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REVIEW ARTICLE

Cognitive Profiling in Autism Spectrum Disorder: What the Cattell–Horn–Carroll Theory Reveals

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ABSTRACT

Autism spectrum disorder (ASD), or autism for short, has always been identified by its classical triad of impairments (TOI) which is difficulty with communication, difficulty with behavior or social interaction, and difficulty with social skills, as first established by Lorna Wing and Judith Gould in 1979. This TOI has become generally accepted as the key criteria for identifying children suspected and/or observed to have ASD. While the concept of TOI has set as the central plank of the construct of ASD, it should never be taken as an end in itself with the symptomatic definition of the condition. It should, however, remain a transitional idea that continues to evolve from the level of behavioral manifestation to that of cognitive processing. As a result, the author of this short article has taken a different approach in examining the concept of ASD by applying the Cattell-Horn-Carroll (CHC) theory in terms of cognitive strengths and weaknesses in the diagnostic evaluation of the autistic condition.

Keywords: *autism spectrum disorder, CHC theory, cognitive strengths and weaknesses, PSW model*

1. INTRODUCTION

Autism spectrum disorder (ASD), or autism, is a complex neurodevelopmental disorder that remains incompletely understood. Its definition has evolved over the past century as scientific knowledge has advanced. The term *autism* was first introduced in 1911 by the Swiss psychiatrist Eugen Bleuler to describe a symptom of dementia praecox, a group of schizophrenic disorders (Bleuler, 1950). This usage differs from the modern understanding of ASD (Ames, 2018).

In 1926, the Ukrainian child psychiatrist Grunya Efimovna Sukhareva published observations of six children displaying autistic traits in a German psychiatry and neurology journal (Posar & Visconti, 2017). Later, in 1938, the American psychologist Louise Despert described 29 cases of childhood schizophrenia, several of which resembled what is now recognized as autism. In 1943, the American psychiatrist Leo Kanner published a landmark article describing 11 children with autistic characteristics, later termed *infantile autism* (Kanner, 1943). Around the same time, the Austrian pediatrician Hans Asperger reported on four children with high-functioning autism, a condition later known as Asperger syndrome (Asperger, 1944).

The first edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM), published in 1952 by the American Psychiatric Association (APA), classified children with autistic symptoms under childhood schizophrenia (Sasson et al., 2011; Cantor, 1988). Four years later, the American child psychiatrist Leon Eisenberg reported outcomes for 63 children with autism who had been followed for an average of nine years. Approximately one-third achieved at least moderate social adjustment, and prognosis was strongly associated with the presence of functional speech by age five, which served as an indicator of autistic severity (Eisenberg, 1956).

Autism received increasing research attention during the late 1960s and 1970s. The condition was not formally classified as ASD until the publication of the DSM, Fifth Edition in 2013 (APA, 2014) and its later revision, DSM, Fifth Edition, Text Revision (TR) (APA, 2022), which consolidated previously separate subcategories found in the DSM-IV and DSM-IV-TR (APA, 2004).

Both Ames (2018) and Iannelli (2020) provide concise histories of autism research. According to Ames (2018), autism typically becomes apparent between ages two and three. However, advances in screening now allow ASD to be identified as early as 12 to 18 months. By age two, a diagnosis made by an experienced professional is generally reliable (Lord et al., 2006). Earlier diagnosis enables earlier intervention, which is associated with improved developmental outcomes.

2. RESEARCH METHODOLOGY

The author of this article has adopted a conceptual and narrative literature review approach to examine the diagnostic profiling of cognitive strengths and weaknesses in individuals with autism spectrum disorder (ASD) through the lens of the Cattell-Horn-Carroll (CHC) theory of cognitive abilities. Relevant scholarly literature was identified through a review of peer-reviewed journal articles, books, diagnostic manuals, and published empirical studies relating to autism, cognitive assessment, intelligence testing, and the CHC framework. Particular attention was given to studies reporting patterns of strengths and weaknesses (PSW) in ASD, including performance on standardized cognitive assessment tools such as the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV) and the Stanford–Binet Intelligence Scale–Fourth Edition (SB-4).

The reviewed literature was analyzed qualitatively to identify recurring trends in cognitive functioning, especially in broad and narrow CHC abilities associated with verbal and nonverbal functioning, working memory, processing speed, fluid reasoning, and crystallized intelligence. A narrative synthesis approach was employed to compare convergent and divergent findings across studies and to evaluate the potential diagnostic utility of CHC-based cognitive profiling in understanding ASD (Flanagan et al., 2013; Schneider & McGrew, 2012). This methodological approach enabled the author to integrate historical, theoretical, and empirical perspectives to construct a more cognitively informed understanding of ASD.

