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Introduction

The Gf-Gc theory of cognitive abilities is a psychometric theory of intelligence based on intelligence and ability tests. Evidence in favor of the theory has largely been gathered via factor analytic and developmental studies of intelligence, but also with respect to school/education achievement and biological/genetic evidence. The theory was first formulated in terms of fluid and crystallized cognitive abilities by Raymond Cattell in 1943. The theory posits its fundamental assumption, that intelligence (or rather, human cognitive abilities) is not a unitary construct but entails the lifelong coordination of at least two classes of abilities: fluid (Gf), which refers to the ability of understanding relationships among the components of an abstract problem and using such relationships to solve the problem, and crystallized (Gc), which refers to the knowledge accumulated through experiences. Fluid abilities are general in nature, in that they can be applied to any novel abstract situation that requires solving a novel problem, while crystallized abilities are specific, in that they require specific knowledge (learned from one's cultural milieu) to solve familiar problems (this distinction is similar to, and partially built upon, what Donald Hebb proposed in 1942 in terms of Intelligence A and Intelligence B). Two particular aspects of this hypothesis, which set it apart from previous ones, are its structural and its kinematic predictions. Structural evidence in favor of the Gf-Gc hypothesis comes from many studies showing that by relying on factor-analytic methods it is possible to demonstrate that a single factor of intelligence, called *g*, does not describe the relations among broad cognitive abilities, representing primary-level abilities, as well as models with multiple factors. Kinematic predictions come from studies that analyze age gradients or, more directly, age changes in cognitive performance. These studies conclude that while during childhood both classes of abilities increase, starting in young adulthood fluid abilities decrease, while crystallized abilities remain constant (or may even increase). A third set of predictions is dynamic in nature, and it is captured especially by the investment theory, which postulates that during childhood fluid abilities are necessary to accumulate crystallized ones. In practice, it is certainly not simple to measure the two broadest abilities in adults; with respect to Gc abilities, because of the influence of experience, interest, motivation, professional skills, and years since schooling (on which most general Gc tests are based, like vocabulary); and as for Gf abilities, especially in older adults, processing speed generally decreases during adulthood, and most Gf tasks are timed, which leads to confounds between the two classes of cognitive tasks. Opponents of the theory have pointed out that, in practice, Gf is highly collinear with a general factor of intelligence (*g*), while Gc abilities further contribute little in terms of individual differences in cognitive performance.

Historical Context

In 1943, the psychologist Raymond B. Cattell (b. 1905–d. 1998) published a highly influential paper in *Psychological Bulletin* entitled "The Measurement of Adult Intelligence" (he also presented portions of the paper at the forty-ninth annual meeting of the American Psychological Association in 1941 in the form of Cattell 1941). Therein, Cattell noted the increase of adult testing during World War I, first by the US government to recruit and attribute specific positions within the army's hierarchy, then more generally to assess intellectual abilities in children and adults. Cattell 1943 lists forty-four existing intelligence tests, which cover various domains, such as written and oral verbal, nonverbal, and perceptual abilities. However, Cattell also points out that such tests are neither standardized nor published, while the majority were conceived for college students (hence are probably not generalizable to a wider population). In the end, he notes a dearth of intelligence tests for adults of a general population. Cattell also observes that the heterogeneity of the tests stems from different theoretical perspectives on intelligence, but also from a variety of methodologies employed to validate such tests. Within this historical context, Cattell outlines the foundations of the hypothesis of fluid and crystallized ability (Gf-Gc). While this hypothesis somewhat resembles a number of other then-current propositions about intellectual human abilities, such as Intelligence A and Intelligence B (Hebb 1942), power intelligence and speed intelligence (Lorge

1936), and the distinction between energy and engines of intellect (Spearman 1927), Cattell points out the salient differences that warrant the originality of his Gf-Gc hypothesis. Nevertheless, as affirmed in Cattell 1943 (p. 179) and as pointed out in the recent review Brown 2016, Cattell's hypothesis relies heavily on the proposition of Intelligence A and Intelligence B (Hebb 1941, Hebb 1942), to the point that, according to Brown 2016, "Cattell's Gf-Gc theory of intelligence" should be named "the Hebb-Cattell theory." Kent 2017 and Kaufman, et al. 2020 provide a brief overview of the origin of the theory of fluid and crystallized intelligence. Schneider and McGrew 2018 provides the last revision of the CHC taxonomy, which integrates the Cattell-Horn model and Carroll's theory.

