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From gifted to high potential and twice exceptional: A state-of-the-art meta-review

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ABSTRACT

Despite the abundant literature on intelligence and high potential individuals, there is still a lack of international consensus on the terminology and clinical characteristics associated to this population. It has been argued that unstandardized use of diagnosis tools and research methods make comparisons and interpretations of scientific and epidemiological evidence difficult in this field. If multiple cognitive and psychological models have attempted to explain the mechanisms underlying high potentiality, there is a need to confront new scientific evidence with the old, to uproot a global understanding of what constitutes the neurocognitive profile of high-potential in gifted individuals. Another particularly relevant aspect of applied research on high potentiality concerns the challenges faced by individuals referred to as “twice exceptional” in the field of education and in their socio-affective life. Some individuals have demonstrated high forms of intelligence together with learning, affective or neurodevelopmental disorders posing the question as to whether compensating or exacerbating psycho-cognitive mechanisms might underlie their observed behavior. Elucidating same will prove relevant to questions concerning the possible need for differential diagnosis tools, specialized educational and clinical support. A meta-review of the latest findings from neuroscience to developmental psychology, might help in the conception and reviewing of intervention strategies.

KEYWORDS

Gifted; giftedness; high potential; intelligence; learning disorders; twice exceptional

Aim and scope

The aim of this meta-review is to report and synthesize important findings in the field of high intelligence research putting into light their contribution to culture and terminology shifts. In the first part of this paper, we report the different subtending models of high potentiality, notably the behavioral models such as the psychometric and multidimensional models and the anatomo-functional models such as the cognitive and network models and discuss their contribution to scientific terminology and culture related perceptions. We then attempt to align the neural correlates of this singular ability to epidemiological evidence on developmental trajectories and discuss the implications of model framework selection on research on high intelligence as well as the gap to be breached to establish an overall picture on the phenomenon of high potentiality.

In the light of the current rise in media interest regarding the prevalence of high potential individuals facing academic distress and soliciting professional and clinical assistance, the second part of this review attempts to address the accumulated epidemiological and scientific evidence available to date on the specificities and neuro-cognitive mechanisms underlying the co-occurrence of high potential and neurodevelopmental disorders impacting learning.

Literature search strategy

For each section, reviews which were relevant to the topic of interest and which were cited more than twenty times, were identified from google scholar and Summon database with selected filters and keywords as listed in the [Appendix](#). From there, sub-articles were selected for each section of the paper, narrowing down the search to specific topics through a secondary choice of keywords entered with conjunctions “and” and “Or.” Only articles published in English and French, cited more than twenty times and falling with the limits of the first hundred listed articles were selected. Where fields of research became highly specific, articles cited more than 15 times were selected. Articles published between 2000 and 2022 were selected except where historical papers were cited. Our threshold for high intelligence in the selection of articles was set at an FSIQ score $\geq 130 \pm 5$ on the Wechsler scale for children or adults, although we took into consideration, where applicable, variation in the inclusion range for certain papers (for example in the case of heterogeneous profiles as defined by a difference of at least 23 points between the higher and the lower index score). Articles were retrieved from November 2021 to August 2022, with review and editing in 2023.

From gifted to high potential: a review of terms, models and neural correlates

Definition and terminologies

Several definitions have been used to designate people with exceptional abilities and historically, the terms “gifted” and “talented” were used indistinctively to describe individuals with outstanding skills in academic or nonacademic domains (Carman, 2013; Ziegler, 2009; Ziegler & Raul, 2000). Galton (1869) is considered amongst the early investigators of giftedness with his work on heritability of intelligence traits. Several years later, the term “gifted” was used for the first time by Terman (1925) in his longitudinal study of children with high intellectual abilities. The upsurge of psychometric testing and factorial analysis (e.g., Spearman, 1904; Wechsler, 1939) made “giftedness” synonymous to a high intellectual capacity as demonstrated by elevated psychometric test score results while the term “talent” became by opposition ascribed to exceptional aptitudes that were “non-IQ measured” (Gagné, 1985). Spearman’s conception of a broad ability or general component of intelligence that acts as a dominant latent variable for multiple cognitive skills was challenged by Thurstone’s factor-analysis approach (Thurstone, 1931, 1975), segregating intelligence into seven primary latent factors including reasoning, spatial visualization, number facility, verbal comprehension, word fluency, perceptual speed and associative memory. Cattell Horn-Carroll’s model (CHC model) (Carroll, 1995) pushed the cognitive model further with their three stratum theory of intelligence, stratifying the third-factor general intelligence, “g,” into a number of lower influencing second order-factors of broad intelligence such as fluid intelligence, crystallized intelligence, short-term memory (Gsm) and processing speed (Gs) and the last stratum of minor or narrow ability factors representing individual differences as measured by cognitive tests. The stratification of general intelligence in different aspects gave rise to a multidirectional conception of intelligence, with aspects such as fluid or crystallized intelligence subsequently shown to have different developmental trajectories (Kent, 2017) with debated influence on each other (Au et al., 2015; Unsworth et al., 2014).

While the CHC model advocates for an underlying general ability, critics of “g-factor” have argued intelligence should be perceived as being multi-dimensional rather than being fruit of a general broad ability. Renowned models include Sternberg’s triad for analytical, synthetic and practical intelligence or Gardner’s multiple intelligence models (Gardner, 1993; Sternberg, 1985). Such theories proposed a more encompassing approach to “high-abilities” including dimensions such as creativity or socio-affective abilities and have led the way to new conceptions of intelligence. Gagné’s differentiated model of giftedness (Gagné, 2004, 2010, 2013) has acknowledged the role of environmental factors and chance in the process of converting an individual’s potential into a developed skill and Renzulli’s three-ring conception of giftedness (Renzulli, 1988) has recognized the importance of motivation or commitment and creativity in the construction of gifted behavior. His model distinguished between

school-house giftedness characterized by high skills in test taking and creative-productive house giftedness demonstrated by individuals highly capable of producing original material and products (Renzulli, 2011). By highlighting the role and effect of learning, practice, motivation and of environmental factors on intelligence, their models contributed to a terminology shift from “giftedness” to “high potential” on the basis that exceptional “natural abilities” have the potential to turn into “talents” by the mediation of internal and external factors (Stoeger et al., 2018) and by the interference of socioenvironmental catalysts. Accordingly, “talent” soon became perceived as the actualization of “high innate potential” into “high performance” or “competence” such that one could be of high potential without being talented, while the opposite would be impossible (Nijs et al., 2014). Such models allowed for the innate (nature) versus acquired (culture) debate and contextualized the distinction between subgroups of “high potential individuals” which could be then end up to be “academically talented” or who could also present disabilities in attentional, emotional or language tasks such as reading and writing. These models, considered to be more ecological to child development and education have been adopted by many educational policies all over the world, notably in North America and Australia (Heuser et al., 2017).