3. TRIAD OF IMPAIRMENTS: BEHAVIORAL MANIFESTATION VS COGNITIVE PROCESSING

In the late 1970s, the exceptional pioneering work, notably that of Wing and Gould (1979), gave rise to the concept of the triad of impairments (TOI) as the central plank of the construct of ASD, i.e., impairment in communication, impairment in social skills, and a restricted and repetitive behavior (stereotyped behavior). With the introduction of the TOI concept, it provided a clear articulation of the structures of the little understood phenomenon of autism, allowing a new perspective for both professionals and families with their loved ones identified with ASD to see and understand the condition, as well as to better relate to those with ASD. Just like with many evolutionary concepts, the TOI model remained and is still very much a transitional idea. The original TOI postulated by Wing and Gould (1979) has provided the behavioral manifestation of ASD.

However, the author of this article strongly believes the actual TOI in ASD is best understood and better defined at the level of cognitive processing. Termed as the cognitive TOI, it is static and ubiquitous unlike the variable and fluctuating behavioral TOI. Also, the behavioral TOI in autism is visual as opposed to the cognitive TOI which is concerned about linguistic processing, impaired abstract reasoning, and lack of theory of mind. The author believes the cognitive TOI offers the diagnostic key that opens our understanding of what constitutes the condition of ASD. It is for this main reason the author has chosen to take the CHC theory to examine the strengths and weaknesses observed in individuals with ASD based on the assessment data collected from various published articles over the last decades.

4. AUTISTIC PROFILE OF COGNITIVE STRENGTHS AND WEAKNESSES

With a gradual introduction as well as a further development of the CHC theory of cognitive abilities since the early 1940s, data gathered from the diagnostic assessment of children with ASD has taken a more targeted approach. Their interpretation must be both theoretically and psychometrically defensible (Flanagan, Ortiz, & Alfonso).

The cognitive TOI now looks to what the CHC theory has to offer in terms of better understanding of ASD through assessment administered and intervention rendered. More importantly, the diagnostic interpretation of the test data "should not begin with the presumption of preexisting deficits … *but* … should be guided by the assumption that the examinee is not impaired and that his/her performance on tests will be *within the normal limits* (WNL) of functioning" (Flanagan, Ortiz, & Alfonso, 2013). This means that confirmatory bias must be avoided even before the start of assessment. Every examinee is treated as having cognitive abilities WNL and this is taken to be a null hypothesis[1] until test data show otherwise. When that happens, the null hypothesis is rejected in favor of an alternative hypothesis that could best explain the condition identified. The CHC model can use the test data to establish a smooth transition from assessment to intervention.

Previously, several studies carried out to determine the cognitive profiles of individuals with ASD, found that individuals with ASD performed better on nonverbal than verbal tasks (Ankenman et al., 2014; Goldstein et al., 2008; Siegel, Minshew, & Goldstein, 1996). Moreover, these individuals also scored better on tasks relying on visual-spatial abilities as opposed to those tasks depending on verbal skills and understanding on social rules/relations (Mayes & Calhoun, 2008). This is known as Verbal/Nonverbal IQ Score Discrepancy (V/NV-IQsD) Hypothesis. According to Siegel, Minshew and Goldstein (1996), the Verbal/Nonverbal IQ Score Discrepancy is nearly one standard deviation, i.e., twelve IQ points. However, other studies found inconclusive results when cognitive abilities were examined across a wide range of intellectual ability and chronological age (Barbaro & Dissanayake, 2012; Grofer-Klinger et al., 2002; Joseph et al., 2002). For instance, in a study done by Mayes and Calhoun (2003), findings suggested that higher scores in nonverbal IQ were noted in preschool children, and these scores remained consistently the same throughout the early school-age years in children with IQ scores <80. However, this difference disappeared when children were between 6-7 years old with IQ scores >80. In another study conducted by Ankenman et al. (2014), findings revealed that the pattern of Verbal/Nonverbal IQ Score differences was more common in younger children. Table 1 below provides an empirical support for the Pattern of Strengths and Weaknesses (PSW) in the summarized discussion.

[1] "Only the hypotheses specified a priori or a posteriori are actually tested and evaluated directly in light of the data; opinion and conjecture are not" (Flanagan, Ortiz, & Alfonso, 2013, p. 123).

