The role of performance-based measures and informant-rating scales of executive functions in identifying attention deficit hyperactivity disorder.

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Abstract

Research commonly finds low-level correlations between different informants reporting on a child's symptoms of attention deficit hyperactivity disorder (ADHD). However, findings in the relationship of child's, parent's, and family's factors to parent-teacher rating discrepancy are limited. Study One began with a narrative review on factors related to parent-teacher discrepancy in reporting ADHD from previous studies. Followed by a secondary data analysis, this pool of factors was then examined using the 2004 UK Mental Health of Children and Young People survey. Factors, such as male children, younger parents, and parents with emotional issues, played a role in predicting parent-teacher discrepancy in reporting hyperactivity/inattention problems.

In Study Two, the same dataset as in Study One was used to assess the predictive power of informant patterns on ADHD identification and to examine the relationship of the factors examined in Study One with the interaction of informant patterns and ADHD diagnosis. In general, the number of false omissions (i.e., receiving diagnosis when informants reported low risk) was very low, while the number of false discoveries (i.e., not receiving diagnosis when informants reported high risk) was moderate. Factors including male children and parental mental health were found to be associated with false discoveries and false omissions. In some cases their contribution differed dependent upon informant agreement patterns. Study Three further examined screening accuracy by adding executive functions measures, which have previously been found to aid ADHD screening. Analyses were based on the US Adolescent Brain Cognitive Development Study. Findings showed that neither parent ratings nor child performance on executive functions predicted ADHD diagnosis alone or improved ADHD screening accuracy. However, when studied in combination with parent- and teacher-ratings of attention problems, both executive function measures significantly predicted false discoveries and false omissions. Together, these studies extended the understanding on how informant discrepancy and executive function measures contribute to ADHD identification.

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designed to recruit more than 10,000 children age 9-10 and follow them over 10 years into early adulthood. The ABCD Study® is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041048, U01DA050989, U01DA051016, U01DA041022, U01DA051018, U01DA051037, U01DA050987, U01DA041174, U01DA041106, U01DA041117, U01DA041028, U01DA041134, U01DA050988, U01DA051039, U01DA041156, U01DA041025, U01DA041120, U01DA051038, U01DA041148, U01DA041093, U01DA041089, U24DA041123, U24DA041147. A full list of supporters is available at https://abcdstudy.org/federal-partners.html. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/consortium_members/. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators. The ABCD data repository grows and changes over time. The ABCD data used in this report came from Curated Annual Release 4.0 (doi:10.15154/1523041). DOIs can be found at https://nda.nih.gov/study.html?id=1299.

Declaration and Note on Presentations arising from this thesis.

I, the author, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means (www.sheffield.ac.uk/ssid/unfair-means). This work has not been previously been presented for an award at this, or any other, university.

The research presented in Chapter Two has been accepted for presentations:

Chan, H. K., Rowe, R., & Carroll, D. (2021, September). Interrater agreement among parent-, teacher-, and self-reported attention deficit hyperactivity disorder as predictive factors on ADHD diagnosis: findings from a UK national sample. Paper presented at Early Career Researcher Children & Young People's Mental Health Forum, online.

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List of Abbreviations

ABCD Study	the Adolescent Brain Cognitive Development [SM] Study
ADHD	attention deficit hyperactivity disorder
AP scale	Attention Problems scale
ASD	autism spectrum disorder
ASEBA	Achenbach System of Empirically Based Assessment
AUC	area under the receiver operating characteristic curve
BPM/T	teacher-reported Brief Problem Monitor
CBCL	Child Behavior Checklist
CI	confidence interval
CPT	Continuous Performance Test
DAWBA	Development and Well-Being Assessment
DSM	Diagnostic and Statistical Manual of Mental Disorders
GHQ	General Health Questionnaire
H-L statistic	Hosmer-Lemeshow statistic
ICD	International Classification of Diseases
KSADS-COMP	Kiddie Schedule for Affective Disorders and Schizophrenia for DSM-5
LR	likelihood ratio
MHCYP survey	Mental Health of Children and Young People survey
NDA	NIMH Data Archive
NICE	National Institute for Health and Care Excellence
NPV	negative predictive value
OR	odds ratio
PPV	positive predictive value
RRR	relative risk ratio
SDQ	Strengths and Difficulties Questionnaires
SES	Socioeconomic Status
UKDS	UK Data Service
VIF	variance information factor
WHO	World Health Organization

Chapter One: Introduction

Chapter abstract

This thesis focuses on the role of informant rating scales and performance-based measures of executive functions in identifying attention deficit hyperactivity disorder (ADHD). This chapter will first present an overview of definition, etiology and pathophysiology, symptom presentations, prevalence, and prognosis of ADHD. Second, it will then discuss the challenges of identifying ADHD by introducing ADHD-related measurements and diagnostic procedures. Third, it will discuss the problems encountered when using these measures. Current research gaps in the literature are presented along with the research aims for the current project. The thesis structure is then briefly described.

1.1 Definition, symptom presentations, prevalence, and prognosis of ADHD

1.11 Defining ADHD in a historical perspective

ADHD, with major features of developmentally inappropriate levels of hyperactivity, impulsivity and/or inattention, is one of the most common but complex neurodevelopmental disorders that affect around 7.2% of school-age children (American Psychiatric Association, 2022). The concepts of attention and hyperactivity have been described in various forms of terminology over 200 years (e.g., Crichton, 1798). Numerous elaborative reviews of the evolution of the ADHD concept have been published (Barkley, 2015; Kos & Richdale, 2004; Lange et al., 2010; McGough, 2014; Sandberg & Barton, 2002). The following review summarises and supplements current updates from the literature.

Sir Alexander Crichton (1798) was the first author to describe an ADHD-related condition in medical literature (Crichton, 1798 as cited in Lange et al., 2010). His chapter titled as *On Attention and its Diseases* provided an early definition of attention as "*When any object of external sense, or of thought, occupies the mind in such a degree that a person does not receive a clear perception from any other one, he is said to attend to it* (Crichton, 1798 as quoted in Lange et al., 2010, p. 242)". In addition to the definition, Crichton (1798) further explained factors affecting attention: normal inattention was believed to be caused by mental stimuli, volition, or education; abnormal inattention was believed to be induced by "*sensibility of the nerves*" and nervous disorders (Crichton, 1798 as cited in Lange et al., 2010). Another early reference to attention and hyperactivity was *Der philosophische Arzt* by Melchior Adam Weikard (1787) (Weikard, 1787 as cited in Barkley & Peters, 2012). A chapter from *Der philosophische Arzt* titled "*Attentio Volubilis* (lack of attention)" described

attention deficit as "*have a lack of attention, are generally characterised as unwary, careless, flighty and bacchanal* (Weikard, 1787 as quoted in Barkley & Peters, 2012, p. 627)". Similar to Crichton (1798), Weikard proposed several causes, such as learning method, habit, lifestyle, inefficient sensations and perception, to illustrate how inattention in children might develop (Barkley & Peters, 2012). These descriptions of alternative exploration for attention deficits are congruent with the "modern" concept of differential diagnosis, which will be described below.

Sir George Frederic Still (1902) provided an early definition of an ADHD-like condition, although at this time the discussion focused on moral control (Barkley, 2014; Conners, 2000). The symptoms listed by Still (1902) included aggressive, defiant, resistant to discipline, and problems with concentration and sustained attention, and therefore included a broader construct than is currently defined by ADHD (Still, 1902 as cited in Lange et al., 2010). Other than the moral perspective, minimal brain damage or dysfunction was purposed by Tredgold (1908) to describe symptoms resembling hyperactivity (Tredgold, 1908 as cited in Lange et al., 2010). Minimal brain damage accompanied by the encephalitis epidemic between 1917 and 1928 caught clinicians' further attention to study hyperactivity-like symptoms (Rafalovich, 2001). The shift to investigating the relationship between brain damage and hyperactivity-like symptoms was influential in pointing to research to investigate the biological aspects of ADHD.

The case report by Kahn and Cohen (1934) emphasised on the effect of biological structure on excessive behaviours, which proposed they resulted from post-encephalitic "brain-stem" changes (Kahn & Cohen, 1934, as cited in Kos & Richdale, 2004). Meanwhile, the work of Kramer and Pollnow in the 1930s was important to distinguish between postencephalitic behaviour disorder and hyperkinetic disease in childhood (Neumärker, 2005). The review by Neumärker extracted the listed symptoms by Kramer and Pollnow as "*lack of concentration, insufficient goal orientation, increased distractibility, walking around aimlessly, touching of chairs, boards, etc*. (Neumärker, 2005, p. 438)". The descriptions resembled the current concept of ADHD (Lange et al., 2010). The assumption of minimal brain damage was challenged and replaced as minimal brain dysfunction, which later was modified into specific terms for behavioural and developmental disorders (Sandberg & Barton, 2002).

In the 1960s, the first ADHD-related terms were included in the main psychiatric classificatory systems (Kos & Richdale, 2004), where contained specific criteria for a disease or disorder, and assisted clinicians to identify and determine the nature and basis of the concern for diagnostic decision making (American Psychological Association, n.d.-b; Garb, 2001). *Hyperkinetic Reaction of Childhood* first appeared in the second edition of Diagnostic and Statistical Manual of Mental Disorders (DSM; American Psychiatric Association, 1968), solely describing extreme overactivity in children. The name was revised as *Attention Deficit Disorder* in its third edition (American Psychiatric Association, 1980) and the major features of the disorder were distinguished as inattention, impulsivity and hyperactivity. A different label, *Hyperkinetic Syndrome of Childhood*, was used to describe children with the same features, under the chapter of behaviour disorders in childhood in the eighth version of International Classification of Diseases (ICD; World Health Organization [WHO], 1967).

ADHD was classified as a behavioural-based disorder in childhood under DSM-III and DSM-IV (Mallett et al., 2015). DSM-5 (American Psychiatric Association, 2022) reflects a different conceptualization, such as longevity and nature of the disorder, compared to previous versions (Eapen & Črnčec, 2014). In this new edition, ADHD has been re-clustered into the neurodevelopmental disorders, separating the disorder from oppositional defiant disorder and conduct disorder (American Psychiatric Association, 2022). This change better assists ADHD identification with emphasising on both behavioural and cognitive functioning (Coghill & Seth, 2011). Other modifications, such as rewording symptom criterion with elaborations and examples in terms of possible presentation in the lifespan, greater emphasis on cross-situational symptom impairment, and removing previous exclusion in the presence of a pervasive developmental disorder, are some examples of endorsement from the industry, which are believed to enhance availability of treatment (Coghill & Seth, 2011; Prosser & Reid, 2013; Tannock, 2013). The continuously revised diagnostic criteria reflect how ADHD has been conceptualised in clinical practice and research in recent decades (Blumenthal-Barby, 2014; Coghill & Seth, 2011; Doernberg & Hollander, 2016; Kupfer et al., 2008; Thyer, 2015).

1.12 Symptom profiles

1.12.1 Core symptoms: Inattention, hyperactivity, and impulsivity

Attention, a condition whereby a person and/or animal is able to focus and respond to a stimulus. Attention requires cognitive resources (American Psychological Association, n.d.-

a). Conversely inattention has been described in the DSM-5 in behavioural terms as "*wandering off task, lacking persistence, having difficulty sustaining focus and being disorganized* (American Psychiatric Association, 2022, p. 61)". An additional important concept is hyperactivity, which is defined as "*the state or condition of being overly active*" or "*increased levels of function or activity especially when considered abnormally excessive*" (Merriam-Webster, n.d.), while impulsivity is described as "*actions which are poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation and that often result in undesirable consequences*" (Durana and Barnes, 1993, as cited in Winstanley et al., 2006, p. 380). These two concepts, which were previously separate, are now combined into one domain under hyperactivity/impulsivity both in the DSM-5 and ICD-11 (American Psychiatric Association, 2022; WHO, 2018).

The core symptoms vary across the lifespan (Caye et al., 2016; Faraone et al., 2006; Halmøy et al., 2009; Newcorn et al., 2001). Longitudinal studies found that symptom dimensions followed different developmental trajectories, with declining hyperactivity-impulsivity over time, but stability in inattention (Faraone et al., 2006; Francx et al., 2015; Hinshaw et al., 2006; Hinshaw et al., 2012; Lahey et al., 2004; Lahey et al., 2005; Lahey & Willcutt, 2010; Larsson et al., 2006). For example, in the study by Francx et al. (2015), both hyperactivity/impulsivity and inattention reported were significantly lower at follow-up compared to baseline, but more improvements were observed in the hyperactive/impulsive domain. In contrast, results in comparing attentional processing in unmedicated males ranging from 6 to 11 years old to a control group were inconsistent (Erdogan Bakar & Karakas, 2020). Significant group differences in all attention types were found at six years of age compared with age-matched control, but both groups presented changes in attention and by 10:00-10:11 years age range, no significant differences between ADHD group and control group was found (Erdogan Bakar & Karakas, 2020). The presentation of ADHD core symptoms is complex across the lifespan.

The grouping of core symptoms, i.e. inattention and hyperactivity-impulsivity, is useful for understanding the structure and definition of ADHD (Nikolas & Burt, 2010; Willcutt et al., 2012). Previous research suggested that these two dimensions described best the disorder with satisfactory discriminant power and sufficient internal consistency (Willcutt et al., 2012). The classification of the two dimensions was also supported by avoiding collinearity problem between hyperactivity and impulsivity comparing to the three-dimensional

hypothesis in meta-analysis (Willcutt et al., 2012). Core symptoms from the two dimensions also distinguished the ADHD diagnosis from the other disorders such as oppositional defiant disorder, conduct disorder, or internalizing disorders (Willcutt et al., 2012). In addition, other evidence from genetic and environmental studies also supported this distinction and suggested the differences implied different etiology and risk factors contributing these two dimensions within ADHD (Nikolas & Burt, 2010).

Clinical presentation of ADHD can be specified as combined, predominantly inattentive, and predominantly hyperactivity/impulsivity in the DSM-5 (American Psychiatric Association, 2022). These specifications were treated as subtypes in the DSM-IV (Mallett et al., 2015). Research has been exploring differences among the presentations/subtypes, such as genetic factors, brain characteristics, neuropsychological functioning, occurrence of comorbidities, and function impairments (Willcutt et al., 2012). There is no conclusion yet about how core symptoms of ADHD vary among presentations/subtypes. For example, Tucha et al. (2006) found that ADHD combined and ADHD hyperactivity/impulsivity subtypes seriously impaired attentional functioning, not only in impulsivity, compared to control groups. However, the differences between the two ADHD subtypes did not reveal clear distinctions in terms of attentional functioning. Similar results showed that differences between ADHD combined and ADHD inattention subtypes were only observed in terms of accuracy of attentional control, whilst there were no other significant differences in terms of selective attention and sustained attention (Lemiere et al., 2010). The presentations/subtypes reflect both the impairment variety among the ADHD core symptoms and their functional impairments.

1.12.2 Functional impairments

In order to fulfil the diagnosis of ADHD, the core symptoms need to negatively impact social, academic or occupational functioning of an individual (American Psychiatric Association, 2022). Learning problems are one of the common referral reasons for ADHD assessment and additional support needs for children and youths (Lau et al., 2012; Sekhar et al., 2023). Attention difficulties strongly correlate with problems in academics, while symptoms of hyperactivity/impulsivity correlate more with behavioural issues in schools (Evans et al., 2020; Garner et al., 2013; Willcutt et al., 2012). Compared to their peers, individuals with ADHD encounter more problems in academics and tend to have lower grades and academic achievement, which results in a higher percentage of absence, grade

retention, suspension, and/or expulsion (Daley & Birchwood, 2010; Kent et al., 2011; Kuriyan et al., 2013; Loe & Feldman, 2007; May et al., 2020). Higher baseline ADHD symptom severity in childhood was found to be correlated with a reduced probability of completing high school (Fredriksen et al., 2014) and undergraduate studies (Roy et al., 2017). Although a decreasing trend in academic impairment with age was observed (Frazier et al., 2007), there was still a significant deficit in work performance among college students with ADHD (Shifrin et al., 2010). Higher levels of persisting ADHD inattention symptoms in adulthood were also related to greater long-term work disability and occupational impairment (Fredriksen et al., 2014). Individuals with ADHD encounter more challenges at work, such as increased risk of workplace injuries (Kupper et al., 2012), higher rates of occupational under-achievement, and increased likelihood of unemployment (Gjervan et al., 2012; Roy et al., 2017; Uchida et al., 2018).

ADHD core symptoms also impact social relationships negatively (Andrade et al., 2009; Bunford et al., 2015; Solanto et al., 2009). Compared to typical children, children with ADHD were rated poorer in social skills by both parents and teachers (Solanto et al., 2009) and perceived lower levels of satisfaction in peer relations (Grygiel et al., 2018). Descriptions from hyperactivity/impulsivity criteria in DSM-5, such as "*f. talk excessively*" and "*i. often interrupts or intrudes on others*" (American Psychiatric Association, 2022, p. 60), also highlight the social impairments that individuals with ADHD might encounter. For example, a higher level of hyperactivity in performance tasks also predicted more social problems in children with ADHD (Andrade et al., 2009). In addition, a higher level of hyperactivity/impulsivity symptoms predicted more longer-term peer rejection (Evans et al., 2020). Children with ADHD have a higher chance to be rejected by peer (Ros & Graziano, 2018) and classroom disruption, but less resistance to peer provocation (Frankel & Feinberg, 2002).

1.13 Prevalence

Estimated prevalence rates of ADHD varied (Dalsgaard et al., 2013; Huang et al., 2016; Huss et al., 2008; Pham et al., 2015; Richa et al., 2014; Rowland et al., 2015; Skounti et al., 2007; Wolraich et al., 2014). For example, two major meta-analyses of worldwide-pooled prevalence of ADHD were conducted in 2007. Results from reviewing 39 studies from 1992 through 2006 presented reported rates of ADHD varied from 2.2% to 17.8% in children and adolescents (Skounti et al., 2007). After summarising factors affecting the included studies

such as population characteristics, methodology features, ethnic and cultural differences and diagnostic criteria, Skounti et al. (2007) suggested that the estimation of prevalence of ADHD could not be concluded by existing studies due to lack of standardised designs. Another study included 102 studies from 1978 to 2005 to estimate the worldwide-pooled prevalence: the prevalence of ADHD was estimated to be 5.29% (Polanczyk et al., 2007). The authors noted that using multiple informants and the measure of functional impairment accounted for some of the variation around the pooled prevalence rate. For example, studies using levels of impairment and multiple informants had significantly lower prevalence rates (Polanczyk et al., 2007).

Similar results were replicated: research methodology, such as the choices in diagnostic criteria, source of information, and impairment requirement for the diagnosis, rather than geographical location and year of study, contributed to the variability of estimated prevalence rates (Polanczyk et al., 2014). Although researchers attempted to identify factors affecting the variability of estimated prevalence rates of ADHD over time and across countries (Polanczyk et al., 2007; Polanczyk et al., 2014; Skounti et al., 2007; Thomas et al., 2015; Willcutt), the estimated prevalence rates of ADHD remain variable. Prevalence rates were estimated 5.47% and 2.32% higher when they were based on teacher only and excluding measures of impairment respectively (Polanczyk et al., 2014). Furthermore, including different editions of the DSM, the pooled prevalence of ADHD over time was estimated as 7.2% from another meta-analysis (Thomas et al., 2015). Thomas et al. (2015) noted that restriction on languages in the included studies and exclusion of studies based on non-DSM-IV criteria were some limitations in previous two studies by Polanczyk et al. (2007) and Skounti et al. (2007).

A birth cohort in US from 2006 to 2012 indicated that cumulative incidence of ADHD was highest for White children, comparing to Asian, Black, and Hispanic children (Shi et al., 2021). The cultural factors might possibly impact on diagnostic decision making. For example, children in ethnic minorities are found less likely to receive ADHD diagnosis and treatment (Coker et al., 2016). Cultural background might affect attitudes towards and knowledge of ADHD, thus influencing how raters interpret children's behaviours and their help-seeking behaviours (Bussing et al., 2016). Although cultural factors might affect the incidence of ADHD among ethical groups, however, a current meta-analysis showed no significant difference on ADHD prevalence among White, Asian, Black, and Hispanic children (Cénat et al., 2022).

1.14 Gender features

ADHD has been reliably found to be more common in males than in females: the male-to-female ratio of ADHD diagnosis has been estimated as around 2:1 in children and 1.6:1 in adults (American Psychiatric Association, 2022; Arnett et al., 2015; Bauermeister et al., 2007; Ramtekkar et al., 2010). The diagnosed incidence and prevalence of female children and adolescence were found to be far lower (Huang et al., 2016; Huss et al., 2008; Skounti et al., 2007). Males have been found to be more likely to be over-diagnosed in community samples, while females have been found to be more likely to be over-diagnosed in clinical samples (Gershon, 2002). Hyperactivity/impulsivity and conduct problems predict clinical diagnosis and receiving pharmacological treatment in females than in males (Mowlem et al., 2019). One study showed that school suspensions were likely to be observed in males with ADHD in a community sample among children aged 4 to 17, while risk factors, such as family burden, negative discipline, and quality of parent-child relationship, were the same for boys and girls with ADHD (Bauermeister et al., 2007). The discrepancy of gender features in ADHD, which might be explained by referral reasons and process, gender-related referral bias, clinical expression of symptoms, perceived gender differences in ADHD, has been a sensitivity concern for diagnosing female (Gershon, 2002; Klefsjö et al., 2020; Quinn & Wigal, 2004; Sciutto et al., 2004).

ADHD symptoms may vary across gender. For example, females with ADHD showed more intellectual impairment and internalising problems, but they demonstrated lower levels of ADHD core symptoms and lower rates of other externalising behaviours (Gaub & Carlson, 1997; Gershon, 2002; Yoshimasu et al., 2018). Another study found that in a community sample among children aged 4 to 17, more mood disorders were comorbid with the combined subtype in males and more anxiety disorders were comorbid with inattentive subtype in females (Bauermeister et al., 2007). On the basis of a continuous performance test, a meta-analysis suggested significant gender difference was only observed in impulsivity but not inattention among children with ADHD and without ADHD (Hasson & Fine, 2012). This gender effect is larger in children with ADHD than in children without ADHD (Hasson & Fine, 2012). In addition, more ADHD symptom severity in males was observed by Arnett et al. (2015). In this study, gender difference in ADHD severity was mediated by cognitive functions, including processing speed, inhibition and working memory. Males with ADHD were also found to have more impairment in inhibition than girls with ADHD, but no differences were observed in response speed across gender (Seymour et al., 2016). A recent

meta-analysis also revealed that males with ADHD presented more hyperactive behaviours and more problems in inhibition and cognitive flexibility, but not in working memory, planning or attention (Loyer Carbonneau et al., 2020). The diversity in symptom presentations across gender and the interaction between the symptoms and other problems may add to the complexity of the diagnostic procedure.