In parallel, developmental research on the emergence of differences in intelligence in high potential individuals have taken into account the time dimension by showing that mental processes and functions form quantitatively and qualitatively as the individual transition through various stages of cognitive development (Vraive-Douret, 2011; Steiner & Carr, 2003; Reis & Renzulli, 2004). Such theories have opened horizons to new integrative models attempting to align stages of biological development of brain architecture with the development of cognitive skills. Based on psychomotor and linguistic evidence from longitudinal studies, giftedness was soon associated with a precocious form of ability development (Vraive-Douret, 2011) bringing the terms “precocious children” to the jargon. Developmental models have highly influenced the educational realm, where precocious talking, reading, or walking was assimilated as an indicator of giftedness.

These 21st century models have taken a complete overturn challenging the notion of general ability, interpreting “g” as an emergent property arising from positive correlations between test scores rather than a latent causal variable (Conway & Kovacs, 2015). The Process Overlap Theory by Kovacs and Conway (2019a, 2020), presents g as a formative construct that arises because cognitive tests are designed in such a way that there could be an overlap of executive processes during tasks, that is they require the individual to tap both into domain-general executive processes, such as attention control (Frischkorn & Schubert, 2018), as well as domain-specific processes involved in specific tasks. This paradigm shift has certain implications for the diagnosis of high intelligence, where psychometric g has reigned for decades as the standard diagnosis tool. Novel theories argue that IQ scores are merely weighted sum scores (Van der

Maas et al., 2014) and its utility should rather rely in the separate indices which could provide an interpretation of specific cognitive skills (Kovacs & Conway, 2019b).

The continuous evolution of models of intelligence has brought not only new terminology, but has altered the conception of what high intelligence or potential means. New models of high intelligence have enriched psychological diagnosis with supplementary evaluation tools, although Psychometric *g* remains to date the official diagnosis tool of giftedness (OMS), due to its empirical robustness (Deary et al., 2010). As perceptions of high potentiality are culturally-influenced, these new models also seem to have directly impacted the identification procedures, the direction and philosophy of educational programs and interventions for high potential children across countries (Pfeiffer, 2012).

Neural correlates of high intellectual potential (HIP): from localized to distributed approaches

Perceptions on intelligence and models have also greatly shaped functional and anatomical research. Highly intelligent individuals are known to demonstrate higher levels of performance in tasks requiring cognitive flexibility, inhibitory control, working memory and planning (Fiske & Holmboe, 2019; Vaivre-Douret, 2011). Under the postulate of a broad general ability laying the foundation for intelligence, research in neuroanatomy investigated the fronto-parietal regions, already implicated from lesion studies in the control of superior cognitive functions (Barbey et al., 2012). Such studies have associated IQ scores with structural correlates such as cortical thickness, gyrification, grey and white matter volume and density in the fronto-parietal lobes with correlation coefficient varying from 0.3 to 0.60 (Bajaj et al., 2018; Choi et al., 2008; Ryman et al., 2016). Functional studies have also demonstrated the implication of the lateral prefrontal cortex in *g*-related tasks (Barbey et al., 2013; Choi et al., 2008).

With the accumulation of neuroimaging evidence for a distributed network of cortical regions involved in *g*-related tasks and the rise of the CHC model emphasizing the contributive role of secondary broad abilities such as working memory, and processing speed, the localizationist approach gradually gave way to the network approach to high intelligence. The Parietal-Frontal Integration Theory (P-FIT) (Barbey et al., 2012; Jung & Haier, 2007); a network mediating the integration of information between the frontal and parietal cortices came of interest and was correlated to fluid, crystallized, and spatial intelligence (Colom et al., 2009).

A central feature of the P-FIT model is the role of sub-cortical connections, in particular white-matter fiber tracks (WM)—an important contributor of processing speed and working memory performance— in enabling efficient inter-cortical region communication. Greater intra- and inter-hemispheric connections in the fronto-parietal regions as well as increase in myelination in the corpus callosum is thought to contribute to the superior processing speed ability demonstrated by high IQ individuals (Luders et al., 2007). Recently, diffusion tensor imaging carried out on a

population of children with high intellectual abilities demonstrated a correlation of WM fiber-bundles as well as density and homogeneity of WM brain networks with high intelligence scores (Basten et al., 2015; Ryman et al., 2016; Suprano et al., 2019).

Today, it is known that high IQ related tasks are supported by communications distributed across widespread cortical regions, that include but does not limit itself to the prefrontal and parietal areas but also interactions with basal ganglia, between dorsal attention and default model networks (Gläscher et al., 2010; Hearne et al., 2016; Jiang et al., 2020; Santarnecchi et al., 2017). Research has also extended its interest to structural differences memory systems of HIP children and has shown that they are differently sized and connected compared to the brains of typically developing children (Amat et al., 2008). Such differences are thought to contribute to superior working memory, differential learning strategies and superior language capacity (Goriounova & Mansvelter, 2019). Other scholars (Alnæs et al., 2018) have veered their interests in the cortico-striatal-thalamic-cortical circuit, suggesting that superior connections observed in high IQ individuals could account for their higher anticipation and sensitivity to reward, henceforth altering their learning abilities. Yet others (Pezoulas et al., 2017), have investigated the cerebellum which bears numerous connections with the pre-frontal and posterior parietal brain lobes.

