Cattell’s Intelligence: Fluid vs Crystallized Thinking

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Fluid and crystallized intelligence

In psychology, fluid and crystallized intelligence (abbreviated Gf and Gc, respectively) are factors of general intelligence originally identified by Raymond Cattell.

Fluid intelligence or fluid reasoning is the capacity to think logically and solve problems in novel situations, independent of acquired knowledge. It is the ability to analyze novel problems, identify patterns and relationships that underpin these problems and the extrapolation of these using logic. It is necessary for all logical problem solving, especially scientific, mathematical and technical problem solving. Fluid reasoning includes inductive reasoning and deductive reasoning.

Crystallized intelligence is the ability to use skills, knowledge, and experience. It should not be equated with memory or knowledge, but it does rely on accessing information from long-term memory.

The terms are somewhat misleading because one is not a "crystallized" form of the other. Rather, they are believed to be separate neural and mental systems. Crystallized intelligence is indicated by a person's depth and breadth of general knowledge, vocabulary, and the ability to reason using words and numbers. It is the product of educational and cultural experience in interaction with fluid intelligence.

Fluid and crystallized intelligence are thus correlated with each other, and most IQ tests attempt to measure both varieties. For example, the Wechsler Adult Intelligence Scale (WAIS) measures fluid intelligence on the performance scale and crystallized intelligence on the verbal scale. The overall IQ score is based on a combination of these two scales.

Theoretical development

Fluid and crystallized intelligence are discrete factors of general intelligence, or g. Although formally recognized by Cattell, the distinction was foreshadowed by Charles Spearman who originally developed the theory of g and made a similar observation regarding the difference between eductive and reproductive mental ability.

According to Cattell, "...it is apparent that one of these powers... has the 'fluid' quality of being directable to almost any problem. By contrast, the other is invested in particular areas of crystallized skills which can be upset individually without affecting the others." Thus, his claim was that each type, or factor, was independent of the other, though many authors have noted an apparent interdependence of the two.

Fluid versus crystallized

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Fluid intelligence includes such abilities as problem-solving, learning, and pattern recognition. Evidence is consistent with the view that Gf is more affected by brain injury. Fluid intelligence is predominant in individuals with Autism spectrum disorders, including Asperger syndrome.

Crystallized intelligence is possibly more amenable to change as it relies on specific, acquired knowledge. For example, a child who has just learned to add numbers now owns a new piece of crystallized intelligence; but his or her general ability to learn and understand, Gf, has not been altered. An example of the flexibility of, or ability to revise, crystallized intelligence can be seen in beliefs about Santa Claus. A five year-old child may believe that Santa Claus lives at the North Pole. Later, when the child is eight years old, he learns there is no Santa Claus. His belief that Santa lives at the North Pole was then invalidated and new knowledge is gained: there is no Santa Claus. The prior knowledge was revised in order to accommodate the new learning. Vocabulary tests and the verbal subscale of the Wechsler Adult Intelligence Scale are considered good measures of Gc.

Not surprisingly, people with a high capacity of Gf tend to acquire more Gc knowledge and at faster rates. This is sometimes called investment. Researchers have found that criminals have disproportionately low levels of crystallized intelligence. This may be a result of these people investing their ability into skills that are not measured on IQ tests.

Some researchers have linked the theory of fluid and crystallized intelligence to Piaget's conception of operative intelligence and learning. Fluid ability and Piaget's operative intelligence both concern logical thinking and the education of relations. 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.

Factor structure

Fluid intelligence generally correlates with measures of abstract reasoning and puzzle solving. Crystallized intelligence correlates with abilities that depend on knowledge and experience, such as vocabulary, general information, and analogies. Paul Kline identified a number of factors that shared a correlation of at least r=.60 with Gf and Gc. Factors with median loadings of greater than 0.6 on Gf included induction, visualization, quantitative reasoning, and ideational fluency. Factors with median loadings of greater than 0.6 on Gc included verbal ability, language development, reading comprehension, sequential reasoning, and general information. It may be suggested that tests of intelligence may not be able to truly reflect levels of fluid intelligence. Some authors have suggested that unless an individual was truly interested in the problem presented, the cognitive work required may not be performed because of a lack of interest. These authors contend that a low score on tests which are intended to measure fluid intelligence may reflect more a lack of

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interest in the tasks rather than inability to complete the tasks successfully.