1.15 Etiology

The exact cause of ADHD is not yet fully understood (Luo et al., 2019; Rapport & Chung, 2000). ADHD is highly heritable, ranging from .20 to .65 heritability (Polderman et al., 2015) across the lifespan as estimated in twin studies (Faraone & Larsson, 2019; Larsson et al., 2014; Nikolas & Burt, 2010). Similar estimated rate of heritability, around 70%, was observed in several studies (e.g., Faraone & Larsson, 2019; Larsson et al., 2014; Nikolas & Burt, 2010). Nikolas and Burt (2010) estimated heritability and compared genetic and environmental influences on subtypes of ADHD and found that the subtype of ADHD was marked by different genetic influence, suggesting significant differences in the genetic etiology. The estimated effect of non-shared environment was small to moderate (Larsson et al., 2014; Nikolas & Burt, 2010), suggesting the environmental influences in addition to a genetic predisposition contributing the disorder. Several non-genetic factors, such as prematurity and low birth weight (Franz et al., 2018), chemical exposure in childhood (Nilsen & Tulve, 2020), maternal smoking during pregnancy (He et al., 2020), are associated with increased risk in ADHD. However, not all individuals who have been exposed to these environmental factors develop attention or hyperactive-impulsive problems, thus suggested a complex interaction between genetic and environment factors (Thapar et al., 2013). For example, hyperactivity/impulsivity was associated with one of the ADHD-related genes only in children who had been exposed to prenatal smoking (Kahn et al., 2003). This combined effect of genetic risk and environmental exposure to prenatal smoking doubled the risk of ADHD compared to children without either risk factor (Neuman et al., 2007). However, no effects from the interaction between another ADHD-related gene and maternal prenatal smoking on ADHD symptoms or diagnosis were observed in some other studies (Altink et al., 2008; Langley et al., 2008). The up-to-date evidence in the effect of gene-environment interaction on ADHD is not fully understood (Palladino et al., 2019).

1.16 Neurobiology and neuropsychological deficits

Neurobiology, in terms of brain function and neurochemistry, was found to be different between people with ADHD and without ADHD (Hoogman et al., 2017; Krain & Castellanos, 2006; McCarthy et al., 2014). For example, longitudinal studies have suggested that the sequence of cortical development in attention capacities are similar but they are delayed in individuals with ADHD (e.g., Berger et al., 2013; Shaw et al., 2007; Shaw et al., 2012b). These findings support the proposed hypothesis of delayed maturational brain development as an explanation of ADHD (Kinsbourne, 1973). Moreover, compared to control participants, frontal lobe regions of individuals with ADHD were found to be less activated (McCarthy et al., 2014). Deficits in these regions indicating similar cognitive strategies were observed among individuals with ADHD across subtypes (McCarthy et al., 2014).

Many studies have suggested that impairments in executive functions are linked to ADHD (e.g., Willcutt et al., 2005). Executive functions, referring to higher level cognitive processes, include a group of cognitive control processes (American Psychological Association, n.d.-c). The concept of executive functions has been studied for almost five decades, but remains varied definitions which include different possible subcomponents (Jurado & Rosselli, 2007; Pennington & Ozonoff, 1996). Nevertheless, the relationship between executive functions and ADHD has been widely studied (Barkley, 1997b; Nigg, 2000; Pennington & Ozonoff, 1996). For example, group differences between subjects with and without ADHD were significant in both clinic-referred and community samples on all tasks involving executive functions: response inhibition, vigilance, set-shifting, planning/organisation, verbal working memory, and spatial working memory (Willcutt et al., 2005). However, deficits in executive functions were found to be unnecessary or insufficient as the single cause (Willcutt et al., 2005), due to moderate effect sizes and lack of universality of the deficits among individuals with ADHD; the same deficits are often observed in other disorders of childhood (Sergeant et al., 2003; Sergeant et al., 2002; Willcutt et al., 2005). Similar results for ADHD subtype differences in executive functioning were also found in other studies (Geurts et al., 2005; Martel et al., 2007; Pasini et al., 2007). Although executive functions alone do not predict ADHD diagnosis, there is evidence that such additional measures aid ADHD diagnostic decision-making (Toplak et al., 2008; Veloso et al., 2022).

Some models of ADHD also suggest that ADHD affects cognitive and executive functions for self-control, including fluency, planning, working memory, inhibition, and set shifting (Pennington & Ozonoff, 1996). Of these many neuropsychological impairments, inhibitory deficits have become a specific focus of research for ADHD (Barkley, 1997b; Karr et al., 2023). Barkley's (1997b) Model of Behavioural Inhibition proposed that inhibitory deficits in ADHD were foundational problems affecting other executive functions. For example, corelation between inhibition and social impairment is observed in people with ADHD with mediation by hyperactivity/impulsivity (Bunford et al., 2015). Executive functions of children with ADHD were explained by their inhibitory deficits while social impairment in children without ADHD were explained by set shifting problems instead (Karr et al., 2023). This difference suggested the different domains to be considered when exploring executive functions between children with and without ADHD.

1.17 Prognosis and treatment

At least 15% of people with the diagnosis of ADHD continued to meet full diagnostic criteria and 50% met criteria in partial remission by their age of 25 years (Faraone et al., 2006). Only 3% of samples were completely remitted in another six-year longitudinal study (Francx et al., 2015). Despite the impacts across lifespan mentioned in the previous paragraph, individuals with untreated ADHD encounter long-term problems. For example, comparing the long-term academic outcomes between treated and untreated individuals with ADHD, interventions improved both achievement test and academic performance results (Arnold et al., 2020). Other than academic outcomes, poorer outcomes were observed in individuals with untreated ADHD and interventions also improved functional outcomes in antisocial behaviour, driving, substance use, obesity, employment, services use, self-esteem, and social function (Harpin et al., 2016; Shaw et al., 2012a). Moreover, 12% of clinical samples with substance use issues were undiagnosed with ADHD (Huntley et al., 2012). It showed that individuals with undiagnosed ADHD encountered more self-reported impairments in daily life, higher rates of substance use, suicide attempts and depression in their treatment records (Huntley et al., 2012).

Methylphenidate (often brand name, Ritalin), one of the most common stimulant medications, is recommended as the fine-line pharmacological treatment for individuals over five years old with ADHD (National Institute for Health and Care Excellence [NICE], 2018). Results from meta-analytic reviews showed that stimulant medications reduced severity of

ADHD symptoms and their efficacy remained stable disregarding the treatment duration (Castells et al., 2021; Catalá-López et al., 2017). As a stand-alone treatment, stimulant medications were more effective than placebo, non-stimulant medications, and behavioural treatment alone (Catalá-López et al., 2017). Better academic outcomes, such as improvement in completion of schoolwork, observed on-task classroom behaviours, and accuracy in arithmetic, were observed in medicated individuals with stimulants (Prasad et al., 2013). In addition to better academic outcomes, medications also decreased risk of developing mood disorders, and of accidents and injuries (Boland et al., 2020; Ruiz-Goikoetxea et al., 2018).

In addition to medication, nonpharmacological interventions, such as behavioural modification and positive behaviour supports (Fabiano et al., 2021), are commonly prescribed. Nonpharmacological interventions may be applied in combination with medication or as stand-alone treatment. Behavioural approaches, whether in isolation or combining with medication, were found to be more effective than placebo, whilst combining behavioural approaches were more effective than medication alone (Catalá-López et al., 2017). At schools, classroom contingency management strategies significantly lowered the frequency and severity of ADHD symptoms rated by teachers and reduced comorbid externalising problems rated by both parents and teachers (Iznardo et al., 2020). At homes, behavioural interventions conducted by parents not only effectively reduced ADHD symptoms and other behavioural problems, but also improved parental self-esteem (Coates et al., 2015). The reported beneficial effects from treatments rely on identification of ADHD, but identifying ADHD is never an easy process.

1.2 What are the challenges for identifying ADHD?

1.21 The complexity of ADHD evaluation procedure and methods

Diagnostic evaluation involves a comprehensive multi-step process. In the case of ADHD, gathering information from multiple sources is recommended in up-to-date guidelines (NICE, 2018; Wolraich et al., 2019b). The ADHD diagnostic process usually starts with clinical interviews with the individuals and/or their parents, depending on the age of the individuals. During the initial interviews, details of the concern together with a developmental and psychosocial history are gathered. To adhere to clinical practice guidelines, other clinical information is needed to determine possible explanations for the concern. For example, medical conditions, such as epilepsy and thyroid disorders, which share similar features with ADHD, need to be excluded for better conceptualising the concern clinically (Pearl et al.,

2001). Thus, a detailed physical examination is sometimes recommended after the initial interview to rule out possible symptoms accounted for effects from substance and/or of a general medical condition before concluding a diagnosis of ADHD (First, 2013; Wolraich et al., 2019a). To obtain more information outside the clinical interviews, informant rating scales have been more commonly used in paediatric psychiatric (Wolraich et al., 2010) and psychological practice for screening and assessing ADHD over the previous twenty years (Demaray et al., 2003b; Koonce, 2007; Nelson et al., 2019).

1.21.1 Measures of ADHD: Informant rating scales

In general, informant rating scales measure frequency and severity of symptoms using a questionnaire. These measures can be categorised into narrow-band and broad-band measures. Narrow-band measures target a single specific domain and focus on the frequency and severity of symptoms, while broad-band measures focus on a broader picture trying to cover many common dimensions of psychopathology such as conduct and emotional problems as well as hyperactivity. For example, ADHD Rating Scale-5 (DuPaul et al., 2016) is an example of narrow-band informant rating scales for ADHD, which includes 18 items based on the wording of ADHD symptoms from the DSM-5 in the domains of inattention and hyperactivity-impulsivity to be rated by parents and teachers. In contrast, broad-band measures not only gather information about ADHD, but also other information to rule out other potential explanations of the symptoms or to examine potential comorbidity (Collett et al., 2003; Riccio et al., 2010; Wolraich et al., 2019a). For example, the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) and the Child Behavior Checklist (CBCL; Achenbach & Rescola, 2000; Achenbach & Rescorla, 2001), aim at identifying children and youth at high risk of psychiatric disorders. Both are commonly unitised for initial screening and assessing ADHD (Achenbach et al., 2008; Brown, 2000; Seixas et al., 2012).

Despite the efforts of comprehensive reviews available (Angello et al., 2003; Collett et al., 2003; Demaray et al., 2003a), the choice of ADHD rating relies heavily on the clinical judgement of the assessor. The choice of scale may depend partly on its psychometric properties but is influenced by the goal of assessment (Collett et al., 2003; Demaray et al., 2003a). Some scales have better linkage to intervention while some better suit screening comorbidities. For example, when ADHD is a potential concern, narrow-band scales are frequently recommended to be utilised in conjunction with a broad-band rating scale (Brown,

2000). In addition, clinicians also encounter practical concerns (Streinmer, 1993), such as the choice and availability of the intended rater.

1.21.2 Measures of ADHD: Objective measurements

The ADHD diagnostic process always involves subjective measures as mentioned. This might risk influence from informant biases and the application of objective measures might add information facilitating the diagnostic process (Chi & Hinshaw, 2002; Emser et al., 2018; Hartman et al., 2007). Furthermore, diagnostic guidelines recommend that ADHD should be assessed and diagnosed through a detailed multi-step process to gather information from multiple methods and multiple sources (NICE, 2018; Wolraich et al., 2019b). Although the current diagnostic procedure requires no psychometric testing to confirm the diagnosis of ADHD, a number of studies have explored the role of objective measurements in assisting ADHD diagnosis.

Continuous Performance Tests (CPT; Rosvold et al., 1956) and neuropsychological measures are two common objective testing methods in ADHD assessment practice (Demaray et al., 2003b; Koonce, 2007; Nelson et al., 2019). CPTs, which were originally developed for examining brain damage, have also been used for decades to assess performance of an individual's attention and impulsivity in a sustained task (Berger et al., 2017; Ogundele et al., 2011). Reviews examining the validity of laboratory cognitive tasks for assessing ADHD symptoms suggested the potential usefulness of including objective measures in the ADHD screening process (Hall et al., 2016b; Lange et al., 2014; Nichols & Waschbusch, 2004). Objective measurements might enhance current clinical practice, such as reducing assessment time and improving diagnostic accuracy (Hall et al., 2016b). For example, a reduced number of consultations to confirm ADHD diagnosis was observed in service audit research comparing pre-inclusion and post-inclusion of CPT (Hall et al., 2016a).

Standardised cognitive or neuropsychological assessments are always considered as an additional assessment necessity in the ADHD diagnostic decision (Schneider et al., 2020). Cognitive assessments, such as the Wechsler Intelligence Scale for Children (Wechsler, 2003, 2014), are usually included in the assessment battery for ADHD. Some findings suggested a relationship between weaker processing speed and inattention (Kubo et al., 2018; Mayes & Calhoun, 2007; Thaler et al., 2013). However, results from meta-analysis showed that instead of being slower, the performance of individuals with ADHD tended to be more variable than

controls (Kofler et al., 2013). Cognitive testing provides information about relative strengths and weaknesses in various domains of cognitive processing and patterns of inattention and impulsivity (Gualtieri & Johnson, 2005). Empirical studies and meta-analytic reviews about sustained attention deficit in individuals with ADHD have also been inconsistent (e.g., Egeland et al., 2009; Epstein et al., 2003; Huang-Pollock et al., 2012; Tucha, 2009).

1.21.3 Screening accuracy

To understand screening accuracy, positive predictive value (PPV), negative predictive value (NPV), sensitivity, and specificity, which are also known as clinical utility (e.g. Murray et al., 2021), diagnostic accuracy (e.g. Chang et al., 2016) or efficiency (e.g. Algorta et al., 2016), serve as indicators to examine the discriminatory power for detecting a disorder (predict or differentiate various clinical problems/disorders or diagnostic outcomes). Sensitivity measures the probability that, given a diagnosis is present, how well a screening tool can positively identify the diagnosis, i.e., the probability of the test being positive given the diagnosis is positive. Specificity measures the probability that, given the diagnosis is absent, how well a tool can screen-negative for the diagnosis, i.e., the probability of the test being negative given the diagnosis is negative. Different from sensitivity and specificity, PPV and NPV indicate the probability that a tool can classify whether individuals do or do not have a target condition, according to their test results. Full disclosure of sensitivity, specificity, and predictive values are vital for practices and research. In addition to PPV and NPV, which usually bring about trade-offs in selection (i.e., when PPV increases, NPV decreases, and vice versa) making comparison difficult, area under the receiver operating characteristic curve (AUC, the curve that is plotted from the probability estimates from above) is considered as an integrative statistic for our selection between tools (Obuchowski, 2006; Zou et al., 2007). The values of AUC are between 0 to 1, which means that when an AUC of 0 indicates a test predicts 100% inaccurately and when an AUC of 1 indicates a test predicts 100% accurately (Mandrekar, 2010). Given the complex and time-consuming diagnostic procedure of ADHD as well as undesirable consequences of unidentified and untreated ADHD, high predictive values of ADHD screening tool will be essential and crucial in terms of preferability.

A fair to excellent screening accuracy was observed in different ADHD-related rating scales in both clinical and community samples (Arrondo et al., 2024). For example, when completing by parent alone, the AUC ranged from .75 to .97 for the SDQ hyperactivity/ inattention subscale (Algorta et al., 2016; Klasen et al., 2000) and from .79 to .85 for the

CBCL Attention Problem scale (Chang et al., 2016) across culture, gender and age groups. In terms of predictive values of the SDQ hyperactivity/inattention subscale, a systematic review by Bergström and Baviskar (2021) found that the weighted NPVs mean was 97.83 (range: 82.00 - 99.00) from six studies addressing parents' ratings and 98.91 (range: 96.00 - 99.00) from two studies of teacher ratings, while the weighted mean PPVs were 28.22 (range: 17.00 - 87.00) from eight studies using parent ratings and 19.58 (range: 19.00 - 39.00) for two studies using teacher ratings. These mean that the false omission rate (i.e., when an informant rates a child not at risk but receive a clinical diagnosis) was low ranging from 1% to 18% but the false discovery rate (i.e., when an informant rates a child as at risk for a disorder, but the disorder is absent) varied from 13% to 83%. The SDQ hyperactivity/inattention subscale effectively rules out ADHD diagnosis, in terms of the observed low false omission rate. However, the subscale is high on sensitivity with a moderate to high rate of false discovery.

Results for screening accuracy using objective testing were inconclusive. As discussed above, CPT aided screening but did not distinguish well ADHD from non-ADHD (Hall et al., 2016a). High rates of false positives and false negatives were observed when using CPT alone to predict ADHD diagnosis (e.g., Chen et al., 2022; Hirsch & Christiansen, 2017; Zelnik et al., 2012). Poor diagnostic classifications, i.e., inability to differentiate non-ADHD cases with or without other conditions from ADHD cases, were reported when solely using the CPT (e.g., Hult et al., 2018; Johansson et al., 2021; Park et al., 2019; Tallberg et al., 2019). Arrondo et al. (2024) found that CPTs alone were not clinically useful for identifying ADHD in their meta-analysis. Similar results for diagnostic classifications were also observed when neuropsychological measures were used alone (e.g., Crippa et al., 2017; Pineda et al., 2007). A combination of objective measures with other screening tools might be expected to provide more comprehensive and coherent information to support ADHD diagnosis.

1.22 What problems do clinicians encounter when using these measures?

1.22.1 How these measures differentiate malingering?

To start with working on the diagnosis, First (2013) stated that a six-step diagnostic framework could illustrate how to formulate a comprehensive clinical conclusion for a presenting problem with the DSM-5 rules from different perspectives. The first step is to rule out Malingering and Factitious Disorder (First, 2013). Providing an honest and complete description of symptoms from a client is a common assumption being held in most healthcare

providers. However, malingering, which involves an intentional falsification achieving tangible gain, were reported in both children and adults regarding ADHD (Amlani et al., 2016; Ramachandran et al., 2020).

Rating scales are questioned for their ability to distinguish ADHD from malingering (Musso & Gouvier, 2014; Quinn, 2003). For example, Quinn (2003) compared results from a self-reported ADHD rating scale and a performance based test in undergraduate volunteers who were randomly assigned to a control or a simulated malingerer condition with undergraduates with a valid diagnosis of ADHD. Results implied that the self-reported rating scale alone could not distinguish simulated malingerers from the individuals with a valid diagnosis for both childhood and current symptoms. The performance results from CPT may have a greater sensitivity to detect malingering compared with self-report scales. Another review focused on malingered ADHD in college students suggested that measurements for detecting malingered ADHD for adults were limited (Musso & Gouvier, 2014). The authors recommended further research to examine the clinical utility of performance-based measures on the issue. In addition, in a literature review of malingering by proxy which included some cases of malingered ADHD, Amlani et al. (2016) suggested that cognitive and neuropsychological testing were effective to detect implausible inconsistencies in addition to comprehensive clinical consultation and physical examination for the reported psychiatric cases. The current evidence suggested that this step to rule out malingering would be essential and integrating measures might reduce possible over-sensitivity in ADHD diagnosis.

1.22.2 How these measures differentiate other diagnoses?

The step of ruling out other disorders is crucial not only because ADHD is associated with various comorbid conditions, but also because ADHD shares similar clinical presentations with other disorders (American Psychiatric Association, 2022; Belanger et al., 2018; Gibbins & Weiss, 2007; Pliszka & AACAP Work Group on Quality Issues, 2007). Differential diagnosis is used to distinguish a disease or condition from other possible diagnoses with similar signs and symptoms (Stevens & Rodin, 2011). Distinguishing concerns and impairment as a main feature of ADHD from an associated feature of other conditions is necessary. Sixteen conditions, such as oppositional defiant disorder, other neurodevelopmental disorders and anxiety disorders, are enumerated in the DSM-5 (American Psychiatric Association, 2022) as possible alternative causes for ADHD-related symptoms, and some of them can coexist with ADHD (Belanger et al., 2018). Ruling out

other possible causes of ADHD-related symptoms is necessary to facilitate better intervention planning.

ADHD-related symptoms can also be part of another diagnosis. For example, attention impairment can be an associated feature of other conditions, such as Alzheimer's disease, epilepsy, schizophrenia, speech disorder, bipolar disorder, depression and anxiety (Berl et al., 2015; Camelo et al., 2013; Ebert & Kohnert, 2011; Hernandez et al., 2003; Kavros et al., 2008; Lahera et al., 2017; Liu et al., 2002; McGuinness et al., 2010; Perry & Hodges, 1999; Sommerfeldt et al., 2016; Weissman et al., 2012). In the same way, a variety of behavioural problems and restless legs syndrome can provide alternative explanations for hyperactivity which focuses on developmentally inappropriate excessive frequency of movement and/or activities (American Psychiatric Association, 2022; Didriksen et al., 2019). Impulsivity, on the other hand, focusing on inhibitory control, is associated with, not only ADHD, but also conduct disorder, personality disorders, substance use disorders, and bipolar disorder (Barker et al., 2015; Evenden, 1999; Loree et al., 2015; Moeller et al., 2001).

ADHD often coexists with other neurodevelopmental conditions, such as autism spectrum disorder (ASD) and learning difficulties (Larson et al., 2011). Individuals with ADHD also may suffer from other coexisting conditions, such as anxiety, depression, conduct disorder and oppositional defiant disorder (Anastopoulos et al., 2018b; Elia et al., 2008; Jensen et al., 2001; Mitchison & Njardvik, 2019; Pliszka, 2000). A pooled meta-analysis including 546 studies showed that ADHD exhibited high likelihood on comorbid psychopathologies [e.g., oppositional defiant disorder (odds ratio, OR, 7.1 - 26.9], conduct disorder (OR 7.6 - 23.2), generalised anxiety disorder (OR 3.5 - 6.5), separation anxiety disorder (OR 3.4 - 8.7), major depressive disorder (OR 3.9 - 7.4), bipolar disorder (OR 27.3 - 97.7), learning disability (OR 1.9 - 5.7), speech/language disorder (OR 2.4 - 3.6), and tic disorder (OR 3.4 - 8.9)] (Willcutt et al., 2012). Such convergence in evidence strongly supports the existence of a relationship between ADHD and comorbid psychopathologies.

Although an increased usage of including rating scales for assessing comorbidities is observed in ADHD practice patterns (Wolraich et al., 2010), the overlapping part of the features might not be well identified by rating scales in the screening process. For example, ADHD rating scales are not able to separate inattention and hyperactivity/impulsivity in ASD from ADHD (Yerys et al., 2017; Zhou et al., 2020). Additional items, such as impairment

measures in functioning and developmental social issues, are required to differentiate ADHD from learning disorders (Langberg et al., 2010) and ASD (Zhou et al., 2020). In addition, some studies found that ADHD rating scales can separate inattention due to anxiety disorder from ADHD among youth (Elkins et al., 2014). In contrast, using rating scales separately for ADHD and anxiety or combining them together do not discriminate well among adults with ADHD, both ADHD and anxiety, and anxiety alone (Grogan et al., 2018). High false positives rates, which means misidentifying individuals with other concerns as having ADHD, were also observed in a self-reported ADHD rating scale in young adults (Harrison et al., 2019) and parent-reported and/or teacher-reported ADHD rating scale in children (Goodman, 2001). The effectiveness of ADHD-related rating scales in differentiating these symptoms with other diagnoses is limited.