Recently, with the rise of advances in neural networks, biological correlates of intelligence were sought in network topology and efficiency. Under the network efficiency theory, the brain needs to minimize the cost of information processing by balancing competing constraints for local and global efficiency. Local efficiency is supported in networks by high spatial proximity of nodes as the reduction in average length of axonal projections conserves space and material. This leads to higher signal transmission speed. Conversely, long-distance connections cater for global, system-wide function. Structural and functional studies have linked intelligence to small world architecture which consists of high local clustering as well as long-distance connections of shortest path length to promote global information processing (Hilger, 2017; Kocevcar et al., 2019; Suprano, 2019). Solé-Casals (2019) found gifted children to have a more integrated brain network topology as compared to chronologically paired neuro-typical controls. Pezoulas et al. (2017) compared resting state cerebellar functional networks between high and low-IQ individuals and found them to be more efficient in high IQ individuals. Interestingly papers have also revealed gender differences in the organization of brain networks (Allen et al., 2011; Szalkai et al., 2015; Tomasi & Volkow, 2012). In their meta-analysis Hill et al. (2014) argued that men tended to have a more distributed gender specific network supporting working memory tasks including regions of the cerebellum, portions of the superior parietal lobe, and bilateral thalamus. Jiang et al. (2020), demonstrated that in female subjects, functional connectivity nodes (FC) in P-FIT regions as well as regions of the visual word form area, implicated in low-level processes of letters identification and high-level processes of word meaning

were found to be better predictors of IQ in females, whereas FC nodes in the lingual gyrus and subcortical areas such as the basal ganglia, and thalamus (known to participate in procedural learning- a core component implicated in mathematical skills and spatial mnemonic processing), had a more contributing power to IQ in males. Based on their observations they discussed the possibility of males and females capitalizing their most efficient cognitive processes to induce their respective superiority in cognitive domains.

Lastly, global network dynamics approaches from the field of network neuroscience are starting to investigate the capacity of the brain to transition between functional network states (rest or active) to enable rapid information exchange. Barbey (2018) postulated that such phenomenon could account for individual differences in information processing and reflect general intelligence. Research in this area falls into the framework of reflective models of “g” such as the process overlap theory of intelligence, which assumes that reflective “g” arises from the overlapping of networks and from the modulation of its system-wide dynamic states.

Recently Girn et al. (2019) and Langer et al. (2012) demonstrated that the capacity to flexibly transition between functional network states accounted for individual differences in crystallized and fluid intelligence. Schultz and Cole (2016) who studied how functional connectivity (the temporal correlation of activity between distinct locations in the brain) was reconfigured from rest to an activated-task related state, found that the efficiency of these updates in brain network organization is positively related to general intelligence. Individuals with higher scores of general intelligence tended to have less brain network reconfigurations between resting states and task related states and that this association held for various cognitive networks except for the motor system. This suggests that HIP individuals have an intrinsic network architecture that can answer more efficiently to various cognitive demands.

This network neuroscience approach to intelligence transcends past attempts at explaining individual differences in general intelligence with localized functional brain regions, networks or the overlap among specific networks, but provides a basis for general intelligence that relies on the ability of the brain to reorganize flexibly its intrinsic connectivity networks, i.e., neuroplasticity. Undoubtedly, the novel approach of investigating intelligence will shed the light to new specificities in individual differences in human intelligence and challenge our understanding of its neural bases.

Neurodevelopmental and cognitive trajectories of high intelligence

While imaging and network studies confer a time-specific capture of the structural and functional characteristics of the high IQ brain, it must be pointed out that on a neurodevelopmental perspective, the cognitive advantage of high IQ children is thought to arise from a differential long term dynamic process. In their longitudinal neuroimaging study of cortical development in 300 children and adolescents,

Shaw et al. (2006) showed that if cortices of high-IQ group started off as thinner at the younger age compared to controls, by the time adolescence was reached, they had thickened rapidly and significantly outgrew those the average-IQ children, especially the prefrontal cortex. Same was demonstrated by Navas-Sánchez et al. (2014), who found that math-gifted adolescents presented thinner cortices that chronologically-aged average IQ peers and large surface areas in fronto-parietal regions, a phenomenon postulated by them to be attributed by an above-age neural maturation. Yet, one must not forget that in a population reported to be highly inclined to invest themselves in training selectively in areas of excellence structural divergences observed with controls might reflect a combination of intrinsic (genetic) and extrinsic factors (training). Takeuchi et al. (2011) for instance demonstrated that mental calculation training could impact grey matter in the frontal and parietal region.

The same follows for the development of processing speed as might be conferred by differential development of myelination. Early histological studies have shown that myelination of neuronal axons follow a specific spatiotemporal pattern throughout development and these have been correlated to the evolution of cognitive and behavioral ability by functional neuroimaging studies (Deoni et al., 2016; Nagy et al., 2004). Although longitudinal studies investigated the correlation between white matter myelination and structural network development as a function of age in neurotypical infants (Dai et al., 2019), same is difficult to explore in high IQ individuals, due to the late nature of the diagnosis. Further, one must take into account that myelination tends to be activity dependent (Fields, 2015), which is difficult to take into account during a punctual imaging study. If elucidating the similarities of differences in the time-dynamic differential trajectory of myelination in high potential individuals is of interest, especially in refining any sensitive windows of development, the fact that intelligence is a complex dynamic process influenced by socio-environmental, genetic and molecular factors makes generalizations on the structural and functional neurodevelopment HIP population difficult if not impossible to make. The enterprise is even more complicated by difficulties faced by researchers to gather data early in development.

