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ΙΑΤΡΙΚΗ ΣΧΟΛΗ

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ASSOCIATION OF GIFTEDNESS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND/OR SPECIFIC LEARNING DISORDERS IN CHILDREN AND ADOLESCENTS: A SYSTEMATIC REVIEW

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Ευχαριστίες

Ευχαριστώ ιδιαιτέρως τον Επίκουρο Καθηγητή Κο Σεργεντάνη Θεόδωρο για την καθοδήγηση και την υποστήριξη κατά την εκπόνηση της διπλωματικής μου εργασίας, καθώς και για τις γνώσεις που μοιράστηκε μαζί μας σε όλη τη διάρκεια του μεταπτυχιακού προγράμματος. Ευχαριστώ τη συνάδελφο και φίλη Κα Αφροδίτη Κοντάκου, για την άριστη συνεργασία κατά τη διενέργεια της συστηματικής ανασκόπησης, που αποτέλεσε τη βάση αυτής της διπλωματικής εργασίας. Ευχαριστώ τον Κο Τσιαχρίστα Απόστολο για τη βοήθεια που μας παρείχε, ώστε να έχουμε πρόσβαση σε περισσότερες βάσεις δεδομένων. Τέλος, ευχαριστώ την οικογένειά μου και συγκεκριμένα το σύζυγό μου, Διονύση και την κόρη μου, Δανάη για τη στήριξη, την υπομονή και την κατανόηση που έδειξαν όλο αυτό το διάστημα.

Αφιερωμένο στο Διονύση, που είναι πάντα το στήριγμα μου και τη Δανάη, που από τη στιγμή που μπήκε στη ζωή μου με κάνει να βλέπω κάθε δυσκολία με αισιοδοξία

CONTENTS

1. Introduction

Even though giftedness has been studied for many decades now, there is no clear and official definition to describe this term. According to the National Association for Gifted Children (NAGC), gifted individuals are defined as those who demonstrate amazing levels of natural ability (defined as a remarkable capacity to understanding and absorbing information) or talent (established effort or success in the top 10% or rarer) in at least one field. Fields consist of any domain of pursuit (e.g., mathematics, music, language) and/or sensorimotor activities (e.g., painting, dance, sports)" (1). The lack of a consensus in a single definition leads to limitations in research and obstacles in further investigation. Additionally, the exact and impartial prevalence rate of existing talented children is quite difficult to estimate. Approximately 3% of children are considered as gifted by most authorities, although in some cases as many as 15% of children are reported gifted (2). To identify gifted individuals, standardized tests measuring superior Intelligent Quotient (IQ) are used, failing to recognize children with talents in other domains (3). Moreover, their exceptional aptitude may be masked by environmental conditions such as impoverishment, prejudice, cultural boundaries, physical or learning problems, motivational or emotional difficulties.

There are cases of gifted individuals that also have a special need or disability. These children are described as "twice exceptional" or "2e" (4). Although significant research has been administrsted on the gifted individuals with neurodevelopmental disorders (NDDs), this study will take into account only gifted children with Attention-Deficiticit/Hyperactivity Disorder (ADHD) or Specific Learning Disorder, as described in the Diagnostic and Statistical Manual of Mental Disorders V (DSM V). In DSM-V, NDDs emerge typically in the developmental period, revealing impairments that produce difficulties in functioning (5). According to the American Psychiatric Association (APA), ADHD is a common diagnose among children with mental difficulties. Inattention (difficulty to focus), hyperactivity (to many improper movements) and impulsivity (rushed acts that arising in an instant without thinking) are mainly the symptoms of the disorder. Approximately 8.4% of individuals are reported to be diagnosed with ADHD, commonly boys, and it is usually first identified in school years when children confront difficulties with schoolwork and have interruption in the classroom (6). On the other hand, Specific Learning Disorder (SLD) is a neurodevelopmental disorder referring to persistent difficulties in one of three domains, reading, writing, and math, that are crucial to the learning process of

students. Even though symptoms begin at early childhood during, individuals may remain undiagnosed for many years. About 5-15% of students confront a learning difficulty, most often concerning reading disorder (7).

Considering all the above, it becomes obvious that twice-exceptional children are distinctive and unique individuals with extraordinary needs to respond to their social and emotional difficulties and the conceivable underachievement at school and later in life (8).The aim of this study was to examine the relationship between giftedness and ADHD or Specific Learning Disorder in children and adolescents. A systematic review of the literature was conducted, including all cohort, case-control, and cross-sectional studies, correlating giftedness with neurodevelopmental disorders. However in this study are discussed only the results regarding giftedness and ADHD or SLD.

1.1 Giftedness

1.1.1 Definitions and Theories

Giftedness, intelligence, and talent are abstract ideas, displaying differences depending on contexts and cultures. There is a range about the word “gifted”, even within schools, revealing multiple meanings and many nuances to the word. Gifted children usually perform in high level, or are capable to do so, bringing to light the need to furnish them with appropriate educational skills and thoroughly enrich their talents , supporting both the community and the children (9).

Even though definitions of gifted and talented children have been suggested, there is no widespread consensus for a single one. Nearly every state has its own, defining giftedness either by comparing individuals with their peers or by recognizing the need for distinctive educational plan. According to the National Association of Gifted Children, giftedness is presented as exceptional natural abilities, especially to deliberate and comprehend, remarkable skills and outstanding performance in at least one field. Fields consist of clearly defined activities including their symbols like mathematics, music, language and sensorimotor masteries like painting, dance and sports (9). In the 1972 Marland Report to Congress was firstly reported a national definition of giftedness and after several modifications the final form was adopted: Individuals with apparent ability of high performance in any domain between

academic, artistic or leadership capacity, or in particular academic area and who require exceptional academic programs in order to totally expand their talents (10).

Research in giftedness has already started since the 19th century, however it was mainly based on observation. Lately, many mental health providers showed an interest in gifted individuals, describing students with above average intelligence ability, identifying common characteristics of this population, and obtaining better information to implement educational measures. In 1909, Alfred Binet, the father of the concept of “mental age”, observed school-age individuals who were “too intelligent” and educational programs where deficient for them (11). In the first place, giftedness was principally connected with intellectual abilities. Before Binet, the diagnosis of the condition relied on interviews from doctors or other specialists. Despite the advantages of Binet’s diagnostic tests, soon thereafter the necessity of improved measure methods emerged. While different methods are used to discover predictors of mental exceptionality, only the Intelligence Quotient (IQ) is a universally accepted measure to identify intellectual giftedness. IQ is a fractional quantity, invented by William Stern in 1914 and was calculated like so: IQ= mental age/chronological age. This ratio was multiplied by 100 and rounded to the nearest integer, interpreting that a child with an IQ of 75 is advancing 75% as fast as the average child. To compensate for the disadvantages of the above measurement, David Wechsler reconceptualized the IQ calculation afterward (12). Nowadays the most widely used and objective criterion assessing IQ in children is the Wechsler Preschool and Primary School Intelligence (WPPSI) and the Wechsler Intelligence Scale for Children (WISC) (12, 13).These scales evaluate three subcategories of Intelligence Quotient, Verbal IQ (VIQ), Performance IQ (PIQ), and Full-Scale IQ (FSIQ) in different ages.

Among many theories developed in order to describe giftedness are those of Joseph Renzulli, Francoys Gagné, Howard Gardner, and Robert Sternberg. Particularly, Renzulli described giftedness as consisting of three fundamental groups of characteristics basic, exceptional capabilities, remarkable motivation, and outstanding creativity. He noted that gifted and talented children exhibit or have the capability to develop the above characteristics and utilize them in any precious circumstance. Children who demonstrate, or are able to do so, an interaction among those groups demand many different academic chances and educational programs that are lacking from the ordinary instructional services (14). According to Francoys Gagné, The Differentiated Model of Giftedness and Talent suggests an explicit

differentiation between giftedness and talent. Giftedness indicates the assets and application of untrained and instinctively revealed natural aptitudes in at least one field in the level of the top 10% of all same age children. On the contrary, the term talent refers to the exceptional skill of methodically developed capacities and knowledge in one or more domains in the level that sets individual's success to the top 10% of his or her age-peers. Moreover, his model described natural abilities in five fields, academic, inventive, socio-affective, sensorimotor and others that are defined by an evident genetic base and are presented in everyday schoolwork (15). Another theoretical conception of giftedness reported by Howard Gardner in the late 1970s and early 1980s is the Theory of Multiple Intelligence. This theory is based on eight or more relatively autonomous intelligencences, including linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, naturalistic, interpersonal, and intrapersonal. Using these intelligences one can produce goods and figure out solutions regarding the community they live in (16). Besides, Gardner developed the non quantifiable conception of the Emotional Quotient (EQ) as well. EQ scales combine the sentimental and efficient experience of children using certain assessment (17). In addition, according to Sternberg, Successful Intelligence is described as the capacity to succeed in life, in compliance with one's willing and environmental background (18). Furthermore Sternberg presented the triarchic mind, a concept of giftedness including analytical, practical and creative components (19).

1.1.2. Characteristics of gifted children

It is well known currently that gifted children reveal extraordinary abilities in different domains and the estimation only of intelligence is inadequate to anticipate the subsequent social or intellectual achievement (11). Methods for assessing IQ do not consider originality and are inadequate to estimate exceptionality in any other area (3). Gifted children are able to achieve fluent reading without training in younger age, to play musical instruments effectually without instruction, to solve mathematical problems addressed to adults (20). Consequently gifted individuals may reveal superior ability in different areas like academic or even art, music and athletics.

Taking into account all the above, gifted children may reveal talent in many areas or exhibit exceptional skill in only one domain. Despite a lot of characteristics that are similar between gifted children, no gifted individual is exactly the same. Children with giftedness may be able to make connections efficiently, demonstrate interest, like to learn new things and get new talents easily (3). Some other characteristics defining

gifted children include the interest in patterns and relationships, the skill to find the linkage between different ideas and the capacity to remember dilemmas that were not fully understood. Impressive long-term memory, the bravery to think differently and the delight when figuring out difficult problems are also features picturing gifted individuals. Further attributes reported in gifted children are the advanced sense of humour, the intensity of feeling and emotion, the sensitivity and the perfectionism. Moreover children with giftedness may develop the ability to complete actions autonomously, understand ideas rapidly and intuitively, and the skill of insatiable curiosity and perceptive questions. They may even be able to be a part of discussion and interests like adults. In addition to their talent in specific areas, like drawing, music, games, mathematics or reading, gifted children may reveal advanced language and reasoning skills (2). As regards their behaviour, gifted individuals often report spontaneity and boundless enthusiasm, they used to be really active, needing little rest or deeply concentrated to emotions, resisting to change activities when fascinated in their own talents. They are characterized with perseverance, impulsivity and eagerness as well. On the contrary, sometimes gifted children may often report irritation, or irascible mood, especially when they have to manage with difficulties or failure. Besides their sensitivity or empathy to others' feelings, gifted children often have feelings of frustration due to high expectations of self and others. Referring to affective traits of gifted children, it is worth mentioning the necessity to assist them to manage their feelings and to correspond the relationship between values and actions. Furthermore talented individuals are often characterized with ethical discrimination, utopianism and sense of equity. Their ability for fantasy, their flexibility and the radicalism they may appear are quite remarkable (21).

1.1.3. Prevalence of Giftedness

Given the ambiguous definition of giftedness, incidence rates are approximately specified (2). As long as there is no clear discrimination between gifted and typical children, the prevalence rates remain inexact, varying by how different schools describe giftedness. Universal prevalence varies from 3% to 15%, depending on racial, and socioeconomic standards, among others. Surprisingly, there are parents expecting their children to be labelled gifted and press teachers to promote the diagnose of giftedness (22). According to the National Association of Gifted Children the difficulties in estimating the exact number of gifted children arises from the dependence of the different measurements and methods used in each area to recognise talented individuals. Moreover the exceptional aptitude of gifted children

may be masked by social conditions like impoverishment, unfairness, cultural obstacles, health problems. However, it is considered that individuals that perform in a degree of 10% or greater than average are defined as gifted (9).

The United States Department of Education's Office of Civil Rights estimates that 6% of children join special educational programs for gifted individuals, whereas gifted children from low socio-economic background are 2.5 times less likely to be recognised and enrolled in those programs. It is well known likewise, that incidence of talented children is higher in middle than lower-class communities, despite of hereditary factors, and chances that may be provided to them (2). Considering that 45% of students in the United States in 2010 is from minority groups, it becomes obvious that there is a cultural and linguistic diversity between young individuals (23). Subsequently, the need to contribute enhanced and of high quality educational programs to every child with gifted potential becomes indispensable.

1.1.4 Special Educational Needs of gifted children

Talented individuals are a community with special educational needs that are often misunderstood and consequently underserved. Although giftedness can be explicit in young children as it was well described above, the abilities and the talents may present progression throughout life. Attainment and inspiration are of paramount importance, while children reach adulthood. Different factors can either improve or impede the advancement and presentation of abilities (1). Even though many school districts recognize the unique needs of gifted individuals, legislation and finances provided differ, emerging discrepancy between services that are available on each district. In some cases, successful nurturing of gifted children is based on parents' persistence and teachers' responsiveness to confront their exceptional educational needs. Family, teachers and society have the duty to promote all children to achieve their highest potential. It is crucial to reinforce the advancement of all aspects of the talented child, including mental, sentimental and social traits.

Supporting gifted individuals is a process taking place firstly at home, where family may recognise their child's exceptionality. Given the fact that giftedness may present with challenges in individuals everyday living, parents recognize these disparities between their individuals and typically developing children (24). When parents first receive the diagnosis of giftedness for their child, despite the delight they feel, they briefly feel anxiety about how to manage the situation and provide their child

adequate support. They meet difficulties such as the feeling of being not good enough, unprepared and unequipped or frustrated with the nurturing of their unique child. Their child may be bored, under-challenged, underachieving, or unhappy, demanding extra time, energy, and financial resources. Parents are obligated to find the perfect balance between the appropriate curriculum for their child's cognitive abilities, maturity, and academic interests and their child's desire and puerility. They are also called to decide educational options that will best fit their child's need. Criteria that should be considered include his or her IQ, educational level, and social and emotional development (22). In parents' power is the engagement to furnish their children with motivation and academic opportunities and to collaborate with educational to manage their child's particular needs (24).