On the other hand, mixed results were observed in applying objective measures alone to distinguish ADHD from other conditions. CPT alone cannot discriminate between children with ADHD from children with reading disorders or other clinical controls (McGee et al., 2000). Although group differences in inhibitory control were observed between ADHD and ASD, this measure cannot separate ADHD from ASD (Sinzig et al., 2008). Furthermore, objectively measured inhibitory control was found to differentiate not only ADHD from ASD but also ADHD and ASD respectively from other comorbid conditions (Tye et al., 2014). Combining ADHD ratings with objective measures improved diagnostic classification compared to other disorders. For example, Mesquita et al. (2016) found that variance of attention impairment observed in an objective test among the adult population was contributed by ADHD ratings but not depression. In addition, when combining objective measure with rating scales in ADHD and ASD, objective measure improved classification between ADHD and ASD in an adult clinical population (Groom et al., 2016). The implications might suggest the utility of an assessment battery that includes both subjective ratings and objective measures to facilitate ADHD screening that can differentiate the disorder from similar conditions.

1.3 What problems do clinicians encounter when integrating information?

1.31 Discrepancies between objective measures and informant ratings

The discrepancies between these measures have been a concern in the diagnostic process. Some studies found that CPT scores were not associated with parent and/or teacher ratings of ADHD symptoms (Barnard et al., 2018; Sims & Lonigan, 2012). Parent-reported attention

symptoms were also not associated with performance tasks in sustained attention or shifting and flexibility of attention (Bünger et al., 2021). In contrast with these findings, behavioural rating scales stay satisfactorily congruent to performance tasks in attention (Bledsoe et al., 2020). These findings suggested that these measures may assess different aspects of psychopathology.

Moreover, the relationship between ADHD rating scales and objective measures appeared to have different patterns across gender, but results are inconsistent. Skogli et al. (2013) found that parent ratings might have better discriminatory power in males than in females, due to higher risk of behavioural problems in males with ADHD symptoms; however, neuropsychological measures distinguished individuals equally well across males and females. In contrast, Arnett et al. (2015) reported that males with ADHD had more severe scores on the inattention, hyperactivity/impulsivity and total ADHD scores than females from both neuropsychological measures and parent- and teacher-ratings. This may imply the necessity of multidimensional measurement from both rating scales and objective measures in assessing ADHD.

1.32 Discrepancies across informants

Low to moderate levels of correlations among informants are commonly observed in all forms of paediatric psychopathology (Achenbach et al., 1987; Carneiro et al., 2020; De Los Reyes et al., 2015). There is no exception for hyperactivity/inattention problems for this phenomenon regardless of the tools that are applied that parent-teacher agreement correlations are usually low-to-moderate according to Cohen's conventions (Cohen, 1992). Estimated range from .34 to .64 with mean of .48 (Cheng et al., 2018) using the SDQ (Goodman, 1997) hyperactivity/inattention subscale and from .17 to .60 (Rescorla et al., 2014) using the DSM-attentional problems from the CBCL (Achenbach & Rescorla, 2001). The issue of parent-teacher discrepancies is not unique to ADHD symptoms but also commonly found in other problems, such as social skills (Gresham et al., 2010; Thompson & Winsler, 2018) and oppositional defiant disorder (McNeilis et al., 2018). Various processes may contribute to discrepant results in ADHD ratings including but not limited to rater effects and cross-situation variability on behaviour presentations and demand (De Los Reyes et al., 2013; Martel et al., 2017).

There are no best solutions to combine the discrepant results (Martel et al., 2015). This adds complication to the ADHD diagnostic decision-making process not only theoretically in terms of the criteria requirement for symptom presentations in at least two settings (American Psychiatric Association, 2022), but also in practical decisions that clinicians must make (Martel et al., 2017). For example, it is common to observe different numbers of symptoms reported by parents and teachers in ADHD (Kennerley et al., 2018; Wolraich et al., 2004). Summing up the endorsed items across informants using OR or AND logic, where symptoms are scored present if endorsed by either informant or both informants respectively, or averaged across reporters can generate a single integrated rating (Horton & Fitzmaurice, 2004). They simplify the process of integration, but they may either over-diagnose or under-diagnose ADHD (Martel et al., 2017; Martel et al., 2015). For example, using the AND algorithm to integrate ratings from different informants leads to problems on missing cassness with reported NPV 81.3% when applying OR rule and 45.4% when applying AND rule (Martel et al., 2021). More intuitively, out of 483 true positive cases in the study, 419 children were identified using the OR rule and 144 only were reported using the AND rule. The OR rule does not specify if the symptom endorsed occurred in only one of the settings. This classification might be an issue with the DSM diagnostic criteria especially when most of the endorsed symptoms are only from one source. This classification might not fit the diagnostic criteria that symptoms/impairments observed in one setting should not be qualified as fulfilling the diagnostic criteria and discrepant reported symptoms across settings might not be contributed by ADHD. Informant discrepancy and integrating methods have varied influences on the diagnosis classification assigned (Achenbach, 2011; Johnson et al., 2014; Kennerley et al., 2018). Research on integrating informant-ratings (including their discrepancy) and other measures (e.g., objective measures) is a priority for developing screening approaches in ADHD.

1.4 General limitations of the research literature

Previous research has investigated the relationship between child's, parent's and family's factors with parent-teacher disagreement in ADHD, but the findings are inconsistent. For example, some studies (e.g., Harvey et al., 2013; Lawson et al., 2017) found that ethnicity was related to parent-teacher disagreement in reporting ADHD while some studies did not (Saffer et al., 2021). Moreover, relatively few studies (e.g., Harvey et al., 2013) have reviewed factors of parent-teacher discrepancy in reporting ADHD comprehensively. However, Harvey et al. (2013) focused on preschool samples, and that replication including

school age children is important to test the generalisability of these results. In addition, the parent-teacher agreement/disagreement patterns used in most studies either could not distinguish the rater (e.g., Harvey et al., 2013), or did not include all potential rating combination groups (e.g., parent screen positive, teacher screen negative) for comparison (e.g., Johnson et al., 2014). The integrating methods mentioned above also do not indicate the presence of symptoms across sources (Horton & Fitzmaurice, 2004). Information might be left out in the previous classification approaches, especially when the comparison with true negatives is necessary. A modified categorisation, which will be introduced in Chapter Two, helps to provide holistic comparisons among all the groups. Furthermore, relatively few studies have reviewed integration of rating scales and objective measures of executive functioning as additional measures for ADHD identification, especially in the context of parent-teacher discrepancy. Even fewer research studies have considered how informant discrepancy could be handled to optimise screening accuracy. The current study will address these gaps to provide insights for clinical assessment batteries in ADHD identification.

1.5 Thesis overview

This thesis investigates the factors associated with parent-teacher discrepancy in hyperactivity problems, the relationship of parent-teacher discrepancy and ADHD diagnosis, and the role of performance-based measures and informant-rating scales of executive functions in identifying ADHD. The main research questions are:

1. To explore factors associated with parent-teacher agreement in reporting ADHD symptoms.
2. To examine how parent-teacher agreement predicts diagnosis and to test how factors associated with informant agreement may influence the screening accuracy.
3. To explore whether executive function measures improve the overall accuracy of the screening process for ADHD beyond informant-based ADHD ratings and how executive function measures may influence the screening accuracy.

Chapter Two first summarises findings from the previous literature on parent-teacher agreement in reporting ADHD symptoms and reports an analysis on exploring factors associated with parent-teacher agreement. The chapter investigates screening accuracy in the context of informant discrepancy. Chapter Three reports an analysis on how parent-teacher agreement influences screening accuracy and tests factors that may be associated with screening accuracy in the context of multiple informants. Chapter Four reports an analysis

including additional measures of executive function that might enhance the ADHD screening process. Chapter Five summarises the findings from these chapters in the broader context of the existing literature and discusses insights from the findings to the ADHD identification, limitations of the studies and possible future research directions.

Chapter Two: Factors associated with parent-teacher hyperactivity/inattention screening discrepancy: Findings from a UK national sample.

2.1 Abstract

To fulfil the ADHD diagnostic criteria, symptoms should be observed in at least two settings. This means that ADHD diagnostic procedures require information from different settings. It is common that the observations from schools to be reported by teachers and from home to be reported by parents/caregivers at home. This study aims to examine parent-teacher agreement in reporting hyperactivity/inattention and its relationship with child's, parent's, and family's characteristics. Data was taken from the 2004 United Kingdom Mental Health of Children and Young People survey, including 7977 children aged 4 to 17. The SDQ hyperactivity/ inattention subscale was completed by parents and teachers, with a single screen positive cut-off identified. The characteristics of different informant agreement patterns were assessed by multinomial logistic regression. Low (weighted kappa = .34, 95% CI: .31, .37) parent-teacher agreement was observed in the SDQ hyperactivity/inattention subscale, which is consistent with previous studies. This study confirms that some characteristics, such as male child and parental emotional distress, were associated with higher likelihood of parent-teacher discrepancy. The identified characteristics were partly consistent with previous research.

2.2 Introduction

ADHD, a disorder with features of developmentally inappropriate levels of hyperactivity, impulsivity and/or inattention, affects both children and adults worldwide (American Psychiatric Association, 2022; Polanczyk et al., 2007; Willcutt, 2012). Identifying ADHD is essential for accessing interventions for improving functioning (Roy et al., 2017), minimising possible longer-term consequences (Batstra et al., 2012), and reducing poorer outcomes from undiagnosed and/or untreated ADHD (Okumura et al., 2021). To assess children's and adolescent's problems, parents and teachers are key informants to provide information. As discussed in Chapter One, parent-teacher rating discrepancy is one of the common dilemmas that clinicians face in practice in all forms of paediatric psychopathology (Achenbach et al., 1987; Carneiro et al., 2020; De Los Reyes et al., 2015), including hyperactivity/inattention problems. The level of teacher-perceived stress is higher when teaching students with ADHD compared to teaching students without ADHD (DeShazer et al., 2023; Greene et al., 2002). Although not much research had addressed the relationship between teacher's stress and ADHD ratings, the existing literature supported that teachers' stress is likely to affect ADHD ratings by teachers (Saffer et al., 2021). Understanding the reasons for informant-discrepancy informs evidence-based practice for both researchers and practitioners, facilitating the integration and interpretation of different informant ratings when screening for psychiatric disorder (De Los Reyes, 2013). Several factors have been investigated in previous research as follows:

Child's Characteristics

Age. ADHD symptom presentation changes across development, with declining hyperactivity-impulsivity as age increases, while inattention remains relatively stable (Caye et al., 2016; Faraone et al., 2006; Halmøy et al., 2009; Newcorn et al., 2001). Children age influences in both parent and teacher ratings of hyperactivity/impulsivity, in which higher ratings are observed in younger children by both informants (Gomez et al., 1999; Narad et al., 2015). Murray et al. (2018) found that parent-teacher discrepancy was independent of child's age and that there is an opposite trend in inattention along age of child, with parent-reported symptoms increasing while teacher-reported symptoms decrease. Meanwhile, Chamorro et al. (2021) found a similar trend that teachers reported less ADHD symptoms as children developed whereas parents-reported symptoms remained stable, inducing an increase in the discrepancy in later childhood. Overall, studies are inconsistent in their results regarding the effect of age on informant agreement of children's ADHD behaviours and parent-teacher

agreement has been found to be unrelated to age in some studies (Du et al., 2008; Narad et al., 2015; Saffer et al., 2021; Sherman et al., 2010; van Widenfelt et al., 2003).

Gender. ADHD has been reliably found to be more common in males (Arnett et al., 2015; Bauermeister et al., 2007; Ramtekkar et al., 2010; Sagiv et al., 2013). Gender biases on assessing behaviours might affect ratings by informants even when similar problem behaviours are displayed in the same setting (Sheaffer, 2021). Research conducted on 789 Mexican students from six elementary school grades reveals that the discrepancy regarding hyperactivity may be greatest in girls (Chamorro et al., 2021). However, other studies have found no gender difference in parent-teacher agreement (Harvey et al., 2013; Saffer et al., 2021; van Widenfelt et al., 2003).

Parent-rater's Characteristics

Gender. Mothers have a tendency to identify more ADHD symptoms than fathers in screening assessments (Caye et al., 2017). Regardless of moderate mother-father agreement in ADHD (Sollie et al., 2013), there is little evidence available regarding whether the parental gender will affect parent-teacher discrepancy. Some studies have found parental gender is not associated with parent-teacher agreement in ADHD (Falt et al., 2018; Sollie et al., 2013). Consistently, reporting genders or roles of caregivers would be helpful in improving such analysis on the gender-related impacts on discrepancies.

Age. Previous studies found inconsistent results regarding the relationship between parental age and parent-teacher agreement in reporting child's behaviours (Munzer et al., 2018; Stone et al., 2013). Stone et al. (2013) found lower parent-teacher agreement with young mothers only in externalising behaviours in samples of 5 to 12 year-old children, while Munzer et al. (2018) observed higher parent-teacher agreement with young parents and lower parent-teacher agreement with older parents in both internalising and externalising behaviours in pre-schoolers. However, there is limited existing research exploring how parental age may relate to parent-teacher agreement in ADHD.

Education. Parent-teacher disagreement could result from differences in perception under the influence of parent's characteristics (Stone et al., 2013). Education level is associated with awareness of, knowledge about and acceptance of treatment for ADHD (Amiri et al., 2016; Dodangi et al., 2017; Partridge et al., 2012). Parents with higher education levels may obtain more accurate information about ADHD providing a greater awareness and knowledge of ADHD (Amiri et al., 2016; Dodangi et al., 2017). Regarding the effect of received education by parents on parent-teacher agreement in ADHD, limited evidence is available and the result

is also inconclusive (Saffer et al., 2021; Yeguez & Sibley, 2016). Parents with higher education levels predicted more severe reports of inattention than teachers (Yeguez & Sibley, 2016). Parents with higher education levels were most accurate in predicting ADHD diagnosis compared with teachers, and parents who received less education were the least accurate (Tahillioglu et al., 2021). A relationship between parental education level and parent-teacher disagreement in ADHD was observed in some studies (Tahillioglu et al., 2021; Yeguez & Sibley, 2016). However, other evidence indicates that parental education level was unrelated to parent-teacher agreement in both community and clinical samples (Saffer et al., 2021).

Mental Health. The depression-distortion hypothesis suggests that when a parent suffers from depression, their rating on their child's behaviours would be less accurate and hence affect cross-informant agreement (Richters & Pellegrini, 1989). Results from Harvey et al. (2013) supported this hypothesis finding that mothers, but not fathers, with depression were more likely to rate child attention problems more highly than teachers. However, comparing mothers with and without depression, Madsen et al. (2020) found that mother-teacher disagreements were reduced among mothers with depression. Instead of parental depression, van der Oord et al. (2006) observed that when a parent reported more parenting stress, parent-teacher discrepancy in rating ADHD symptoms was greater. Higher parenting stress predicted more reported ADHD symptoms by mothers than teachers (Yeguez & Sibley, 2016). Results from Chen et al. (2017) supported the findings of association between parenting stress and informant disagreement from van der Oord et al. (2006) and Yeguez and Sibley (2016). On the other hand, parental ADHD symptoms are associated with parent-teacher discrepancy (Yeguez & Sibley, 2016). Yeguez and Sibley (2016) found that mothers with self-reported ADHD symptoms significantly predicted reporting more ADHD symptoms in their children than teachers reported. However, there was limited evidence on the relationship between parental ADHD symptoms and informant agreement, so replications are required (Saffer et al., 2021). The current findings are not conclusive on the influence of parental depression, parenting stress and parental ADHD on cross-informant agreement, especially on the mechanism of how psychological well-being might influence the agreement. Other than reporting bias from the parent, it is also possible that a parent with depression, parenting stress, or ADHD symptoms may be more likely to encounter more behavioural problems at home and more impaired parent-child interaction (Jacob & Johnson, 1997).

Family's Characteristics

Ethnicity. Cultural diversity affects attitudes towards ADHD, knowledge of ADHD, and help-seeking behaviours (Bussing et al., 2016). Children in ethnic minorities are also less likely to receive ADHD diagnosis and treatment (Coker et al., 2016). An association between ethnicity of parents and parent-teacher disagreement in ADHD has been observed in previous work (Takeda et al., 2020). Parents from ethnic minority were more likely to rate inattention and hyperactivity lower than teachers (Harvey et al., 2013; Lawson et al., 2017; Takeda et al., 2020), while Latina mothers were more likely to rate hyperactivity higher than teachers (Harvey et al., 2013). Compared to non-Latino, teachers were more likely to identify symptoms in Latino youths while parents were less likely to identify symptoms (Haack et al., 2018). However, these patterns have not been found consistently. Another study found that parents identified more symptoms than teachers but that the disagreements between parents and teachers were not related to ethnicity (Wexler et al., 2022). Although some studies are available, the literature is not yet sufficiently developed to conclude on how informant agreement in ADHD varies across cultures (Harvey et al., 2013; Phillips & Lonigan, 2010; Saffer et al., 2021; Takeda et al., 2020).

Socioeconomic Status (SES). Children in lower income families are more at risk for ADHD diagnosis and ADHD medication use (Sagiv et al., 2013). Lawson et al. (2017) found lower SES leads to higher parent-teacher discrepancy. There was a higher chance of disagreement regarding inattention symptoms and better agreement on hyperactivity/impulsivity symptoms. However, Takeda et al. (2020) found no significant relationship between SES and parent-teacher agreement despite using the same measure of SES as Lawson et al. (2017). Saffer et al. (2021) also found household income was unrelated to parent-teacher discrepancy.

Family Structure. The structure of a family, such as number of children in the household and parental partnership status may affect how an informant perceives and rates a child's behaviour. For externalising problems, mother-teacher agreement was the best in the single child group and discrepancy was greater when more siblings were present (Castagna et al., 2020). The authors suggested that increased family size might create more parenting stress and lower tolerance for behavioural problems, which increased the chance to rate more symptoms. However, Harvey et al. (2013) did not find support for the hypothesis on the relationship between number of children in a household with parent-teacher agreement in ADHD. Single parents experienced more parenting stress with a child with ADHD (Theule et al., 2010) which may affect their rating. However, marital status was not associated with parent-teacher agreement in ADHD (Yeguez & Sibley, 2016).

Limited evidence is currently available for a solid conclusion about the relationship of child, parent, and family factors with parent-teacher informant agreement in ADHD. In the present study, we explored how the factors discussed above were associated with parent-teacher agreement/disagreement in ADHD screening. We examined the correlations of parent and teacher reports on the hyperactivity/inattention scale of the SDQ (Goodman, 1997) in the United Kingdom's 2004 survey of Mental Health of Children and Young People (MHCYP) (Green et al., 2005). We expected to find a low correlation between reporters, following Vaz et al. (2016) who found low agreement [weighted kappa = .31, 95% confidence interval (CI): .13, .48]. Second, we examined the effects of characteristics of the parent, child, and family on parent-teacher agreement. We expected to identify relationships between the informant agreement and the selected factors, such as age, gender, ethnicity, family structure, socioeconomic characteristics, and parent's mental health condition. For instance, we predicted that parents with lower education levels may identify fewer problems, even if the child presents with inattention-hyperactivity symptoms, which will result in discrepancies with teacher reports.

2.3 Methodology

Sample and Data Collection

The data was taken from the 2004 MHCYP survey in the United Kingdom (Green et al., 2005). Details of this survey can be found at Green et al. (2005). The data consisted of multiple informants reporting on children aged 4 to 17. A sample of 12,294 families was identified from the Child Benefit Register, and 10,496 (85% of the sample) families were invited to participate in the interview. Fifteen percent of identified families were not interviewed due to opt-outs, moving without trace, and ineligibility. From the completed (n = 7977) interviews, 10.4% of children (with 25.3% missing responses) were reported having officially recognized special needs by teachers and 3.8% (with 1.4% missing responses) were reported by parent "having hyperactivity". Parents and children aged from 11 to 17 completed the interview and answered a self-rated questionnaire. Consent from parents was sought to contact a nominated teacher who was then invited to participate in the study.

Missing Data

In the existing dataset, 7977 families achieved complete interviews with data from up to three reporters. Ninety four percent of families provided parental consent for teachers' participation and 6236 (78% of all interviews) teachers provided a response. In the current study, any

participant providing one missing or unrecognised coding was excluded. Pairwise deletion was used in the current analysis. This meant a sample of 5781 children with both parent- and teacher-reported ratings remained, after data cleaning.

Measures

Hyperactivity/inattention

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) is a 25-item brief informant questionnaire for screening psychopathology of children from 4 to 17 over the past six months and available for parents, teachers, and children over 11 years old. The hyperactivity/inattention subscale contains five items addressing restlessness ("*restless, overactive*" and "*constantly fidgeting or squirming*"), distraction ("*easily distracted, concentration wanders*"), and impulsivity ("*thinks things out before acting*" and "*sees tasks through to the end*"). It has been shown to be a useful screening tool for ADHD (e.g. Algorta et al., 2016; Hall et al., 2019). The SDQ has been shown with satisfactory internal consistency (e.g., Becker et al., 2006) and external validity with high correlation of rho = .71 with other tools like the Conners' Parent Rating Scale (Greven et al., 2018). The SDQ items were scored as "*not true = 0*", "*partly true = 1*" and "*certainly true = 2*", with two items reverse coded. The sum of the five items of this subscale from all informants can be categorised into "*normal (0-5)*", "*borderline (6)*" and "*abnormal (7-10)*" (Goodman, 1997). The categorisation instead of the total scores of the subscale were used for comparisons. The current study proposes a categorical variable set for informant patterns. using the SDQ band category system (Goodman, 1997), the "*borderline* (6)" and "*abnormal* (7-10)" were regrouped in one group ("*at risk*"), which is consistent with previous approaches (Vaz et al., 2016), and formed a 2×2 matrix of parent-teacher agreement/disagreement patterns as displayed in Figure 2.1.

Figure 2.1. *Categorisation for parent-teacher agreement/disagreement patterns on the SDQ hyperactivity/inattention scale.*

Rater/Rater	Teacher	
Parent	"*Normal*"	"*Borderline*" or "*Abnormal*"
"*Normal*"	Both agreed not at risk	Teacher-reported only
"*Borderline*" or "*Abnormal*"	Parent-reported only	Both agreed at risk

Background Measures

Demographic variables, such as age, gender [‘female’ (0), ‘male’ (1)], ethnicity [‘White’ (0), ‘Non-White’ (1)], family structure [‘not lone parent’ (0) or ‘lone parent’ (1), and number of children in household], socioeconomic characteristics [‘above national average income’ (0) or ‘below national average income’ (1) (Office for National Statistics, 2020)], family’s employment status [‘both parents or one parent working’ (0) or ‘neither parent working’ (1)], parents’ educational level [‘completed at least a formal degree’ (0) or ‘did not completed any formal degree’ (1)]. The last variable in the current study was the parent’s self-reported mental health condition which was measured using the 12-item General Health Questionnaire (GHQ; Williams & Goldberg, 1988). The GHQ items were scored as “*more so than usual or same as usual* (0)” and “*less so than usual or much less than usual* (1)”. A total score ranging 0 to 12 was calculated and grouped into “screened positive for an emotional issue (1)” for a total score of three or more and “not screened positive for an emotional issue (0)”, as defined by Green et al. (2005).

Ethical Considerations

The MHCYP study was conducted by the Office for National Statistics and commissioned by the Department of Health and the Scottish Executive Health Department in the United Kingdom. Informed consent was obtained from parents and children. Consents from parents were sought to contact the nominated teacher for providing data. Ethics approval (Reference Number: 040880) for the current analyses was obtained from the Ethics Committee at the University of Sheffield, adhering to ‘Research Ethics: General Principles and Statements’ for secondary analysis.