Indeed, scientific studies on the maturation of cognitive functions in high potential infants and toddlers are scarce and has for long been subjected to the bias of retrospectives questionnaires as diagnosis typically comes in after language acquisition. Yet, recent works on the contribution of infant and early childhood competence in terms of attention and executive function as predictors of adult cognitive abilities and IQ scores builds in optimism that childhood measurements could also provide sound grounds for elucidating the developmental trajectory of high IQ individuals from infancy (Blankenship et al., 2019; Wu et al., 2017). Rose et al. (2012) for instance found that psychomotor speed, attention, information encoding measurements in infancy contribute to later competence at 11 years of age. If such works support the early differentiation hypothesis, caution is hence in order in discussing the chronological acquisition of

any cognitive advantage in the context of high potentiality, especially considering that a study on HIP kinder-garden children has shown that great variability prevails in measures of cognitive, and executive functioning at this age (Hernández Finch et al., 2014).

Methodology-wise, it is also known that studying the cognitive advantages conferred by the substrates of high intelligence is delicate and requires careful task selection. For instance in early studies high IQ individuals could sometimes not process sensory stimuli at an increased speed compared to controls, and it was shown that results were confounded by attentional resources (Bates & Stough, 1997). In those studies where high IQ individuals did in fact display an advantage at processing sensory stimuli, Melnick et al. (2013) have argued that only a relatively small proportion of the variance in individuals IQ was explained by the results. Using a low-level visual task, they demonstrated that both processing speed and perceptual suppression strongly correlated with IQ and that individuals with high IQ, although faster at perceiving small objects, exhibited large deficits in motion perception as stimulus size increased. By conjecturing that not only information processing speed but sensory suppressive processes constituted key bottlenecks in both perception and intelligence, their study is one amongst other that exemplify the complex nature of brain processing systems involved in testing procedures and how difficult it is to study same in children where the systems involved still follow the course of typical or atypical developmental trajectories.

Past studies by Jensen and Munro (1979), replicated by Carlson and Jensen (1982), demonstrated negative correlations between movement time (MT) and scores to the Raven test in a test requiring participants to turn off a series of lights as fast as possible. If such results suggest that high potential children outperform controls in terms of overall movement time little is known as to whether this advantage is being conferred by globally more efficient functional networks subtending information processing and movement execution or if this advantage could be subtended by the investment of superior cognitive processes directed at optimizing procedural learning strategies. Interestingly, Spit and Rispens (2019) found no significant difference in procedural memory between high IQ children aged 8 to 13 and controls at a serial reaction time task involving visuospatial sequence learning. Further investigation in the area is needed, particularly as to whether the advantage in Movement time of HIP children persists in adults in tasks requiring different levels of complexity of movement execution would prove informative. Further, there is also little evidence as to whether high potential individuals bear differences in movement preparation and execution as compared to age-related peers. Unfortunately this lack of investigation possibly reflects the fact that models of intelligence consider high motor performance, such that those reached by high level athletes as not IQ-related talents. The investigation of the cognitive advantages or bottlenecks that might arise in HIP children during movement planning, execution and automation is however not only relevant to the field of physical education but also takes in importance in the

linguistic and educational realm, where handwriting is an essential competency defining academic success (Dinehart, 2015). Understanding the developmental trajectory of sensorimotor systems in young HIP children might shed the light on how handwriting acquisition is automated in this population.

Contrary to motor performance, executive function performance and development in high potential individuals have also been greatly studied, considered a possible contributor to their superior performance in information processing and cognitive regulation. Authors have argued that high performance at executive function contribute to academic success which has in turn fueled massive research on the topic (Brock et al., 2009; McClelland & Cameron, 2019). Categorized into three high order cognitive group of skills (Diamond, 2013), namely, Working Memory—involved in the recovery and processing of previous acquired knowledge, Inhibitory Control—including both cognitive and behavioral inhibition, and lastly Cognitive Flexibility comprising the ability to evaluate, select and adapt multiple cognitive strategies to achieve a purpose, executive functions have been showed to develop prematurely in gifted individuals (Bildiren, 2018; Vaivre-Douret, 2011). Johnson et al. (2003) found high IQ children aged between six and eleven to score higher on mental-attentional tasks and significantly demonstrated higher effortful inhibition capacity during interference loaded tasks. In their meta-analysis of 17 articles comparing executive functions in gifted versus non-gifted Rodríguez-Naveiras et al. (2019) supported the verbal and visual working memory superiority hypothesis in the high potential group, yet warned against the effect of sample size and WM testing tools. Such effects could yet again explain the discrepancies in results.

Metacognitive and emotional profiles of high potential individuals

Aside from information processing, executive control, and regulation skills, research has also focused on metacognition and emotional regulation and control of children with high potential. Metacognition, as defined by the fields and neuropsychological and educational science, denotes one's ability to reflect on his or her cognitive processes and to adjust the behavioral outcome accordingly. Many studies have demonstrated that HIP children outperform average peers in metacognition strategies (Berkowitz & Cicchelli, 2004; Oppong et al., 2019; Snyder et al., 2011). Development-wise, research has accumulated evidence that gifted individuals demonstrate superior metacognitive skills as from the age of seven (Annevirta & Vauras, 2006), although some argue that metacognitive awareness might already appear in the HIP child as early as in the preschool age (Barfurth et al., 2009).

As for the development of emotional skills and profiles of HIP individual, there is still to date, no clear consensus on how emotional intelligence (EI) should modeled, measured and how it is correlated to cognitive intelligence (Zeidner & Matthews, 2017; Zeidner et al., 2003). Currently, there exists two main models of EI: one ability-based measured by

performance tests at perceiving, assimilating, understanding and managing emotions (e.g., Mayer–Salovey–Caruso EI Test (MSCEIT); Mayer et al., 2003), and another perspective conceptualizing EI as a non-cognitive attribute, encompassing affective, motivational and personality traits and best measured by self-reports such as the Schutte Self-Report Inventory (SSRI) (Murphy & Janeke, 2009).