By the side of parents should be the healthcare providers and especially the paediatricians, in order to support them to identify their child's exceptional potential and suggest to them possible educational options appropriate to his/her talent. Paediatricians used to be the first to respond to parents' requests concerning their talented child's proper life opportunities in all domains. The most frequent question that parents express, concerns educational options for their gifted child. Paediatricians should assist parents promote adequate academic chances and provide alternatives on preventing over-scheduling the child, by permitting free time during the day, and maybe giving them the chance to offer their services to help others through volunteering (3).

Educator's role in promoting gifted children's academic achievement is notoriously significant. Their role is mainly to support talented individuals enhance their mental and educational potential in cooperation with the child's family. Educating talented individuals can be both exhilarating and demanding, because of their exceptional needs. Teachers should provide knowledge of every spectrum facilities and aptitudes to assist children achieve their best in learning and maturing process. Particular techniques such as flexibility in groups, acceleration and specially designed programs are required when teaching gifted children (24).

In order to support gifted children to learn faster than their peers, a wide range educational plan is required. Modifications in the status and the speed of school syllabus as well as extracurricular programs should be part of the plan. Remarkable diversity between talented individuals often demands supplementary and peculiar intercession, including more extensive evaluation, family training and particularly

modified programs (1). Intelligent adolescents who exhibit dreariness and lack of motivation and inspiration in the classroom may sometimes respond better to dual enrolment peer classes and web classes. Counselling is specifically productive when the supportive schedule meets the exceptional needs of the talented child (22).

Giving superior chances for inspired classes assists talented individuals to keep their attention, adopt new abilities, and progress rapidly either in classes with typically children or in groups with talented peers. Since an individual is identified as gifted in any domain, either by educators or family, enrichment activities have been suggested and categorised in 3 fundamental types: push forward, go deeper, and broaden horizons. According to the “push forward” strategy, gifted children are pushed ahead to meet superior competences. Hence it is suggested by some families and teachers that individuals with special talents should skip a grade in order to attend classes of higher level. In this way, children will be engaged in a class that provides them adequate challenges in their particular talented area and the opportunity to urge forward toward academic success. Disadvantages of this method may appear if gifted children have difficulties managing with the social, emotional, or behavioural setting between older children. Additionally this procedure may efficiently speed up and abbreviate childhood. By “going deeper”, advanced learning intervention is based on endorsing talented individuals to go deeper into their domain of giftedness. Specifically this strategy focuses on providing learning opportunities in the particular domain of talent of each gifted child. Finally, the “broaden horizons” activity is based on giving the opportunity to some students to expand horizons in other directions as well, when certain subject areas are easier. Children who learn with passion, eagerness and inquisitiveness will probably receive more chances in their area of interest (3).

Outstanding educational options for gifted children include as well part day older class or early school entrance, supporting acceleration in early childhood, and specified parents’ activities supporting enrichment. On the contrary, in elementary school other methods of acceleration, like diagnostic test-prescriptive teaching, cross-grade grouping, multi-age classroom and self-contained class are suggested. Additionally, in the same age enrichment can be accomplished with cluster grouping, in-class “compacting” and extension, or summer lessons. Lastly, classes of higher level, classes through correspondence, summer courses, classes specified to math-science, and college entrance in advance are alternatives proposed for successful

acceleration in secondary school, whereas honours classes, boarding schools, special interest clubs and contests nurture enrichment in the same age level (2).

Although the development of the abilities and the talents of gifted individuals is especially significant, there are children facing difficulties to present remarkable success because of the setting of their life restricting their potential. Conditions like impoverishment, injustice, social obstacles may limit individual's opportunities in life. Physical or learning disabilities and motivational or emotional problems as well may lead to obstacles, unless students are promoted to improve their skills and comprehend their gifted potential. In spite of demonstrating accomplishment, gifted individuals may need arduous schedules and supplementary reinforcement programs, to reach their exceptional potential (1).

Targeted guidance and support will definitely benefit gifted individuals especially during transition to adulthood. The adequate high-level tutoring and specially designed learning programs will ultimately lead to independent adults, capable of contributing to the enhancement of the entire society and its target to different domains. Additionally, inspiration, endurance and innovation are essential equipment for a successful adult life (1).

Last but not least, policy makers should be aware of these special educational needs of exceptional individuals as mentioned above. Providing gifted children with typical education, the society is led to a level below average, considering that this population will predetermine a significant quotient of the leadership of subsequent generations within the arts, sciences, letters, politics, etc (1).

According to a national survey developed by the University of Connecticut site of The National Research Centre on the Gifted and Talented (NRC/GT) in 1996, each school district spends only a tiny percentage of their budget to special educational programs. Specifically, only 4% of districts' total educational funds is spend on expert advancement trainings concerning talented programs (25). Bringing into alignment the allocation of resources controlled by policy makers to the benefit of all will support trainers of extremely qualified children to utilise these resources effectively. An ethical government should support and promote the advancement of all civilians, including both gifted and learning disabled students. Particular funding in supporting talented

individuals is of great necessity in order to build a community showing respect to its own needs (1).

1.2. Attention-Deficit/Hyperactivity Disorder (ADHD)

Attention-deficit/hyperactivity disorder is a frequent neurodevelopmental disorder among children, affecting adults as well. Although ADHD often lasts into adulthood, it is usually first diagnosed in younger age. The clinical presentation of a child with ADHD includes inattention, hyperactivity and/or impulsivity (26). Specifically, a child with inattention may avoid activities, lack insistence and dedication, struggle to pay attention and to be organised, while hyperactivity is presented with constant movements, even in awkward settings, or excessive knocking, touching, or talking. Impulsivity describes a child who acts abruptly, in the absence of a rational before the action and have great possibilities to hurt him/herself and others or have the urge to instant recompense. An impulsive individual is usually noisy when in public and unreasonably interrupts others, concludes to significant determination without the appropriate thinking of the subsequent outcomes (27). In spite of having trouble to focus or to behave appropriate, which is normal even for typically developing children, individuals with ADHD have behaviour problems that persist, are more intense and may lead to frustration at class, or with friends and family. A child with ADHD may daydream a lot, fail to remember things or waist things frequently, speak a lot, make inattentive errors, risks excessively or have difficulties getting along with others (26).

1.2.1. Diagnosis and Criteria

Attention-deficit hyperactivity disorder has been improved and enhanced the last five decades, from a concurrent characterisation of hyperkinetic reaction in childhood recorded in the Diagnostic and Statistical Manual of Mental Disorders (second edition, DSM-II), to its present definition in DSM-5 (5).

According to the American Psychiatric Association's DSM-5, ADHD is defined in young individuals, aged up to 17 years old, as the occurrence of at least six of the described symptoms in any of the following domains, inattention or hyperactivity and impulsivity, presenting the past six months. As regards individuals older than 17 years old, five symptoms of each or both domains are necessary for the diagnosis. The criteria, as described in DSM-5, are:

1. Inattention Domain:
   - Difficulties on concentration to specific information and making reckless mistakes in different settings.

• Difficulties focusing on actions.

• Individuals appear like they don’t hear when spoken to straight.

• Difficulties to proceed directions and to complete classes activities, or any other task.

• Difficulties planning assignments or actions.

• Individuals evade or hesitate to take part in actions that require cognitive exertion.

• Individuals waste objects that are necessary for particular actions.

• Individuals are frequently absentminded.

• Individuals forget frequently everyday activities.

2. Hyperactivity and impulsivity Domain

• Individuals use to twitch or wriggle or clap their hands or feet.

• Difficulties to remain seated when they have to.

• Difficulties to get involved in free-time activities noiselessly.

• Individuals frequently acts like they are “on the go” or “driven by a motor”

• Individuals frequently talk extremely

• Individuals frequently response so quick before even the question has heard.

• Difficulties to stand by until it’s their turn.

• Individuals frequently disrupt or interfere to others (5).

Even though ADHD is chronic in nature, the trajectory of the disorder may be different between patients. More than four trajectories based on age of onset have been suggested: starting in preschool years, starting between 6 to 14 years and persisting beyond adolescence, starting between 6 to 14 years decreasing during adolescence, and starting in adolescence or adulthood (32).

ADHD diagnosis, like other neurodevelopmental disorders, is based on clinical criteria, since there are not any biomarkers with adequate sensitivity and specificity. In order to achieve definitive diagnosis, criteria should be vigilantly examined and other possible diagnoses eliminated. A precise developmental history, family history, a psychological evaluation and a physical evaluation should be assessed. Data and details from family and educators associated with the child as well, such as teachers, are essential, so as to integrate information from multiple observers from different areas of a child's daily life. To set ADHD diagnosis, it is required that symptoms lead to impairment of individual’s performance in social environment. Although most of individuals with ADHD have normal neurocognitive functions, a valid intelligence evaluation is necessary to exclude reduced intelligence and accomplish a reliable ADHD diagnosis (33). Examining a patient's functional impairment is also essential for

an ADHD diagnosis (34). Moreover, possibly underlying somatic or neurologic disease, such as thyroid disease, sight or hearing loss, epilepsy, should be ruled out. Differential diagnoses that need to be distinguished from ADHD include depression, conduct disorder and rarely schizophrenia, attachment disorders and bipolar prodromes as well (33). In addition, excluding environmental components such as tension at home, intimidating between peers, difficulties to go to sleep, or having too many daily activities that may mimic ADHD symptomatology, is obligatory. For instance, repetitive changes in schools may lead to academic obstacles that can be mistaken for ADHD (34). Structured interviews, checklists and disorder-specific questionnaires directed to parents, teachers or even the child him/herself are useful diagnostic tools to assist clinical evaluation. However, the health care provider should take into account all findings, such as questionnaires, behavioural observation, developmental history and psychological testing as well, in order to avoid weakening the validity of the diagnosis (33). The medical history in combination with impartial measurements is the principal method to ADHD identification. Paediatric evaluation tools that are easy to use in the doctor's room are more convenient than standardized medical tools. Particularly, the Vanderbilt ADHD Diagnostic Teacher Rating Scale is useful in ADHD diagnosis, though the Vanderbilt ADHD Diagnostic Parent Rating Scale is used only for individuals younger than 12 months. Additionally, the Conner's Third Edition scale can be performed to validate a baseline before the beginning of the treatment, and to observe alteration over time. Standardized tools to strengthen the usefulness of medical history involve the Diagnostic Interview Schedule for Children and Adolescents and the Schedule for Affective Disorders and Schizophrenia in School-Age Children–Present and Lifetime Version (34).

1.2.2. Epidemiology of ADHD

The precise estimation of children with ADHD in a community population is crucial for medical service schedules, so as to identify complications concerning the diagnosis and to promote the appropriate investment. Moreover the validity of ADHD diagnosis might be more desirable due to the precise epidemiological reports throughout years and areas, and evidences regarding its origin might come to light. A wide range of prevalence occurred by most of primary studies as well as the high increase of medicated individuals, preoccupied societies incompatible and exorbitant diagnosis, leading to disagreements concerning the validity of the diagnosis (32).

Prevalence rate variability has arisen between states. Particularly, Nevada reported the lowest proportion (4.2%), whereas in Arkansas 14.6% of individuals aged between 4 and 17 years was diagnosed with ADHD (35). International assessment of ADHD diagnosis rate varies from 2.2% to 17.8% (36). Particularly, a worldwide estimated prevalence rate of ADHD was 5.29% in two studies from 35 countries in six continents (37). Furthermore, it was recorded that the difference in formerly measured ADHD proportion was based on the variety in methodology between studies. ADHD prevalence seems to remain the same when same study methods are used, as arose from the study that reported no differences between the prevalence of the disorder in Europe, Oceania, South America, Asia, Africa, Middle East and the prevalence in North America. The prevalence was also stable across time from 1985 to 2012 (37, 38). On the contrary, adults younger than 45 years old seem to be diagnosed with ADHD in 2.5% (39). It was also estimated that in 15% of children with ADHD, symptomatology will remain until adulthood and approximately half of them will be categorized as partial remitters (40). Identifying more ADHD case among adults than was anticipated demonstrates the occurrence of new diagnoses during maturity, indicating probably an additional classification of the disorder (41). When using the stricter ICD-10 criteria, the prevalence is estimated lower, approximately at 1–2% (38). Additionally, clinical samples have evaluated a higher prevalence in males (3–4:1), whereas epidemiological studies estimated that ADHD is diagnosed twice more often in males than females. The diagnosis seems to be associated with a lower socio-economic status as well (33).

Given the fact that, the majority of the available epidemiological studies examine individuals from North America and Europe, more research based on different regions continents should be encouraged. Additionally more research upon preschoolers as well as adults is needed. Moreover, longitudinal epidemiological studies focused on developmental trajectories and indicators of perseverance of ADHD in adulthood will be essential, as well as other medical, neurological, hereditary and neuroimaging studies, which will report possible prevention programmes (42).

1.2.3 Pathophysiology and Risk Factors of ADHD

Deficits across a range of perceptual territories are observed in individuals with ADHD. However, there is a remarkable variability among individuals with ADHD, as regards executive function impairment. Even though some children demonstrate a permitting model of deficits in executive functions, some of them show insightful deficit in a specific executive function, whereas others demonstrate no executive function impairment at all (32). Additionally, these deficits are not specific to ADHD and may also characterize individuals with many other psychiatric disorders, like autism and schizophrenia (43, 44). Inconvenience in managing individual's mental situation responding to different environmental settings (45), and altered patterns of motivation as well, describe deficits in other domains in a child with ADHD (46). Moreover, regarding that individuals with ADHD may respond differently to positive and negative reinforcement, obstacles postponing pleasure or standing by for significant upcoming results are motivational hallmarks for them (47). Because of either the impotence to control behavioural desires, or the superb reactions to the anticipation of the impeding compensation, the motivational difficulties mentioned above are coming into light and expressed with great heterogeneity (32).