Statistical Analysis

STATA17 (StataCorp., 2021) was used for all analyses. Cross-informant correlation on the hyperactivity/inattention subscale was examined using weighted kappa (Cohen, 1960; Cohen, 1968), where kappa lower than .20: no level of agreement; .21-.39 minimal; .40-.59: weak; .60-.79: moderate; .80-.90: strong, and above .90: almost perfect (McHugh, 2012). Multinomial logistic regression was conducted to explore predictors of parent-teacher agreement/disagreement patterns. Tests of assumptions [variance information factor (VIF) for multicollinearity between variables, Hosmer-Lemeshow (H-L) statistic for homogeneity of multinomial logistic regression] of the regression analyses were also conducted. Wald tests

on coefficients were employed to test the impact of each factor on likelihood of falling into different agreement/disagreement groups.

2.4 Results

Sample Description

The dataset contained 7977 parent/child dyads. The majority of parent-informants were female (94.40%) and approximately half of the sampled children were male (51.54%). Child ages ranged from 4 to 17 with a mean age 10.54 years (SD = 3.40). The age of the interviewed parent ranged from 18 to 78 years old (M = 39.08, SD = 6.43). Ethnic origin of White (88.22%) and non-White (11.78%) are recorded. In terms of family structure, the percentage of lone parents was 24.29 and the mean number of children in a household was 2.13 (SD = 1.07). Regarding annual household income, 51.02% of families were below national average income. Regarding the family's employment status, the percentage of neither parent working was 15.42. The percentage of interviewed parents reported completing any educational qualifications was 81.82. In terms of emotional issues measured by the GHQ-12, 22.58% of interviewed parents scored as "screened positive". Child's age had low correlations with the other most other predictor variables, although there was a moderate correlation with adult age (r=.45). Some of the other predictors also showed moderate correlations, for example, lone-parent – below income (r=.46), lone parent – no parent work (r=.47). Additive properties might not present among the variables are observed with the highest VIF, that of lone parent, as low as 1.50 [attached in Appendices A and B]. Most children fell into the not-at-risk range on the SDQ hyperactivity/inattention subscale. Cross-informant agreement on the hyperactivity/inattention subscale was low (weighted kappa = .34, 95% CI: .31, .37).

Table 2.1. *Frequency of categorisation for parent-teacher agreement/disagreement patterns the SDQ hyperactivity/inattention subscale.*

Teacher-reported Parent-reported	Not at-risk N = 4931	At-risk N = 997
Not at-risk N = 6265	Both agreed not at risk n = 4201 (72.67%)	Teacher-reported only n = 508 (8.79%)
At-risk N = 1494	Parent-reported only n = 607 (10.50%)	Both agreed at risk n = 465 (8.04%)

Characteristics of Parent-Teacher Discrepancy

Four categories were formed according to the parent-teacher agreement/disagreement patterns: both agreed not at risk, parent-reported at risk only, teacher-reported only, and both agreed at risk, as shown in Table 2.1. Multinomial logistic regression (LR $chi^2 = 558.58$, $p<.001$, pseudo $R^2 = .06$) was used to regress the categorical outcome variable onto child (gender, age), parent (gender, age, emotional issue, and education level), and family characteristics (marital status of parents, employment, household income, number of children in household, and ethnicity). Descriptive statistics and relative risk ratios are displayed in Table 2.2, including the distribution of the four parent-teacher agreement/disagreement patterns. Wald tests comparing the informant-agreement categories on each factor are shown in Table 2.3.

Table 2.2. *Multinominal logistic regression of parent-teacher agreement/disagreement patterns predicted by risk factors.*

Risk factors		Mean/Rate[a]				RRR/CI (base: Both agreed not at risk)		
		Both agreed not at risk (n^b=4201)	Parent-only (n^b=607)	Teacher-only (n^b=508)	Both agreed at risk (n^b=465)	Parent-only	Teacher-only	Both agreed at risk
Child	Male	44.80%	59.97%	73.23%	75.05%	**1.93*** (1.61, 2.32)**	**3.29*** (2.65, 4.08)**	**3.87*** (3.06, 4.89)**
	Age	10.43	9.92	9.91	9.68	.97 (.94, 1.00)	.97 (.94, 1.01)	**.96* (0.93, 1.00)**
Parent	Male	4.48%	4.94%	7.09%	3.44%	1.17 (.75, 1.82)	1.46 (.97, 2.22)	.78 (.43, 1.40)
	Age	39.31	37.81	38.13	36.88	**.98** (.96, .99)**	**.98* (.96, 1.00)**	**.96*** (.95, .98)**
	Positive for emotional issue	19.99%	29.57%	22.85%	33.19%	**1.62*** (1.32, 1.99)**	1.15 (.90, 1.46)	**1.77*** (1.40, 2.23)**
	Without a formal degree	14.84%	18.67%	22.66%	28.51%	**1.69** (1.24, 2.29)**	1.22 (.90, 1.65)	**2.41*** (1.55, 3.75)**
Family	Lone parent	20.73%	25.04%	28.35%	34.84%	.89 (.69, 1.15)	1.00 (.76, 1.32)	1.09 (.83, 1.45)
	Neither parent working	11.32%	16.45%	20.28%	27.65%	1.09 (.81, 1.48)	**1.61** (1.18, 2.19)**	**1.61** (1.19, 2.18)**
	Below average income	44.54%	55.26%	56.28%	67.70%	**1.33** (1.08, 1.65)**	1.27 (.99, 1.61)	**1.73*** (1.33, 2.24)**
	Number of children in household	2.12	2.19	2.20	2.22	1.01 (.92, 1.11)	.98 (.89, 1.09)	.98 (.88, 1.10)
	Ethnicity as Non-White	10.93%	9.72%	14.2%	7.96%	**.60* (.41, .88)**	1.22 (.88, 1.69)	**.50** (.31, .80)**

RRR, relative risk ratio; CI, confidence interval. Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.

[a] All numbers correspond to rates, except for age given in mean number of years and for numbers of children in household given in mean number of children.

[b] Numbers can be slightly different due to variance of missing data for each risk factor.

Table 2.3. *Wald test and chi-squares between RRR of informant pairs.*

	Parent only vs Teacher only	Parent only vs Both agreed at risk	Teacher only vs Both agreed at risk
Child's characteristics			
Male	**15.22*** **	**23.59*** **	1.12
Age	.06	.11	.30
Parent-informant's characteristics			
Male	.64	1.32	3.39
Age	.01	.86	.96
Positive for emotional issue	**5.51***	.35	**7.69****
Without a formal degree	2.45	1.83	**6.76****
Family's characteristics			
Lone parent	.48	1.40	.22
Neither parent working	3.72	**3.91***	.00
Below average income	.12	2.55	3.28
Number of children in household	.18	.16	.00
Ethnicity as Non-White	**8.89****	.36	**10.60****

Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.

In terms of child's characteristics, male children were more likely to be rated as at risk by parent alone (RRR = 1.93, p<.001, CI: 1.61, 2.32) and by teacher alone (RRR = 3.29, p<.001, CI: 2.65, 4.08), comparing to when both informants rated as not at risk. Male children were less likely to be rated as at risk by parent-alone compared to teacher-alone (chi^2 = 15.22, p<.001) and by both informants (chi^2 = 23.59, p<.001) as at risk. Child' age was not related to parent-teacher discrepancy in the current study.

In terms of parent's characteristics, children rated by older parents were found to be less likely of being rated as at risk by parent alone (RRR = .98, p<.01, CI: .96, .99) and by teacher alone (RRR = .98, p<.05, CI: .96, 1.00), compared to when both informants rated as not at risk. Parents who are screened as positive for an emotional issue were more likely to rate their children as at risk by parent alone (RRR = 1.62, p<.001, CI: 1.32, 1.99) compared to when both informants reported the child as not at risk. We also found that when parents with positively screened emotional issues, their children were more likely to be rated by parent alone (chi^2 = 5.51, p<.05) and by both informants (chi^2 = 7.69, p<.01) than by teacher alone as at risk. For parents without a formal degree, children were more likely to be rated by

parent alone (RRR = 1.69, p<.01, CI: 1.24, 2.29) as at risk, compared to when both informants rated as not at risk. They were also more likely to be rated as at risk by both informants than being rated by teacher only (chi^2 = 6.76, p<.01). Parental gender was not related to parent-teacher discrepancy.

In terms of family's characteristics, children from families where neither parent was working were more likely to be rated as at risk by teacher only (RRR = 1.61, p<.01, CI: 1.18, 2.19) in comparison to both informants rated as not at risk. They were slightly more likely to be rated by both informants (chi^2 = 3.91, p<.05) as at risk than by parent only. Family with below average income (RRR = 1.33, p<0.01, CI: 1.08, 1.65) and parents who identified themselves as White (RRR = .60, p<.05, CI: .41, .88) were more likely to rate their children as at risk by parent alone, when compared to both informants rated as not at risk. Our results also found that non-White children were more likely to be rated by teacher-alone as at risk compared with parent-alone (chi^2 = 8.89, p<.01) and both informants (chi^2 = 10.60, p<.01) as at risk. Parental marital status and number of children in the household were not associated with discrepancy in the current study.

2.5 Discussion

Cross-Informant Correlations

As hypothesised on the basis of previous research, we found a weak to moderate correlation between informants' hyperactivity ratings that was consistent with the relationships found in all forms of paediatric psychopathology (e.g., Achenbach et al., 1987; Carneiro et al., 2020; De Los Reyes et al., 2015; Duhig et al., 2000). Similar findings of low parent-teacher correlations on the SDQ hyperactivity/inattention subscale were observed in previous research in both clinical (e.g. Coutinho et al., 2021) and community (e.g., Español-Martín et al., 2021) samples.

Characteristics of Parent-Teacher Discrepancy

The present study also explored relationships among child's, parent's, and family's characteristics with the informant agreement/disagreement patterns. The current study considered a pool of covariates in analysis simultaneously to jointly distinguish the marginal effects of the factors. Some of the relationships found were consistent with the previous literature. Our findings are partly consistent with previous research on factors not significantly associated with parent-teacher agreement/disagreement patterns on reporting

ADHD symptoms, such as child's age (Du et al., 2008; Narad et al., 2015; Saffer et al., 2021; Sherman et al., 2010; van Widenfelt et al., 2003), parental gender (Falt et al., 2018; Sollie et al., 2013), number of children in a household (Harvey et al., 2013) and marital status (Yeguez & Sibley, 2016).

Regarding child's characteristics, male children were more likely to fall into parent-teacher disagreement in our study, which is consistent with previous findings for externalising disorders (e.g., Cheng et al., 2018). It is also consistent with previous research about gender features of ADHD where it has classically been found that symptoms and diagnosis are more common in males, whether in single-informant or both-informant ratings (e.g. Kovess-Masfety et al., 2021). However, it is noticeable that parent-only screen-positive is less likely than teacher-only and both-informant rating among male children. This may imply the interaction of gender with informant agreement, for example, teacher-informants may have a higher likelihood to overestimate the incident among male children.

Regarding parental characteristics, younger parent-informants were more likely to fall into parent-teacher disagreement. This is consistent with Cheng et al. (2018) finding that younger mother-informants were associated with externalising problems measured by the SDQ. The current result is parallel with previous studies on younger parental age as a risk factor for informant discrepancy when screening ADHD and other externalising problems in children (Munzer et al., 2018; Stone et al., 2013). In addition, our results showed that parent-teacher disagreement was more common when parents were screen-positive for facing emotional issues. Harvey et al. (2013) reported similar findings regarding the association between maternal depression and mother-teacher disagreement; mothers with depression reported more attention problems in their children than teachers. Our findings were consistent with the depression-distortion hypothesis (Richters & Pellegrini, 1989), indicating that parents with psychological distress tend to rate more symptoms and are more likely to screen positive alone or to agree with the teacher that the child screens positive.

An association between parental education level and parent-teacher disagreement was observed in our study. This is consistent with previous research that has found a positive correlation between parental education levels and knowledge of ADHD (Amiri et al., 2016; Dodangi et al., 2017) and a positive effect of parental education on ADHD identification (Tahillioglu et al., 2021). Parents with higher education levels are suggested to have more

knowledge regarding ADHD and are more likely to report higher ADHD symptoms of their children.

Regarding family's characteristics, some measures of SES, such as number of working parents, and average household income, were significantly associated with parent-teacher disagreement in reporting ADHD symptoms. Our findings suggested that children from families with below average income were rated to have less symptoms by teachers, which is contradictory to previous findings. For example, in one study of pre-school children (Lawson et al., 2017), both parents and teachers report more symptoms for children with lower SES. This contrast may be due to different measures of SES in the current study (income only) or another unexplained mechanism. Difference in measures of SES may have hindered comparison of current results with previous studies.

Our findings also suggested that parents who identified their ethnicity as Non-White rated lower hyperactivity than teachers, which is consistent with previous studies (Harvey et al., 2013; Lawson et al., 2017; Takeda et al., 2020). Our findings also suggested that children rated by Non-White parent-informants were more likely to be rated as at risk for ADHD by teacher alone. This finding is similar to a previous study comparing Non-Latino and Latino youths, which found that Latino youths were rated for more symptoms by teachers (Haack et al., 2018). However, the results might not be directly comparable, as the classification of ethnicity in this previous study is Latino-oriented. This might suggest the phenomenon appearing across different minor ethnicities. Parental marital status and number of children in the household were not associated with discrepancy in the current study.

The current study has brought insights to both scientific and practical issues. For example, when disagreement in rating occurs, clinicians might consider the factors identified to predict interrater discrepancy, such as parental age and mental status. The current study utilised a large, nationally representative sample that measures many factors that have been studied as predictors of parent-teacher discrepancy. However, interpretation of our results must be considered in the light of some limitations. There are other possible characteristics that were not included in the current dataset that might contribute to parent-teacher discrepancies. For example, teacher's characteristics, such as ethnicity and stress level, were not measured. Our analysis might have benefited from including such information for exploring possible linkage of informant characteristics with informant agreement/disagreement, as suggested by

previous study (e.g. Gershenson et al., 2016). Nevertheless, our findings confirm results from the previous literature. Future research should focus on enhancing further understanding on the relationships between informant discrepancy with ADHD diagnosis for exploring the impact of agreement/disagreement on screening accuracy.

Conclusion

We found low informant agreement in the hyperactive/inattention subscale, consistent with previous studies. Several characteristics, such as gender of child and parental age, were associated with parent-teacher agreement/disagreement patterns. In conclusion, the current research has found several factors that played a role in informant rating discrepancy, and thus may be important in interpreting screening results especially when informants disagree with each other. As ADHD diagnosis requires symptoms to present in two or more settings, it is important to explore how the informant discrepancy induced then could have influenced the diagnosis, for example, how actual diagnosis might be different between parent-only and teacher-only screening scenarios, and the impacts of screening accuracy. Further research evaluating the screening accuracy from the informants, and the utilisation of all the information attainable in the clinical process, to facilitate the usage of informant rating in aiding clinical diagnosis may be an important next step.

Chapter Three: Characteristics of parent-teacher screening discrepancy and attention deficit hyperactivity disorder diagnosis: Findings from a UK national sample.

3.1 Abstract

Integrating ADHD screening from informants in different settings not only fulfils the diagnostic criteria for ADHD, but also improves screening accuracy. The commonly observed low to moderate correlations between informant reports adds to the challenge when integrating cross-informant information. Previous studies have explored the characteristics associated with false discovery and false omission associated with single informant ratings in ADHD. Exploring this issue in a multi-informant context will extend the understanding of how screening results relate to ADHD diagnosis and thus provide an opportunity to improve ADHD screening accuracy. This study aims to test ADHD screening accuracy using the informant agreement patterns demonstrated in Chapter Two. Informed by the analysis on the relationship between different characteristics and informant agreement patterns in Chapter Two, the current study also aims to explore how various covariates of informant disagreement influence screening accuracy. Data was extracted from the 2004 United Kingdom Mental Health of Children and Young People survey. Screening accuracy of the SDQ hyperactivity/inattention subscale was assessed by binary logistic regression compared against the Development and Well-Being Assessment (DAWBA). The characteristics of false discovery and false omission in multi-informant context were assessed by multinomial logistic regression. This study confirms that when combining parent and teacher reports on the SDQ hyperactivity/inattention subscale to predict ADHD diagnosis, the false omission rate was very low, when both raters screened negative; while the false discovery rate was moderate. Some factors, such as older children, were found associated with a higher chance of receiving an ADHD diagnosis and with false discovery and false omission in the content of multiple informants. The findings extended previous literature on the association of the characteristics with false discovery and false omission in multi-informant contexts.

3.2 Introduction

Even with numerous proposed clinical guidelines for ADHD diagnostic evaluation (NICE, 2018), clinical decision making is always challenging when lacking any specific diagnostic test for psychological disorders. ADHD assessment guidelines (NICE, 2018; Wolraich et al., 2019b) and the diagnostic criteria, such as DSM-5 (American Psychiatric Association, 2022) and the 11th revision of ICD (WHO, 2018), emphasise the importance of meeting both the symptoms and impairment criteria in two or more settings. This may be achieved by combining reports from teachers in school and caregivers at home. It implies that diagnostic procedures require not only observations reported by informants in different settings, but also integration of the information, as one of the common challenges discussed in Chapter One. Weak to moderate correlations among informants from different settings, as demonstrated in Chapter Two and in the previous literature (e.g., Achenbach et al., 1987; Carneiro et al., 2020; De Los Reyes et al., 2015), add to the challenge of cross-informant information integration.

As described in Chapter One, a comprehensive ADHD assessment involves various tasks and procedures. It is neither realistic nor desirable to provide a full clinical assessment for every individual due to limited availability of specialist services. To facilitate the diagnostic process, informant rating scales have been developed for the purpose of screening and identifying people at risk for ADHD. An effective screening tool is valuable for generalist practitioners to conduct clinical assessment, particularly differentiating the ADHD diagnosis from cases with no ADHD diagnosis. If the screening identifies likelihood of the presence of ADHD, then a referral can be made for a comprehensive evaluation process (First, 2013; Wolraich et al., 2019a). Screening instruments need to have low resource demand in terms of time to train those who administer the tests and in terms of time to complete and score the instruments (Streinmer, 1993). Acceptability for reporters is also essential (Goodman & Scott, 1999). For example, as described in previous chapters, the SDQ (Goodman, 1997) is a common but brief ADHD screening instrument with extensive evidence for validity and reliability in different informant formats in both clinical and community populations worldwide (Kersten et al., 2016; Stone et al., 2010; Woerner et al., 2004).

As described in Chapter One, regardless of the choice in screening tools, ADHD screening completed by one informant is not sufficient enough to identify ADHD and combining ratings from different raters improves the screening accuracy (Arrondo et al., 2024; Hall et

al., 2019; Johnson et al., 2014). For example, the SDQ hyperactivity/inattention subscale from different raters can be combined with the SDQ impairment score to generate a risk level, as specified in the SDQ predictive algorithm (Goodman et al., 2000c). Combining parent and teacher ratings improved ADHD screening sensitivity. For example, the sensitivity of the SDQ ADHD screening for children aged 5 to 10 was increased from 29.9% by parent alone and from 41.9% by teacher alone to 75.2% when integrating parent and teacher ratings (Goodman et al., 2000b). Results were similar for children aged 11 to 15 in the same study. Goodman et al. (2000b) also found that combining information from three raters rather than two raters provided a negligible increase in sensitivity. A similar conclusion for the importance of using both parent and teacher informants were observed by Johnson et al. (2014) that diagnostic accuracy improved from 73.3% to 90.3%, when comparing usage of both parent and teacher ratings with either one rating, from the SDQ hyperactivity/inattention subscale.

Taking a clinical sample, Hall et al. (2019) tested the predictive effectiveness of the SDQ screening for hyperkinetic disorder. With the majority of the sample being diagnosed with ADHD, the SDQ performed satisfactorily in identifying children with ADHD, having PPV 64.1%, NPV 57.3% for ICD-10 hyperkinetic disorder; PPV 81.0%, NPV 41.3% for DSM IV/5 ADHD; and PPV 91.1%, NPV 28.1% for clinician diagnosis (Hall et al., 2019). It should be noted that, Hall et al. (2019) clinical sample had a high chance of ADHD diagnosis, making the prevalence unusually high. Thus the PPV and NPV are of opposite patterns compared to community samples (Johnson et al., 2014; Lehmann et al., 2014; Rimvall et al., 2014). That is, a much higher predictability in identifying children with ADHD (high PPV) and lower predictability in identifying children without ADHD (low NPV). Overall, this body of work indicates that integrating two informants, such as parent and teacher, can enhance the predictive power of the SDQ for identifying an ADHD diagnosis.

Although screening is useful for identifying children who are at risk for a disorder, it is common to observe a considerable number of children who screen-positive but do not receive a diagnosis in a full clinical diagnostic assessment (Cuffe et al., 2005; Goodman et al., 2000b; Madsen et al., 2018). For example, when using the SDQ predictive algorithm, 63.5% and 50.8% of the samples who were screened positives received a hyperkinetic disorder and DSM-IV ADHD respectively (Goodman et al., 2000b). Goodman (2001) suggested a false

discovery rate of 83% and a false omission rate of 1% by parent-rating and a false discovery rate of 81% and a false omission rate of 1% by teacher-rating. Another study also found that using the SDQ predictive algorithm increased to around 3% in false omission, while the false discovery was improved to 50.45 (range: 26.70 - 93.00) from the weighted PPV mean of 28.22 (range: 17.00 - 87.00) using parent ratings and of 19.58 (range: 19.00 - 39.00) using teacher ratings (Bergström & Baviskar, 2021). Understanding the characteristics that predict false discovery and false omission is critical to improved screening utility. Some studies have explored the characteristics associated with false discovery and false omission associated with single informant ratings. For example, Cuffe et al. (2005) found that more males without parent-reported lifetime ADHD diagnosis were identified as screen-positive using the SDQ hyperactivity/inattention subscale. Madsen et al. (2018) found that female children and children from a lower socioeconomic status background were likely not to receive an ADHD diagnosis when comparing a parent-reported ADHD screening measure with the diagnosis. Exploring this issue will be valuable in extending our understanding of how screening results relate to full diagnosis. This may provide an opportunity to improve screening accuracy.

Notably agreement between multiple informants provides the most accurate prediction of a possible/probable diagnosis (e.g., Johnson et al., 2014). The diagnostic decision making would be simpler if informants agree the endorsed symptoms with each other. However, this is not common in both clinical practice and research. While a single high rating from one rater (parents or teacher) and a low rating from another rater cannot rule out the possible diagnosis of ADHD, the likelihood of diagnosis is much lower than when both raters agree on high levels of hyperactivity/inattention being present. Parent- and teacher-rating have been found to be equivalently useful for ADHD diagnosis; there is no difference between screening positive by parent-rating only or teacher-rating alone (Tahillioglu et al., 2021), the attributes might be contributed to various demographics (Johnson et al., 2014). The existence of disagreement between informants may itself imply difficulty in determining the diagnosis. It may also imply that hyperactivity/inattention is observed in one situation only and that this does not constitute ADHD according to the diagnostic criteria, which require symptoms to pervade across more than one context. Disagreement may also reflect false omission and false discovery of ADHD diagnosis from screening tools. In the previous chapter several factors relating to informant discrepancy have been explored, and how they might be brought into agreement/disagreement are suggested. For example, male children and children who had a parent with emotional distress are more likely to be associated with parent-teacher

discrepancy in ADHD screening. These factors may be leveraged to improve screening accuracy.