Under the first model, EI being a cognitive trait should demonstrate a positive manifold and correlate with other psychometric measures of intelligence, while being distinct from other sub-factors of *g*. One study, proposed by MacCann (2010) reported that EI could indeed measure a kind of intelligence by constituting a latent factor distinct from fluid and crystallized intelligence (*Gc*, *Gf*). Yet its strong correlation with “*Gc*” (*Gc*/EI: $r = .71$) posed the question as to whether the abilities measured constitute a new form of intelligence or whether they could be considered a different for “*Gc*.” On the same trend, authors have postulated that EI should be related to both crystallized verbal ability, in that it relies on the accurate identification and naming of emotions for the establishment of a coping strategy, and on fluid ability of reasoning in the implementation of self-regulation mechanisms in the face of new emotionally loaded situations (Kong, 2014; Zeidner et al., 2005). Yet evidence of same is lacking (Zeidner & Matthews, 2017), and Zeidner et al. (2005) demonstrated that individual differences in EI are measure dependent, gifted students scoring higher on MSCEIT tests when compared to controls but lower on the SSRI tests. To date, there is no consensus as to whether being intellectually gifted provides a cognitive advantage at emotional intelligence.

To make matters more complex, mass media has nourished the stereotype that high intelligence is associated with emotional and social difficulties. The gifted child is portrayed as the bearer of intense emotion, hypersensitive and aloof in his social relations, some even arguing that such constitutes the psychological profiles of the gifted population. While scholars today tend to agree that high potential individuals do not present emotional deficits (Ogurlu, 2021), results from studies focusing on the emotional and social behaviors of this population vary greatly mostly due to methodology. Peyre et al. (2016) found no significant differences in sensitivity analyses between their 23 gifted preschool children aged from 5 to 6 years compared to controls. Conversely, Gere et al. (2009) stipulated that based on the responses of parents to the Dunn’s (1999) Sensory Profile questionnaire, gifted children group demonstrated heightened emotional responses and sensitivity to their environment. The same issue arises in studies on anxiety in gifted children, some authors reporting increased anxiety among gifted children presumably because of their heightened sensitivity and hyper-acuity, others found reduced anxiety levels, attributed to protective factors such as better coping mechanisms (Chuderski, 2015; Zeidner & Shani-Zinovich, 2011), and yet others found no link (Guérolé et al., 2013).

Considering the rise of reports of depression and social isolation in gifted children, it is not surprising that the

psychological well-being of the population is thoroughly investigated, though yet again literature on psycho-cognitive profiles of HIP individuals has a long history of conflicting evidence. The perpetuation of the scientific blur on the psycho-cognitive profiles of gifted individuals despite giftedness being one of the most investigated topics in cognitive and neuropsychology is astounding. Indeed, recent authors have attempted to explain the contrasted data by possible methodological biases brought about by small sample sizes, unclear high potential definitions and non-validated assessment tools in past publications. As discussed below, it is important hence that future research attempts to account for those artifacts if progress on the topic is not to be hindered by false interpretations.

Identification of high potential individuals: threshold issues, heterogeneous sub profiles and sampling bias

The discrepancy observed in literature with regards to studies on high potential individuals has engendered much questioning about the identification and inclusion methods used in the scientific publications. Despite, international consensus for HIP diagnosis to be defined by a minimum score of 130 on the Wechsler’s scale, identification tools for high potential individuals in scientific research vary as some authors argue for the superiority of other intelligence tests related to their robustness against cultural and educational influence (Pfeiffer & Blei, 2008; Renzulli, 2012; Sternberg, 2003, 2016). Others, have questioned the varying strategies applied to sample inclusion and exclusion scores in research methods, as some scholars prefer to set the threshold inclusion limit below an FSIQ of 130 to account for the margin of error (Silverman, 2018).

Another confounding factor includes high variability between indices of the IQ test scores. If a dispersion of 12 points between the highest and the lowest index is considered a frequent phenomenon (40% of the general population), a difference of 23 points is only reached by 8% to 18% of the population and is considered to constitute a heterogeneous profile. Some authors have argued that children with heterogeneous profiles could be part of a distinct subgroup of HP population displaying distinct vulnerabilities and risks (Guérolé et al., 2015). Vaivre-Douret (2011) argued for instance that precocious maturation of sensorimotor functions would appear between the ages of 0 and 36 months in HP individuals with homogeneous IQ profile, whereas psychomotor asynchrony, as described by Terrassier (1979) would more likely appear in heterogeneous profiles. Boschi et al.’s study (2016) found that the homogeneous HIP children outperformed the heterogeneous HIP children in memory and motor skills at school age. Nusbaum et al. (2017) showed that neural substrates differed homogeneous high IQ and heterogeneous high IQ individuals, with a left hemispheric lateralization distinctive of heterogeneous high IQ individuals who frequently demonstrate high verbal indices. Suprano et al. (2019) who used graph theory to compare brain networks of HP children also found differences in network topology between the two sub profiles of

homogenous and heterogeneous IQs (based on verbal comprehension index and perceptual reasoning index).

While evidence is accumulating in favor of a distinctive cognitive profile for HP-heterogeneous the question arises as to the possible risk factors it could constitute to academic achievement. If underachievement occurs across all academic populations, gifted or not; gifted underachievers are for their part operationally defined by negative deviations on the regression of school achievement on general intelligence (Gilar-Corbi et al., 2019). Counselors as well have argued that HP children in academic distress tend to demonstrate negative attitudes toward learning and school, a negative self-concept as well as emotional and behavioral problems (Blaas, 2014). Of course, the underlying mechanisms of underachievement in gifted population are complex and multidimensional yet it is interesting to note that individual-based risk factors such as motivation and self-regulation are implicated in gifted students' learning and well-being (Al-Dhamit & Kreishan, 2016). Knowing that a more heterogeneous IQ-profile puts high potential children at greater risk of adaptation and learning difficulties, it is hence legitimate to question the prevalence of such profiles in academic underachievers.