Table 1. CHC-Based and CHC-Relevant Studies on Cognitive Profiling in Autism Spectrum Disorder

Author(s) & Year	Sample / Population	Cognitive Assessment / Framework	CHC Ability Examined	Major Findings in ASD	Implication for CHC-Based Profiling
Harris, Handleman, & Burton (1991)	Young children with autism	SB-4	Gf-I, Gc-K0	Weaknesses in verbal fluid reasoning and absurdities tasks	ASD individuals showed poorer performance in verbally mediated reasoning tasks
Siegel, Minshew, & Goldstein (1996)	High-functioning autism	Wechsler IQ profiles	Verbal vs. Nonverbal abilities	Nonverbal performance exceeded verbal performance by nearly one SD	Supported Verbal/Nonverbal IQ Score Discrepancy (V/NV-IQsD) hypothesis
Bennetto, Pennington, & Rogers (1996)	Individuals with autism	Memory assessment	Gwm	Mixed findings on working memory; both intact and impaired functioning observed	Working memory deficits in ASD may not be universal
Goldstein et al. (2008)	Children and adults with high-functioning autism	Intelligence structure analysis	Multiple CHC broad abilities	Better performance in nonverbal relative to verbal domains	Cognitive profile in ASD may be uneven and domain-specific
Coolican, Bryson, & Zwaigenbaum (2008)	Children with ASD	SB intelligence scales	Gf-RQ, Gv	Stronger nonverbal and visual-spatial reasoning skills	Visual and quantitative reasoning may represent cognitive strengths in ASD
Dawson et al. (2007)	Individuals with autism	Cognitive functioning analysis	Gf, Gc	Preserved or enhanced nonverbal intelligence but difficulty with social understanding	Supports uneven CHC cognitive profile in ASD
Kuschner, Bennetto, & Yost (2007)	Young children with ASD	Nonverbal cognitive measures	Gv, Gf	Stronger untimed visual-spatial functioning	Visual reasoning may be a relative strength
Mayes & Calhoun (2008)	Children with high-functioning autism	WISC-IV and WIAT-II	Gf-I, Gv, Gc, Gs	Strong Matrix Reasoning and Picture Concepts; weaknesses in Comprehension and Coding	Supports PSW profiling under CHC taxonomy
Barbaro & Dissanayake (2012)	Infants and toddlers with ASD	Developmental profiling	Broad cognitive abilities	Inconsistent cognitive discrepancy findings	Cognitive profiles may vary by developmental stage
Oliveras-	High-	WISC-IV	Gs-R9	Processing	Gs deficits may

Rentas et al. (2012)	functioning ASD			speed weaknesses linked to communication difficulties	contribute to adaptive impairments
Ankenman et al. (2014)	Children with ASD	Cognitive discrepancy profiling	Verbal/Nonverbal abilities	V/NV discrepancy more common in younger children	Age may influence CHC-related cognitive patterns
Kercood et al. (2014)	Individuals with ASD	Literature review	Gwm-MS, Gwm-MW	Weaknesses reported in working memory and recall	Gwm impairments may affect learning and classroom functioning
Lim & Chia (2017)	Case profile of male crypto-savant with low-functioning autism	Psycho-educational evaluation	nv-Gf	Strength in nonverbal fluid reasoning	CHC useful for identifying unique cognitive strengths
Marjanović (2017)	Review of ASD intellectual functioning	CHC interpretive framework	Gf, Gc, Gwm, Gs	ASD associated with strengths in nonverbal reasoning and weaknesses in social-verbal cognition	CHC model offers a useful framework for cognitive profiling

Abbreviations: Gf = Fluid Intelligence; Gc = Crystallized Intelligence; Gwm = General Working Memory and Learning; Gv = Visual Processing; Gs = Processing Speed; PSW = Pattern of Strengths and Weaknesses; WISC-IV = Wechsler Intelligence Scale for Children-Fourth Edition; SB-4 = Stanford-Binet Intelligence Scale-Fourth Edition.

Table 2. The Three Strata of Intellectual Abilities

Stratum	Term	Descriptor
Stratum III	General intelligence [denoted by g]	Known as *g* factor, it accounts for the correlations among the broad abilities at Stratum II.
Stratum II	Broad abilities [denoted by G with a lowercase letter thereafter, e.g., Gf, Gc]	There are eight broad abilities. They are as follows: (1) Gf - fluid intelligence; (2) Gc - crystallized intelligence; (3) Gwm - general memory and learning; (4) Gv - broad visual perception; (5) Ga - broad auditory perception; (6) Grl - broad retrieval ability; (7) Gt - broad cognitive speediness; and (8) Gs - processing speed.
Stratum I	Narrow abilities [denoted after a hyphen which is followed by either alphabetic or numeric symbols or both, e.g., Gs-R9, Gf-I]	These are more specific abilities under each of the broad ability as identified under the Stratum II.