Current study

In the current study we address: (1) screening accuracy of the SDQ, in terms of sensitivity, specificity, predictive values and AUC; (2) how different informant patterns of parent-teacher disagreement predict diagnosis; (3) how various covariates of informant disagreement influence screening accuracy. The current study will assess the predictive power of informant screening agreement/disagreement patterns on full ADHD diagnostic assessment. Analyses are informed by the findings of Chapter Two where characteristics influencing parent-teacher agreement were identified. These factors are included in the current analysis to test how they contribute to the links between parent-teacher screening agreement and ADHD diagnosis.

3.3 Methodology

Sample, Data Collection and Missing Data

This study uses the same dataset as used in Chapter Two and the preparation is described there.

Measures

Hyperactivity/inattention

The SDQ hyperactivity/inattention subscale was described in Chapter Two.

Perceived Hyperactivity Difficulties

As symptoms alone were not a good indicator of diagnosis, Goodman (1999) suggested that adding a single item measuring perceived difficulties could enhance the prediction of caseness. We used a parent interview item measuring perception of whether their child had a problem with hyperactivity [answered 'no' (0) or 'yes' (1)]. This item was used in preference to the impact questions included in the extended version of the SDQ (Goodman, 1999) as they are not specific to hyperactivity/inattention but rather address all symptomatology covered by the SDQ.

ADHD Diagnosis

As part of the MHCYP survey, the Development and Well-Being Assessment (DAWBA; Goodman et al., 2000a) was completed by parents for children of all ages and by children

over 11, and the short version was administered to teachers. The DAWBA is a combination of highly structured multi-informant interviews, semi-structured probes for reported problems and questionnaires which covers common psychiatric diagnoses in children. The interviews were recorded verbatim for subsequent review by trained clinical raters to decide whether to accept the diagnosis assigned by a computer algorithm, overturn it, or include a diagnosis not made by the algorithm based on the qualitative comments. Diagnoses are based on the criteria of ICD-10 (WHO, 1993). In the current study, the variable named as hyperkinetic disorder from the original MHCYP survey which generated by the DAWBA was used to indicate ADHD diagnosis. In the existing dataset, there was no information regarding ADHD diagnosis made external to the study.

Background Measures

Demographic variables were described in Chapter Two.

Ethical Considerations

The ethical consideration, and procedures of both the original MHCYP study data and the current secondary analysis study were described in Chapter Two.

Statistical Analysis

STATA17 (StataCorp., 2021) was used for the analyses. Due to the criteria that the symptoms of ADHD should be existing in two or more settings (American Psychiatric Association, 2022), the current study proposed a categorical variable set for informant patterns without assuming any necessity of specific weighting for parent or teacher report. Four groups of informant agreement/disagreement patterns using the SDQ band category system (Goodman, 1997) were formed, as described in Chapter Two. Screening accuracy, in terms of sensitivity, specificity, predictive values and AUC, were calculated. The factors that may contribute to the agreement patterns as studied in Chapter Two were added into the prediction of diagnosis via hierarchical binary logistic regression.

To explore the relationship among measured characteristics, parent-teacher agreement, and ADHD diagnosis, eight groups were formed by parent-teacher agreement/disagreement pattern with/without ADHD diagnosis (Figure 3.1). The first two categories, parent-rated and teacher-rated, give the screening results of the children from the informant rating scales. The

multinomial variable then gives the eight categories of screening by informants × diagnosis according to their properties. When both parent and teacher rate as at risk (P1T1) and the ADHD diagnosis turns out to be positive (Dx1) too, the child belongs to the P1T1Dx1 category, that is a true positive. When a child is indicated with low risk by both informants (P0T0) and receives no diagnosis (Dx0), that is a true negative. When a child is rated as low risk by both informants (P0T0) and receives a diagnosis (Dx1), that is a false omission by both informants. When a child is reported by both informants as high risk (P1T1) and receives no diagnosis (Dx0), that is a false discovery by both informants. When high risk is rated by parent only (P1T0) and the child receives a diagnosis (Dx1), that is a teacher false omission. When the high risk is reported by the teacher only (P0T1) and the child receives a diagnosis (Dx1), that is a parent false omission. It is a parent false discovery when a child is rated by only the parent as at risk (P1T0) without receiving the diagnosis (Dx0), while it is a teacher false discovery when the risk is reported by the teacher only (P0T1) for a child receiving no diagnosis (Dx0). These eight groups were regressed on the factors from Chapter Two. To illustrate further how the disagreement may contribute to false omission and false discovery. Multinomial logistic regression was adopted due to the dependent variable being a multinomial categorical variable (Bull et al., 2002; Dwivedi, 2015). Wald tests on coefficients help us to understand the difference among these eight groups. Tests of assumptions, VIF for multicollinearity between variables and H-L statistic for homogeneity, of the regression analyses were also conducted.

Figure 3.1. *Groups categorised according to informant screening and ADHD diagnosis.*

	Diagnosed without ADHD (Dx0)			Diagnosed with ADHD (Dx1)	
Screenings	Teacher rated as not at risk (T0)	Teacher rated as at risk (T1)	Screenings	Teacher rated as not at risk (T0)	Teacher rated as at risk (T1)
Parent rated as not at risk (P0)	True Negative (P0T0Dx0)	Teacher False Discovery (P0T1Dx0)	Parent rated as not at risk (P0)	Both False Omission (P0T0Dx1)	Parent False Omission (P0T1Dx1)
Parent rated as at risk (P1)	Parent False Discovery (P1T0Dx0)	Both False Discovery (P1T1Dx0)	Parent rated as at risk (P1)	P1T0Dx1 Teacher False Omission	True Positive (P1T1Dx1)

3.4 Results

Sample Description

Details of the sample relevant to this analysis were presented in Chapter Two. Around 1.4% of children in the current samples received an ICD-10 ADHD diagnosis from the DAWBA.

The Spearman rank coefficient between the ADHD diagnosis and the SDQ hyperactivity/inattention subscale by parent and by teacher are respectively, parent: rho = .22 ($p<.001$, 95% CI: .20, .25), and teacher: rho = .21 ($p<.001$, 95% CI: .18, .25). The correlation between the ADHD diagnosis and perceived problem by parent: rho = .37 ($p<.001$, 95% CI: .31, .43).

Factors and Parent-Teacher Agreement/Disagreement Patterns predicting ADHD Diagnosis

A binary logit, with/without the ADHD diagnosis, was regressed on the risk factors mentioned in Chapter Two, the parent-teacher agreement/disagreement patterns, and the parent-perceived problem item. The model showed a high likelihood-ratio [LR chi^2 (15) = 344.10, $p<.001$], AIC = 407.82 and BIC = 513.16, McFadden R^2 = .48, and with a H-L statistic of 13.79 ($p>.05$) not rejecting the parallel line assumption of logistic regression (Hosmer et al., 2013). The predictive power of the estimation regression achieved overall of 98.88%, with 1.01% false omission rate, 31.58% false discovery rate, and AUC .96. The likelihood ratio test of the association between informant-discrepancy groups and covariates showed that the covariates brought additional information on the diagnosis of ADHD [LR change (11) = 20.78, $p<.05$].

Table 3.1 displays the binary logistic regression predicting ADHD diagnosis with the informant agreement/disagreement patterns. Only child's age (OR = 1.14, $p<.05$, 95% CI: 1.03, 1.26) and perceived problem reported by parent (OR = 16.58, $p<.001$, 95% CI: 8.96, 30.66), significantly predicted ADHD diagnosis once the parent-teacher agreement/disagreement pattern categories were included as predictors. Taking the both agreed not at risk group as the base category, Wald tests comparing all the pairs of coefficients are displayed in Table 3.2. In general, the both-agreed not at-risk group were significantly different from all other groups on predicting ADHD. The both agreed at risk group was also differentiated from all others on predicting ADHD. There was no significant difference between parent-reported only and teacher-reported only groups in predicting ADHD diagnosis.

Risk Factors Distribution according to Informant Agreement and ADHD Diagnosis

Descriptive statistics for the predictors across the eight groups are shown in the Appendix C.

Table 3.1. *Binary logistic regression of ADHD diagnosis prediction by parent-teacher agreement/disagreement patterns.*

Variables	OR	95% CI	LR change
Block 1			**323.33*** **
Both-agreed not at risk	baseline	baseline	
Parent-reported only	**32.56****	**3.97, 266.81**	
Teacher-reported only	**43.38****	**5.17, 364.20**	
Both-agreed at risk	**185.78*****	**24.09, 1432.98**	
Parent perceived difficulties	**16.58*****	**8.96, 30.66**	
Block 2			**20.78***
Child's characteristics			
Male	2.11	.96, 4.65	
Age	**1.14***	**1.03, 1.26**	
Parent's characteristics			
Male	.39	.04, 3.39	
Age	.99	.94, 1.04	
Positive for emotional issue	1.11	.61, 2.02	
Without a formal degree	.42	.15, 1.15	
Family's characteristics			
Lone parent	.87	.40, 1.87	
Neither parent working	1.50	.69, 3.26	
Below average income	.78	.37, 1.64	
Number of children in household	.77	.57, 1.05	
Ethnicity as Non-White	.95	.24, 3.74	

OR, odd ratio; CI, confidence interval, LR, likelihood ratio.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.

Table 3.2. *Wald test and chi squares among parent-teacher agreement/disagreement patterns on ADHD diagnosis.*

	Both agreed not at risk	Parent-reported only	Teacher-reported only
Parent-reported only	**25.68*****	-	-
Teacher-reported only	**26.66*****	.27	-
Both agreed at risk	**34.30*****	**18.75*****	**9.90****

Bold figures denote statistically significance at: **p<.01; ***p<.001.

False discovery by both raters. Table 3.3 shows that 8.04% of children were rated as at risk by both informants in the current sample. Among them, 12.69% of children received an ADHD diagnosis, meaning that 87.31% of those that did not receive a diagnosis even with both informants reported them as at risk. Of those that were screened positive by both reporters, males were more likely to be diagnosed than females. Comparing with the true negatives group, children who are male, had a parent-informant with an emotional issue, a parent without a degree qualification, with neither parent working, and were from a family earning below average income will be more likely to be falsely discovered; while older children, children with older parent informants, and children rated by Non-White parents were less likely to be falsely discovered by both informants**.**

Table 3.3. *Characteristics distributed between false discovery by both raters.*

	Tests	Multinomial logistic regression		Wald Test
		RRR/CI (base: P0T0Dx0)		chi-squares
	Factors	P1T1Dx0 (n^a=406)	P1T1Dx1 (n^a=59)	P1T1Dx0 vs P1T1Dx1
Child	Male	**3.44*** (2.70,4.38)**	**14.65*** (5.25,40.84)**	**7.34****
	Age	**.96* (.92,.99)**	1.00 (.91,1.10)	.72
Parent	Male	.92 (.51,1.67)	.00 (.00, -)	.00
	Age	**.96*** (.94,.98)**	.98 (.93,1.03)	.26
	Positive for emotional issue	**1.76*** (1.38,2.25)**	1.79 (.97,3.29)	.00
	Without degree	**2.72*** (1.67,4.44)**	1.21 (.45,3.26)	2.11
Family	Lone parent	1.13 (.84,1.51)	.86 (.41,1.84)	.44
	Neither parent working	**1.47* (1.07,2.03)**	**3.05** (1.42,6.55)**	3.13
	Below average income	**1.68*** (1.28,2.22)**	2.02 (.95,4.28)	.21
	Number of children in household	1.01 (.90,1.13)	.82 (.60,1.12)	1.57
	Ethnicity as Non-White	**.51** (.31,.83)**	.43 (.10,1.80)	.05

RRR, relative risk ratio; CI, confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
^{a}Numbers can be slightly different due to variance of missing data for each risk factor.

False discovery by either rater (Table 3.4). Compared to true negatives, male children, children with younger parent informants, and children from families with a below average income were more likely to be falsely discovered by either informant. Younger children, children with parents with emotional issues and without a degree, and children rated by parents who identified themselves as White were more likely to be falsely discovered by parent, but not teacher. Children from families with no parent working were more likely to be falsely discovered by teachers, but not parents. Comparing between parent and teacher false discovery, male children, children from families where neither parent works, and children rated by parents who identified themselves as White were more likely to be falsely discovered by the teacher report. Children with a parent with emotional issues were more likely to be falsely discovered by parents.

Table 3.4. *Characteristics distributed between false discovery by either rater.*

Tests		Multinomial logistic regression		Wald Test
Factors		RRR/CI (base: P0T0Dx0)		chi-squares
		P0T1Dx0 (n^a=501)	P1T0Dx0 (n^a=598)	P0T1Dx0 vs P1T0Dx0
Child	Male	**3.25*** (2.62,4.04)**	**1.94*** (1.62,2.33)**	**14.25*** **
	Age	.97 (.94, 1.01)	**.97* (.94,1.00)**	.06
Parent	Male	1.50 (.99,2.27)	1.20 (.77,1.87)	.60
	Age	**.98* (.96,1.00)**	**.97** (.96,.99)**	.08
	Positive for emotional issue	1.10 (.86,1.40)	**1.62*** (1.32,1.99)**	**6.78****
	Without qualification	1.20 (.88,1.64)	**1.69** (1.24,2.29)**	2.55
Family	Lone parent	.99 (.75,1.31)	.91 (.70,1.17)	.27
	Neither parent working	**1.62** (1.19,2.20)**	1.07 (.79,1.44)	**4.27***
	Below average income	**1.32* (1.03,1.68)**	**1.33** (1.07,1.66)**	.01
	Number of children in household	.99 (.89,1.09)	1.02 (.92,1.12)	.17
	Ethnicity as Non-White	1.20 (.87,1.67)	**.60* (.41,.89)**	**8.14****

RRR, relative risk ratio; CI, confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
^{a}Numbers can be slightly different due to variance of missing data for each risk factor.

False omissions by both raters. In the current sample, only one child received an ADHD diagnosis with both parent and teacher rated as not at risk, comparison is not available due to the singular data point (n=1).

False omissions by either rater (Table 3.5). Compared to true positives, male children were less likely to be falsely omitted by teachers. Moreover, children with parents screened positive for emotional issues were more likely to be falsely omitted by parents. Children from families with a below average income were less likely to be falsely omitted by parents.

Table 3.5. *Characteristics of children false omission by either rater.*

Tests		Multinomial logistic regression			Wald Test		
Factors		RRR/CI (base: P0T0Dx0)			chi-squares		
		P1T1Dx1 (n^a=59)	P0T1Dx1 (n^a=7)	P1T0Dx1 (n^a=9)	P0T1Dx1 vs P1T1Dx1	P1T0Dx1 vs P1T1Dx1	P0T1Dx1 vs P1T0Dx1
Child	Male	**14.65*** (5.25,40.84)**	7.50 (.89,63.01)	1.54 (.41,5.77)	.31	**6.99*** **	1.53
	Age	1.00 (.91,1.10)	1.06 (.82,1.38)	1.03 (.82,1.29)	.17	.05	.03
Parent	Male	.00 (.00,-)	.00 (.00,-)	.00 (.00,-)	.00	.00	.00
	Age	.98 (.93,1.03)	.87 (.74,1.03)	1.03 (.92,1.16)	1.72	.78	2.84
	Positive for emotional issue	1.79 (.97,3.29)	**12.66** (2.33,68.78)**	1.92 (.47,7.92)	**4.57***	.01	2.81
	Without degree	1.21 (.45,3.26)	2.11 (.21,21.31)	1.72 (.20,14.75)	.19	.08	.02
Family	Lone parent	.86 (.41,1.84)	3.63 (.42,31.35)	.19 (.02,2.14)	1.52	1.37	3.18
	Neither parent working	**3.05** (1.42,6.55)**	5.89 (.12,279.03)	6.18 (.82,46.43)	.11	.42	.00
	Below average income	2.02 (.95,4.28)	**.01* (.00,.70)**	.99 (.19,5.11)	**5.96***	.60	**3.90***
	Number of children in household	.82 (.60,1.12)	.55 (.21,1.40)	.71 (.33,1.54)	.64	.11	.18
	Ethnicity as Non-White	.43 (.10,1.80)	2.48 (.26,23.36)	.00 (.00,-)	1.69	.00	.00

RRR, relative risk ratio; CI, confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
[a]Numbers can be slightly different due to variance of missing data for each risk factor.

3.5 Discussion

Predicting ADHD diagnosis from Parent-Teacher Screening and additional risk factors

The current study explored the relationship among parent-teacher agreement/disagreement patterns, ADHD diagnosis, and risk factors. In the current sample we combined SDQ categories of "*borderline*" and "*abnormal*" into "*at risk*", for the SDQ hyperactivity/inattention subscale as described in previous chapter. The false omission rate was very low, while the false discovery rate was moderate. That means it was unlikely that ADHD diagnoses were missed by the SDQ screen but there was a moderately to high chance of false identification. We found that older children were more likely to receive an ADHD diagnosis, which is consistent with the findings of Danielson et al. (2018). In addition, children whose parents reported they had a hyperactivity problem were more likely to receive an ADHD diagnosis in this study. Screening alone did not predict diagnosis well in the current study. Our results fitted with a previous study which suggested that the item of parental perceived difficulties was more predictive than perceived burden or reported duration of symptoms (Goodman, 1999).

In our study, children reported as at risk by either parent- or teacher-reported but not both were more likely to receive an ADHD diagnosis, but their chances were far less than for children where both raters agreed they were at risk. The current findings are similar to Johnson et al. (2014) who used the same measure, i.e. the SDQ, but with different categories. Johnson et al. (2014) showed that the SDQ screening accuracy from one rater can be improved by adding another one, demonstrating the importance of considering both raters in terms of screening accuracy. Our study extended this work to test how different characteristics play a role in the relationships between agreement/disagreement-diagnosis groups and diagnostic outcome. Moreover, the parent-teacher agreement/disagreement patterns used in the current study were modified from the categorisation used by Johnson et al. (2014). Their approach did not include the comparison of other rater agreement patterns with the true negatives, which was a feature of the current analysis. In addition, the Goodman (1999) SDQ predictive algorithm could not distinguish the contribution of different raters because this information was hidden after combining the ratings and impact scores. The current study modified the categorisation to differentiate the four separate categories such that comparisons between each of the pairs could be possible, that is, between either reported at risk versus both reported at risk, between parent-reported at risk versus teacher-reported at risk, and between either reported not at risk versus both reported not at risk. This

categorisation found moderate to high screening accuracy, while it also suggested that some information remained unanalysed and hidden within the informant disagreement.

Our finding of no significant difference between parent-reported only and teacher-reported only groups on ADHD diagnosis is consistent with Tahillioglu et al. (2021) finding that there was no significant difference on the predictability of ADHD diagnosis from only one informant, either parent or teacher. However, this does not indicate that impacts from either informant are identical, and is similar to the ideas suggested by Johnson et al. (2014) that each of the informants explained a different component of the ADHD diagnosis. In addition, the Wald tests between the magnitude of the coefficients provided us with some insights about multiple informant screening. It was found that both agreed not at risk and both agreed at risk groups were differentiated from each other and from the groups that were screen positive by only one rater in the prediction of ADHD diagnosis. This illustrates the impact of informant agreement/disagreement patterns on predicting ADHD diagnosis.

In the current study, when both parent and teacher rated the child as at risk on the SDQ hyperactivity/inattention subscale, a large number of children were falsely identified as screen positives as they did not meet diagnostic criteria. This can be explained by the community sample; the low community prevalence can increase the false discovery rate (Stone et al., 2010; Trevethan, 2017). This result is also consistent with Posserud et al. (2014) which compared different instruments for screening and diagnosing ADHD. The DAWBA identified fewer children for ADHD diagnosis, thus this low prevalence may favour the false discovery which may be hindered when applying a sample with pooled estimate of around 5% prevalence (Polanczyk et al., 2007), with a trade-off of increasing in false omission. There is also a possibility that the DAWBA might be conservative in assigning ADHD diagnoses.

Risk Factors Distributed according to Informant Agreement and ADHD Diagnosis

The current study explored how the risk factors influence informant agreement/disagreement and the outcome of ADHD diagnosis. The multinomial logistic regression with the seven groups (after removal of the category of agreed not at risk but met diagnostic criteria was removed as it contained only one observation) helped to illustrate the multivariate pattern of associations with ADHD diagnosis. Our findings highlight the relationship between mental

health of parents, household income, and child's gender with informant disagreement on reporting ADHD with diagnosis present or not.

Children's characteristics.

Gender. Male children were at risk of being falsely discovered by both or either of the informants. This is consistent with the gender difference in developmental trajectories of attention and impulsivity in the general population. Boys are observed to have more attentional problems, more externalising problems, and more impulsivity than girls (Bongers et al., 2003; Côté et al., 2002). Less teacher-reported false omissions were found among male children. In schools, boys tended to have more classroom problems and more externalising behaviours from kindergarten throughout elementary school (McIntosh et al., 2012; Silver et al., 2005). This may be related to the lower rate of false omissions reported by teachers only that we found. The high sensitivity of the SDQ for male children may also have contributed to this pattern, making it less likely to omit male children with ADHD, but there being a higher chance of a falsely discovering male child without ADHD. This result is also consistent with Posserud et al. (2014) finding that more boys were identified with ADHD using the SDQ, which the authors suggested that the hyperactivity/inattention subscale could be highly sensitive for identifying such cases.

Age. Younger children were found to have a higher chance of false discovery in general, when both informants reported the child as at risk and when only parents reported the child as at risk. In previous research, it was observed that younger children tended to be rated for more ADHD-related symptoms in both parent and teacher ratings (Gomez et al., 1999; Narad et al., 2015). Externalising behaviours in normative developmental trajectories that younger children were scored with more problems (Bongers et al., 2003), which can be explained by the more mature development of self-regulation and ability to sustain attention in older children (Barkley, 1997a; Zhou, 2007).

Parents' characteristics.

Gender. There was no risk of false discovery or false omission attributed to parental gender. Neither did it act as a facilitator for the SDQ screening effectiveness.

Age. Children with younger parents were more likely to be falsely discovered. Unlike the situation of male children, where both informants tended to contribute to the false discovery, children with younger parents were not more likely to be falsely discovered by the teacher alone, but were more likely to be falsely discovered by the parent alone. Younger parental

age is one of the risk factors for general neurodevelopmental problems for children, that children with younger parents tend to present more attention problems (Veldkamp et al., 2021). This might suggest that younger parents might be more likely than older parents to face challenges in psychosocial domains, such as single parenthood, and low SES (Veldkamp et al., 2021). The challenges affect how the informant perceives and reports problems of their children, which is possible that it is a reporter bias.

Education. Children with parents without a formal degree were more likely to be falsely discovered by both or by teacher alone. Parents who achieved higher education levels tend to receive more accurate information about ADHD and have higher levels of awareness and knowledge of ADHD, thus they might provide more accurate reporting of children's behaviours (Amiri et al., 2016; Dodangi et al., 2017). Our finding of higher likelihood of false discovery is consistent with Mieloo et al. (2012) who found that parents with lower parental education levels reported more problems in children. This might lower the screening accuracy compared to parents with higher parental education level (Tahillioglu et al., 2021).