Since there is rising information concerning ADHD difficulties, the pathophysiology of ADHD is considered differently nowadays, indicating the dynamic nature of cognitive deficit in this disorder. ADHD symptomatology is more obvious in tasks requiring more time and repetitions than in tasks with quick changes and interesting content, displaying that ADHD alters considerably among different environments. The changes in reaction time and accuracy as the rate of stimulus presentation is varied, is used as the gold standard of laboratory indication to adjust the profile of ADHD individuals (32). It is recorded that brain capacity is decreased by 3-5% in individuals with ADHD, with the gray matter affected the most. The severity of ADHD symptoms are associated with the volume of brain loss which is reported mainly in the prefrontal areas, the basal ganglia, and the cerebellum (33). The cognitive and motivational outlines related to ADHD are improved with neuroimaging research that focuses mainly on the prefrontal cortex, presenting functional and maturational defectiveness related to the disorder (48, 49). It has been described that individuals with ADHD exhibit a delay in the development of the cerebrum, revealing difficulties in attention and motor planning (50). Several large neural networks, like the Default Mode Network (DMN), dorsal and ventral attentional networks, salience networks, and frontostriatal and mesocorticolimbic circuits are involved in ADHD

pathogenesis (52). Regarding the DMN, it has been demonstrated by functional neuroimaging studies that children older than 6 years old with ADHD have reduced connectivity and delayed neuromaturation (53). The Default Mode Network seems to be associated with the regular ability for mind-wandering and self-analysis, however in children with ADHD may indicate a predisposition to inattention. Unexpected interactions between the DMN and the dorsal and ventral attentional networks, are also reported, illustrating that the DMN may impose or interrupt attentional networks' ability to provide superb concentration (54). Additionally, peculiarities in the dopaminergic mesolimbic system, which is responsible for motivated behaviours, expected results, and assisted enlightenment is manifested in ADHD individuals (55). Children with ADHD demonstrate decreased capacity of the nucleus accumbens, a key node within the mesolimbic system (56), decreased activation of the mesolimbic system when expecting rewarding results (57) and decreased fractional anisotropy within white matter tracts of the mesolimbic system (58).

Although research in neurobiology of ADHD has progressed, limitations emerge, requiring further investigation. The majority of neuroimaging studies are cross-sectional, in design, and therefore incapable of reaching casual interpretations. It is suggested to combine neuroimaging and Randomized Control Trials (RCTs) in order to identify causal effects of interventions on brain structure and function (59). Moreover, most neuroimaging studies have small samples and poor reproducibility, leading to possible false findings due to insufficient control over many statistical comparisons, imaging confounds and insufficient clinical phenotyping. Lastly, neuroimaging is difficult to be used as a diagnostic tool, because of the small effect sizes reported, unless significant methodological advances are made (32).

Despite that research has already investigated the brain networks presenting abnormalities in ADHD, it is important to make the next step towards the explanation of these findings in clinical practice. The first step has already been done in neuroscience with the presentation of machine learning approaches, like vector machine, which try to interpret neuroscientific results at individual patient level instead of group level, as provided by results of current studies (50). These approaches based on MRI data are used in more and more studies as a way to validate ADHD diagnosis, with different levels of success (60). Despite the great progress of neurocognitive studies in ADHD comprehension, it is suggested to integrate genetics, clinical, neurocognitive and neuroimaging findings in order to portray, through

machine learning approaches, response to therapies, tolerability profiles and functional trajectory of the disorder during time (42).

Considering the available study results, ADHD is regarded as a multifactorial disease. Both genetic and environmental risk factors, sometimes in combination, seem to affect brain development in both structural and functional ways. Each factor pertains to only a few affected children, has a weak effect and is not specific to ADHD, revealing a high degree of etiological heterogeneity and supporting the hypothesis that ADHD symbolises one end of a dimension of characteristics that is constantly distributed in the general population (33).

It is found that first-degree relatives have greater risk of being diagnosed with ADHD (61). However, even though a high heritability for ADHD (60-90%) is indicated by studies of twins and adopted children as well (62), finding the responsible genes underpinning this heritability is deeply challenging. Firstly, the “candidate gene” approach to recognize these genes, focused a priori on genes hypothesised to take part in the ADHD pathway and revealed about 10 genes (63), accounting for a small fraction of the total ADHD heritability. Subsequently, the “genome-wide association studies (GWAS)” approach analysed many common single-nucleotide polymorphisms of the genome, without success because of the small available sample (64). Finally, a more recent approach examined rare “copy number variants (CNV)”, replications or deletions of the DNA, and revealed that they are over-represented in ADHD, explaining a small part of ADHD heritability (42, 65).

1.2.4. Treatment of ADHD

ADHD often affects more than one functional domain of children’s life, impacting physical health, academic and social functioning as well. Multiple elements, like psycho-education, learning and academic reinforcement, school accommodation, parental practices, and evaluation and treatment of coexisting disorders, should be taken into account before treatment decisions are taken. Evolving treatment approaches, so as to fulfil different needs in different ages, is often necessary as well. In order to manage ADHD symptomatology, the use of psycho-stimulant medication has been suggested in the United States of America (USA), Canada and Europe(72-74), however it is recommended to start with psycho-education and behavioural management, specifically in children with mild symptoms. On the contrary in the USA, it is suggested medication as initial treatment (72). There is a consensus though,

regarding children younger than 6 years old, recommending as initial treatment the behaviour management in the form of parent training and reserving medication use for more severe or unresponsive cases (32, 74)

Medication for ADHD includes either stimulants or non-stimulants, in different forms and pharmacokinetic profiles. Stimulants, like methylphenidate and amphetamine, are first-line medications for treatment of ADHD symptoms with similar action mechanisms. In order to manage with side effects, individuals may discontinue stimulant use during holidays and summers (79). Additionally, it has been reported an association between stimulant treatment and cardiovascular events, which however has not been confirmed by large scale registry studies (80). In spite of concerns for potential increased possibility of subsequent substance abuse due to euphorigenic effects of stimulants, it is shown that stimulants have eventually the opposite effect, decreasing the risk of substance abuse (81).

The second option for medication treatment of ADHD involves non-stimulant drugs including specifically the norepinephrine transporter inhibitor, atomoxetine, and the α-2 agonists, guanfacine and clonidine. Non-stimulant medication seems to have lower responses and effect sizes and therefore is considered as second-line treatment for ADHD. Consequently, this drug category is recommended to patients with poor response or intolerable side-effects when treated with stimulants (32). For instance, NICE guidelines suggest switching from methylphenidate or amphetamine to atomoxetine or guanfacine, when the first show poor results to manage ADHD symptomatology in children(74).Additionally, non-stimulants are often used as adjuvants, when patients with ADHD treated only with stimulants respond poorly or when they are also diagnosed with aggression, insomnia or tic-disorders (82).

Besides the medication treatment, there are also non-pharmacological approaches, adjusted to other clinical areas or used complementary to medication. These approaches play a significant role for children with ADHD aged 3-5 years old for whom medication is not suggested, when medication is not prefered or develops resistance (32). Behavioural treatment as initial intervention instead of medication has been shown to be more cost-effective through the years. Concerning children aged 4-5 years old, it is recommended by the American Academy of Pediatrics to begin with behavioural treatment (90). In addition, it is found that initial treatment with behavioural interventions has better results than initial treatment with medication and lower doses of pharmacotherapy are required when medication is combined with

behavioural therapy (91). As regards non-ADHD symptoms, behavioural intervention shows modest advantages compared to medication (92), like the active role of caregivers in managing child obedience, social activities and classroom attitude instead of the passive role of prescribing medicine only. Moreover, teachers and parents are able to raise consistency and expand the reach of change (35).

According to the MTA study, treatment either only with methylphenidate or combined with psychosocial treatment in children aged 7-9.9 with ADHD, reported similar effects on symptoms management, while combined treatment had better effect on academic performance, parent–child relations, and social skills (93). Similarly, a stimulant combined with parent training is preferred as treatment for most children with ADHD rather than medication alone (72), while monotherapy with parent training has ambiguous results. In compliance with the National Institute of Mental Health multimodal treatment study, children who received medication and their parents changed their own behaviour as well, showed normalized behaviour (94), indicating the importance of parent training. Considering that parents are responsible to control their children's behaviour by themselves, with little coaching and help, the need for parent training is crucial. Although medication reduces ADHD symptomatology, improved functioning cannot be achieved unless a multimodal approach is taken to assist individuals adapt to demanding situations, accomplish personal goals and participate in social relationships (35).

A systematic review published in 2013 by the European ADHD Guidelines Group (EAGG) addressed the effects of behavioural interventions, diet interventions, cognitive training and neurofeedback on ADHD core symptoms (95). Considering that the study viewed two conflicting outcomes, those arising when individuals were not blinded to the treatment condition and those arising when they were likely blinded to treatment, impressively different results were reported. Specifically, interventions were more efficient than the control condition in reducing ADHD core symptoms, as regards non-blinded ratings, while in view of blinded ratings, only free fatty acid supplementation and artificial food colour elimination remained significantly more effective than the control conditions (95). On the contrary, behavioural interventions seem to be efficient at enhancing parenting and conduct problems, regarding probably blinded ratings as well (96). Cognitive training, especially when targeted to several neuropsychological aspects rather than just one part of cognitive functioning, was reported effective in upgrading verbal and visual memory (97). Apropos neurofeedback, it is not found to be efficacious on neither neuropsychological nor

academic outcomes (98). Furthermore, interventions such as physical exercise or meditation seem to have supplementary benefits, however there is only a little evidence concerning short-term and long-term results in symptomatology management (99, 100). Using interactive computer games, like Cogmed Working Memory Training, to train attention and executive functioning, may lead to improved performance on the training tasks (97). Overall, despite the fact that some non-pharmacological interventions may be efficacious in certain domains of impairment, they are not recommended as extremely efficient treatments for ADHD symptomatology (42), indicating the need for further research upon the efficacy of them and their combination with medication.

1.3. Specific Learning Disorders (SLD)

Specific learning disorder is usually diagnosed as a neurodevelopmental disorder, during the first school-years and regards issues in any of the following domains; reading, writing and mathematics. Even though learning disorders can lead to lower academic achievement, they may impact a person's life as well, by increasing the risk of psychological distress, mental health issues, drops out of school and unemployment. The prevalence of school-age children with a learning disability is estimated between 5% and 15% and 80% of them are diagnosed specifically with reading disorder, also known as dyslexia. It is also estimated that males have a higher risk to develop a specific learning disorder compared to females with a ratio range from 2:1 to 3:1. In addition, one third of individuals diagnosed with a learning disability are estimated to also have ADHD (5).

Learning disorders cannot be diagnosed unless formal education has started. According to DSM-5, the diagnosis of a specific learning disorder requires four criteria, based on the conjunction of medical history, teacher's statement and psycho-educational evaluation:

A. Any of the following symptoms persevering for six months or more.
    1. Difficulties in word reading.
    2. Difficulty reading comprehension.
    3. Inability to correct and effortful spelling.
    4. Inability to express himself in written form.
    5. Problem with numbers and calculation.
    6. Difficulties in mathematical thinking and rationale.

B. The impaired abilities are mainly beneath than expected regarding individual's chronological age and interfere in their daily-life activities, educational and professional fulfilment.

C. The symptoms begin when first starting school, however may be masked until learning requirements overcome the child's insufficient abilities.

D. Other impairment, like auditory or visual disorders, intellectual disability and mental or neurological disorders should be excluded (5).

Although specific learning disorder is a lifelong diagnosis, it starts and is diagnosed usually during the first school years. However, the clinical presentation varies between different environments and depends on the severity of one's difficulties and abilities, potential comorbidity and the support and interventions

provided by the community. Nevertheless, symptoms may change with age, revealing an either continuous or changing range of learning problems through the lifespan. Clinical expression in preschool-age children may involve decreased interest in games with sounds, and difficulty in learning nursery rhymes. Baby talk and mispronounced words are often used as well. Difficulties in recalling names of letters, numbers or days of the week and in recognizing letters in their names characterize preschool individuals with learning disorders. Children in kindergarten-age have troubles in recognizing and writing letters, writing their own name, analyzing words to syllables and identifying words that rhyme. As regards individuals in elementary school, they often have trouble learning letter-sound correspondence, articulate word decoding, spelling or math facts, whereas children in primary grades manifest difficulties recognizing and managing phonemes, reading common one-syllable words, identifying common irregularly spelled words and recalling number facts or arithmetic methods. Children in middle grades may be unable to pronounce long, multisyllable words, remember names or dates and finish homework or tests on time. Moreover, they are often characterized by poor comprehension, spelling and written work, leading sometimes to fear of reading aloud (5).

Prematurity, low birth weight and prenatal exposure to nicotine increase the risk for developing a specific learning disorder. Despite environmental risk factors, a high heritability for learning disabilities has been demonstrated as well. Particularly, first-degree relatives of individuals with reading or mathematical disorders have a higher relative risk to develop these learning difficulties compared to individuals without a family history (101). However, a high covariation between different clinical expressions of learning difficulties has been recorded, indicating that genes involved in one manifestation have a high correlation with genes involved in another manifestation (5).

1.3.1. Reading Disorder (Dyslexia)

In opposite to DSM 4 (102), that describes children with reading disorder as those who perform poorly in reading when other disorders, like visual, hearing, neurological or mental, have been excluded, DSM 5 (5) refers to reading disorder as a specific learning disorder characterized by erroneous and strenuous reading, difficulties in comprehension and spelling. About 5%-15% of school-age children in

the USA are diagnosed with dyslexia, whereas in Germany the same proportion is estimated at approximately 15% (103).