Measurement of fluid intelligence

There are various measures that assess fluid intelligence. The Cattell Culture Fair IQ test, the Raven Progressive Matrices (RPM), and the performance subscale of the WAIS are measures of Gf. The RPM is one of the most commonly used measures of fluid abilities. 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. 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.

Standardized IQ tests such as those used in psychoeducational assessment also include tests of fluid intelligence. In the Woodcock-Johnson Tests of Cognitive Abilities Gf is assessed by two tests: Concept Formation (Test 5) in the Standard Battery and Analysis Synthesis (Test 15) in the Extended Battery. On Concept Formation tasks,the individual has to apply concepts by inferring the underlying "rules" for solving visual puzzles that are presented in increasing levels of difficulty. Individuals at the preschool level have to point to a shape that is different from others in a set. As the level of difficulty increases, individuals increasingly demonstrate an understanding of what constitutes a key difference (or the "rule") for solving puzzles involving one to one comparisons, and on later items identifying common differences among a set of items. For more difficult items, individuals need to understand the concept of "and" (e.g. 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 require fluid transformations and cognitive shifting between the various types of concept puzzles that the examinee has worked with previously.

Concept Formation tasks assess inductive reasoning ability. In the Analysis-Synthesis test, the individual has to learn and orally state the solutions to incomplete logic puzzles that mimic a miniature mathematics system. The test also contains some of the features involved in using symbolic formulations in other fields such as chemistry and logic. The individual is presented with a set of logic rules, a "key" that is used to solve the puzzles. The individual has to determine the missing colors within each of the puzzles using the key. Complex items present puzzles that require two or more sequential mental manipulations of the key to derive a final solution. Increasingly difficult items involve a mix of puzzles that require fluid shifts in deduction, logic, and inference. Analysis Synthesis tasks assess general sequential reasoning.

In the Wechsler Intelligence Scale for Children-IV (WISC IV) the Perceptual Reasoning Index contains two subtests that assess Gf: Matrix Reasoning, which involves induction and deduction, and Picture Concepts, which involves induction. In the Picture Concepts task, children are

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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 assesses the child's ability to discover the underlying characteristic (e.g. rule, concept, trend, class membership) that governs a set of materials. Matrix Reasoning also tests 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 are presented a series or sequence of pictures with one picture missing. Their task is to choose the picture that fits the series or sequence from an array of five options. Since Matrix Reasoning and Picture Concepts involve the use of visual stimuli and do not require expressive language they are considered to be non-verbal tests of Gf.

Development and physiology

Fluid intelligence, like reaction time, peaks in young adulthood and then steadily declines. This decline may be related to local atrophy of the brain in the right cerebellum. Other researchers have suggested that a lack of practice, along with age-related changes in the brain may contribute to the decline. Crystallized intelligence increases gradually, stays relatively stable across most of adulthood, and then begins to decline after age 65.

Working memory capacity is closely related to fluid intelligence, and has been proposed to account for individual differences in Gf. Furthermore, recent research suggests that cognitive exercise can increase working memory and also improve Gf.

Improving fluid intelligence with training on working memory

According to David Geary, Gf and Gc can be traced to two separate brain systems. Fluid intelligence involves 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.

Susanne M. Jaeggi, from the University of Michigan, found that 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 statistically significant increases in their scores on a matrix test of fluid intelligence taken before and after the training than a control group who did not do any training at all.

More recently, a study conducted in Hangzhou, China, at the University of Technology supports Jaeggi's results, independently. After student subjects were given a 10 day training regime, based on the dual-n back working memory theory, their scores on the Raven's Standard Progressive

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Matrices, were found to have increased significantly.

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