Brown, Richard E. 2016. Hebb and Cattell: The genesis of the theory of fluid and crystallized intelligence. *Frontiers in Human Neuroscience* 10 (December): 606.

Brown reviews the currently existing evidence about the origins of the Gf-Gc hypothesis of intelligence, and he concludes that "Cattell's theory was Hebb's idea" (p. 9) and that "The theory of fluid and crystallized intelligence therefore, should be called the Hebb-Cattell theory" (p. 11).

Cattell, Raymond B. 1941. Some theoretical issues in adult intelligence testing. *Psychological Bulletin* 38:592.

This abstract corresponds to Cattell's oral contribution to the forty-ninth annual meeting of the American Psychological Association (1941, Northwestern University, Evanston, IL, USA) and is cited as the first evidence of Cattell naming his theory of fluid and crystallized intelligence. However, the abstract does not contain that nomenclature. This presentation was later elaborated upon to become the influential paper Cattell 1943.

Cattell, Raymond B. 1943. The measurement of adult intelligence. *Psychological Bulletin* 40.3: 153–193.

This is the seminal paper most often cited as the first written account of the Gf-Gc theory of intelligence by Cattell. This paper was in progress in 1941, and portions of it were presented in Cattell 1941.

Hebb, Donald O. 1941. Clinical evidence concerning the nature of normal adult test performance. *Psychological Bulletin* 38:593.

This is the abstract of Hebb's oral contribution to the same APA conference attended by Cattell that year. According to evidence reported in Brown 2016, during this conference Hebb first presents his hypothesis of Intelligence A and B, which is later elaborated upon and renamed by Cattell as Gf and Gc.

Hebb, Donald O. 1942. The effect of early and late brain injury upon test scores, and the nature of normal adult intelligence. *Proceedings of the American Philosophical Society* 85.3: 275–292.

The author proposes a hypothesis about intelligence in normal (i.e., non-injured) adults. The hypothesis posits that in any performance of intellectual ability, two factors are involved: the power of reasoning (Intelligence A) and skill (Intelligence B), which is largely due to experience. These obviously resemble Cattell's Gf and Gc, respectively. Cattell was strongly inspired by this hypothesis.

Kaufman, Alan S., W. Joel Schneider, and James C. Kaufman. 2020. Psychometric approaches to intelligence. In *Human intelligence: An introduction*. Edited by Robert J. Sternberg, 67–103. Cambridge, UK: Cambridge Univ. Press.

In this chapter, the authors provide an overview of the psychometric approaches to intelligence. Cattell's theory of Gf and Gc, and the "expanded Gf – Gc theory" are described. Other psychometric models are presented like Spearman's, Thurstone's, Carroll's, and CHC models.

Kent, Phillip. 2017. Fluid intelligence: A brief history. *Applied Neuropsychology: Child* 6.3: 193–203.

Provides a historical overview of the origins of the Gf-Gc theory of cognitive abilities, with several citations by Cattell and Horn to exemplify their perspective. Furthermore, it examines the neuropsychological and neurological components of fluid intelligence, which, according to Kent, remain unclear.

Lorge, I. 1936. The influence of the test upon the nature of mental decline as a function of age. *Journal of Educational Psychology* 27.2: 100–110.

The author administered eleven rather different intelligence tests to 142 adults aged twenty to over seventy years. Some tests (called “power”) had no time limits for administration, while others (called “speed”) imposed time constraints. The author observes that the “speed” tests led to stronger negative age gradients than the timed “power” tests. He argues that “speed” tests contaminate power with speed measurements.

Schneider, W. Joel, and Kevin S. McGrew. 2018. The Cattell-Horn-Carroll theory of cognitive abilities. In *Contemporary intellectual assessment: Theories, tests, and issues*. 4th ed. Edited by Dawn P. Flanagan and Erin M. McDonough, 73–163. New York: Guilford.

A very detailed description of the origin and advances of the Gf-Gc theory of Cattell and Horn integrated within Carroll’s analysis, resulting in the Cattell-Horn-Carroll theory (the most comprehensive and empirically supported psychometric theory of the structure of intelligence). New broad abilities were introduced, such as emotional intelligence (Gei).

Spearman, Charles. 1927. *The abilities of man: Their nature and measurement*. London: Macmillan.

In this seminal book, Spearman outlines the work he and his students carried out for twenty-three years on the nature of intelligence. He describes his theory of intelligence, where each intellectual assessment is due to two factors, referred to as “energy” of intellect (called *g*, the general factor of intelligence) and the “engine” of intellect (called *s*, the specific or special factor). Many scholars only remember the former *g* component.

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