Mental Health. Children rated by parents who screened positive for emotional issues had a higher chance of being falsely discovered by parents or by both informants. The SDQ screening effectiveness is jeopardised also in terms of false omission on top of this by the parents only. The problems of such false discovery and omission do not occur when we consider screened positive by the teacher alone as the informant. Parental mental health conditions affected their perception and reporting of children's behaviours, making parents' overrating more feasible when teachers overrate or not. Although false discovery by both informants remained mysterious, which might be results of unobserved variables such as parent-teacher interaction, inflated ratings in children's problems by parents can be observed when parents are suffering from emotional issues (Najman et al., 2000; Ringoot et al., 2015). This might be explained by the depression-distortion hypothesis, that mental health conditions might affect how individuals perceive and recognize problems, thus it might affect how parents report child's behavioural problems (Richters & Pellegrini, 1989).

Family Characteristics

Ethnicity. Children with ethnic minority parents had lower levels of false discovery by parents or by both informants. Cultural background might affect attitudes, knowledge and reporting of ADHD symptoms (Bussing et al., 2016). Our finding is consistent with previous research that parents from ethnic minority backgrounds tended to report less ADHD-related

symptoms than teachers (Harvey et al., 2013; Lawson et al., 2017; Takeda et al., 2020), possibly reflecting cultural impacts on ADHD rating.

Socioeconomic Status (SES). Unlike most other risk factors, children with no parents working were more likely to be falsely discovered by the teacher report. In addition, children with parents below average income were also more likely to be falsely discovered in general, by both or either of the informants, given the absence of ADHD. Previous research observed that children from a lower SES background also encounter more stressful life situations and tend to be more likely to develop mental health problems (Reiss et al., 2019), thus children who display similar behavioural problems might have different underlying causes other than ADHD. Children from a lower SES background also had more behavioural problems at school (Horoz et al., 2022). From our results, parents are less likely to falsely omit but are more likely to falsely discover. When comparing with true negative, parents with below average income also falsely omitted the child from ADHD diagnosis.

Family Structure. There was no risk of false discovery or false omission related to the number of children in a household and parental marital status. Neither did they facilitate the SDQ screening effectiveness.

Limitations

Our findings and conclusions must be considered in the light of several limitations. First, as the current study is a secondary data analysis from a national community survey, the sample size of children with an ADHD diagnosis is relatively small. It is likely that due to the nature of the DAWBA, which is based on symptoms reported on similar behaviours from the same informants, children who are scored high on the SDQ hyperactivity/inattention subscale will also be likely to cross the DAWBA diagnosis thresholds. Second, the data used in the current study was collected in 2004. The age of the dataset resulted in different diagnostic criteria, such as a different age of onset. For the DSM-IV-TR or ICD-10, the age of onset should be before seven, but the onset age in DSM-5 and ICD-11 changed to before 12 (American Psychiatric Association, 2022; WHO, 2018). Replication of the current study with a more up-to-date dataset might benefit the analysis and the interpretation of our findings. Moreover, other possible characteristics were not included in the current dataset that might explain more about the relationship of parent-teacher discrepancies and ADHD diagnosis. For example, teacher's characteristics, such as ethnicity and stress level, were not included in the current study. Our analysis might have benefited from including such information to explore possible

linkage of teachers' characteristics with informant agreement/disagreement and ADHD diagnosis.

Conclusion and future directions

As hypothesised in Chapter Two, we found that some characteristics from the child, the parent-informant and the family were associated with false discovery and false omission in the content of multiple informants. Our findings extended previous literature on the association between false discovery and false omission with the characteristics in single informant ratings (Madsen et al., 2018). The factors studied can be easily collected within the informant rating process so including them does not add burden to clinicians in the screening effort and are worthy for exploration of improving screening accuracy. The factors measured here, such as parental emotional status, can be routinely measured in screening to facilitate diagnostic decision making especially when informants do not agree with each other. Even with the inclusion in the screening process of the factors discussed here, screening accuracy based on parent and teacher reports will still have some inaccuracies. Therefore, further measures may be needed such as including objective measures of attention, hyperactivity and/or impulsivity and ADHD-related domains to enhance the understanding of the relationship with the diagnosis. Additional measures might be able to improve the current large number of false positives in the current study, suggested by Trevethan (2017). The addition of screening tests on other dimensions, e.g., executive functioning, might greatly benefit the ruling out of false discovery. Conducting such additional screening procedures might not consume much more effort on top of the SDQ and could be highly cost-efficient in improving the overall accuracy of the screening process. The next chapter addresses the contribution of executive functioning measures to screening procedures.

Chapter Four: Can informant rating and performance measures of executive functions improve prediction of ADHD diagnosis in children and teens?

4.1 Abstract

In Chapter Three, it was shown that integrating information from parents and teachers improved diagnostic accuracy while minimising false omissions. However, large numbers of false discoveries remained. Enhancing specificity remains important in clinical research. Adding information on executive functioning offers a potentially useful addition to the ADHD screening process as supported by some preliminary evidence in the literature. Informed by previous chapters, this study explores the relationships between parent-reported executive function ratings and child performance tasks with false discovery and false omission in a multi-informant screening context. Analyses were based on the Adolescent Brain Cognitive Development Study, which included a sample of 11876 children aged 9 to 10 at baseline across 21 United States study sites. The ADHD diagnosis was measured using the parent interview of Kiddie Schedule for Affective Disorders and Schizophrenia for DSM-5 (KSADS-COMP). The screening accuracy of parent- and teacher-reported Attention Problems scales combined with parental executive functions ratings and child executive task performance was assessed. The characteristics of children who were falsely discovered and falsely omitted on the basis of the Attention Problems scales were examined in terms of the executive function measures and the factors studied in previous chapters. Although neither executive function ratings nor task performance predicted ADHD diagnosis alone, both measures significantly predicted false discovery and false omission. Therefore, these executive functioning measures provided additional information that can help distinguish true negatives and true positives during the ADHD screening process.

4.2 Introduction

Integrating parent and teacher ratings improves ADHD screening accuracy (Goodman et al., 2000b; Raiker et al., 2017) and fulfils the cross-setting symptom presentation as required in the diagnostic criteria of the disorder (e.g., American Psychiatric Association, 2022; WHO, 2018). As illustrated in the previous chapter, improved screening accuracy resulted from the integration of two informants to effectively reduce false omissions. The commonly observed large number of false discoveries, remain a challenge for ADHD screening (e.g., Martel et al., 2021). Our findings in the previous chapters showed how informant discrepancy and screening-diagnostic accuracy are related to contextual factors reported. However, the mechanisms underlying how contextual factors affect both the parent-teacher discrepancy and the ADHD screening-diagnostic accuracy remain underexplained. A range of factors have been shown to predict informant discrepancy and screening-diagnostic accuracy. For example, in Chapter Two, we observed that parent-teacher discrepancy may be due to overrating by parent-informants when they are influenced by emotional distress. In Chapter Three, we observed that children are more likely to be falsely discovered by parent-informants who screened positive for emotional issues. This implies that the approach of integrating ADHD ratings from both parents and teachers is not fully efficient. Research examining other ways to improve specificity is important to enhance the process of screening before referring for ADHD diagnostic assessment.

In Chapter Three, it was found that integrating ADHD screening from both parent and teacher improved diagnostic accuracy with minimised false omissions, which improved on the limitations from similar research where single informants were only included (Ezpeleta et al., 2015). However, the number of false discoveries remained substantial. Integrating information from multiple informants did not resolve the problem of the high false discovery rate associated with informant rating scales (Chen et al., 2022). Enhancement of specificity remains an important goal for clinical research. Trevethan (2017) recommended that in order to reduce the number of false discoveries, follow-up tests should be performed especially when these are inexpensive, easily and quickly performed, and not stressful for both examinees and informants. Information on executive functioning, whether from informant reports or performance measures offers a potentially useful additional perspective to the screen process (Chen et al., 2022) which could address this specificity problem (Rauch et al., 2012).

As described in Chapter One, individuals with ADHD tend to perform worse than control samples in executive function tasks (e.g., Willcutt et al., 2005). Executive dysfunctions, such as impairments in response inhibition, vigilance, and working memory, are reported as associated weaknesses in ADHD samples compared to non-affected clinic-referred and community samples (Pievsky & McGrath, 2018). However, the relationship between executive functions and ADHD diagnosis remains controversial (Brown, 2007). There is evidence that measures of executive functions do not act alone as significant predictors but are complementary to ADHD rating scales in screening facilitation (e.g., Ezpeleta et al., 2015). For example, none of the executive function performance measures were able to classify children with ADHD from children without ADHD (Tan et al., 2018). In contrast to executive function performance measures, executive function rating scales had fair to excellent diagnostic utility in differentiating children with ADHD from children without ADHD (e.g., Karr et al., 2021; O'Brien et al., 2021; Tan et al., 2018). While results for diagnostic utility of performance measures of executive functions alone bring cautions in implementation, integration of information from the rating scales and performance measures do facilitate the classification accuracy for ADHD (e.g., Tan et al., 2018; Veloso et al., 2022).

Although CPTs alone were not clinically useful for identifying ADHD (Arrondo et al., 2024), when used in addition to behavioural informant report, ADHD screening utility was improved by objectives measures (Bledsoe et al., 2020; Chen et al., 2022; Tallberg et al., 2019). Emser et al. (2018) found that overall accuracy improved from 78% (objective measures alone) to 86.7% (integrating parent-reported ADHD rating and objective measures) to predict ADHD diagnosis in children. The informant ratings explained most of the prediction, the objective measurements did not add much over the data from informant ratings. Post-test probability of screening accuracy were improved when CPT was implemented, not only among the groups where parent-teacher rating was convergent but also when the ratings were divergent (Tallberg et al., 2019). In addition to improved overall diagnostic classification rates, there were improvements in AUC (from .81 to .87) in preschool children samples when integrating ADHD-related informant rating with CPT (Chen et al., 2022). There were also improvements in sensitivity (from 65.79% to 81.58), and predictive values (PPV: from 83.33 to 86.11; NPV: from 67.50 to 79.41) but specificity was unchanged (84.38%) (Chen et al., 2022). Previous studies support the integration of ADHD rating scales and objective measures highlighting the best prediction when they are included in the same model.

In addition to the evidence that informant ratings of executive functions predict ADHD diagnosis (Toplak et al., 2008), there is evidence that such additional measures aid ADHD diagnostic decision-making (Veloso et al., 2022). For example, when integrating executive function informant ratings and performance tasks, the rating scales were significant predictors while the performance tasks were not (Toplak et al., 2008; Veloso et al., 2022). In contrast, another study found that parent-reported rating of inattention, but not parent-rated impairment in executive functions, predicted ADHD diagnosis significantly and performance in executive functions did not improve the prediction (Bünger et al., 2021). Limited research has focussed on the predictive power of informant ratings in executive functions as additional measures to ADHD rating scales for screening the disorder. Thus, further study on the improvement of diagnostic accuracy by integrating informant rating of ADHD and measures of executive functions would be informative regarding possible improvement that these measures could bring to screening accuracy in clinical practice.

In the current chapter, we investigate bringing executive function rating and performance tasks into the process of screening for and diagnosing ADHD. First, the analysis in Chapter Two will be replicated. Replicating the approach will enhance our understanding on the relationship between parent-teacher discrepancy on reporting ADHD symptoms and the listed covariates, especially with a more-up-to dataset, as mentioned in Chapter Three. Second, the current study aims to explore if both informant rating and performance tasks in executive function improve the overall accuracy of the screening process for ADHD beyond informant-based ADHD ratings. Third, we include measures of executive functions to analyse how the characteristics explored in Chapter Two and informant agreement/disagreement patterns may contribute to the distribution of false omission and false discovery by multinomial logistic regression. This design modified from the Chapter Three illustrates how executive function assessment may conduct the complementary role of helping to rule out those who are not likely to have ADHD (i.e., being specific) and in cases where ADHD informant ratings identify the possibility of ADHD (i.e., being sensitive).

4.3 Methodology

Protocol Pre-Registration

The objectives, research questions, and hypotheses were pre-registered with the Open Science Framework as secondary data preregistration (https://osf.io/zsnw9) on March 2, 2023. Prior to the approval of accessing the dataset, the data structure was viewed via the

Data Dictionary of the National Institute of Mental Health Data Archive (https://nda.nih.gov). The availability of targeted variables in the dataset was explored after downloading the dataset when preparing the pre-registration documentation. Some modifications were made compared to the pre-registered procedure. First, the original targeted variable, ADHD diagnosis, was originally included in the selected dataset, however, the diagnostic data was not publicly available in the Release 4.0 due to previous programming algorithm errors (Jernigan et al., 2021). Thus, the ADHD diagnosis was derived from the items corresponding to the DSM-5 diagnostic criteria in the parent diagnostic interview from Kiddie Schedule for Affective Disorders and Schizophrenia for DSM-5 (KSADS-COMP; Townsend et al., 2020), which will be discussed in detail in the Measures section below. Second, although the timeframe of data collection for analysis was not specified in the pre-registered document, the three-year follow-up was targeted for analysis. Key variables, such as ADHD diagnosis, parent and teacher ADHD screening, performance and rating of executive function were collected at this time point as indicated from their protocol. However, according to the same Release Notes (Jernigan et al., 2021), the items from KSADS-COMP for ADHD diagnosis were missing at this data collection point. In addition, some items from the executive function rating were not listed in the original study. To test the stated hypotheses, we selected data from the two-year follow-up, where alternative ratings of executive functioning and ADHD diagnosis were available.

Sample and Data Collection

The data for this study was taken from the longitudinal Adolescent Brain Cognitive Development (ABCD) Study. The study dataset was accessed via the NIMH Data Archive (https://nda.nih.gov/abcd/), which is made available with an approved Data Use Certification by an authorised signatory official from a sponsored institution to access. The dataset provides a sample of 11876 children aged 9 to 10 at baseline recruited during September 2016 to October 2018 across 21 United States study sites. The baseline and follow-up contact points collect data of various areas on the children by multiple informants. The study protocol was described in Garavan et al. (2018) and summaries of timeline and protocols of each stage can be found at https://abcdstudy.org/scientists/protocols/. Data analysis in the current study was conducted using the two-year follow-up data on the Curated Annual Release 4.0.

Missing Data

In the existing dataset from the two-year follow-up, 10414 families completed interviews. The percentages of missing values of variables except three variables (ADHD screening by parents and teachers and the executive function performance task) were between 0% and 8.54%. In the current study, for any variables with any one item missing or unrecognised coding was recoded as missing. The completion rates were 77.64%, 39.12% and 76.20%, for parent-reported ADHD screening, teacher-reported ADHD screening, and the executive function task respectively. Pairwise deletion was used for the logistic regressions.

Measures

ADHD Screening

The Attention Problems (AP) scale from the parent/caregiver-reported CBCL and teacher-reported Brief Problem Monitor (BPM/T), as parts of the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach et al., 2011; Achenbach & Rescorla, 2001), are available in the current dataset. Both CBCL and BPM/T measures behavioural and emotional problems in children aged 6 to 18 years. Psychometric properties were good in the original format, its abbreviated versions and its translations (e.g., Achenbach & Rescorla, 2001; Leung et al., 2006; Richter, 2015). The CBCL-AP scale includes 11 items relating to inattention, hyperactivity, and impulsivity, addressing the past six months. The BPM/T-AP scale consists of 6 relevant items over a time intervals indicated by the rater. The items from the CBCL were scored as "*not true (as far as you know) = 0*", "*somewhat or sometimes true = 1*" and "*very true or often true = 2*" and items from the BPM/T were scored as "*not true (as far as you know) = 0*", "*somewhat true = 1*" and "*very true = 2*". The sum of these scales can be computed into T scores based on norms for age and gender. The T scores can be categorised into "*normal (<65)*", "*borderline clinical (69>65)*" and "*clinical (>70)*" for the CBCL-AP subscale and "*normal (<65)*" and "*elevated (>65)*" for the BPM/T-AP scale. The T scores range from 50 to 100 for the CBCL and from 50 to 75 for the BPM/T. The CBCL-AP scale was found to be clinically useful for identifying ADHD with pooled sensitivity and specificity of .77 and .73 respectively (Chang et al., 2016). Sensitivity and specificity of the longer version of the teacher-reported AP scale for identifying ADHD ranged from .51 to .56 and from .68 to .83 respectively (Edwards & Sigel, 2014; Gomez et al., 2021). Prediction of ADHD diagnosis was improved when integrating the parent-reported AP scale with teacher rating in ADHD-related problems (Raiker et al., 2017; Roigé-Castellví et al., 2020). In the current study, the categorisation of T scores over 65 as "*at risk*" and under 65 as "*not at risk*"

instead of the total T scores of the AP scales were used for comparisons. A 2×2 matrix of parent-teacher agreement/disagreement patterns using this cut-off were formed, as displayed in Figure 4.1.

Figure 4.1. *Groups categorised according to parent-teacher agreement/disagreement patterns.*

Parent/Teacher	T-score under 65	T-score over 65
T-score under 65	Both agreed not at-risk	Teacher-reported only
T-score over 65	Parent-reported only	Both agreed at risk

ADHD Diagnosis

As part of the ABCD study, the computerised version of the Kiddie Schedule for Affective Disorders and Schizophrenia for DSM-5 (KSADS-COMP; Townsend et al., 2020) was completed by parents and children. KSADS-COMP is a semi-structured interview using diagnostic criteria from DSM-5 combining screening questions and more detailed modules for childhood mental disorders. Diagnostic categories are probed when the related screening is endorsed. In the current study, as mentioned in the *Protocol pre-registration* section above, ADHD Diagnosis was derived from the items corresponding to the DSM-5 diagnostic criteria from the parent diagnostic interview from KSADS-COMP. Participants were placed into the ADHD group if they met at least six current symptoms from either inattention or hyperactivity for at least six months (criterion A), with onset before age of 12 (criterion B) for two or more settings (criterion C) and with significant impairment (criterion D) at the time of two-year follow-up assessment, as specified in DSM-5 (American Psychiatric Association, 2022).

Executive Functioning Rating

The parent-reported Inhibitory Control subscale, which measure the potential of a child to plan and suppress inappropriate responses, from the Effortful Control scale of the Early Adolescent Temperament Questionnaire-Revised (Capaldi & Rothbart, 1992; Ellis, 2002) was used to measure executive function. The subscale has been found to have mixed reliability, coefficient alpha from .56 to .86, in previous studies (e.g., Ellis, 2002; Ellis & Rothbart, 2001; Fosco et al., 2019). The Inhibitory Control subscale consists of five items and is scored as "*almost always untrue = 1*", "*usually untrue = 2*", "*sometimes true sometimes untrue =3*", "*usually true = 4*" and "*almost always true = 5*" with two reverse

scored items. *"When someone tells me to stop doing something, it is easy for me to stop"* is an example item of this subscale. In the current study, the sum is computed for current analysis. Higher scores of this subscale reflect more behavioural control. The Effortful Control scale has been found to have a significant negative association with ADHD symptoms, from -.31 to -.53 (e.g., Krieger et al., 2019; Martel et al., 2011) and externalising problems measured by the CBCL (Oldehinkel et al., 2004). It has also been found to moderately correlate with inhibition tasks (Krieger et al., 2019).

Executive Functioning Performance

The Flanker Inhibitory Control and Attention Test from the NIH Toolbox® (Weintraub et al., 2013), is used to measure executive functioning performance in the current study. The test was developed from the Eriksen Flanker task (Eriksen & Eriksen, 1974), which measures participants' capability to inhibit response to irrelevant visual stimuli while focusing on a given stimulus. Scores are calculated from twenty trials, in which higher scores represent higher levels of inhibitory control for attention. The uncorrected standard scores, which compares the performance with the general US population disregarding any demographic variables, were gathered during the development of the NIH Toolbox national norms. The intraclass correlation coefficient for test-retest reliability from 3 to 15 years old children is .95 (Weintraub et al., 2013). The test was found to be positively correlated with D-KEFS Inhibition raw scores in samples from 8- to 15-year-olds (Zelazo et al., 2013). It has demonstrated the executive functions of children aged four to ten are positively correlated (Spearman correlation = .55) with signal detection by neurological measures (Zhou et al., 2021).

Demographic Variables

Parent's/caregiver's age, gender ['female' (0), 'male' (1)], parents' educational level ['completed a formal degree or above' (0) or 'did not complete a formal degree' (1)], and self-reported mental health condition were included as characteristics of parent-informant. Self-reported parental mental health condition were measured by the Depressive Problems Scale, a subscale based on DSM-5 depressive disorders criteria, from the Adult Self Report questionnaire of the ASEBA (Achenbach & Rescorla, 2003). The items were scored as "*not true = 0*", "*somewhat or sometimes true = 1*" and "*very true or often true = 2*". The sum is converted into T scores based on norms for age and gender and the T scores can be categorised into "*normal (<65) = 0*", "*borderline/clinical (>65) =1*". Family characteristics

consist of ethnicity [‘White’ (0), ‘non White’ (1)], family structure [‘not lone parent’ (0) or ‘lone parent’ (1), and number of children in household], socioeconomic characteristics [‘household income above 75k’ (0) or ‘household income below 75k’ (1) (Nagata et al., 2022; approximate median annual income in the United States)], family’s employment status [‘both parents or one parent working’ (0) or ‘neither parent working’ (1)].

Ethical Considerations

The ethics framework and guideline of the ABCD study can be found in Clark et al. (2018). Ethical review and approval of the research protocol of ABCD study was obtained at the University of California, San Diego, with procedures approved from local institutional review boards (Auchter et al., 2018). Written informed consent was obtained from parents/caregivers of the child participants and children participated with their verbal consent. Ethics approval (Reference Number: 051265) for the current study was obtained from the ethics committee at the University of Sheffield, adhering to ‘Research Ethics: General Principles and Statements’ during the study.

Statistical Analysis

STATA17 (StataCorp., 2021) was used for the analyses. The current study takes the same analysis approach as the previous two chapters. Firstly, correlation between parent- and teacher-reported ADHD screening is explored with weighted kappa to demonstrate the agreement/disagreement between the AP scales. A higher value of kappa shows that there is stronger agreement between informants. Secondly, a multinomial logistic regression was used to predict the pattern of parent-teacher agreement/disagreement from the factors explored in previous chapters. The relative risk ratios of the specific factors indicate the likelihood of falling into the specific agreement/disagreement groups compared to the baseline group, and significance from the Wald test will indicate significant differences in the likelihood of falling into different agreement/disagreement groups.

Thirdly, the current study will repeat the prediction of ADHD diagnosis using the same factors in the previous study, i.e., covariates and AP scales, with the executive functions rating and task. This hierarchical binary logistic regression on ADHD diagnosis identifies which of the factors contribute to the prediction of ADHD diagnosis in the screening process independently from covariates, with AP scales T-scores normed with age and gender. Higher ORs in the logistic regression demonstrate higher likelihood of ADHD diagnosis from the

specific variables. The likelihood ratio test shows incremental effect from the addition of variables, i.e., the covariates, on top of the informant agreement/disagreement categories, and a significant Wald test demonstrates difference between two specific groups in prediction of likelihood of ADHD diagnosis (e.g., comparing between informant-agree at risk group to respective informant-disagree groups).

