fluid intelligence is a predictor of a person's capacity to work well in environments characterised by complexity, uncertainty, and ambiguity. The Cognitive Process Profile (CPP) measures a person's fluid intelligence and cognitive processes. It maps these against suitable work environments according to Elliott Jacques Stratified Systems Theory.

4.5. Factors Related to Measuring Intelligence

Some authors have suggested that unless an individual is truly interested in a problem presented on an IQ test, the cognitive work required to solve the problem to may not be performed owing to a lack of interest. These authors contended that a low score on tests which are intended to measure fluid intelligence may reflect more a lack of interest in the tasks themselves rather than any sort of inability to complete the tasks successfully.[16]

5. Development Across Life Span

Fluid intelligence peaks at around age 20 and then gradually declines.[17] This decline may be related to local atrophy of the brain in the right cerebellum, a lack of practice, or the result of age-related changes in the brain.[18][19]

Crystallized intelligence typically increases gradually, stays relatively stable across most of adulthood, and then begins to decline after age 65.[19] The exact peak age of cognitive skills remains elusive.[20]

6. Fluid Intelligence and Working Memory

Working memory capacity is closely related to fluid intelligence, and has been proposed to account for individual differences in g_f.[21][22]

6.1. Neuroanatomy

According to David Geary, g_f and g_c can be traced to two separate brain systems. Fluid intelligence involves both the dorsolateral prefrontal cortex, the anterior cingulate cortex, and other systems related to attention and short-term memory. Crystallized intelligence appears to be a function of brain regions that involve the storage and usage of long-term memories, such as the hippocampus.[23]

6.2. Research on Training Working Memory and the Training's Indirect Effect on Fluid Ability

Because working memory is thought to influence g_f, then training to increase the capacity of working memory could have a positive impact on g_f. Some researchers, however, question whether the results of training interventions to enhance g_f are long-lasting and transferable, especially when these techniques are used by healthy children and adults without cognitive deficiencies.[24] A meta-analytical review published in 2012 concluded that "memory training programs appear to produce short-term, specific training effects that do not generalize."[25]

In a series of four individual experiments involving 70 participants (mean age of 25.6) from the University of Bern community, Jaeggi et al. found that, in comparison to a demographically matched control group, healthy young adults who practiced a demanding working memory task (dual *n*-back) approximately 25 minutes per day for between 8 and 19 days had significantly greater pre-to-posttest increases in their scores on a matrix test of fluid intelligence.[26] There was no long-term follow-up to assess how enduring the effects of training were.

Two later n-back studies[27][28] did not support the findings of Jaeggi et al. Although participants' performance on the training task improved, these studies showed no significant improvement in the mental abilities tested, especially fluid intelligence and working memory capacity.

Thus the balance of findings suggests that training for the purpose of increasing working memory has short-term or no effects on g_f.

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