Children with reading disorder (RD) often read two to three times slower than typically developing children, indicating that reading disorder presents with considerably reduced reading speed. This may lead to difficulty comprehending what has been read, especially when regarding longer sentences. Additionally, individuals with reading disorder may read other words with similar letters instead of words they find difficult to read, probably due to their inability to associate specific letters with their corresponding sound quickly enough to avoid mistakes. The effort to understand the meaning of a sentence by the other words it contains, although specific words are read inaccurately, characterize some individuals with reading disorder as well. Children with spelling disorder make a considerably high number of spelling mistakes, spelling correctly approximately 10% of 40 test words. Moreover, it is observed that these children often avoid certain words that they find difficult to spell, giving the impression of having limited vocabulary or lacking linguistic ability (104).

Complete clinical evaluations as well as neuropsychological testing, to exclude other diagnoses, are necessary for a comprehensive investigation of children with potential reading difficulties. In addition, recognizing children with risk factors for developing reading disorder and providing the appropriate preventive treatment are essential procedures as well. Although dyslexia is usually diagnosed formally when the child starts to learn written language, he/she may develop early clinical signs like late oral language acquisition, confusing speech sounds and trouble with rhyming. Clinical assessment of a child with reading disorder reveals difficulties in grapheme-phoneme conversion rules and failure to automatize the connection between visual symbols and elementary sound segments. Because of the significant role of phonological symptoms these children typically present, standardized tools are used to investigate whether they can identify different phonemes, distinguish them from the rest of the word and hold relevant phonological details in verbal short-term memory.

Regarding possible risk factors, the development of reading difficulties depends on genetic, environmental, cognitive and noncognitive factors combined and interacting with each other in different ways. 40%-60% of children with a first-degree relative diagnosed with reading difficulties will develop reading difficulties themselves as well, indicating the heritability of the disorder (105). Hence, arises the need for detailed family history as regards reading disorder and the need to monitor children

with positive family history for potential development of the same difficulties. In addition, there are indications that associate weak oral language skills at the chronological stage of learning to read with an elevated risk of developing reading difficulties in the future. It has been shown that age-appropriate oral language skills may act as a protective factor against reading difficulties, even regarding children at family risk, maybe due to their ability to compensate their weakness with their strengths in oral language. Particularly, impairments in phonological skills and letter knowledge are fully related to difficulties in decoding, word reading, and spelling, indicating the importance of phonology knowledge in successful early word reading. Children with adequate phonic skills can enhance a memory store of word spellings and pronunciations. Phonemic awareness among other relative factors is a strong predictor of future reading abilities (106), however learning to read can also result in better phonemic awareness (107). Furthermore, letter and vocabulary knowledge is also strongly associated with future reading abilities, word spelling abilities and reading comprehension respectively. Alongside phonemic knowledge, knowledge of letter names and sounds is crucial for learning of grapheme-phoneme correspondences (108). Likewise, poor oral vocabulary knowledge is strongly associated with poor reading comprehension (109), since children need to understand every word in a text to comprehend it. Moreover, morphological awareness plays a significant role in word reading, spelling and reading comprehension, as knowledge about morphology supports correct spelling and promotes access to meaning. Morphological skills facilitate children to understand the meaning of new words that are not in their vocabulary, as long as they are aware of the constituent morphemes (110). However, children with reading disorder usually exhibit weak or atypical morphological skills. Other cognitive factors that seem to be related to reading abilities include rapid automatic naming, short-term memory, working memory and executive functions, however with ambiguous evidence regarding the causal relationship (110).

To diagnose reading disorder in children, hearing as well as speech sound difficulties and visual impairment have to be excluded. Deafness and hearing loss can have an impact on the quality of exposure to spoken language, affecting phonological skills and vocabulary and therefore affecting reading. Hence, seriously deaf children are at increased risk of literacy difficulties, with most children by the end of elementary school developing reading skills equal to children about three years younger. Similarly, children with mild or moderate hearing problems are also at increased risk of developing reading difficulties compared to normal-hearing children,

though less severe (110). Moreover, children with visual problems read slowly, laboriously and inefficiently, even after adequate experience, as their reading relies on letter-by-letter decoding without being able to read the whole word (111). Likewise, children with speech sound disorder are at greater risk of reading difficulties as well (110), indicating the need for early identification and diagnosis of these conditions. Additionally, it is important to investigate carefully for potential comorbidities that may affect the prognosis of reading disorder. Specifically, Specific Language Impairment (SLI), Developmental Coordination Disorder (DCD), intellectual giftedness, ADHD and psychiatric disorders may co-occur with dyslexia, as the functional regions involved in learning to read are part of a vast network (111).

Treatment of reading disorder requires an appropriate multidisciplinary team consisting of a neurologist, a paediatrician, an educational psychologist, speech therapists, encouraging the active participation of educators, parents and the child as well (111). Interventions providing concentrated instructions in phoneme awareness, alphabetic principle and phonics, word analysis, reading fluency, and reading comprehension are recommended (112). Accuracy problems may be treated easier than fluency problems that are associated with reading experience, however early intervention in kindergarten and first grade seems to prevent fluency problems as well (113). Therefore, it is important to provide early intervention to children even though they have not experienced repeated failures yet (114). Regarding treatment, interventions should be provided to small groups and should emphasize phonics instructions. In addition, practicing phoneme awareness, reinforcement to read progressively difficult connected text, training in writing, and comprehension strategies are suggested as valuable treatment methods (115). Phonics-based instruction is suggested as a very effective treatment method (116), especially instruction in small groups for about 5-18 hours per week is recommended ideally. Improvement of phonic skills can also be achieved with re-educative settings, such as the use of daily “video game” training with temporally modified acoustic stimuli (FastForWord®). It is reported that this method can improve phonological awareness and pseudoword reading in dyslexic children after only 5 weeks of training. However, a meta-analysis regarding the effectiveness of this intervention program showed that there is no significant effect on improving oral language or reading difficulties, indicating that the program is ineffective for treating dyslexia (117). Thoroughly practice upon acoustic elements of the speech signal may improve phonological awareness and reading in children with dyslexia, and it has been reported as well that improvements in oral language and reading are accompanied by reactivation of

regions of previous hypoactivity and activation of novel regions (111). In particular, efficient intervention seems to support normalization of activity in the left hemisphere reading and language network, which is reduced in dyslexia, while right hemisphere activation seems to increase after treatment (115).

1.3.2. Writing Disorder (Dysgraphia)

DSM-5 (5) does not define writing disorder as a separate diagnosis, but it is included in the category of “specific learning disorder”, as it is mentioned above. However, the term writing disorder or dysgraphia is still used to describe any writing difficulty, involving letter illegibility, spelling difficulties, slow writing, and difficulties in syntax and composition. Dysgraphia concerns impairment in written expression, particularly problems in spelling accuracy, grammar and punctuation accuracy, and clearness or formulation of written expression. A child with writing disorder is characterized by writing skills that are lower than expected by his/her age and by his/her cognitive level, presenting alone or combined with other learning or psychiatric disorders (118). Although the difficulties usually appear in early school years, the diagnosis may delay, indicating the significant role of educators, primary physicians, and parents in recognition of the problem. Writing difficulties appear at approximately 10%-30% of children, with boys affected more often than girls (118, 119). Moreover, about 30%-47% of children with writing difficulties also appear reading difficulties, and dysgraphia may occur together with other neurologic and developmental disorders, like autism spectrum disorder, ADHD, developmental coordination disorder, and cerebral palsy (118).

Writing system requires the coordination of motor planning and motor execution as well as brain organization and executive function to produce written letters, words and texts (120). Firstly, children are taught the basic skills to coordinate visual and motor systems when copying symbols and they have learned to write usually until the second grade. As they get older, writing automaticity is established and they have to practice language skills as well as the connection between words and sounds (121, 122), to manage and execute a coherent and cohesive product. According to the National Centre of Learning Disabilities, different manifestations of dysgraphia depend on the age at presentation (123). Particularly, pre-school children may adopt an awkward grip or body position to write, they may tire easily when writing or even avoid writing and drawing tasks. Besides the above traits, school-aged children often

demonstrate illegible handwriting, and difficulties in word-finding, sentence fulfilment, and written comprehension and they may switch between cursive and print handwriting. Lastly, teenagers and young adults may present difficulties to write their thoughts organized and problems with syntax and grammar in written tasks (118). In addition, achieving automaticity in writing is associated with better assignments in elementary, high school and college and academic achievement depends among others on the development of handwriting as well. However, difficulties in any domain of the writing process can affect the child's ability to perform written language at an adequate level (124), leading sometimes to low self esteem and problems in relationships with peers (125).

Unlike dyslexia that affect both phonologic and orthographic processes, dysgraphia affects the verbal working memory from phonologic (word sounds) to orthographic memory (written letters), often called the "graphomotor loop". In addition, other parts of higher-order language processing are affected as well, like storage and executive function (126). Dysgraphia is also associated with difficulties in coordinating movements to write letters, indicating potential deficiencies in fine motor tasks and may lead to slow and poorly formed letters and words, also called "motor dysgraphia". However, in order to explain the different causes and mechanisms of writing disorder, a combination of language centres, motor coordination and development of automaticity should be taken into account. It is also showed, through functional imaging studies, that cerebellum has a significant role in automaticity and language probably by affecting the development of neural system over time (127). Moreover, functional magnetic resonance imaging (fMRI) have revealed different patterns of brain activation in individuals with learning disorders compared to normal controls with correlations evident among family members. Besides, there are many studies demonstrating a potential genetic basis for developing writing disorder (128), however more research is required in these fields.

To diagnose dysgraphia usually a professional setting including a psychologist, an occupational or physical therapist, and a special education teacher is required. The diagnosis depends on the clinical presentation and no special medical work-up is indicated. However, some tests assist the evaluation, examining a child's posture when writing, the pencil grip, and other writing habits and visual motor integration. The effects of writing difficulties on an individual's ability to access educational achievement should be taken under consideration and other learning difficulties or potential co-morbidities should be excluded. Referrals to subspecialists, like a

developmental-behavioural paediatrician, child neurologist, or child psychiatrist are often essential if co-occurring conditions, such as ADHD, autism, anxiety, and depression, are suspected (118).

Intervention is focused on motor and orthographic tasks including activities with clay, graphic puzzles, tracing letters or hand excercises like rubbing or shaking hands and figertapping. Moreover, particular tasks may foster individuals to retrieve letters from long-term memory in order to compose sentences. However, higher-order writing tasks such as planning, organizing, reviewing, and revising should be supported as well. Interventions for children with learning disorders are organized into three main categories. Firstly, interventions regarding accommodation aim to provide access to the general curriculum. Different adjuvant may be used in the classroom, such as certain writing tools of larger size or with appropriate grips, papers with raised lines, tape recorders, and spell checkers, to support individuals with writing difficulties. Providing additional time for written assignments is suggested as well as using technological advances such as computer keyboards or voice-recognition software. However, technology devices should not replace completely all written implements, because handwriting plays a significant role in everyday activities. Although accommodations may be helpful for individuals with dysgraphia, they will not assist in developing any higher-order writing impairments such as planning and organization. Secondly, modification procedures aim to change individual’s tasks and expectations to minimize the repercussions of their handicap. Such modifications may include smaller assignments instead of largely written texts or giving alternatives like oral reports and presentations. Teachers are recommended to focus on subject or spelling for the class, providing the least restrictive environment for students with dysgraphia. Reducing written expression in length or complexity may assist individuals with writing difficulties to cooperate with school demands and be part of a general education classroom unless more specialized interventions are required. Thirdly, remediation refers to interventions specialized to an individual's needs. A response-to-intervention (RTI) model is suggested and contains three tiers. First of all, screening is administered to everyone, then additional intervention focusing on a smaller group characterized by special challenges is taking place and finally, specialized treatment is provided to individuals that require supplementary support (118).

1.3.3. Mathematical Disorder (Dyscalculia)

Developmental Dyscalculia refers to specific learning difficulties in arithmetical skills persisting usually into adulthood. Both girls and boys are affected equally, however some studies claim that girls are affected more often. The prevalence rate is estimated approximately between 3 and 7% of all children, adolescents and adults, however the significance of this diagnosis remains underestimated. Poor mathematical abilities constitute a brake on individual's and society's advance, as it is shown that individuals take more psychosocial and economic risks, drop school earlier, end up unemployed and develop depressive symptoms more often. Comorbidity with other learning disorders is often described, since dyslexia is diagnosed approximately to 30-40% of children with dyscalculia and ADHD symptoms are observed in about 10-20% of individuals with math disorder as well. Both hereditary and environmental components are associated with development of dyscalculia, indicating the heterogeneity this disorder appears (129, 130).

Individuals with math disorder typically develop difficulties in processing numbers and quantities as well as in basic arithmetic operations and other mathematical assignments. The association between numbers and quantities is not fully understood, revealing difficulties in comprehension of basic computation rules. Individuals often fail to recall math facts, like the multiplication table, and use counting strategies to calculate. Finger-counting may be used for frequently repeated, easy calculating tasks as well. Additionally, impaired inner number sense, inadequate mapping and transfer of number representation, lack of understanding the place-value system and how to decompose difficult problems into easier ones are traits of children with developmental dyscalculia. As mathematical complexity increases, difficulties become worse, impeding school achievement. Furthermore, visuospatial working memory is also impaired and inhibition from distracting stimuli is less effective (129, 130).

The complexity of the disorder as well as the heterogeneity of an individual's strengths and weaknesses demonstrate the need for a detailed diagnostic evaluation (129). Clinical examination in combination with history and further psychosocial assessment, as well as psychometric testing of mathematical performance is required to establish the diagnosis (130). A complete personal, familial, and developmental history is necessary, considering the wide range of possible neurodevelopmental and mental comorbidities that emerged with dyscalculia. Additional, non-numerical cognitive domains, as well as social and emotional factors, should be estimated.