Lastly, a tabulated 2×2×2 multinomial variable which resembles Figure 3.1 in the last chapter is adapted to give the eight categories of screening by informants × diagnosis according to their properties. A hierarchical multinomial logistic regression will be run on these groups from the covariates plus the executive function rating and task. Significance in the relative risk ratios from a factor suggests a significant difference in likelihood of the specific factor (e.g., a higher chance of teacher false discovery on female children compared to the baseline category, the True Negative group). The likelihood ratio test shows incremental effect by addition of executive functioning on the covariates in explaining the outcome categories. Additional Wald test will demonstrate the significant difference, if any, between any two of the categories of interest. Tests of assumptions [VIF for multicollinearity between variables, H-L statistic for homogeneity of multinomial logistic regression] of the regression analyses were also conducted.

4.4 Results

Sample Description

The final dataset from the two-year follow-up assessment consisted of 10414 parent (11.43% male, 87.73% female, .85% missing) /child (52.36% male, 47.64% female) dyads. Child ages ranged from 10 years 7 months to 14 years old with mean age 12 years (SD = 7.95 months). The age of the interviewed parent/caregiver ranged from 24 to 82 years with mean age 42.19 with standard deviation 6.78 years. Ethnic origin of White (65.04%) and non-White (33.57%) are recorded. In terms of family structure, the percentage of lone parents was 24.94% and the mean number of children in a household was 2.61 with standard deviation 1.30. Regarding annual household income, 37.72% of families were below 75k US dollars, which is the approximate median annual income in the United States (Nagata et al., 2022). Regarding the family's employment status, the percentage of neither parent working was 1.71. The percentage of interviewed parents reported completing at least a formal degree is 61.54. In terms of emotional issues measured by the Depressive Problems Scale from Adult Self

Report, 8.64% of interviewed parents were scored as "*at risk*". The percentage of children who met all criteria set in the methodology as the ADHD group is 5.4.

In the current study, parent-teacher correlation at the AP subscale was low both in terms of informant-reported attention problems using cut-off of T scores 65 (Cohen's weighted kappa = .20, p<.001, CI: .15, .25) and using T scores from each informant (Cohen's weighted kappa = .27, p<.001, CI: .25, .29). The parent-reported Inhibitory Control subscale was unrelated to the Flanker Test (Pearson correlation = -.01, n.s.) and was positively correlated with both parent- (Pearson correlation = .18, p<.001) and teacher-reported (Pearson correlation = .07, p<.001) AP subscale using T-score. The Flanker Test was negatively correlated with both parent- (Pearson correlation = -.10 , p<.001) and teacher-reported (Pearson correlation = -.14, p<.001) AP subscale using T-score. The ADHD diagnosis was positively correlated with the Inhibitory Control subscale (Spearman's r = .08, p<.001) and negatively correlated with the Flanker task (Spearman's r = -.03, p<.05). The ADHD diagnosis was positively correlated with both parent- (Spearman's r = .35, p<.001) and teacher-reported (Spearman's r = .22, p<.001) AP subscale using T-score.

Characteristics of Parent-Teacher Discrepancy

Four categories were formed according to the parent-teacher agreement/disagreement patterns: both agreed not at risk, parent-reported only, teacher-reported only, and both agreed at risk. In current analysis, 3541 pairs were used. Multinomial logistic regression was used to regress the categorical outcome variable onto parent (gender, age, emotional issue, and education level), and family characteristics (marital status of parents, employment, household income, number of children in household, ethnicity) (LR chi^2 = 135.21, p<.001, pseudo R^2 = .04). Descriptive statistics and relative risk ratios are displayed in Table 4.1. The results of Wald test comparing RRR of informant pairs are listed in the Appendix D.

Regarding parent's characteristics, children with parents who were screened as at risk for depression were more likely to be rated as at risk by parent alone (RRR = 4.30, p<.001, CI: 2.70, 6.83), compared to when both informants reported not at-risk. They were less likely to be rated by teachers alone as at risk, compared to parents alone (chi^2 = 21.31, p<.001) or rated at risk by both informants (chi^2 = 14.61, p<.001). Children with a parent without a formal degree were more likely to be rated as at risk by teacher alone (RRR = 1.54, p<.01,

CI: 1.11, 2.14), compared to when both informants reported as not at-risk. Parental age and gender were not associated with parent-teacher discrepancy in ADHD screening.

In terms of family characteristics, children with lone parents (RRR = 1.54, p<.05, CI: 1.11, 2.15), and from a family with household income less than 75k (RRR = 1.67, p<.01, CI: 1.19, 2.34) were more likely to be rated by teacher alone as at risk, compared to when both informants reported as not at risk. Number of working parents and number of children in the household were not associated with parent-teacher discrepancy in ADHD screening.

Table 4.1. *Multinomial logistic regression of parent-teacher agreement/disagreement patterns predicted by risk factors.*

Risk factors	Mean/Rate[a]				RRR/CI (base: Both agreed not at risk)		
	Both agreed not at risk (n^b=3498)	Parent-only (n^b=145)	Teacher-only (n^b=290)	Both agreed at risk (n^b=74)	Parent-only	Teacher-only	Both agreed at risk
Parent characteristics							
Male-informant	12.09%	9.66%	9.66%	2.70%	.83 (.45,1.52)	.86 (.54,1.35)	**.23* (.05,.94)**
Age	42.64 (6.30)	42.91 (7.59)	41.48 (7.39)	42.15 (8.42)	1.02 (.98,1.05)	1.01 (.98,1.03)	.99 (.95,1.03)
Screened positive for emotional issue	7.63%	27.59%	6.90%	22.97%	**4.30*** (2.70,6.83)**	.88 (.51,1.49)	**3.99*** (2.17,7.32)**
Without a formal degree	29.07%	37.93%	50.00%	47.30%	1.07 (.66,1.74)	**1.54** (1.11, 2.14)**	1.63 (.90, 2.98)
Family characteristics							
Lone parent	19.13%	33.10%	36.55%	33.78%	1.38 (.83,2.28)	**1.54* (1.11,2.15)**	1.44 (.78,2.67)
Neither parent working	0.91%	0.69%	1.72%	2.70%	.76 (.10,5.99)	1.36 (.46,4.04)	2.99 (.64,13.88)
Below average income	27.56%	37.24%	46.21%	44.59%	1.39 (.84,2.29)	**1.67** (1.19,2.34)**	1.37 (.72,2.59)
Number of children in household	2.64 (1.28)	2.41 (1.27)	2.62 (1.35)	2.43 (1.25)	.90 (.77,1.06)	.99 (.90,1.10)	.82 (.67,1.01)
Ethnicity minority	24.36%	32.41%	37.24%	29.73%	1.02 (.65,1.62)	1.07 (.79,1.46)	.88 (.49,1.60)

RRR, relative risk ratio; CI, 95% confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
[a]All numbers correspond to rates, except for age given in mean number of years and for numbers of children in household given in mean number of children.
[b]Numbers can be slightly different due to variance of missing data for each risk factor.

Factors predicting ADHD Diagnosis

Table 4.2 shows the hierarchical binary logistic model that regressed ADHD diagnosis on the risk factors mentioned in the previous chapter, the parent-teacher agreement/disagreement patterns, and executive functioning measured by parent-reported rating and performance task. A likelihood ratio test between the first block of informant discrepancy groups [LR change (3)= 351.92, p<.001] and the second block showed that the covariates bring additional information to the prediction of ADHD [LR change (9) = 42.23, p<.001]. The likelihood ratio test on the last two blocks [LR change (1) = .00 and 1.81 respectively, both n.s.] showed that the measures of executive functions do not improve the prediction of ADHD. The overall model had a high likelihood-ratio [LR chi^2 (14) = 395.96, p<.001], AIC = 1073.04 and BIC = 1165.09, McFadden R square = .28, and with a H-L statistic of 9.24 (p>.05) not rejecting the parallel line assumption of logistic regression (Hosmer et al., 2013). The predictive power of the estimation regression was 95.06%, with 3.74% false omission rate, 42.45% false discovery rate, and AUC .83, with sensitivity 32.97%, specificity 98.61%, PPV 57.55%, and NPV 96.26%. Taking the both agreed not at risk group as the base category, Wald tests comparing the agreement/disagreement patterns of coefficients are displayed in Table 4.3.

Table 4.2. *Hierarchical binary logistic regression of ADHD diagnosis prediction by pant-teacher agreement/disagreement patterns.*

Variables		OR	95% CI	LR change
Block 1				**351.92*** **
	Both-agreed not at risk	baseline	baseline	
	Parent-reported only	**44.44*** **	**27.01, 73.10**	
	Teacher-reported only	**5.55*** **	**3.40, 9.05**	
	Both-agreed at risk	**54.31*** **	**29.36, 100.48**	
Block 2				**42.23*** **
parent	Male-informant	**.32** **	**.15, .67**	
	Age	1.01	.98, 1.04	
	Screened positive for emotional issue	**3.16*** **	**1.96, 5.10**	
	Without a formal degree	.89	.57, 1.40	
family	Lone parent	.61	.35, 1.05	
	Neither parent working	.19	.02, 1.86	
	Below average income	.85	.52, 1.38	
	Number of children in household	1.03	.89, 1.18	
	Ethnicity minority	.78	.50, 1.21	
Block 3				.00
	Executive function rating	1.00	.93, 1.08	
Block 4				1.81
	Executive function performance	1.02	.99, 1.04	

OR, odd ratio; CI, confidence interval, LR, likelihood ratio.
Bold figures denote statistically significance at: **p<.01; ***p<.001.

Table 4.3. *Wald test and chi-squares among parent-teacher agreement/disagreement patterns on ADHD diagnosis.*

	Both agreed not at risk	Parent-reported only	Teacher-reported only
Parent-reported only	**37.38*** **	-	-
Teacher-reported only	**23.25*** **	**45.76*** **	-
Both agreed at risk	**37.71*** **	.33	**41.18*** **

Bold figures denote statistically significance at: **p<.01; ***p<.001.

Risk Factors Distributed according to Informant Agreement and ADHD Diagnosis

Descriptive statistics for the eight groups, followed by the multinomial logistic regression, are shown in Appendix E (LR chi^2 = 283.51, p<.001, pseudo R^2 = .07). Executive functions rating [LR change (7) = 42.99, p<.001] and performance task [LR change (7) = 39.56,

p<.001] also show a significant incremental effect on prediction of the parent-teacher agreement/disagreement patterns × diagnosis categories.

False discovery by both raters. In the current sample, 1.85% of children were rated as at risk by both informants, but only 48.65% of them were rated by both informants as at risk but did not receive an ADHD diagnosis. As displayed in Table 4.4, compared to true positives, children who are with lower scores in parent-rated executive function (chi^2 = 10.18, p<.01) will be more likely to be falsely discovered by both informants. Compared to the true negatives, children with a lone parent, a parent with depression, and have a higher score in parent-reported executive function will be more likely to be falsely discovered; when children with higher scores in executive function performance and more siblings are less likely to be falsely discovered.

Table 4.4. *Characteristics distributed between false discovery by both raters.*

Tests		Multinomial logistic regression		Wald Test
Factors		RRR/CI (base: True Negative, P0T0Dx0)		chi-squares
		Both False Discovery P1T1Dx0 (n^a=32)	True Positive P1T1Dx1(n^a=36)	P1T1Dx0 vs P1T1Dx1
Parent	Male-informant	.00 (.00,-)	.45 (.10,1.93)	.01
	Age	.97 (.91,1.04)	.98 (.92,1.04)	.00
	Screened positive for emotional issue	**3.43* (1.23,9.57)**	**4.51*** (1.95,10.43)**	.00
	Without a formal degree	1.22 (.47,3.15)	1.56 (.66,3.69)	.30
Family	Lone parent	**2.76* (1.09,6.96)**	.89 (.33,2.40)	3.06
	Neither parent working	6.55 (.70,61.31)	2.81 (.33,24.23)	.14
	Below average income	.93 (.33,2.61)	.93 (.36,2.36)	.89
	Number of children in household	**.61** (.42, .88)**	.92 (.69,1.21)	2.72
	Ethnicity minority	.70 (.27,1.81)	1.27 (.56,2.85)	.17
EF	Performance	**.92** (.88,.97)**	.97 (.93,1.02)	2.46
	Rating	**1.21* (1.01,1.45)**	**1.23* (1.04,1.44)**	**10.18****

EF, executive functions; RRR, relative risk ratio; CI, 95% confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
[a]Numbers can be slightly different due to variance of missing data for each risk factor.

False discovery by either rater. In the current sample, 10.61% of children were rated as at risk by either informant, but 77.46% of them were falsely discovered by either rater. As illustrated in Table 4.5, compared to true negatives, children of parents with depression, of ethnic minority, with higher parent-reported executive functioning and with lower scores in executive function performance are more likely to be falsely discovered by teacher-informant only. Children with parents of no degree, with a lone parent, of below average income, with higher parent-reported executive function, and with lower scores in executive function performance are more likely to be falsely discovered by parent-informant only. Comparing between parent or teacher false discovery, children from an ethnic minority background (chi^2 = 12.44, p<.001) and higher parental executive function rating (chi^2 = 25.33, p<.001) were more likely to be falsely discovered by teacher but not parent.

Table 4.5. *Characteristics distributed between false discovery by either rater.*

Tests		Multinomial logistic regression		Wald Test
Factors		RRR/CI (base: True Negative, P0T0Dx0)		chi-squares
		Teacher False Discovery P0T1Dx0 (n^a=67)	Parent False Discovery P1T0Dx0 (n^a=256)	P0T1Dx0 vs P1T0Dx0
Parent	Male-informant	1.21 (.54,2.74)	.98 (.61,1.56)	.20
	Age	1.01 (.97,1.06)	1.00 (.98,1.02)	.21
	Screened positive for emotional issue	**3.78*** (1.95,8.11)**	.77 (.42,1.43)	2.54
	Without a formal degree	1.38 (.67,2.83)	**1.57* (1.10,2.23)**	.00
Family	Lone parent	1.21 (.56,2.63)	**1.57* (1.10,2.23)**	1.22
	Neither parent working	1.58 (.18,14.11)	1.54 (.51,4.70)	.11
	Below average income	.82 (.37,1.84)	**1.67** (1.15,2.40)**	3.40
	Number of children in household	.85 (.66,1.09)	.99 (.89,1.11)	.37
	Ethnicity minority	**1.95* (1.04,3.65)**	1.01 (.72,1.41)	**12.44****
EF	Performance	**.94*** (.91,.97)**	**.96*** (.95,.98)**	2.07
	Rating	**1.35*** (1.19,1.54)**	**1.08* (1.01,1.16)**	**25.33****

EF, executive functions; RRR, relative risk ratio; CI, 95% confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
^{a}Numbers can be slightly different due to variance of missing data for each risk factor.

False omissions by both raters. In the current sample, 5.57% of children received an ADHD diagnosis and 40.64% of them were falsely omitted by both informants. As illustrated in Table 4.6, compared to true negatives, children with female parent-informant, with parents encountering emotional distress, with higher rating in executive function are more likely to be falsely omitted by both informants. Meanwhile, compared to true positives, children with higher parental ratings in executive function ($chi^2 = 9.80$, $p<.01$) were more likely to be correctly identified instead of being falsely omitted by both informants.

Table 4.6. *Characteristics distributed between false omission by both raters.*

Tests		Multinomial logistic regression		Wald Test
Factors		RRR/CI (base: True Negative, P0T0Dx0)		chi-squares
		Both False Omissions P0T0Dx1 (n^a=89)	True Positives P1T1Dx1 (n^a=36)	P0T0Dx1 vs P1T1Dx1
Parent	Male-informant	**.20** (.06, .64)**	.45 (.10,1.93)	1.05
	Age	1.01 (.97,1.06)	.98 (.92,1.04)	.74
	Screened positive for emotional issue	**5.60*** (3.17,9.88)**	**4.51*** (1.95,10.43)**	.59
	Without a formal degree	1.13 (.60,2.11)	1.56 (.66,3.69)	.00
Family	Lone parent	.51 (.21,1.25)	.89 (.33,2.40)	.03
	Neither parent working	.00 (.00,-)	2.81 (.33,24.23)	.36
	Below average income	.59 (.29,1.21)	.93 (.36,2.36)	.37
	Number of children in household	.94 (.78,1.15)	.92 (.69,1.21)	.69
	Ethnicity minority	.93 (.50,1.71)	1.27 (.56,2.85)	.18
EF	Performance	1.00 (.97,1.04)	.97 (.93,1.02)	1.09
	Rating	**1.12* (1.00,1.25)**	**1.23* (1.04,1.44)**	**9.80****

EF, executive functions; RRR, relative risk ratio; CI, 95% confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
^{a}Numbers can be slightly different due to variance of missing data for each risk factor.

False omissions by either rater. As displayed in Table 4.7, compared to true positives, children with higher parental ratings in executive function are less likely to be falsely omitted by either informant. No factors significantly distinguished these cases from false omissions by which of the informants.

Table 4.7. *Characteristics distributed between false omission by either raters.*

Tests		Multinomial logistic regression			Wald Test		
Factors		RRR/CI (base: True Negative, P0T0Dx0)			chi-squares		
		Parent False Omission P0T1Dx1 (n^a=66)	Teacher False Omission P1T0Dx1 (n^a=28)	True Positive P1T1Dx1 (n^a=36)	P0T1Dx1 vs P1T1Dx1	P1T0Dx1 vs P1T1Dx1	P0T1Dx1 vs P1T0Dx1
Parent	Male-informant	.49 (.17,1.40)	.26 (.03,1.97)	.45 (.10,1.93)	1.10	1.49	.14
	Age	1.02 (.97,1.07)	1.03 (.96,1.11)	.98 (.92,1.04)	.01	.18	.29
	Screened positive for emotional issue	**4.98*** (2.56,9.69)**	2.21 (.64,7.59)	**4.51*** (1.95,10.43)**	.54	.63	.04
	Without a formal degree	.94 (.46,1.92)	.90 (.32,2.56)	1.56 (.66,3.69)	.00	.00	.00
Family	Lone parent	1.25 (.59,2.67)	1.04 (.35,3.10)	.89 (.33,2.40)	.01	.44	.39
	Neither parent working	.00 (.00,-)	.00 (.00, -)	2.81 (.33,24.23)	.80	.63	.00
	Below average income	1.43 (.69,2.96)	1.62 (.58,4.49)	.93 (.36,2.36)	2.44	.00	2.13
	Number of children in household	.93 (.75,1.17)	1.05 (.78,1.43)	.92 (.69,1.21)	.29	.04	.08
	Ethnicity minority	.52 (.23,1.15)	1.28 (.51,3.22)	1.27 (.56,2.85)	.04	.90	1.32
EF	Performance	**.96* (.92,.99)**	1.01 (.95,1.07)	.97 (.93,1.02)	.27	1.06	2.43
	Rating	**1.17* (1.03,1.33)**	.96 (.80,1.16)	**1.23* (1.04,1.44)**	**11.38****	**6.22***	5.81

EF, executive functions; RRR, relative risk ratio; CI, 95% confidence interval.
Bold figures denote statistically significance at: *p<.05; **p<.01; ***p<.001.
[a]Numbers can be slightly different due to variance of missing data for each risk factor.

4.5 Discussion

This chapter built on the findings of previous chapters by exploring factors associating with parent-teacher agreement/disagreement patterns in reporting ADHD symptoms and the relationship between factors and parent-teacher agreement/disagreement patterns × ADHD diagnosis categories. Relationships among parent's, and family's characteristics with the

informant agreement/disagreement patterns were examined by replicating the analyses of the previous chapter with a few modifications. In addition, executive functions were included in the analysis to explore how parent-reported rating or performance task in executive functions can facilitate the screening accuracy on ADHD diagnosis.

Parent-Teacher Correlation in Reporting ADHD symptoms

The parent-teacher correlation in reporting ADHD symptoms was low, which was consistent with Rescorla et al. (2014) that it is estimated from .17 to .60 when using the AP subscales. The finding is similar with previous research (e.g., Achenbach et al., 1987; Carneiro et al., 2020; De Los Reyes et al., 2015; Duhig et al., 2000) and the results from the previous chapter.

Characteristics of Parent-Teacher Discrepancy

Regarding parent's characteristics, which is consistent with Chapter Two, our results showed that parental mental health was significantly associated with parent-teacher disagreement. When a parent screened positive for an emotional issue, it is more likely for the parent to rate the child as at risk than the teacher. This supports the depression-distortion hypothesis (Richters & Pellegrini, 1989) that parents with emotional distress tend to rate more symptoms which leads to a higher chance of parent-teacher disagreement (Chi & Hinshaw, 2002). Our results also showed that parent-teacher disagreement was significantly observed when a parent did not complete a formal degree, however, the disagreement is attributed to a different informant, compared to results reported in Chapter Two. In the current study, children with a parent without a formal degree were more likely to be rated as at risk by teacher alone, whilst in the previous chapter, they were more likely to be rated by parent alone as at risk. The discrepancy of findings might be caused by the datasets coming from different countries or from different measures being applied to rate ADHD symptoms.

Regarding family's characteristics, one of the SES measures, household income, was found to be significantly associated with parent-teacher disagreement in reporting ADHD symptoms. However, the disagreement is attributed to different informants, compared to Chapter Two. The current results suggested that children from families with below average income were rated to have more symptoms by teachers, which is contradictory to results from the previous chapter where they were rated to have more symptoms by parents. The findings are consistent with previous research on parent-teacher contrast in reporting more symptoms

for children with lower SES (Lawson et al., 2017). In addition, in the current study, our finding showed that children with lone parents were significantly associated with parent-teacher disagreement in reporting ADHD symptoms. Children of lone parents have a higher chance of being reported by teacher only. This is consistent with a previous study that found single parenthood predicted more inattention problems reported by teachers (Sasser et al., 2015). This might be related to the correlation between single parenthood and parenting stress (Theule et al., 2010). More parenting stress could lead to higher parent-teacher discrepancy in reporting ADHD symptoms (van der Oord et al., 2006) by biasing parent reports. The parenting stress from single parenthood might also increase child's attention problems therefore leading to higher parent and teacher ratings. However, the mechanism remains unexplained and the current finding is inconsistent with the results from previous chapter and with other work that found that parents' marital status was not associated with parent-teacher agreement in ADHD (Yeguez & Sibley, 2016). Our findings are also partly consistent with previous research on factors not significantly associated with parent-teacher agreement on reporting ADHD symptoms, such as parental gender (Falt et al., 2018; Sollie et al., 2013), ethnicity (Wexler et al., 2022), and number of children in a household (Harvey et al., 2013).

Predicting ADHD diagnosis from parent-teacher screening, risk factors and measures of executive functions

The current study explored how parent-teacher agreement/disagreement patterns, risk factors and measures of executive functions might be associated with ADHD diagnosis. The false omission rate was low, while the false discovery rate was moderate in the current sample. That means, children with ADHD were unlikely to be missed by the AP subscales and had a moderately high chance to be falsely identified by the AP subscales. From the hierarchical binary logistic regression, either parent-reported executive functions of child or performance task in executive functions by child predict ADHD diagnosis alone, which is consistent with previous evidence (Arrondo et al., 2024; Bünger et al., 2021). Although executive dysfunctions were commonly observed in people with ADHD, the dysfunctions can be observed in a wide range of conditions and cannot uniquely predict ADHD (Willcutt et al., 2005).