According to Marjanovic (2017), the V/NV-IQsD Hypothesis has already been abandoned in today's cognitive assessment and results interpretation. Most of the current cognitive assessments are designed to include disparate capacities defined by the CHC model of cognitive abilities. The CHC model provides a comprehensive taxonomy of human cognitive abilities empirically validated by the psychometric theory of cognitive abilities. This theoretical model (also known as the three-stratum theory) is derived primarily from Spearman's (1927) model of general intelligence and Horn and Cattell's (1966) theory of fluid (Gf) and crystallized (Gc) intelligence. It is organized hierarchically into three different strata as follows (Carroll, 1997; Schneider & McGrew, 2012) (see Table 1).

Using the CHC-based PSW model (Schultz, Simpson, & Lynch, 2006) to aid in understanding as well as profiling of individuals with ASD, the cognitive strengths of such individuals could be found to lean on nonverbal Fluid Reasoning (nv-Gf) tasks (Lim & Chia, 2017), e.g., the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) subtests of Matrix Reasoning (Gf-I) and Picture Concepts (Gf-I) (Mayes & Calhoun, 2008). Based on the CHC taxonomy, both the WISC-IV subtests - Matrix Reasoning and Picture Concepts - fall under the broad ability of Fluid Intelligence, denoted by Gf, which is defined as “the deliberate but flexible control of attention to solve novel, on-the-spot problems that cannot be performed by relying exclusively on previously learned habits, schemas, and scripts” (Flanagan, Ortiz, & Alfonso, 2013), and also under the same narrow ability denoted by the letter I, which refers to Induction (or inductive reasoning). Gf-I, in turn, is defined as “the ability to observe a phenomenon and discover the underlying principles or rules that determine its behaviors” (Flanagan, Ortiz, & Alfonso, 2013).

In three separate studies, the PSW of nonverbal cognitive functioning in children with ASD showed stronger nonverbal skills on untimed visual-spatial tasks in WISC-IV subtests of Picture Completion (Gv-CF) and Mazes (Gv-SS) as well as quantitative reasoning tasks (Gf-RQ) in SB-4 Quantitative Reasoning domain (verbal and/or noverbal) (Coolican, Bryson, & Zwaigenbaum, 2008; Dawson et al., 2007; Kuschner, Benetto, & Yost, 2007). Quantitative reasoning, denoted by RQ, is a narrow ability under the broad ability Gf in the CHC taxonomy, and it is defined as “the ability to reason with quantities, mathematical relations, and operators” (Flanagan, Ortiz, & Alfonso, 2013). In summary, the PSW of ASD can be determined to a limited extent based on the CHC taxonomy (i.e., the pattern of cognitive strengths found in Gf-I and Gf-RQ) in the diagnostic profiling of such individuals.

On the contrary, a pattern of weaknesses in individuals with ASD are frequently found in “crystallized ability (Gc) tasks that encompass understanding of social rules” (Marjanovic (2017). Moreover, Harris, Handleman and Burton (1991) also reported the pattern of weaknesses in individuals with ASD especially in the poor performance on verbal fluid reasoning (v-Gf-I) tasks, e.g., Absurdities test in the SB-4 domain of Fluid Reasoning (Thorndike, Hagen, & Sattler, 1986). Under the CHC taxonomy, the SB-4 Absurdities task also came under the broad ability of Crystallized Intelligence (Gc) and its narrow ability of General Verbal Information (Gc-K0). The broad ability of Gc is defined as “the depth and breadth of knowledge and skills that are valued by one’s culture” (Flanagan, Ortiz, & Alfonso, 2013), while Gc-K0 refers to “the breadth and depth of knowledge of one’s culture” (Flanagan, Ortiz, & Alfonso, 2013).