Moreover, arithmetical testing and clinical examination are obligatory to diagnose dyscalculia, while other sensory and motor deficits should be excluded. Children at potential risk for math disorder should be identified before school years, to get access to early intervention (129).

Intervention should be provided to individuals by appropriately trained personnel including both educational specialists and healthcare professionals when necessary. All recommended methods should be scientifically estimated, ensuring beneficial outcomes unrelated to other factors like the relationship between the therapist and the child. Considering the lack of evidence-based treatment methods for all ages in addition to the better outcomes emerging when intervention is adapted to individual's needs, it is suggested to structure the treatment methods on a case-by-case basis, paying attention mainly to domains evaluated as problematic (130). According to a German meta-analysis (131), domain-specific treatment based on game-like procedures seems to advance neuroplasticity in functional circuitry and encourage children with dyscalculia to better comprehend numerical concepts. Computer interventions are associated with reduced math anxieties and are popular among children, revealing a helpful tool for management of children with math disorders however, conventional learning therapy by trained therapists remains more effective (131). These programs, when structured carefully to target in individual learning profiles and based on current scientific information, may contribute along with conventional learning therapies to better results. The meta-analysis (131) also demonstrated that a single training intervention adapted to individual performance levels is more effective than interventions taking place in class. Nonetheless, many repetitions during learning therapy and interventions centred both on basic numerical understanding and on school material make treatment impactful. Providing early intervention to children with risk factors for developing math disorder is essential, as it seems to be efficient in improving mathematical skills and scholastic performance (132). Lastly, it is important to decide the appropriate duration of the treatment. Considering the response to treatment as well as potential co-morbidities and other changing individual factors, the interdisciplinary team caring for the child should determine how long the therapy will continue (130).

1.4. Twice-Exceptional

The term twice-exceptional refers to individuals characterized by two exceptionalities, giftedness and a disability. A child is defined as twice-exceptional when he or she is talented in a particular domain while confronted with a learning, emotional, physical, sensory, or developmental disability (133). During the last thirty years, these dually diagnosed students have captivated the interest of teachers, healthcare providers, and parents, as the number of them seems to increase. It is estimated that children characterized by remarkable talents as well as difficulties in learning, attention, or behaviour are approximately 180,000 - 360,000 (134, 135). Although recent evidence led to an acknowledgment that talented individuals may have difficulties in learning, behaviour and/or attention as well, there is sometimes a denial by scholars that students with deficits in one domain can actually be gifted in another. However, according to empirical recent evidence, there is no doubt that extraordinary gifts and talents can also characterize children already diagnosed with specific learning disorder, attention deficit disorder or other disabilities and vica versa.(136) Additionally, research gravitates towards the apprehension of all traits and characteristics these children have during their academic and social life, in order to understand the challenges they have to deal with in each domain. The fact that definitions of neither exceptionalities can fully describe these students may reveal challenges in their educational journeys. The need for a clear definition of twice-exceptional students is crucial in order to specify all traits and needs of this population and implement appropriate supportive guidance to their academic life. Notwithstanding the evolving knowledge about twice-exceptional students and their needs, the enhancement of convenient services and identification systems is essential (8).

During the last few years, many multidisciplinary symposiums and meetings have taken place in order to review and discuss all the existing literature and research regarding the twice-exceptional population and propose a new definition. According to Reis et al., it is suggested to define twice-exceptional learners as students characterized by the potential of high achievement or creative productivity in any field, like technology, art, science, etc and also demonstrate one or more deficits such as specific learning disorder, autism spectrum disorder, attention-deficit/hyperactivity disorder, or other emotional/behavioural difficulties. These characteristics demonstrate a very special population that may be confronted with many challenges in their academic and social life. It is observed that sometimes their talents are disguised by their deficits as well as the deficits may be concealed by their gifts,

demanding a thorough evaluation of each individual with a view to identifying both potential exceptionalities. Notably, the greatest challenge in identifying and serving these children concerns co-morbidity issues (8). Even though all evidence, including information from test scores, observation, and analyses of profiles and behaviours, are collected and evaluated by multidisciplinary teams of experts (137), the complexity remains due to the stereotypes of gifted students and students with learning disabilities. Especially regarding students with learning disabilities, they may fail to participate in gifted programs because of the difficulty in identifying their co-existed giftedness (138). Most eligibility criteria for gifted programs contain full-scale IQ scores, excluding many twice-exceptional students, because they are not able to achieve high scores in subtests regarding working memory or processing speed, even though they perform above average scores in other subtests requiring conceptual thinking (139). On the other hand, twice-exceptional students may use their creativity to avoid tasks they can't finish because of their learning difficulties and perform high scores in behaviour tasks by masking their anxiety. Particularly, as regards gifted students, it is very common to fail to be diagnosed with co-existed Specific Learning Disorder, because usually, individuals with SLD are characterized by failures rather than achievements. Contrariwise, gifted students with SLD may perform very well or achieve high grades in an easy curriculum or when advocating great effort (140). Likewise, gifted students with ADHD are underdiagnosed, especially because of similarities between characteristics of giftedness and ADHD. It is reported that gifted learners who don't receive the appropriate educational intervention, may become inattentive and distracted by ideas or other activities resembling individuals with ADHD. Nonetheless, gifted students with ADHD often appear similar behaviour with average-ability learners with ADHD. Distinguishing disabilities among talented children can be as challenging as identifying giftedness in individuals with developmental disabilities. A team of specialists, particularly cognizant of both giftedness and neurodevelopmental disabilities, is necessary to evaluate, diagnose and suggest the appropriate intervention (8).

Interventions should support the talents these individuals appear and foster their high achievement potential, as well as serve the difficulties they confront in their academic and social life. Separated strategies, instructional accommodations and modifications, specialized services, and chances to upgrowth are entailed to develop individuals' gifts and manage their difficulties. Although scholars highlight the need for specialized education for twice-exceptional youth, they may not provide them access to services that support their dual diagnosis. Serving the academic and social-

emotional deficits of this population contributes to twice-exceptional individuals' opportunities to cope with their disabilities better, and support them to manage challenges in their academic and social environment. Particularly, supporting their social and emotional difficulties seems to help individuals to manage any emotional obstacle evolving from their asynchronous development, since many of them feel anxiety and struggle to accept their dual diagnosis (8).

2. Materials and methods

2.1 Literature Search Strategy

Studies were identified by searching four different electronic databases (PubMed, Google Scholar, PsycInfo and Embase) and scanning reference lists of articles. The last search was run on 31 December 2020. We applied the following algorithm to Pubmed (1968 - Present) and Google Scholar (1970 - Present): (gifted OR giftedness OR talented OR "high ability" OR “high intellectual potential” OR “high IQ” OR “high intelligence quotient”) AND (("Asperger's syndrome" OR autism OR ADHD OR "attention deficit" OR “developmental disorders” OR “developmental disorder” OR “developmental disability” OR “developmental disabilities” OR “neurodevelopmental disorder” OR “neurodevelopmental disorders” OR “communication disorder” OR “communication disorders” OR “specific learning disorder” OR “specific learning disorders” OR dyslexia OR dyscalculia OR “movement disorders” OR “tic disorders” OR “tic disorder” OR “Tourette syndrome”) OR “twice exceptional”) AND (child OR children OR student OR adolescents OR adolescence OR teens OR teenagers). This algorithm was adapted for PsychInfo (1965 - Present) and Embase (1974 -Present).

2.2. Eligibility Criteria

The eligibility criteria were based on the PICOS (Participants, Intervention, Comparison, Outcomes, Study design) acronym (141):

Types of Participants. Individuals younger than 21 years old.

Types of Intervention/Exposure. Neurodevelopmental disorders.

Comparison. The association between neurodevelopmental disorders and giftedness.

Outcomes. Giftedness.

Types of Studies. Prospective cohorts, cross-sectional and case control studies.

Given the various study designs, studies correlating percentages of neurodevelopmental disorders in individuals with giftedness vs. no giftedness were considered eligible as well. Moreover, non-comparative studies describing scores of giftedness in the studied disorder, or scores of disorders in gifted youth, were eligible but were presented in separate Tables (Table 1, Table 2).

Only the articles written in English language were deemed eligible. Case reports and review articles were excluded.

Eligibility assessment was accomplished solitarily by authors working in pairs in a blinded fashion. The most articles were screened by title and abstract and only in a few cases it was necessary to review the full text publication. Disagreements between authors were solved by consensus in a meeting in which the full texts were reviewed (Figure 1).

2.3. Data Collection Process

A data extraction Excel sheet was devised. From each study data, including study period, study design, sample size, gender, age, study population, matching factors, definition and technique of studying giftedness and neurodevelopmental disorders and main study findings were collected.

2.4. Quality Assessment of Included studies

The Newcastle-Ottawa scale was used in order to assess risk of bias of individual studies.(142) The quality of cross-sectional studies was assessed by this scale.

2.5. Compliance with Ethics Guidelines

The study was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (141).

3. RESULTS

Selection of eligible studies the literature search resulted in 6068 studies, after excluding duplicates. 5929 articles were excluded from title and abstract, while 139 were evaluated from the full text. From them, 106 were removed and finally 32 studies (9904 subjects) published between 1988 and 2020 were included in the systematic review, whereas only 21 of them were concerned with ADHD or Specific Learning Disorders (142-163). The PRISMA flowchart is presented in Figure 1. The general characteristics and the quality assessment of the studies are presented in Table 1 (comparative studies) and Table 2 (noncomparative studies).

3.1 Giftedness and ADHD

A positive association between ADHD and giftedness was noticed in two included studies. Comparing creativity in gifted children with ADHD to gifted children without ADHD, Fugate et al. (143) recorded that the former had significantly greater creative potential. Although poor working memory may impede the capacity to remember information and therefore make it difficult to integrate information and be creative Fugate et al. reported that the poorer the working memory of a student the higher the creativity he develops, when regarding gifted individuals. Although typical students seem to compromise their creativity due to their poor working memory, gifted students with ADHD appear to have significantly greater divergent thinking than their gifted peers without ADHD (143). Ten et al. (144) revealed that students with ADHD that were not taking medication had higher scores in divergent thinking than their ADHD-medicated peers and typically developing children. Creativity includes not only divergent thinking that was assessed by open ended assessment, but remote associates thinking and insight thinking as well assessed by closed-ended assessments. Therefore, according to Ten et al. (144), unmedicated students with ADHD showed better performance in divergent thinking in all three aspects, compared to medicated peers with ADHD and non-ADHD individuals, whereas the medicated group with ADHD perform similarly to typically developing groups, indicating the advantages of unmedicated individuals with ADHD in divergent thinking. On the contrary, all participants performed in the same way in closed-ended assessments, indicating no differences in remote associate thinking and insight thinking between the three groups (144).

Conversely, Rommelse et al. (145) related higher IQ to lower levels of attention problems and hyperactivity/impulsivity problems compared to average IQ, but no statistical test was performed. The study presented parents reporting more often than teachers, attention problems in children with high IQ, while teachers seem to recognize more attention difficulties in students with low estimated IQ. The researchers concluded that ADHD symptoms in highly intelligent individuals are raised more and detected more at home than in class, in comparison with students of average intelligence, whereas comprehensively intelligent students develop less attention and hyperactivity/impulsivity difficulties (145). Gomez et al. (146) investigated the differences in inattention and hyperactivity/impulsivity symptomatology between talented individuals whether they had ADHD or not, and found that inattentiveness characterizes more often individuals with ADHD and without giftedness, whereas gifted children with ADHD seem to differ from the gifted children without ADHD, as regards certain hyperactive and impulsive behaviours. Researchers compared inattention (IA), hyperactivity/impulsivity (HI), and total ADHD scores between four groups, children with ADHD, talented individuals with ADHD, talented individuals without ADHD, and typically developing controls. They reported higher scores in both ADHD groups. Particularly, children with ADHD scored higher in inattention and total ADHD tests than ADHD-talented individuals, whereas regarding hyperactivity and impulsivity symptoms, children with ADHD scored similarly whether they were gifted or not. Contrastingly, the above scores did not have significant differences between the gifted/without ADHD and the control group (146).

Other studies did not document any significant associations between ADHD and giftedness; Minahim et al (147) and Peyre et al. (148) revealed no significant correlation between ADHD and intellectual giftedness. Specifically, Minahim et al. (147) aimed to assess whether gifted individuals may present ADHD symptoms. Although a positive correlation between ADHD and giftedness was demonstrated, the findings were not statistically significant. Acknowledging the lack of methodological validity, nonetheless it is worthy of note that a higher frequency of ADHD cases among gifted children was reported (147). Additionally, Peyre et al. (148) studied the hypothesis that giftedness may be associated with emotional, behavioural or social difficulties and therefore 1100 children were assessed using the Strengths and Difficulties Questionnaires (SDQ). However, no difference between gifted children and normative sample were found (148).

Healey et al. (149) examined creativity in relation to ADHD and revealed no differences between individuals with or without ADHD. However, it was reported that creative individuals exhibit ADHD symptomatology more often than expected within the general population, indicating that inattention and hyperactivity/impulsivity difficulties is a common issue among the creative population. Although high percentages of ADHD symptomatology were reported by parents, teachers' ratings did not reveal significant differences between creative and non creative children, maybe because of the special school circumstances creative children are taught in. Even so, parents mentioned that ADHD symptomatology did not struggle children in any domain. Nevertheless, the study showed that, despite the significant levels of ADHD symptomatology displayed by gifted children, full criteria for ADHD were not met, as they did not demonstrate at least six of the nine necessary criteria for ADHD (149). In another study by Healey et al. (150), it was also explored the association between ADHD and intellectual giftedness or creativity, but it was not established any significant differences. Particularly, both ADHD and control group scored similarly in full scale IQ, and in all tests measured creativity. Overall, it was reported that children display no differences on any domain of giftedness that was measured regardless of their attention and/or hyperactivity/impulsivity difficulties, and deduced that creativity is not more common among children with ADHD (150). Likewise, Cadenas et al. (151) demonstrated that both highly intelligent group with ADHD and average intelligent control group performed similarly in the Wechsler Intelligence Scale for Children (WISC) or Wechsler Adult Intelligence Scale-III (WAIS). Diagnostic methods seemed to modify the associations between ADHD and giftedness, indicating the similarity of cognitive profiles between individuals with ADHD despite their intelligence scores. All tests performed indicated no significant differences between the two groups, supporting the hypothesis where attention and hyperactivity/impulsivity difficulties are masked by the giftedness of intelligent children with ADHD (151).