This would prove to be ultimately critical if the same population ended up seeking clinical help for diagnosis and intervention. Already, many have warned against the sampling bias and perception bias that could occur in studying HP individuals known to therapists and extrapolating observations to the general HP population. More often than not HP individuals who come to be known to relevant authorities also present confounding comorbidities such as neurodevelopmental disorders (dyslexia, developmental coordination disorders—DCD and/or ADHD) or socio-affective disorders (autism, depression) and their close relatives (parents, teachers) are already sensitized, desperate or burdened by their behavior making rating surveys and questionnaires difficult to interpret objectively (Pfeiffer, 2015). Also, little is known to date on the relative prevalence of homogenous versus heterogeneous profiles of HP individuals known to clinical support systems and such investigations should be carried out to eliminate risks of over extrapolating specific cognitive attributes of a subgroup to the general HP population.

Twice exceptional HP children

Over the past decades a subgroup of the gifted population, has been the subject of increased attention from educators and practitioners: the “twice-exceptional” or 2E. The term designates individuals who simultaneously possess a high ability and a learning, emotional, physical, sensory and/or developmental disability (Foley-Nicpon et al., 2011; Foley-Nicpon et al., 2013). While consensus on the term is not yet reached in research, it is widely used in education as the label “exceptional” was already used to designate children with exceptional ‘strengths’ or exceptional “weaknesses.” If research has for long focused on “learning disabilities,” leaving other forms of disabilities (emotional, sensory, physical

and developmental) pending, works from Foley Nicpon et al. (2011) and Foley-Nicpon et al. (2013) have shown that giftedness in students could be paralleled with deficits in attention, social awareness, thereby encompassing autism spectrum disorders (ASD), specific learning disabilities (SLD), attention deficit hyperactivity disorder (ADHD), and emotional disturbances (ED) in the 2e group. According to Ronksley-Pavia (2015), an extensive research gap in the literature is still to be breached regarding children with other exceptionalities.

If in the field of education, the prevalence of 2E is nowadays internationally recognized, in what ways does the cognitive functioning and do the neural substrates of 2E differ or resemble those of purely gifted individual (or those with the isolated disability) is still debated, given the difficulty of assessing the comorbidity effect (Foley-Nicpon et al., 2010). Further, the occurrence of 2E puts at test current models of intelligence and reliance on medical models fail to provide a clear boundary between gifted/non-gifted and disabled/non-disabled. Indeed, the spearman's model of a broad ability (1904) cannot account for gifted individuals having intellectual disabilities. While models such as Gardner's (1983,1993) or Gagné's (1995) tend to be more accommodating since high ability in one area does not imply corresponding abilities in others, dynamic models considering the spectrum of possible interactions at the interface between giftedness and disability are scarce.

For long, the observation and diagnosis of twice-exceptional children was difficult, as high abilities were thought to compensate for the expression of the disability and conversely that disabilities could be hidden by giftedness. This interplay between cognitive “strengths” and “weaknesses,” referred to as the “masking effect (Assouline et al., 2010), has been speculated to be an underlying mechanism explaining the differentiated performance of the 2E population compared to the gifted or disabled under certain tasks. Currently opposite views argue that 2E individuals display distinct cognitive profiles from gifted individuals or disabled individuals that is not the result of a simple additive or subtractive effect. Same will be discussed with regards to specific learning and neurodevelopmental disorders.

Dyslexia and high potential

Dyslexia is a learning disability which arises in ~7% of children across cultures (Goswami, 2022) which is characterized by difficulties in reading fluently despite normal intelligence and in the absence of sensory deficits in vision or hearing (American Psychiatric Association, 2000). Phonological skills which include various abilities such as phonological memory (verbal short-term memory or VSTM), rapid automatized naming (RAN) or phonological awareness (PA), are nowadays known to participate considerably in the acquisition of literacy (Araújo & Faisca, 2019; Norton & Wolf, 2012) and that deficits in such skills underlie the difficulties presented by dyslexia (Goswami, 2011; Ramus et al., 2003). According to Tallal's theory (1980) on the mechanisms of dyslexia as was supported by numerous subsequent studies,

children with dyslexia present deficits in the temporal processing of speech at the basic auditory level which is due to an inability to assimilate sensory information delivered rapidly.

A more recent theory, “temporal sampling theory” (Goswami, 2011) argues that the successful representation of the different temporal rates and amplitude modulation of complex speech signals requires the efficient sampling of the speech stream by auditory cortical networks. These are mediated by the emergence of specific cortical networks oscillatory frequencies operating at different time scales (Giraud & Poeppel, 2012; Leong & Goswami, 2014; Poeppel, 2003). According to the theory, children with dyslexia could present difficulties in specifying linguistic units such as syllables, because of atypical oscillatory sampling at one or more temporal rates. Further, some authors (Casini et al., 2018; Gori & Facoetti, 2015; have postulated that temporal sampling deficits might extend to the visual modality based on studies relating dyslexia to impairments in the magnocellular-dorsal (M-D) pathway (Gori et al., 2014, 2016) known to be sensitive to rapidly changing information. From their results showing that children with dyslexia exhibit a larger perceptual variability when doing temporal tasks involving both the auditory and visual modality, Casini et al. (2018) argued that time perception could be implicated in dyslexia with an atypical functioning of the ‘internal clock’ of dyslexic children.

The investigation of the impact of high potentiality on dyslexia is quite new, yet two theories prevail. The first presumes that the core deficits in phonological processing associated with dyslexia are unaffected by intelligence. According to the core-deficit view, high ability in more general skills cannot compensate for deficits in the phonological processes underlying word reading, although they are probably beneficial for reading comprehension (Van Viersen et al., 2015). Under this hypothesis, high potential individuals would hence demonstrate comparable deficits in core processes such as phonological awareness (PA), verbal short-term memory (VSTM), and rapid automatized naming (RAN) to those by non-HP dyslexics. Tanaka et al. (2011) compared differences in brain activations during a phonological processing between poor readers with high IQ and low IQ and found that both groups showed reduced activation in brain areas such as left parieto-temporal and occipito-temporal regions, suggesting that phonological deficit could be independent of IQ.