According to Marjanovic (2017), individuals with ASD performed badly or scored poorly on the following cognitive tasks:

(i) Understanding of social situations and rules (Dawson, et al., 2007; Siegel et al., 1996), e.g., poor score on the WISC-IV Comprehension subtest, under the broad-and-narrow ability of Gc-K0 (i.e., Crystallized Intelligence-General Verbal Information), which refers to “the breadth and depth of knowledge of one’s culture” (Flanagan, Ortiz, & Alfonso, 2013);

(ii) Speed of information processing (Oliveras-Rentas et al., 2012; Wallace, Anderson, & Happé, 2009), e.g., poor score on the WISC-IV Coding subtest, under the broad-and-narrow ability of Gs-R9 (i.e., Processing Speed-Rate of Test Taking), which refers to “the speed and fluency with which simple cognitive tests are completed” (Flanagan, Ortiz, & Alfonso, 2013);

(iii) Retention and recall of information (Kercood, et al., 2014), e.g., poor score on the WISC-IV Digit Span subtest, under the broad-and-narrow ability of Gwm-MS (i.e., Working Memory-Memory Span), refers to “the ability to encode information, maintain it in primary memory and immediately reproduce the information in the same sequence in which it was represented” (Flanagan, Ortiz, & Alfonso, 2013); and

(iv) Working memory capacity (Kercood et al., 2014; Nakahachi et al., 2006) may be indicated by low scores on WISC-IV subtests such as Arithmetic and Letter-Number Sequencing, which fall under the CHC ability domain Gwm-MW (Working Memory–Working Memory Capacity). This ability refers to the capacity to focus attention while holding and mentally manipulating information, such as combining, transforming, or organising information in short-term memory, while ignoring distractions and efficiently retrieving relevant information from long-term memory (Flanagan, Ortiz, & Alfonso, 2013). Table 3 provides a summary of the pattern of strengths and weaknesses - based on the administration of various subtests of IQ tests, such as WISC-IV and SB-4, as reported in various published studies (e.g., Harris, Handleman, & Burton, 1991; Lim & Chia, 2017; Marjanovic, 2017) found in the identification of ASD based on the CHC taxonomy.

Table 3. Pattern of Strengths and Weaknesses in ASD Profiling

Examples of Strength	**Examples of Weakness**
1. WISC-IV Matrix Reasoning (Gf-I)	1. SB-4 Absurdities (v-Gf-I; Gc-K0)
2. WISC-IV Picture Concepts (Gf-I)	2. WISC-IV Comprehension (Gc-K0)
3. WISC-IV Picture Completion (Gv-CF)	3. WISC-IV Coding (Gs-R9)
4. WISC-IV Mazes (Gv-SS)	4. WISC-IV Digit Span (Gwm-MS)
5. SB-4 Quantitative Reasoning (Gf-RQ)	5. WISC-IV Arithmetic (Gwm-MW)
	6. WISC-IV Letter-Number Sequencing (Gwm-MW)

However, there are also other studies that refuted what was believed to cognitive impairments due to ASD. One good example is the working memory. As mentioned in the fourth point of the paragraph above, working memory was believed to be severely impaired in individuals with autism. However, Ozonoff and Strayer (2001) reported otherwise. In contrast, Bennetto, Pennington and Rogers (1996) reported that both intact and impaired working memory could be found in individuals with ASD. In addition, low or poor performance on nonverbal measures (Gf) is noted when the task is presented verbally (v-Gf task) but high or better performance when the presentation is nonverbal (nv-Gf task). However, not all measures on verbal tasks are low for individuals with ASD. Marjanovic (2017) rightly pointed out that performance of individuals with ASD on these verbal tasks is very much dependent on their language proficiency.

5. CONCLUSION

The CHC theory/model/taxonomy has been “considered the state-of-the-art of the psychometric tradition about intelligence” (Gomes et al., 2014). It has also garnered a panoply of research support in the application of classifying the intelligence attributes in terms of broad and narrow cognitive abilities. Assuming the CHC approach is valid and reliable, it would be a useful method for identifying a pattern of strengths and weaknesses in order to establish a profile of an individual with ASD. Its diagnostic or clinical utility, which refers to the **value of information to the individual being tested,** is useful only if the results can provide information that is of the value to that individual so that the information can be used to seek an appropriate and effective treatment or preventive strategy for the condition of ASD.

However, even until today, the validity of the CHC model using the dual discrepancy/consistency (DD/C) model (Kranzler et al., 2019) to identify whether an individual has specific learning disability (SLD) shows "a very low probability of accurately identifying true SLD … assessment data with the DD/C method does not result in a high level of identification accuracy … its use is grounded largely on the illusion of validity" (Maki, Kranzler, & Moody, 2022), and what Lilienfeld et al. (2007) called it the *alchemist's fantasy*. What about the application of CHC model in accurately identifying an individual with ASD? The answer to the question remains unascertainable and evasive (Gomes et al., 2014; Beaujean et al., 2018). The author of this article strongly advocates for more studies on the diagnostic utility of the CHC model in identification of ASD are needed.

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11. ETHICS APPROVAL

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