Rosengren et al. (152), perform divergent results based on the assessment scales used. Firstly ADHD was evaluated with the Test of Variables of Attention (TOVA), and it was revealed that talended children were more attentive than the typically developing children but equally impulsive. However when Conners' Parent or Teacher Rating Scale was used the results were similar between the two groups. (152). Abraham et al. (153), who studied the correlation between creative ability and ADHD, reported divergent findings as well, which depended on the task used for assessment. The recently activated knowledge task (RAK) revealed significant differences in the total score, indicating that children with ADHD perform better than

their typically developing peers. On the other hand, when creativity was assessed by conceptual expansion task, no significant differences were reported. In the creative imagery task the ADHD group demonstrated poorer results in practicality dimension and similar results in the originality dimension compared to controls. In addition, the alternate uses task showed no differences in creative ability when comparing individuals with ADHD to typically developing children in both fluency and uniqueness dimensions (153).

3.2 Giftedness and specific learning disorders

Karolyi et al. (154) pointed out that children with dyslexia had better global visual-spatial processing ability as they recognized impossible figures more quickly, even though less accurately than their typically developing peers. The correlation between reading disorder and precipitation of identification of impossible figures was emerged by two investigations, suggesting that reading disorder is related to the capacity to procedure visual-spatial information globally. Although individuals with dyslexia experience difficulties in reading and present slow naming speeds, this study reported that individuals with reading disorder are faster than those without dyslexia in any task, articulating surprising results. Hence, the above findings emphasize the possibility of a child with dyslexia to be also talented (154). Nevertheless, Leikin et al. (155) studied the possible correlation between Specific Learning Impairment and creativity, by comparing children with SLI with typical controls. To assess children's creative ability, two different tests measuring general and mathematical creativity were used, Pictorial Multiple Solutions Task (PMS Task) and Creating Equal Number Task (CEN) Task. The CEN task revealed better performance in SLI children than the younger controls and worse performance when compared to older controls, as regards fluency and flexibility. On the other hand, the PMS task demonstrated that SLI individuals perform better than younger typically developing children and equally to older controls, as concerns originality and creativity. Thus, it was indicated that the two tests examine different skills and therefore different domains of creativity. Comprehensively, the findings displayed that even though general creativity seems to develop similarly in individuals with SLI and typically developing children, a slower rate was reported (155). Johnston et al. (156) examined how different poor readers perform in reading depending on their IQ level. It was observed that poor readers with higher IQ levels struggle in phonological approach and to exhibit superiority in reading high frequency regular words. They also have difficulty reading nonwords accurately enough for their age. On the contrary, it was reported that individuals with lower IQ levels and poor reading perform higher than those without poor reading in reading of regular words of high and low frequency. Regarding the nonword reading approach, they presented slower but similarly accurate results (156).

According to Das et al. (157) children with reading disorder perform similarly to those without reading disorder on parts of Cognitive Assessment System (CAS), that exclude articulation and phonological coding. There was, though, an exception observed in Figure Memory, where nondyslexic individuals scored better with

significant difference. It was reported though that successive task and tasks of attention may discriminate children with dyslexia from typically developing peers. Moreover, the study found that poor readers perform differently than average/good readers as regards nonsense words of the phonemic segmentation task, however similar results were observed with meaningful words. Finally, the researchers disclosed poorer performance of individuals with dyslexia compared to controls on the rest successive tests, and concluded that overall IQ effect was marginally significant (157). Snart et al. (158) examined cognitive functions in children with different IQ level with and without learning difficulties. Individuals with learning difficulties demonstrate worse performance on sequential than on simultaneous tasks, however children without learning difficulties scored similarly in all tasks. Of interest is that high IQ did not reinforce students with learning difficulties to perform better in sequential tasks. Concerning the selective attention tasks, non-LD (Learning Difficulties) children showed better performance than the LD group when lexical access was allowed, however the opposite findings were observed when direct visual matching was required (158). Duranovic et al. (159) concluded that children having reading disorder demonstrated similar performance with their typically developing peers on the bigger part of the assessment, except the analytic spatial test, where their performance were better. It was reported as well that they had impairment in tasks requiring implicit memory. Specifically, there were tasks in which children with dyslexia scored higher than controls, like the Paper Folding Test and tasks that demonstrated the opposite findings, such as the Immediate Recall condition of the Rey-Osterrieth Complex figure. The two groups perform similarly on the Test of Visual Perception indicating that children with and without dyslexia perform similarly in solving tasks requiring spatial scanning ability (159). Alves et al. (160) did not reveal a significant difference as well, when comparing creativity between individuals with dyslexia and TD (Typically Developing) sample. Although differences were observed, with typically developing children to score better in most evaluations, these were not statistically significant, exhibiting that generally individuals with developmental dyslexia perform equivalently to children without reading and/or writing disability in creativity tasks (160). Likewise Yates et al.(161) perform divergent results depending on the diagnostic criteria used. It was found that writing difficulties are revealed more often when relative criteria are used for the diagnosis, whereas absolute criteria made less diagnoses known. The findings of the study confirmed the researcher's initial hypothesis that higher level cognitive processes in writing are different between gifted and average children, however lower level processes are similar in both groups. The results clarified that the poor writing performance of gifted children is not caused by

laziness, boredom, or lack of motivation, as it was thought before, but it was described as an outcome of their low-level transcription deficits. Moreover, it was emphasized that gifted children who achieve high-level writing skills, do not fundamentally achieve equally in low-level writing (161). Similarly, Toffalini et al. (162) revealed that measuring Full Scale IQ, the proportion of learning disabled children diagnosed as gifted was substantially and significantly lower than children without learning disorder and lower than expected by the theoretical distribution. Conversely, when only the General Ability Index (GAI) was taken into account, the results were the opposite. The study showed an important diversity of outcomes, featuring different aspects of each individual's traits, regardless of whether they were gifted or learning disabled. It was concluded that GAI may embody the main characteristics of intelligence in a better way for the LD population, whereas when measuring FSIQ, the proportion of giftedness in learning disabled children was less than expected in the typically developing population. Furthermore, it was reported that gifted children with learning disabilities performed better than non-gifted individuals with LD, but worse than gifted peers without LD, as regards specific tasks of working memory and processing speed (162).

3.3. Non-comparative studies

Non-comparative studies (Table 2) did not reveal important differences between giftedness and neurodevelopmental disorders. Particularly, Kaplan et al. (163) pointed out that IQ levels of children with ADHD and children with Reading Disorder (RD) were similar to a normal distribution. The study examined the possibility that ADHD group may present high IQ, investigating the differences of performance between individuals with ADHD, individuals with RD and individuals with both diagnoses in vocabulary and block design tasks. It was found that there are no significant differences in distribution of estimated FSIQ neither when comparing the three groups to the normal, nor between the three groups. Therefore, it was deduced that children with ADHD have similar possibilities to present above-average IQ with the general population (163). Lastly, Tordjman et al. (164) noticed that the percentages of the Hyperactivity Disorder (HD) in a gifted population differed depending on the evaluators for the Hyperactivity Index score. Particularly, it was reported that fathers, compared to mothers and educators, identify more often HD in children, whereas teachers tend to recognise less HD cases overall. In addition, mothers distinguish hyperactivity symptomatology as much as the children themselves. The finding that revealed less HD cases observed in the school environment compared to the home avowedly stood out, indicating the need to acknowledge hyperactivity symptoms in the context of the particular environment that provokes each specific behaviour (164).

4. DISCUSSION

Lately literature, studying individuals with neurodevelopmental disorders that perform extraordinary skills in different fields, as well as talented individuals that struggle with another diagnosis arises increasingly. The present study is based on a systematic review that is an effort to gather and study all the existing literature and data in order to determine the association between giftedness and each neurodevelopmental disorder in particular. However, here are presented and therefore discussed only the findings regarding the correlation between giftedness and ADHD or any specific learning disorder.

Interestingly, a positive correlation was pointed out mostly while examining creativity in ADHD individuals (143, 144). In particular, gifted students with ADHD characteristics seemed to have significantly higher inspiration than gifted individuals without ADHD (143). Although, there is previous research showing a compromise among creativity and working memory in typically developing students (165), Fugate et al. (143) demonstrated significantly greater divergent thinking among talented individuals with ADHD compared to gifted peers without ADHD. Nonetheless, comparable findings were reported by Cramond et al. (166) that assessed creativity in students with ADHD and pointed out that half of them scored high on creativity tasks, whereas another study reported no differences (150). Moreover, similar findings were reported by Ten et al. (144) that also indicated that creativity is domain-specific. Specifically, it was revealed that even though unmedicated children with ADHD perform better when divergent thinking is assessed, there were no significant differences in remote associates and insight thinking between the unmedicated individuals with ADHD and those medicated or the controls. Additionally, contrary to existing literature (167) that had reported lower fluency and originality in medicated students with ADHD in contrast to unmedicated individuals with ADHD and typical students, the later study found that flexibility is affected as well. Regarding medication of ADHD, there is also literature assessing individuals with ADHD that were asked not to take their medication the day of the assessment (168). However, it remains impossible to evaluate the potential impact of medication to the participants and their experiences of their treatment. Hence, Ten et al., compared individuals with ADHD that are treated with medication to those not treated at all and investigated the differences between them, concluding to similar results. Nevertheless, it was also reported before that individuals with ADHD present better in divergent thinking than

they do in divergent thinking, a fact that was also confirmed by both Fugate et al. (143) and Ten et al. (144).

Conversely, research also attests no difference between the ADHD and control groups (147-150) or the effect that was found was not confirmed because there was no test performed (145). Although Minahim et al. (147) disclosed an interesting higher frequency of ADHD symptomatology among gifted individuals, gifted and typical students revealed equivalent results. Similar were the results of Peyre et al. (148) that, contrary to Blaas et al. (169), no significant difference between gifted children and control was pointed out, regarding social, emotional and behaviour difficulties. A marginally significant correlation concerning emotional difficulties in children at 5-6 years old was reported, however this was not validated by further sensitivity analyses. Despite the fact that neither the conception that gifted children develop more often emotional or behavioural difficulties nor the converse was supported by the last study, it was mentioned that gifted children may struggle during the preschool period (148). Likewise, it was reported that, likewise previous results (166) a significant proportion rate (40%) of creative children, higher than expected from the normal population, developed ADHD symptoms. Despite the disposition of creative individuals to appear inattention and/or hyperactivity/impulsivity, Healey et al. (150) fail to confirm the correlation between creativity and ADHD because participants did not met full criteria for the diagnosis of ADHD. Previous research also reported a correlation between creativity and inattentiveness (170, 171). Nevertheless it was also found that, among individuals with ADHD and creative children with inattentiveness and/or hyperactivity/impulsivity, the greater the cognitive functioning deficits the more severe appears to be the ADHD symptomatology (150). Contrary to the perception supported by previous research that high creativity is a common feature of ADHD, another study of Healey et al. (149) did not find any significant difference in the creative abilities of individuals with ADHD and those with typically development. It was concluded that IQ, creativity as well as idea generation and abstract thinking are evenly distributed in both ADHD and control children, indicating that children with attention problems and/or hyperactivity/impulsivity are as creative as their typically developing peers. Even though it is described before that there are similarities between the characteristics of children with ADHD and creative individuals, concerning behaviour issues and psychosocial difficulties, this study failed to validate the idea that individuals with ADHD appear to be more creative than those without ADHD. Conversely, no negative correlation between creativity and ADHD was approved, since it was pointed out that children with ADHD, despite their behaviour problems

and their temperamental disposition, are not any less creative than their typically developing peers. Similarly to Marcelino et al. (172), no association between executive functioning and creative process was pointed out (149). Moreover, when Cadenas et al. (151) examined cognitive function in ADHD between talented individuals with ADHD, indicated that gifted students with ADHD presented similar scores with average intelligence controls. Therefore, the hypothesis, where ADHD symptomatology is masked by the extraordinary giftedness of high IQ individuals with ADHD was pointed out (151).

A mostly negative correlation was found between inattention/hyperactivity and IQ (145, 146); specifically, higher IQ scores were most strongly related to fewer attention problems. Although in high-estimated IQ students, teachers reported less attention problems than did parents, as regards low-estimated IQ individuals, teachers seem to recognize ADHD symptomatology more often than parents do. However, no such dissociation was reported about hyperactivity/impulsivity symptoms, suggesting that inattentiveness is expressed more at home than at school environments or that attention problems are easier detected by parents than by educators. Overall, a negative relation was pointed out, as it was shown that higher IQ scores are related to decreased risk for ADHD or ADHD-like symptoms, especially concerning attention problems (145). These findings are opposite to previous research that indicated either a positive correlation between ADHD and intelligence (143, 144), or no significant differences (147-149), however they are in line with the results of Gomez et al. (146) They demonstrated that high IQ may be a protective indicator for attention problems. It was mainly reported that among gifted children with ADHD and those non gifted with ADHD, inattention as well as total ADHD scores were higher in those non gifted, however both groups scored similarly as regards hyperactivity/impulsivity. It became obvious that talented individuals with ADHD seem to be more attentive than non gifted with ADHD and even though they scored similarly in hyperactivity/impulsivity tasks, ADHD gifted individuals reported higher scores specifically when concerning modulation of motor and verbal activity (146).