Proponents of the opposite theory argue that the presence of an intelligence-related cognitive strength relevant for literacy (e.g., working memory demonstrated by Alloway et al. (2009) as a factor of academic progress in the acquisition of literacy) can provoke or stimulate the emergence of compensatory mechanisms that could help circumvent underlying dyslexia-related deficits or subdue their negative effect on literacy development (Van Viersen et al., 2016). Indeed within the framework of the “deficit in temporal processing of speech at the basic auditory level model” of dyslexia, it could be that compensatory mechanisms related to superior sensory information processing skills are at plays in HIP

individuals. Van Viersen et al., 2017 investigated same and found HP individuals with dyslexia to perform in between children with dyslexia and TD children, with deficits in PA and RAN but strengths in VSTM, WM suggesting that a compensating mechanism might indeed occur. Berninger and Abbott (2013) found that this compensation could yet again be dependent on HP profiles as twice exceptional students with average verbal reasoning and dyslexia demonstrated significantly lower reading, spelling, morphological, and syntactic skills than students with high verbal reasoning and dyslexia. In the framework of “temporal sampling theory of dyslexia,” little is also known as to whether the mechanisms underlying the temporal sampling of speech are preserved or deteriorated in individuals with high IQ.

Developmental coordination disorder (DCD) and high potential

Conferring to the DSM-5, DCD is a neurodevelopmental disorder that induces deficits in the acquisition and execution of coordinated fine and gross motor skills compared to age-related peers. With a prevalence of that 5–6% in school aged children and about half of the early diagnoses persisting through adulthood, DCD, can considerably impairs quality of life depending on the severity of the symptoms (Biotteau et al., 2019; Kirby et al., 2014). Children with DCD frequently display handwriting difficulties which impairs academic life (c). Poor c has been shown to be a risk factor for obesity and depression (Karras et al., 2019). Unfortunately, the prevalence of DCD in gifted children has not been investigated much. In children who have portrayed as typically preferring intellectual tasks and having reduced interest in motor-related activities, little is known as to whether the effect of reduced practice, motivation is detrimental or even influential in the case of DCD.

Functional neuroimaging works have started to investigate the neural bases of DCD: Zwicker et al. (2011) demonstrated that children with DCD showed reduced bold signals in cortical regions associated with skilled motor practice amongst which the bilateral inferior parietal lobules, right lingual, middle and middle-frontal gyri, the left fusiform gyrus and cerebellar areas compared to non DCD controls. Fuelscher et al. (2018) showed a differentiated activation pattern of brain areas in manual dexterity tasks. Yet no such works exist to clarify the influence of IQ or what possible compensation mechanisms, if any, that high cognitive function might infer.

While studies have shown the correlation of motor impairment severity and IQ in the context of Autism (Kaur et al., 2018; Surgent et al., 2021), few studies have investigated same in the context of DCD. One of the few, carried out by Vaivre-Douret et al. (2020) found slightly less severe DCD symptoms in certain areas, notably ideomotor and Visio-Spatial/Constructive tasks in high IQ groups with DCD compared to controls. The cognitive functioning of high IQ children with DCD was found to vary from controls, with a better performance executive functioning and visio-spatial skills but lesser performance in auditory attention and

memory tasks. Recently, He et al. (2018) demonstrated that interhemispheric M1 cortical inhibition is impaired in a small sample group of eight adults with DCD compared to controls while intrahemispheric M1 inhibition is preserved. It would be interesting to know if such mechanisms are preserved in HP-DCD groups who are known to have enhanced interhemispheric frontal connectivity between the dorsolateral prefrontal and premotor cortex (Prescott et al., 2010). Today little is known as to whether the sensorimotor processing advantages typically displayed by HIP individuals compensate for deficits brought about by DCD.

Attention deficit-hyperactivity disorder (ADHD) and high potential

Defined by the DSM-V attention deficit-hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects between 2% and 7% of individuals in their childhood (Sayal et al., 2018). Established as a risk factor for other mental health disorders, and correlated to negative outcomes in life such as academic underachievement, poor employability, social distress and criminality, diagnosis and intervention on ADHD has raised many concerns over the past decades. The diagnosis is based on the observations of 18 symptoms categorized into two main focal groups of inattention (IA) and hyperactivity-impulsivity (HI). There are three subtypes of ADHD: the predominantly inattentive type, the predominantly hyperactive/impulsivity type, and the combined type. For long, the validity of the diagnosis of ADHD in gifted children has not been recognized, as proponents of the Dąbrowski's theory (1967) had assimilated giftedness with five types of over excitability, of which a psychomotor over excitability making them hyperactive, impulsive, and inattentive by nature, rather than being due to ADHD symptoms. Other authors argued that gifted children displayed ADHD-like symptoms at school only due to boredom. Today, several reviews and works (Minahim & Rohde, 2015; Mullet & Rinn, 2015) have provided empirical evidence that ADHD can coexist with high intelligence. As for the particularities of being both ADHD and HIP, research is now focusing on elucidating the protective vs. risk factors, or similarities vs. differences to ADHD in the gifted population. Two hypotheses have prevailed: the twice-exceptional theory in this line of work (Budding & Chidekel, 2012) postulated that gifted children would be at greater risk for more severe IA and HI symptoms, based on the over excitability theory mentioned above, while the cognitive reserve concept whereby high IQ would act as a protective factor and reduce the severity of ADHD symptoms (Minahim & Rohde, 2015). A recent study by Gomez et al. (2020) found that for most ADHD symptoms, the results did not uniformly support either theory. Indeed, aside from the observation of significant differences in a few HI symptoms, severity was not different across ADHD-gifted or ADHD-non gifted groups, putting the twice exceptional theory into perspective. In the same vein, while inattention was less prominent in gifted ADHD children when compared to non-gifted ADHD controls same was not observed across all symptoms, thereby not

fully supporting the cognitive reserve concept. The authors suggested that specificities between ADHD gifted children and non-ADHD gifted children might not be generalized but would appear solely on specific HP behaviors (verbal and motor activity modulation and reflective capacity on questions) which would act as a basis for adapted diagnosis in the ADHD-gifted population.

