Diagnostic Profiling of Cognitive Strengths and Weaknesses in Autism Spectrum Disorder: What the Cattell-Horn-Carroll Theory tells Us

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Abstract
Autism spectrum disorder (ASD), or autism for short, has always been identified by its classical triad of impairments (ToI) – difficulty with communication, difficulty with behavior or social interaction, and difficulty with social skills – 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 authors of this short paper have 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.
Key Words: Autism spectrum disorder, CHC theory, Cognitive strengths and weaknesses, PSW model

Introduction

Autism spectrum disorder (ASD), or autism for short, is a multi-faceted neurodevelopmental disorder that is still not fully understood, and whose operating definition has been changing through past decades with new discoveries. The use of the term *autism* is "a little over than 100 years now" (Ames, 2018, para. 4) and was first mentioned in 1911 by a Swiss psychiatrist, Eugene Bleuler (b.1857-d.1939), who used it as one of the symptoms to describe dementia praecox (i.e., a cluster of schizophrenias) (see Bleuler, 1950, for detail), "which is not associated with ASD today" (Ames, 2018, para. 4).

Years later, in 1926, a Ukrainian child psychiatrist, Grunya Efimovna Sukhareva (b.1891-d.1981), in Kiev, published a paper based on her observation and working with six children with autistic traits in a scientific German psychiatry and neurology journal (cited in Posar & Visconti, 2017). Then in 1938, an American psychologist based in New York, Louise Despert (b.1892-d.1982), detailed 29 cases of childhood schizophrenia, some who displayed symptoms that resembled what we know as autism today. It was not until 1943, when Leo Kanner (b.1894-d.1981), an American psychiatrist, published his paper describing 11 patients who manifested autistic traits and what he later named the condition infantile autism (Kanner, 1943). About the same time, the Austrian pediatrician, Hand Asperger (b.1906-d.1990) published a paper on his case study of four children aged six to eleven with high-functioning autism, later known as Asperger Syndrome (Asperger, 1944).

In 1952, the first edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM) was published by the American Psychiatric Association listed children with autistic symptoms under childhood schizophrenia (cited in Sasson et al., 2011; also see Cantor, 1988, for more detail). Four years later, an American child psychiatrist, Leon Eisenberg (b.1922-d.2009) published his paper reporting on 63 children with autism being evaluated at a mean age of 15 years after a mean follow-up period of 9 years. Almost a third of the subjects achieved at least a moderate social adjustment, and the prognosis varied significantly with the presence of useful speech at the age of five, which was taken as an index of the severity of autistic isolation (Eisenberg, 1956).

It was during the late 60's up to mid-70's that autism – not yet officially known as ASD yet until

the publication of the DSM-5[4] (APA, 2014) in 2014 and its subsequent text revision (DSM-5-TR; APA, 2022) when ASD is taken to be a single disorder without its previous subcategories as listed in the DSM-IV and its subsequent DSM-IV-TR (APA, 2004) - began to get more attention, research, and definition. According to Ames (2018), "[H]owever, some of this research was very off the mark" (para. 15). For instance, the Austrian-born psychologist, Bruno Bettelheim (b.1903-d.1990), published a paper (see Bettelheim, 1959, for detail) about a 9-year-old boy with "autism was caused by unloving, cold mothers, and went on to coin the term *refrigerator mothers* to describe these mothers" (cited in Ames, 2018, para. 16). Later, the American research psychologist, Bernard Rimland (b.1928-d.2006), argued against Bettelheim's misconception of refrigerator mothers and debunked it. Rimland (1964) published his book *Infantile Autism: The Syndrome and Its Implication for Neural Theory of Behavior*" to help in defining autism and also to direct autism research at that time (cited in Ames, 2018, para. 17).

Both Ames (2018) and Iannelli (2020) had each provided a brief overview or history of autism timeline. Ames (2018) described the autistic condition as a brain disorder whose onset typically becomes apparent around the ages of 2 to 3 years old. However, with new screening tools, diagnosticians are able to assess and identify ASD at 18 months of age or even younger at one year old. By age of 2 years old, an ASD diagnosis by an experienced professional can be quite reliable (Lord et al., 2006). This is indeed great news as the earlier a young child is diagnosed with ASD, the earlier s/he gets treatment, the better is the prognosis.