Furthermore, there are studies that came to conflicting results, depending on the assessment tool used (152, 153). TOVA assessment generally revealed better performance for gifted than for the non-gifted group, as it was initially hypothesized, however when particularly examined, talented individuals presented higher scores on three out of the five parts of the assessment tool. On the contrary, CTS and CPS did not show any significant differences, supporting the initial hypothesis of the authors

as well (152). Likewise Abraham et al. (153) demonstrated that children with ADHD, compared to controls, appear to perform higher on the recently activated task, whereas they have no significant differences in performance on the expansion task. Divergent were the findings from the creative imagery assessment as well, while children with ADHD reveal poorer performance than controls on the practicality measurement, while on the originality measurement the difference was not significant (153).

Regarding the relationship between reading, writing or mathematic disorder and talents, divergent results were revealed. Specifically, Karolyi et al (154) found that reading disorder is associated with a special type of visual-spatial talent. On the other hand Duranovic et al. (159) did not conclude to the same results. Initially, it was reported that although children with dyslexia are able to recognize impossible figures more rapidly than their typically developing peers, they are less accurate. However, a superiority of individuals with dyslexia was indicated regarding global visual-spatial ability, but with a wide variety across areas. Surprisingly, these findings revealed that dyslexia may be linked not only to a deficit but also to a talent and in addition enable further research on the field of other tasks of visual-spatial processing (154). On the other hand, there is later evidence showing that children, either with dyslexia or without, perform equivalently on most visual-spatial tasks, but specifically students with reading disorder scored higher than controls on the analytic spatial test and worse than controls on implicit memory tasks. Even though no significant differences were reported between individuals with dyslexia and typically developing students concerning mental rotation, visual perception, visuomotor integration and visual memory tasks, it seems that reading disabled have better performance on analytic performance tasks and struggle to solve visual-spatial tasks (159). Additionally, students with dyslexia had no differences from non-dyslexic individuals at any cognitive process, as recorded in an earlier study (157) Das et al. (157) clearly showed that normally achieving children have better performance than reading disabled individuals on all cognition tasks examined, despite their IQ. Similarly, Alves et al. (160) could not find any significant difference concerning creativity among children with dyslexia and individuals without reading and/or writing difficulties. However, in particular, control group revealed better scores in creativity overall, whereas individuals with dyslexia performed higher in most creativity tasks, indicating that both groups had equivalent performances (160). Nevertheless, high IQ in poor readers was linked to more phonological difficulties, as poor readers with high IQ fail to accomplish phonological reading tasks as successfully as poor readers with

average or low IQ. Although it was more likely for poor readers with high IQ to achieve in low frequency words tasks, they were characterized by both decreased phonemic awareness abilities and inaccurate nonword reading. Similarly, low-IQ poor readers had impaired phonemic awareness skills and slow nonword reading however, they performed as well as their reading-age controls as regards nonword and high- and low-frequency word reading (156).

There were also studies (161, 162) that could not conclude at a clear correlation, because different criteria or methods used led to conflicting results. Yates et al.(161)showed that even though gifted children demonstrate advanced high-level writing skills, they are not able to achieve in the same way at low-level writing skills. Moreover, gifted individuals appear to have equivalent transcription skills with their average-IQ peers, a fact that may mask their potential increased text generation skills. Gifted children often struggle to present their thoughts on paper as adequate as parents and teachers expect, and therefore they may develop behaviour challenges, such as loss of motivation or self-esteem (161). Additionally, Toffalini et al. (162) exhibited a lower frequency of giftedness among the learning disabled population compared to normal distribution, indicating a low probability of a gifted child to also have learning difficulties. Concerning the above findings, one should keep in mind the measurement test used for assessment. Particularly, WISC-IV was used to evaluate FSIQ that may be an appropriate measurement to assess typically developing children, but improper to estimate intelligence of learning disabled children, as it includes aspects like working memory and processing speed that are decreased in individuals with learning disabilities. This was confirmed when GAI was used to assess intelligence, excluding tasks requiring either high working memory or high processing speed skills, and revealed higher frequency of giftedness among children with learning disabilities (162).

Finally, the only study (155) investigating the correlation between specific language impairment (SLI) and creativity, showed similar performance in both SLI and control groups. Leikin et al. (155) investigated the correlation between language deficits and creativity by comparing children with SLI to typically achieving younger and older children. Children with SLI seem to perform better than the younger control group, but similarly to the older control group as regards the general creativity task. However, on the mathematic creativity task, even though SLI children had better performance than the younger preschoolers, they did worse than the older age group, indicating that generally creativity characterizes children with SLI as well

as the typically developing population, but at a slower rate. The researchers concluded that language ability may be related to creativity overall, however more clear is the relationship between language impairment and divergent reasoning (155).

Taking into consideration the limitations of the current review, it should be mentioned that most of the included studies were evaluated with low scores as defined by Newcastle Ottawa scale. In addition, the different definitions used for giftedness as well as the different tools used to assess neurodevelopmental disorders may lead to inadequate or weak results. Moreover the fact that some studies had small sample size, and there were included only studies written in English set more limitations to the review. The lack of longitudinal studies contributes to the limitations as regards the identification of a causal association between the two diagnoses. Furthermore given the fact that the present review included both studies comparing percentages/scores of neurodevelopmental disorders in subjects with giftedness vs. no giftedness and vice versa, heterogeneous conclusions were performed.

In conclusion, this systematic review highlights potential associations between giftedness and neurodevelopmental disorders. Given the limitations mentioned above, further investigation in the field is needed.

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Table 1: Characteristics of included comparative studies. Upper panels present studies comparing percentages/scores of giftedness in subjects with neurodevelopmental disorder vs. no neurodevelopmental disorder and lower panels present studies comparing percentages/scores of neurodevelopmental disorder in subjects with giftedness vs. no giftedness.

Study	Region	Study period	Study design	Sample size	Males, %	Mean age	Age range	Study population	Type of giftedness studied	Technique of studying giftedness	Definition of giftedness	Neurodevelopmental disorder studied	Technique of studying neurodevelopmental disorder	Matching factors	Effect sizes and interpretations of the main study findings	NOS Quality Rating
Studies comparing percentages/scores of giftedness in subjects with neurodevelopmental disorder vs. no neurodevelopmental disorder																
Abraham A. (2006)	NR	NR	Cross Sectional (CS)	44	63.6	Attention Deficit Hyperactivity/Impulsivity Disorder (ADHD)group:13.18; CD group: 13.5; Control group: 13.48	12-15 y	local Child and Adolescent Psychiatry Unit, via newspaper advertisements	Creativity	The expansion task (Ward "animal task"); the recently activated knowledge task (RAK); the creative imagery task;	NR	ADHD	NR	Age , Intelligence Quotient (IQ)	• Children with ADHD perform better than the healthy control group on the recently activated knowledge task (H = 7.56, p< 0.05), but worse on the creative imagery task (H = 12.43, p <0.01). • Both groups had comparable performance on the conceptual expansion task (U=111.5, p=Non Significant (NS)), on the alternate uses task (U=98.5, p=NS) and the originality dimension of the creative imagery task (U=80, p=NS)	5/10
Alves R.J.R. (2014)	Campinas, state of Sao Paulo, Brazil	NR	Case-control	26	Case Group:61; Non-case Group: 31	Case Group:10.92; Non-case Group: 10.61	Case Group :9-11; Non-case Group : 10-11	The State University of Campinas Teaching Hospital, in the Neurological Learning Difficulties (LD) Outpatient Center. A local school.	Creativity Intelligence	Raven Colored Progressive Matrices Test (RCPMT); Child Figural Creativity Test (CFCT)	NR	Developmental Dyslexia	School Performance Test (SPT)	NR	• There was no significant difference between the two groups (p=0.91)	3/10
Cadenas M. (2020)	Netherlands	NR	CS	Cohort1: 140 ; Cohort 2: 84	Cohort 1: 56.9; Cohort 2: 81	Cohort 1: 15.3; cohort 2: 11.16	NR	Cohort 1: Dutch node of the International Multicenter ADHD Genetics study; Cohort 2: Tracking Adolescents' Individual Lives Survey,	IQ	WISC/WAIS-III	High IQ=>120	ADHD	• Cohort 1: The Conners parent and teacher questionnaires, PACS, K-SADS-PL. Cohort 2: DISC-IV, CBCL, TRF.	Age and gender	• No significant differences between ADHD and control group's IQ. (F (1, 200) = 0.87, p = 0.35; F (1,80) = 0.49, p = 0.49)	5/10
Das, J. P. (1994)	Edmonton, Canada	NR	CS	112	53.6	9.11 y	8-10 y	Edmonton Public Schools.	IQ	Matrix Analogies Test (MAT), Cognitive Assessment System Experimental Edition (CAS).	IQ > 110	Dyslexia	WRMT, Phonemic Segmentation Task.	NR	• No difference between dyslexic and nondyslexic students on most CAS tasks. There was a difference in Figure Memory ((p<0.01), F(l,108) = 7.76, MSe = 2.43.	4/10
Duranovic M. (2015)	Gradacac and Tuzla, Bosnia and Herzegovina.	NR	CS	80	19	Dyslexia group: 10.03 Control group: 10.00	9-11	public schools, no behavioral, vision, hearing or neurological problems, and normal intelligence	Visual-spatial talent	Vandenberg Test, the Paper Folding Test, Rey–Osterrieth Complex Figure, Electric Grid Test, Test of Visual Memory	NR	Dyslexia	Diagnostic and Statistical Manual-IV(DSM-IV); Dyslexia Screening Test (Duranovic 2013).	age, sex	• Vandenberg Test of Mental Rotations, for the "Electric Grid" Test, the Visual Memory test and the Copy Condition of the Rey–Osterrieth Test: no significant difference • Dyslexia group perform better on the Paper Folding Test F(1.76)=7.28, MS=139.52, p=.009, and worse on the Immediate Recall F(1.57)=6.01, MS=361.30,	6/10

															p=0.017.	
Fugate S.M. (2013)	Glendale Arizona, United States of America (USA)	2012	CS	37	62	NR	10-17	summer camp for gifted individuals.	Creativity	Torrance Tests of Creative Thinking(TTCT); The Woodcock Johnson III Normative Update Cognitive Abilities subtests (WJ III COG NU)	NR	ADHD	Conners–Wells' Adolescent, SelfReport Scale–Short Form (CASS-S)	NR	Gifted children with ADHD perform better creativity potential t(35) = 2.43, p <0 .05, d=0.80.	4/10
Healey D. (2005)	Christchurch, New Zealand.	NR	CS	67	58	NR	10-12 y	Local newspapers, school notices, and an attention deficit disorder support group newsletter.	Creativity; Intelligence	TTCT; Maier's TwoString Problem; WISC-III	NR	ADHD	CRS-R	NR	• Children with ADHD perform similarly to control group on the TTCT, t(65) = 0.13, *Cohen's d= 0.0 and* for Maier's TwoString Problem, t(65) =1.51, *Cohen's d= 0.03*	5/10
Healey D. (2006)	Christchurch, New Zealand	NR	CS	89	53	NR	10-12	Local newspapers, classes with gifted children, school notices, and an Attention Deficit Disorder support group newsletter.	Creativity, IQ	TTCT, WISC-III	>90th percentile on the TTCT	ADHD	Conners' Rating Scales-Revised; the behavioral section of the K-SADS-PL	NR	• Children with ADHD perform similarly non-creative groups in creativity assessments, F (3,88) = 39.04, p< 0.001.	6/10
Johnston, R.S. (2007)	NR	NR	CS	333	NR	9.81	Poor readers: 10-11; Reading-age controls: NR; Chronological-age controls: 10-11	A remedial tuition.	IQ	WISC-R	Extreme Values Subsample by IQ Group: IQ>110	Reading Difficulties (spelling difficulties)	The British Ability Scales Word Reading Test, the Schonell B Spelling Test	No matching between all 3 groups	• No difference regarding the IQ level, F(1, 132) < 1, But there was an association as regards regularity, F(1, 132) = 109.5, p <0.001; and frequency, F(1, 132) = 319.0, p <0.001.	4/10
Karolyi v C. (2003)	USA	NR	Case control	64	55	NR	NR	school for dyslexic children public school	Visual-spatial talent	A set of possible and impossible figures developed by Schacter, Cooper, & Delany by Carrasco and Seamon.	NR	Dyslexia	NR	NR	• Children with reading disorder perform in global visual-spatial processing ability and in recognizing impossible figures. (F (1.60)= 15.079, MSE= 0.871; p =0.0003, d = -0.862).	4/10

Leikin (2018)	Israel	NR	CS	45	51.1	5.2	NR	kindergartens	Creativity	Pictorial Multiple Solutions(PMS)task ; CEN task	NR	SLI	Raven Colored Matrices Test; Goralnik Test	No matching	SLI participants performed similarly to control group on the general creativity task, and scored lower on the mathematical creativity task.	4/10
Snart F. (1988)	Edmonton, Canada	NR	CS	60	80	7.87	NR	The Edmonton Public School District.	IQ	WISC-R; CCAT-non verbal scores;; K-ABC (simultaneous and sequential processing)	NR	Reading Difficulties	Schonell Reading Test	Age, Sex, IQ	• Children with learning disorder and high IQ did not perform higher in sequential processing (X =99.95) as they did in simultaneous (X=110.55), p=0.05.	6/10
Ten W. (2019)	Taiwan	NR	Case control	86	91.8	NR	ADHD children: 8-12; TD children: NR	Students with ADHD receiving special education services.	Creativity	WISC; Raven's SPM , Open-Ended Creativity Assessments: the New Tests of Creative Thinking Closed-Ended Creativity Assessments: CWRAT-C	NR	ADHD	• Scale for assessing emotional disturbance • Student adaptation questionnaire • Personality and behavior scale • Problem behavior screening scale Diagnosis according to DSM-V criteria	Age-, gender- and academic-achievement (or IQ percentile rank)	• Open-Ended Creativity Assessment; significant differences in fluency (F(3,82) = 6.040, MSE=23.507, p=0.001, η2=0.181), flexibility (F(3,82)=4.300, MSE= 9.869, p =.007, η2= 0.136) and originality (F(3,82) =14.188, MSE=26.707, p<0.001, η2=0.342). • Closed-Ended Creativity Assessment: no significant difference in The *Remote Associate Thinking test* results (F(3,82) =2.045, MSE=16.265, p=0.114, η2=0.070) and the Insight Test results (F(3,82) =0.007, MSE=1.192, p =0.999, η2=0.002).	7/10