High functioning autism and high potential

High functioning Autism (HFA) is a developmental disorder that forms part of the autism spectrum disorder (ASD), with specific deficits in social interactions and the demonstration of restricted or repetitive interests or behavior without impairment in language, adaptive skills and cognitive functioning (American Psychiatric Association, 2000). Decades ago, authors who have investigated the scoring patterns of HFA-Gifted population to psychometric tests such as Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) have found that the population tended to exhibit distinct characteristics, notably weaknesses in graphomotor and processing speeds as demonstrated by lower scores to the Digit-Symbol Coding and Symbol Search subtests and visual and verbal reasoning strengths as showed by higher scores to the Perceptual Reasoning Index (PRI), verbal comprehension index (VCI) Information and Matrix Reasoning subtest (Foley-Nicpon et al., 2012; Mayes & Calhoun, 2008). These variabilities across test scores have been argued to impact significantly final IQ scores, such that the use of the General Ability Index (GAI), calculated from VCI and PRI scores was proposed as a more adapted measure of IQ in HFA and individuals with ASD in general (Foley-Nicpon et al., 2012). Considering the possible protective or risk factors that giftedness might bring into light in the context of HFA, very few studies exist to date. Peñuelas-Calvo et al. (2021) showed that in HFA, intelligence quotient positively correlates social cognition as measured by the 'Reading the Mind in the Eyes' Test. The authors have postulated that compensatory mechanisms might arise from shared above-average functional cerebral resources between social recognition and high intelligence or that high ability in problem-solving in gifted individuals might be at play to compensate for lack of facial expression recognition. For instance, it is known that while neurotypical individuals activate their amygdala in facial expression recognition tasks, individuals with ASD seem to compensate with higher activation of frontotemporal regions (Baron-Cohen et al., 2000). Conversely, Dempsey et al. (2021) who compared patterns of age-related declines in adaptive functioning between groups of ASD-gifted and ASD non-gifted found no protective effect of giftedness. Longitudinal Functional Neuroimaging studies comparing HFA gifted and HFA non-gifted might prove to be interesting to infer whether such mechanisms are at play.

Conclusion

In this meta-review, we have attempted to portrait a global picture of what is known to date pertaining to the singular

cognitive, behavioral and developmental profiles of HP individuals. New investigation techniques are now questioning a long history of epidemiological evidence on HIP and providing new frameworks of interpretation the cognitive mechanisms underlying high intelligence. Conceptions of HIP, research methods and terminology must hence evolve accordingly, focusing on scientific evidence rather than years of culturally influenced presumptions.

In reality, despite decades of investigation, there are still numerous limits to our understanding on HP which could be explained by many factors, including small-scale observational studies with small sample size, unstandardized methods of sample selection and sample selection bias with access to individuals diagnosed with confounding co-morbidities. HP individuals recruited in studies are often part of a cohort of patients followed by clinicians for co-existing confounding affective and learning disorders. Responses to retrospective surveys used in developmental research are often confounded by parents and teachers already sensitized to the condition, a bias likely to be exacerbated by the current rise in media coverage.

It is imperative that future investigations seek out to widen sample selection to HP individuals unknown of practicing that have remained under the professionals' radar. Further, it appears that sub profiles of HP with extreme variations on the Weschler's scale (homogenous and heterogeneous profiles) might need to be taken into account regarding the neurofunctional evidence of differential neural bases subtending their cognitive processes. With regards to the co-occurrence of attention, learning or affective disorders with HP, one must not be duped by the term "twice exceptional" as little is known about the potential cognitive mechanisms at play in each respective situation. It hence follows, the fruit of such investigations would prove crucial in determining if the present support system provided to them, academically or clinically, would be efficient as is or would need to be adapted to their HP condition.

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Appendix

Table A1. Keywords used in the literature search listed by section header.

Article section	Keywords
3.1. Definition and Terminology	<i>Intelligence model/theory; giftedness; talent; high potential; definition; IQ; terminology; multiple intelligence, heritability of intelligence; psychometric models; cognitive models; cognitive development; development; precocity; gifted education, gifted program; gifted policy.</i>
3.2. Neural correlates of high intellectual potential (HIP): From localized to distributed approaches	<i>Functional/structural imaging; brain, neural/biological; substrates/correlates, P-FIT, white matter; myelin; neural network; topology, functional connectivity; network efficiency;</i>
3.3. Neurodevelopmental and cognitive trajectories of high intelligence	<i>Neuro/development; infant; early childhood; myelination; Metacognition; motor/psychomotor/ cognitive/executive function; development/al trajectory; memory;</i>
3.4. Metacognitive and emotional profiles of high potential individuals	<i>Metacognition; self-regulation; emotional and social development; Emotional intelligence (EQ/EI); anxiety, sensitivity; psycho-cognitive profiles</i>
3.5. Identification of high potential individuals: threshold issues, heterogeneous sub profiles and sampling bias On the debate of being twice exceptional	<i>Identification; diagnosis; homogeneous; heterogeneous; asynchrony;</i>
4.1. Dyslexia and high potential	<i>Twice exceptional; learning difficulties/disability; identification; behavior; academic achievement/ success; underachievement</i>
4.2. Developmental coordination disorder (DCD) and high potential	<i>Reading deficit/difficulty; dyslexia; mechanisms; models; temporal sampling theory; magnocellular-dorsal (M-D) pathway; compensation; protective and risk factors</i>
4.3. Attention deficit-hyperactivity disorder (ADHD) and High potential	<i>Developmental coordination disorder; sensorimotor/graphomotor/motor processing/execution/; neural correlates; pathway; compensation; protective and risk factors</i>
4.5. High functioning Autism and high potential	<i>attention deficit-hyperactivity disorder; over excitability; diagnosis, identification; compensation; protective and risk factors</i>
	<i>Diagnosis; identification; compensation; protective and risk factors</i>