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 authors of this paper strongly believe 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 authors believe 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 authors have chosen to take the Cattell-Horn-Carroll (CHC) theory to examine the strengths and weaknesses observed in individuals with ASD based on the assessment data collected from various published papers over the last decades.

Autistic Profile of Cognitive Strengths and Weaknesses

With a gradual introduction as well as a further development of the Cattell-Horn-Carroll (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. "Test data must *now* be interpreted in a manner that is both theoretically and psychometrically defensible" (Flanagan, Ortiz, & Alfonso, 2013, p. 121).

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, p. 122-123). 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[5] until test data show otherwise. When that happens, the null hypothesis is rejected in favor of an alternative hypothesis that could best

[4] The most recent editions of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5-TR; APA, 2022) and *International Classification of Diseases* (ICD-11, released in 2021; WHO, 2021) both list ASD as a single disorder.

[5] "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).

explain the condition identified. The CHC model can use the test data to establish a smooth transition from assessment to intervention.

Previously, several studies (e.g., Ankenman et al., 2014; Goldstein et al., 2008; Siegel, Minshew, & Goldstein, 1996) were carried out to determine the cognitive profiles of individuals with ASD. It was found that individuals with ASD performed better on nonverbal than verbal tasks. 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., 12 IQ points. However, other studies (Barbaro & Dissanayake, 2012; Grofer-Klinger et al., 2002; Joseph et al., 2002;) found inconclusive results when cognitive abilities were examined across a wide range of intellectual ability and chronological age. 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.

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):

Table 1. 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[6] - 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.

[6] Gwm was previously known by its abbreviation Gsm for Short Memory.

Using the CHC-based Pattern of Strengths and Weaknesses (PSW) model (see Schultz, Simpson, & Lynch, 2006, for detail in terms of specific learning disability) 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 WISC-IV[7] 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, p. 403), 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, p. 403).

According to three separate studies (i.e., Coolican, Bryson, & Zwaigenbaum, 2008; Dawson et al., 2007; Kuschner, Benetto, & Yost, 2007), 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). 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, p. 403). 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, p. 97). 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, p. 400), while Gc-K0 refers to "the breadth and depth of knowledge of one's culture" (Flanagan, Ortiz, & Alfonso, 2013, p. 400).

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, p. 400);

(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, p. 408);

(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), which 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, p. 408); and

(iv) Capacity of working memory (Kercood, et al., 2014; Nakahachi et al., 2006), e.g., poor scores on the WISC-IV Arithmetic and Letter-Number Sequencing subtests, under the broad-and-narrow ability of Gwm-MW, (i.e., Working Memory-Working Memory Capacity), which refers to "the ability to direct the focus of attention to perform relatively simple manipulations, combinations, and transformations of information within primary memory while avoiding distracting stimuli and engaging in strategic /controlled searches for information in secondary memory" (Flanagan, Ortiz, & Alfonso, 2013, p. 407).

Table 2 (on the next page) provides a summary of the pattern of strengths and weaknesses - based on the administration of various subtests of IQ tests,

[7] WISC-IV stands for Wechsler Intelligence Scale for Children-Fourth Edition (Wechsler, 2003).

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 2. 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 the fourth point of the paragraph above, working memory was believed to be severely impaired in individuals with autism, but Ozonoff and Strayer (2001) reported that "working memory is not one of the executive functions that is seriously impaired in autism" (p. 263). 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.

Conclusion

The CHC theory/model/taxonomy has been "considered the state-of-the-art of the psychometric tradition about intelligence" (Gomes et al., 2014, p. 22). 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 (see Kranzler et al., 2019, for detail) 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, p. 46), 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; also see Beaujean et al., 2018, for more detail). The authors of this paper strongly advocate for more studies on the diagnostic utility of the CHC model in identification of ASD are needed.

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