Toffalini (2017)	Italy	NR	CS	3613	LD:63 ; TD: NR	LD:11.48 years; TD: NR	LD: 7-16 years; TD: 6-16 years	Psychologists, expertised in LD assessment and treatment	IQ	WISC-IV: Full Scale IQ (FSIQ) and general ability index (GAI)	GAI>130	LD	ICD-10 International Coding System:	NR	• Talented TD children were not significantly less than expected, p = 0.28.Talented LD children were significantly less than expected and less than the TD children, p<0.001. • Talented LD children were more than double the proportion of TD children, p < 0.001	6/10
Studies comparing percentages/scores of neurodevelopmental disorders in subjects with giftedness vs. no giftedness																
Gomez R. (2019)	Melbourne, Australia	2004-2017	CS	507	70	10.6	6-17	Academic Child Psychiatry Unit of the Royal Children's Hospital, Melbourne	IQ	WISC-IV	IQ>120	ADHD	Strengths and Weaknesses of ADHD-Symptoms and Normal Behavior Scale, ADISC-IV	Age, fathers' employment, and annual family income	ADHD and gifted/ADHD group scored higher than the control and gifted group. (F [6, 1002] = 27.37, $p < 0.001$; $\eta_p^2 = .141$)	9/10
Minahim D. (2015)	Sao Paulo, Brazil	December 2012	CS	78	70	NR	NR	Colegio Objetivo program for gifted students	High IQ	Raven's Progressive Matrices test; Colored for children	IQ>99th percentile	ADHD	Criteria (SNAP-IV, Bussing , DSM-IV based)	age, gender	No statistically significant differences • SNAP-IV OR**:** 2.18 (p:0.288, 95% CI: 0.42-14.43) • Bussing OR**:** 1.49 (p:0.53, 95% CI: 0.36-6.56) • DSM IV OR: 0.63 (p:0.411, 95% CI: 0.18-2.14)	5/10

Peyre H. (2016)	Nancy, France	NR	CS	1100	Gifted group : 48 Control Group:53	5.66	5-6	EDEN mother–child prospective cohort	IQ	Wechsler Preschool and Primary Scale of Intelligence 3rd Edition	IQ>130	hyperactivity/ inattention	Parent-rated Strengths and Difficulties Questionnaire(SDQ)	Maternal prenatal tobacco consumption, maternal postnatal depression, father's education, family stimulation at 5–6 years and recruitment center	• No significant difference between talented children and control group. (p=0.139)	5/10
Rommelse N. (2017)	5 Municipalities in the northern part of the Netherlands	NR	CS	2230	49.2	11.1	10-12	Children with no intellectual disability or physical illness and Dutch speaking parents	High Intelligence Quotient (IQ)	WISC- Revised (WISC-R) (Vocabulary and Block Design)	IQ>130	ADHD	Parent-reported CBCL 6-18; Youth self report; Teacher Report Form(TRF); DSM IV	NR	Giftedness is associated with less attention problems and hyperactivity/impulsivity problems • CBCL Attention Problems: R^2: 0.041 (F=88.0) • CBCL Hyperactivity/impulsivity:R^2: 0.038 (F=80.2) • TRF Attention Problems: R^2: 0.085 (F=178.0) • TRF Hyperactivity/impulsivity: R^2: 0.029 (F=58.3)	5/10
Rosengren K. (NR)	Newberg, Oregon, USA	NR	CS	90	65	9.3	5-11	A Talented and Gifted program	High IQ	Ravens Progressive Matrices test	IQ>120	ADHD	Test of Variables of Attention; Conners' Parent and Teacher Rating Scales-Revised;	No matching	• TOVA variables: students with high IQ scored better in reaction time assessment and in attention to target stimuli assessment typically developing children. • RPMT(Total Average Response Time) (ms) gifted VS norm: t:-6.86, p<0.001, effect size: -0.75 • VART(Total Average Response Time Variability) (ms) gifted VS norm:t: -8.68 , p <0.001, effect size: -0.92 • OE%= (Omission Errors Percentage) gifted VS norm:t:-6.77, p<0.001, effect size: -0.33 • CTS and CPS Variables:ns difference in ADHD variable between gifted and norm.	8/10
Yates C. (1995)	NR	NR	CS	120	50	NR	NR	120 students drawn from a larger study of 600 students from 5 schools.	IQ	WISC-R	Verbal IQ>122	Writing disabilities	Group Diagnostic Reading Aptitude and Achievement Tests; Wide Range Achievement Test – Revised; Alphabet Task; Finger Succession Task, Phoneme Articulation Task, Receptive Orthographic Coding Test, CPS Test, Homophone/Pseudo homophone Choice Task Expressive Orthographic Coding Task,	Gender, grade, chronological age	Relative criteria: More gifted (43.3%) than typically developing (8.3%) met the criterion in at least one of the writing skills. Absolute criteria: Less talented (11.7%) than typically developing (25%) met criterion in at least one measure.	6/10

WRMT-Revised (Word Attack subtest), WISC-R(verbal subtest)

ADHD: Attention Deficit Hyperactivity Disorder; ADISC: Anxiety Disorders Interview Schedule for Children; CBCL: Child Behavior Checklist;;DSM: Diagnostic and Statistical Manual;FSIQ: Full Scale Intelligence Quotient;IQ: Intelligence Quotient;K-ABC: Kaufman Assessment Battery for Children; K-SADS-PL: Schedule for Affective Disorders and Schizophrenia forSchool-Age Children-Present and Lifetime Version; LD: Learning Difficultiesn; NLD: No Learning Difficulties; NS: not significant; SDQ: Strengths and Difficulties Questionnaire;TD: Typically Developing; WAIS: Wechsler Adult Intelligence Scale; WISC: Wechsler Intelligence Scale for Children;

Table 2: Characteristics of included noncomparative studies. Upper panel present a study on percentages of giftedness in the studied neurodevelopmental disorder and the lower panel present a study on percentages of neurodevelopmental disorders in gifted youth.

First author (year)	Region, country	Study period	Study design	Sample size	Percentage of males	Mean age	Age range	Study population	Type of giftedness studied	Technique of studying giftedness	Definition of giftedness	Neurodevelopmental disorder studied	Technique of studying neurodevelopmental disorder	Main findings of the study	NOS Quality Rating
Studies on percentages of giftedness in the studied disorder															
Kaplan (2000)	Calgary, Canada	NR	Cross sectional	200	77	ADHD group: 12.42; RD group: 11.91; ADHD+RD group: 11.61	NR	Special and private schools, clinical/tutoring settings.	FSIQ	WISC III vocabulary and block design	FSIQ > 110	ADHD; RD	• ADHD: DISC interview, CBCL, Achenbach; Abbreviated Symptom Questionnaire • RD: Word Attack subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised; Spelling subtest of the Wide Range Achievement Test Revised (WRAT-R),; WJ-R Spelling subtest on the AAT	No difference from a normal distribution in FSIQ scores ADHD: z = 0.76, ns, RD: z = 1.04, ns, ADHD + RD: z = 0.62, ns.	6/10
Studies on percentages of disorders in gifted youth															
TordjmanS.. (2007)	France	NR	Cross sectional	37	86	9.71	6-16	schools	IQ	WISC-IV	IQ>130	ADHD	The Conner's Rating Scales - Revised (CRS-R)	More HD cases (21.6%) were referred from fathers and less from educators (8.1%). Mothers and children identified similar HD cases (10.8% and 13.5%).	3/10

ADHD: Attention Deficit Hyperactivity Disorder; CBCL: Child Behavior Checklist; DISC: Diagnostic Interview Schedule for Children; FSIQ: Full Scale Intelligence Quotient; IQ: Intelligence Quotient; NR: Not reported; RD: Reading Disorder; WISC: Wechsler Intelligence Scale for Children

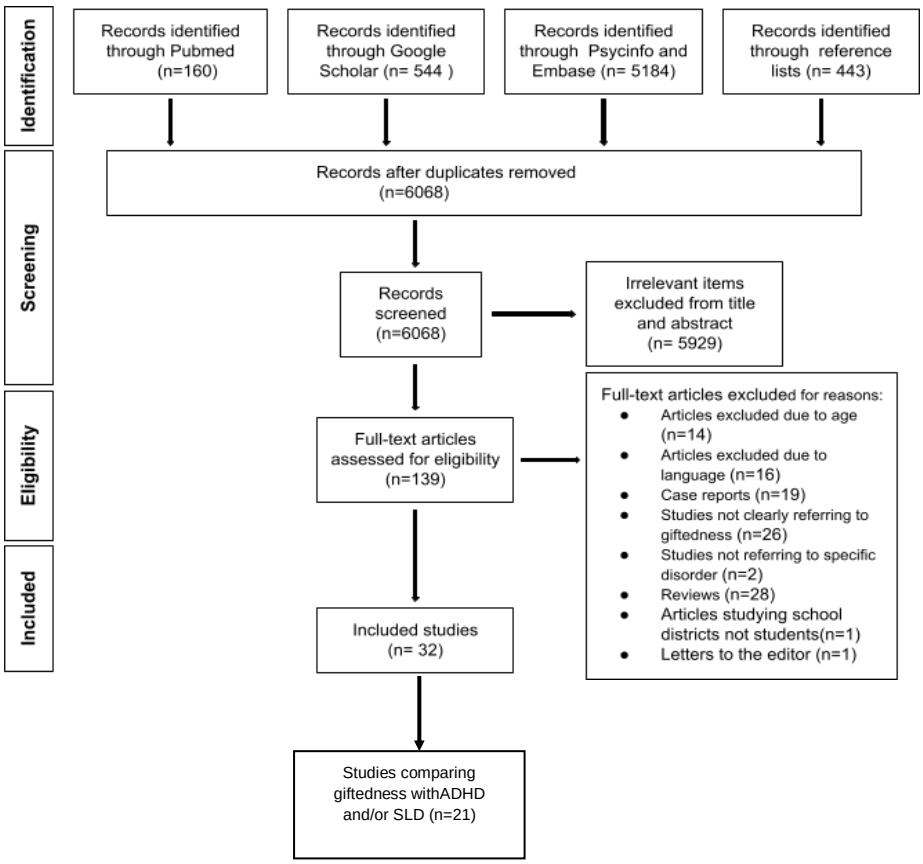

Figure 1. Successive steps in the selection of studies - PRISMA Flow Diagram.

ADHD: Attention Deficit Hyperactivity/Impulsivity Disorder; SLD: Specific Learning Disorder

7. Summary

Objective: The past few years a lot of conversation is taking place regarding children diagnosed with nuerodevelopmental disorder as well as an outstanding talent in different domains. Conversely, gifted children exhibiting special skills may mask their disability with their talent or vice versa. A systematic review was conducted in order to identify the correlation between giftedness and neurodevelopmental disorders. The association between giftedness and attention deficit/hyperactivity disorder or learning disorders is discussed here.

Methods: A systematic review via PubMed, Google Scholar, PsycINFO, and Embase search was performed.

Results: A total of 6069 studies were examined, and 32 of them were deemed eligible for the systematic review. Only 22 of them was referring to the correlation between giftedness and attention deficit/hyperactivity disorder or learning disorders. Divergent findings were revealed, depending on different diagnostic and assessment tools used.

Conclusion: More investigation is required to assess the field of dual exceptionality. Longitudinal studies are necessary, indicating methodological challenges related to variability in the definition of giftedness.

Index terms: giftedness, attention deficit/ hyperactivity disorder, specific learning disorders, children, adolescents

Περίληψη

Σκοπός: Τα τελευταία χρόνια γίνεται μεγάλη συζήτηση σχετικά με τα παιδιά που έχουν διαγνωστεί με κάποια νευροαναπτυξιακή διαταραχή και παράλληλα εμφανίζουν ένα ταλέντο. Διενεργήθηκε συστηματική ανασκόπηση με σκοπό την ανάδειξη της συσχέτισης μεταξύ χαρισματικότητας και νευροαναπτυξιακών διαταραχών. Στην παρούσα εργασία θα αναφερθούμε στη σχέση χαρισματικότητας με διαταραχή ελλειμματικής προσοχής/υπερκινητικότητας ή μαθησιακές δυσκολίες.

Μέθοδος: Διενεργήθηκε συστηματική ανασκόπηση βιβλιογραφίας στις εξής βάσεις δεδομένων: Pubmed, Google Scholar, PsychINFO, Embase.

Αποτελέσματα: Αξιολογήθηκαν συνολικά 6.069 μελέτες, εκ των οποίων οι 32 κρίθηκαν επιλέξιμες για τη συστηματική ανασκόπηση. Από αυτές οι 22 μελετούν τη συσχέτιση χαρισματικότητας με διαταραχή ελλειμματικής προσοχής/υπερκινητικότητας ή μαθησιακές δυσκολίες. Τα αποτελέσματα ήταν διφορούμενα, αναλόγως τις διαφορετικές διαγνωστικές δοκιμασίες και τα εργαλεία αξιολόγησης που χρησιμοποιήθηκαν.

Συμπεράσματα: Απαιτείται περισσότερη έρευνα σχετικά με τις ιδιαιτερότητες των ατόμων με τις δύο διαγνώσεις, ώστε να μπορούμε να καταλήξουμε σε ασφαλή συμπεράσματα σχετικά με τη συνύπαρξη νευροαναπτυξιακών διαταραχών και χαρισματικότητας.

Λέξεις κλειδιά: χαρισματικότητα, διαταραχή ελλειμματικής προσοχής/υπερκινητικότητας, ειδικές μαθησιακές διαταραχές, παιδιά, έφηβοι.