In addition, children rated by female parent-informant and by parents who screened positive for emotional issues were more likely to receive ADHD diagnosis. The gender of the

informant might provide unexpected information regarding the diagnosis of the child. For example, in the study of Anastopoulos et al. (2018a), it is found that when a female informant, parent or teacher, is rating male children, the classification of ADHD diagnosis becomes more likely. Parental depression was also found as a risk for ADHD diagnosis (Robinson et al., 2022).

In the current study it was found that once either or both informants gave a rating of at risk, the child is much more likely to receive an ADHD diagnosis. In the previous chapter, both raters agreeing at risk was differentiated from the informant disagreement groups. Here, it was found that parent-reported was not significantly different from the both reported at risk group. In contrast, the teacher-reported at risk was not as likely as parent-reported and both reported at risk groups to receive an ADHD diagnosis. This can be explained by differences in how ADHD was diagnosed in these two studies. In Chapter Three, the diagnosis was made with the DAWBA, which included information from both parent and teacher. Both parent and teacher reports were equally informative in predicting ADHD in the previous chapter. However, in the current study, the KSADS-COMP applied in the ABCD study was only based on parent interviews. In this study, the findings are similar to a previous study (Shemmassian & Lee, 2016), that parents were found to be more accurately assessing ADHD risk than teachers when the outcome variable, i.e. the ADHD diagnosis, relied on information from parents only. The measurement might be systematically inducing the problem of common method variance which might lead to this outcome.

Risk Factors and Executive Functions Distributed according to Informant Agreement and ADHD Diagnosis

The current study also explored how the risk factors and measures of executive functions are related to informant agreement/disagreement and ADHD diagnosis.

Parents' characteristics.

Gender. There was risk of false omission by both informants attributed to parental gender. Children who were rated by a female parent-informant were more likely to be falsely omitted by both informants. A previous study also suggested that informant gender was associated with the classification of ADHD diagnosis, the mechanism was unclear (Anastopoulos et al., 2018a). Gender of the parent informant was expected to have shown some impacts on their ratings. Interestingly in the current study a male parent reporter was associated with false

omission when both informants rated the child as not at risk. It is possible that data completed by a male parent-informant may reflect atypical family structure and might hence affect a child's behaviours resulting in bias in teacher's observation. In addition, teachers' characteristics, such as gender of teachers, which is not recorded in the current dataset might have also played a role in such a phenomenon (Anastopoulos et al., 2018a).

Age. There was no risk of false discovery or false omission attributed to parental age. Neither did it act as facilitator for AP subscale screening effectiveness.

Education. There was a risk of false discovery by parents only attributed to parental education level. Children with parents without a degree qualification were more likely to be overrated on ADHD-related symptoms by parents. This is consistent with the finding from the previous chapter and a previous study that parents with lower parental education levels tend to overrate problems of their children (Mieloo et al., 2012). As discussed in the previous chapter, parents with higher education levels might report children's behaviours more accurately as they tend to get more accurate information and have higher levels of awareness and knowledge of ADHD (Amiri et al., 2016; Dodangi et al., 2017).

Mental Health. There was risk of false discovery and false omission attributed to parental mental health. Similar to the previous chapter, children with parents rated positive for emotional issues had a higher chance of being falsely discovered by both informants. Parents' mental health conditions might increase risk for a range of psychopathology in their children and this might be falsely discovered as ADHD (Goodman et al., 2011; Ramchandani et al., 2008). However, when the child is rated only by one rater as at risk, the screening effectiveness is jeopardised both in terms of false omission by parents and false discovery by the teachers. When parents encounter emotional distress, their children are more likely to be falsely omitted by both informants. As discussed in the previous chapter, these findings support the depression-distortion hypothesis on how mental health conditions might affect parents reporting child's problems (Richters & Pellegrini, 1989).

Family's Characteristics

Ethnicity. Unlike the previous chapter, ethnicity contributed to risk of false discovery. In the current sample, children from ethnic minorities were more likely to be falsely discovered by teachers but not parents. This finding is consistent with previous research that has found parents from ethnic minority backgrounds report less ADHD-related symptoms than teachers (Harvey et al., 2013; Lawson et al., 2017; Takeda et al., 2020). However, the current result is inconsistent with Hosterman et al. (2008) who found that teachers rated students from ethnic

minorities more accurately with behavioural observation than students from the ethnic majority.

Socioeconomic Status (SES). Similar to the previous chapter, children from families with below average income are more likely to be falsely discovered by parents. As discussed in the previous chapter, children from a lower SES background encounter more stressful life situations and tend to be more likely to display similar behavioural problems (Reiss et al., 2019). The current result is also similar to findings from Madsen et al. (2018) that children from a lower SES background were less likely to receive an ADHD diagnosis even when parents reported risk in ADHD screening.

Family Structure. Unlike the previous chapter, family structure was related to risk of false discovery. Children with lone parents were more likely to be falsely discovered by both informants and by parent-informant only. This might be explained by previous research that observed more parenting stress with a child with ADHD in single parenthood and parents with more parenting stress reported more ADHD symptoms (Theule et al., 2010; Yeguez & Sibley, 2016). It is possible that parents suffering from stress may have lower tolerance for behavioural problems, thus rate more symptoms (Castagna et al., 2020; Jacob & Johnson, 1997). In addition, in the current study, children with fewer siblings were more likely to be falsely discovered by both informants. This fits previous research identifying a contrast effect on informant rating when a child has siblings; when there are more siblings the contrast effect diminishes proportionally to the number of children (Carey, 1986; Pinto et al., 2012; Rietveld et al., 2003).

Executive Functions

Executive function performance. Executive function performance was negatively correlated with AP scales and ADHD diagnosis. However, there was a risk of false discovery by AP scales attributed to children's performance on executive functions. In general, children with lower scores in executive function performance were more likely to be falsely discovered by both informants and by either informant. This implies that, children with less inhibitory control are more likely to be rated at risk for ADHD by informants, but the observed ADHD-related symptoms are contributed to problems other than ADHD. The results are consistent with the finding of a longitudinal study that executive function impairment predicts ADHD symptoms (Orm et al., 2023) and other internalising and externalising problems (Yang et al., 2022). It is common to observe similar behavioural presentations across paediatric disorders, and executive function impairment is one of the common overlapping features among them

(Duff & Sulla, 2015). Executive functions performance does not differentiate well across disorders (Benallie et al., 2021; Crisci et al., 2021), but the level of executive functions is a reliable indicator of presence or absence of clinical problems (Halse et al., 2022).

Parent-reported executive function. Parent-reported executive function was positively correlated with AP scales and ADHD diagnosis while being uncorrelated with executive function performance. In previous studies (Barnard et al., 2018; Soto et al., 2020; Toplak et al., 2013), executive function ratings were also found to be not associated with or weakly correlated with executive function task performance. It should be noted that, the correlation between self-rated inhibition and inhibition tasks were still weak (Krieger & Amador-Campos, 2018). This suggested that informant rating and performance tasks might measure different aspects of executive functioning and might not be comparable: performance tasks quantify responses like reaction time and accuracy in a structured format simulating similar situations such as educational settings, while informant ratings assess functions in more daily life type settings (Krieger & Amador-Campos, 2018). The process requiring executive functions can be different depending on the level of demand and structure of the settings. Soto et al. (2020) examined the inter-relations between executive function rating and performance in the prediction of academic outcomes finding that each provided independent predictions, indicating they are associated with separate portions of variance. In the current study, there was increased risk of false discovery by AP scales attributed to parent-rated executive functions on children. Children with higher scores in executive function reported by parents were more likely to be falsely discovered by both informants, meanwhile they were also more likely to be true positives. It implies that when a child is rated to have better executive functions, there is a higher chance that both informants overrate the ADHD-related problems. It also implies that the reported executive function impairment contributes to problems/diagnosis in addition to ADHD. On the other hand, children with higher parent-reported executive function are more likely to be falsely discovered by either informant. That means that when a child with higher level executive function is rated as at risk in ADHD by only one informant, there is a higher chance that the informant overrated instead of a true ADHD diagnosis presents, especially by teacher than by parents. The reported executive function impairment may reflect psychopathology other than ADHD. Children with higher parent-rated executive function were more likely to be true positives instead of being falsely omitted by parents. This implies that better observed executive functions help parents to identify ADHD symptoms more accurately.

Implications

Similar to findings from Chapter Three, parental gender and parent's emotional issues were found to significantly predict ADHD diagnosis. The results bring some insights for clinicians to be aware of possible influence from these factors affecting the rating, as discussed in the previous chapter. In addition, neither performance tasks nor rating in executive functions in the current analysis predicted ADHD alone. This is consistent with other work demonstrating that executive functions measures are not effective in predicting ADHD diagnosis (e.g., Ezpeleta et al., 2015). However, the current results provide some additional insights on how including measures of executive functions could assist the ADHD assessment battery. In general, both executive functions ratings and executive functions performance tasks were found to significantly improve prediction of false discovery and false omission. It is observed in the current sample that children with higher executive function performance scores were more likely to be classified as true negatives instead of being falsely discovered by both or one of the informants by AP scales. On the other hand, children with higher executive function rating scores were more likely to be classified as true positives instead of being falsely discovered or omitted by both or one of the informants. The integration of both rating and performance tasks of executive functions thus facilitates the screening accuracy from informant ratings by providing additional information regarding both true negatives and true positives. Therefore, this information could assist clinicians when they encounter children on which informants disagree in the screening process. When parent-teacher discrepancy is observed, a higher level of executive function performance might indicate the need to gather more information to rule out other possible neurodevelopmental disorders before concluding the ADHD diagnosis. When informants disagree and a child is rated as having better executive functioning an ADHD diagnosis should be considered more probable. Such implication for measures of executive functions might enhance ADHD diagnosis decision making and may be implemented relatively cheaply.

Limitations

Our findings and conclusions must be considered in the light of several limitations. First, as mentioned in earlier sections, to test the stated hypotheses, alternative variables for the executive functioning rating and ADHD diagnosis were substituted due to data availability of the chosen dataset. Although the Inhibitory Control subscale from the Early Adolescent Temperament Questionnaire-Revised shares one similar concept, i.e. inhibition, with executive functioning (Muris & Meesters, 2008; Zhou et al., 2012), other domains from

executive functions, such as working memory, could not be examined in the current study due to the different constructs available. This might have limited the current results in exploring the relationship of executive functions and the identification of ADHD. Therefore, the current study can be considered as a preliminary study for our hypothesis testing. Moreover, the norm-based T-scores of the AP scale from the CBCL and the BPM/T were designed to adjust for age and gender. Hence, the children's age and gender cannot be included in the regression, which might have limited the current results. Unlike the SDQ hyperactivity/inattention subscale, items from AP scales of the CBCL and the BPM/T were not identical. This might lead to systematic discrepancy. These might also have hindered possible comparisons between results from the current study and the results with previous two chapters. Similar to the MHCYP study discussed in the previous chapter, some potentially important teacher characteristics that might explain more about the relationship of parent-teacher discrepancies and ADHD diagnosis were not measured in the current study. These include teachers' ethnicity, gender, and stress level. Our analysis and interpretations on possible linkage of teachers' characteristics with informant agreement/disagreement and ADHD diagnosis might have been enriched by including such information.

Chapter Five: General discussion

The previous chapters report three empirical studies addressing the main objectives of this thesis. The three primary aims were (1) to examine the association of child, parent, and family factors with parent-teacher informant discrepancy in ADHD screening, (2) to explore how these factors influence the relationship between informant discrepancy and diagnosis screening accuracy, and (3) to examine the relationship among measures of executive functions, parent-teacher informant agreement/disagreement patterns and ADHD diagnosis. This final chapter summarises the main findings of the previous three chapters and discusses how they contribute to current theories and practical implications. This chapter also discusses limitations of the current thesis and suggestions for future research.

5.1 Summary of main findings

Previous studies showed that it has been common to observe a low level of parent-teacher agreement in reporting psychopathology in children. Regardless of the tools applied, informant agreement in hyperactivity/inattention problems is expected to produce similar low-level correlations. Some studies explored factors associated with informant agreement. However, previous findings on the relationship of child, parent, and family factors with parent-teacher discrepancy in reporting ADHD were inconclusive. Study One reported in Chapter Two first narratively reviewed child, parent, and family factors associated with parent-teacher discrepancy in reporting ADHD from previous studies. Then it examined the parent-teacher correlations in reporting hyperactivity/inattention problems using the SDQ and the relationship between the selected factors and the parent-teacher discrepancy. A secondary data analysis using the data from the 2004 MHCYP survey in the United Kingdom (Green et al., 2005) was conducted to address the issue. Four groups of parent-teacher agreement patterns were formed using the SDQ band category system (Goodman, 1997) after combining "*borderline*" and "*abnormal*" into "*at risk*" for comparing with "*not at risk*" for the SDQ hyperactivity/inattention subscale: both agreed not at risk, parent-reported at risk, teacher-reported at risk, and both agreed at risk. As hypothesised, the finding was consistent with previous research. There were weak to moderate correlations between parent and teacher reports hyperactivity/inattention problems using the SDQ. Marginal effects of the factors were identified which explained parent-teacher discrepancy in ADHD symptoms. Factors, including male children, younger parents, parents with emotional issues, SES in terms of no working parents and below average income, and ethnicity as White, were associated with a higher likelihood of parent-teacher discrepancy in reporting hyperactivity/inattention

problems. The results were coherent with previous literature on factors related with parent-teacher discrepancy in ADHD symptoms. Our findings were also consistent with previous research on factors that are unrelated to parent-teacher agreement on reporting ADHD symptoms, including child's age, parental gender, number of children in a household and marital status.

Findings from Study One provided a foundation for Study Two (presented in Chapter Three) to explore how different parent-teacher agreement patterns and the covariates in Study One predict ADHD diagnosis and influence screening accuracy. Study Two assessed the predictive power of informant agreement patterns on ADHD identification. The factors included in the previous chapter were also tested in Study Two and findings showed how they contributed to the links between parent-teacher screening agreement and ADHD diagnosis. The same dataset as the previous chapter was used in Study Two to explore these two issues. The four groups of parent-teacher agreement patterns from Study One were extended into eight groups to illustrate the relationship between different patterns of informant agreement and ADHD diagnosis. In general, the number of false omissions was very low, while the number of false discoveries was moderate, after integrating parent and teacher ratings. That implied that screening with the SDQ hyperactivity/inattention subscale alone did not miss many ADHD diagnoses, but it has moderate possibility to falsely identify children as likely to have ADHD. The high rate of false positives by both raters is commonly observed in community samples, due to a lower community prevalence (Stone et al., 2010; Trevethan, 2017). The study also explored factors associating with false discoveries and false omissions associated with different rater agreement patterns. The group for false omissions by both raters reported as at risk was removed due to a singular data point in the current sample. Study Two found that some of the factors examined in Study One, such as child's gender, mental health of parents, and household income, predicted diagnosis present or not with different informant agreement patterns. The current analysis can be considered as an extension of the previous literature on the association between false discovery and false omission with the characteristics in the context of multiple informant rating patterns (Madsen et al., 2018).

Although Study Two provided evidence of improved diagnostic accuracy with minimised false omissions by integrating parent-teacher ADHD screening, the problem of large numbers of false discoveries was still a concern. To reduce the number of false discoveries in clinical

practice, follow-up tests have been recommended, especially if they are inexpensive, easy, and quickly performed (Trevethan, 2017). Adding measures of executive functioning to the screening process may be valuable for reducing the specificity problem as there is some evidence of usefulness in ADHD screening from previous research (Chen et al., 2022; Rauch et al., 2012). Screening accuracy of executive function rating and performance tasks as additional measures on ADHD rating scale was the focus reported in Study Three illustrated in Chapter Four. Another dataset from the ABCD Study (Garavan et al., 2018) was utilised. The dataset consists of a sample of 11876 children aged 9 to 10 recruited at the baseline study across 21 United States study sites. The analysis in Study One from Chapter Two was first replicated to enrich our understanding on the relationship between parent-teacher discrepancy on reporting ADHD symptoms with a similar pool of covariates. Findings related to parent-teacher discrepancy from Study Three were partly consistent with Study One. For example, in both studies, parental mental health was significantly associated with parent-teacher disagreement, in that it is more likely for parents who were screened positive for an emotional issue to rate the child as at risk than the teacher. Some factors, such as parental education level, were associated with a different disagreement pattern, between these two studies. Study Three then examined whether adding rating and performance task of executive functions on the ADHD rating scale improve screening accuracy and predict false discoveries and false omissions contributed with different rater agreement patterns. In general, the false omission rate was low, and the false discovery rate was moderate, while integrating multiple informant ratings in ADHD, parent rating and performance task of executive functions. It should be noted that direct comparisons between these two studies might be controversial caused by using datasets from different countries or different ADHD rating scales. However, this study confirmed that either rating or performance task of executive functions improve the ADHD screening accuracy or predict the ADHD diagnosis, which is consistent with previous research (Bünger et al., 2021). Study Three also showed significant effect on false discoveries and false omissions with different rater agreement patterns from the rating or performance task of executive functions. Findings extended the understanding on how measures of executive functions aided especially under parent-teacher discrepancy in reporting ADHD symptoms.

5.2 Theoretical and practical implications

One of the major issues with ADHD identification that has been addressed in this thesis is parent-teacher discrepancy and its relationship with ADHD diagnosis. As discussed in earlier

chapters, previous studies which tried to predict informant discrepancy might conduct specification error, i.e., missing important variables that might have also influenced the predicted variable. The current approach of using a pool of child's, parent's, and family's factors simultaneously in exploring their relationship with informant discrepancy can reduce the effects from this error. Findings from Study One and Study Three extended the current understanding in parent-teacher discrepancy in reporting hyperactivity/inattention problems. In addition, methods used in most studies for informant discrepancy either could not distinguish the rater (e.g., Harvey et al., 2013), or did not include all the groups for comparison (e.g., Johnson et al., 2014). The current approach of categorising agreement/disagreement patterns helps to provide comparisons among all groups including true negatives and to demonstrate the effects on each of the specific groups. The modified categorisation in the current study aids to explore not only the effects of informant patterns on diagnosis but also extend the understanding in the relationship of agreement patterns with diagnosis. Findings from Study Two and Study Three showed how different factors were associated with agreement patterns with diagnosis. These provided practical implications in decision making during the screening process. Some factors that have been studied in the current study are easily collected during the screening process. When ADHD rating disagreement occurs, clinicians can consider possible influence from these factors affecting the rating discrepancy and gather further relevant information to facilitate the screening process. Some factors, such as parental emotional status, can be assessed briefly during the screening process. Understanding how these factors affect the ratings and disagreement helps clinicians to explore extra information for diagnostic decision making instead of relying on the ratings alone. One of the remedial measures would be executive functions as shown in Study Three which is discussed below.

Study Three addressed the effectiveness of integrating executive function rating and performance tasks into the ADHD screening process. Previous studies have focused on the association between ADHD diagnosis or symptoms and executive functioning, and the current study also showed that executive functions might not directly act upon the diagnosis itself. Findings from Study Three also suggested that integrating rating and performance tasks of executive functions provided additional information regarding both true negatives and true positives in real life practice: children with better executive function performance were more likely to be classified as true negatives, while children with better executive function reported by parents were more likely to be classified as true positives. This extended the

understanding of the relationship between executive functions and ADHD. Moreover, integrating rating and performance tasks of executive functions with ADHD rating provide additional information under different agreement patterns. When parent and teacher agreed as at risk for ADHD, children with poorer executive function observed by parents were more likely to be falsely discovered, but when parent and teacher agreed not at risk for ADHD, children with better executive function observed by parents were more likely to be falsely omitted by both informants. This implies that, as an additional measure in ADHD screening, parental ratings but not performance tasks in executive functions aid in both identifying ADHD and ruling out non-ADHD under an agreement scenario.

On the other hand, when parent and teacher disagreed on the ADHD rating, children with higher executive function performance were less likely to be falsely discovered by either parent or teacher. In addition, children with higher executive functions reported are more likely to be falsely discovered by either teacher or parent, with teachers being much more likely on this false discovery. Moreover, when there is disagreement in ADHD symptoms between informants, children reported to have better executive functions were less likely to be falsely omitted by either parent or teacher. The findings implied that when parent-teacher discrepancy in reporting ADHD symptoms is observed, additional information in executive functions aids in clinical decision making: a higher level of executive functions performance indicates the needs to gather more information to rule out other possible neurodevelopmental disorders before concluding the ADHD diagnosis; a lower level in executive function rating indicates that an ADHD diagnosis should be considered more probable. Additional information from executive functions displayed different patterns under agreement or disagreement between informants.

5.3 Limitations and future work

The three studies reported in the thesis should be interpreted while considering a number of limitations. Firstly, the current thesis made use of secondary datasets that brought about both advantages and limitations. Although the existing datasets provided accessibility of large-enough samples with desirable variables from theoretical conceptualisation, differences in measures used in the different studies such as the SDQ hyperactivity/inattention subscale in the MHCYP study and the Attention Problems subscales from the ASEBA might induce discrepancy over comparison between studies. Although the SDQ hyperactivity/inattention subscale and Attention Problem scale from the CBCL are moderately correlated in previous

research (Goodman & Scott, 1999), they are slightly different from each other in terms of scoring systems and cut-offs. For example, the CBCL is standardised and age-gender corrected, using the 95th percentile to indicate the borderline range and the 98th percentile to identify the clinical range. On the other hand, the SDQ uses the 80th percentile as the borderline range and the 90th percentile to indicate the clinical range based on the raw score without taking age or gender into account. Mansolf et al. (2022) has shown that there is difficulty in conversions between the CBCL and the SDQ regarding externalising problems, and psychometric comparisons of different cut-offs might influence screening accuracy (Trevethan, 2017).

In addition, the ADHD screenings in all three studies were categorised into dichotomous categories "*at risk"* and "*not at risk"*, while the original scales offer three categories: normal-borderline-abnormal in the SDQ and normal-borderline-clinical in the CBCL. Reduction of the categorisation into dichotomous variables supported the feasibility of the current analyses but information available in the original metrics might have been lost. Compared to the categorisation adopted in the current thesis, the information among groups categorised as "parent-rated as borderline and teacher-rated as normal" or "parent-rated as normal and teacher-rated as abnormal" might be valuable in analyses regarding the discrepancy patterns between raters, especially regarding false discovery and false omission. The current analyses based on two different datasets with differing measurement tools has provided opportunities to test the generalisation of findings across sampling strategies.

Third, not all the variables that might have been useful to these analyses were available in the selected datasets. The screenings in Chapters Two and Three were restricted to ADHD only without inclusion of other developmental disorders due to issues in the selected datasets. In the 2004 MHCYP survey, ADHD was not diagnosed in the presence of ASD according to the DSM-IV-TR criteria. The diagnostic data of ASD was also unavailable in the ABCD dataset due to previous programming algorithm errors (Jernigan et al., 2021). Leaving out ASD which is commonly comorbid with ADHD (Rong et al., 2021) prohibits investigation of a full set of comorbidities. Furthermore, the current studies do not include characteristics from the other informant, i.e., the teacher, and might have hindered information regarding their screening accuracy. The current analysis might have benefited from including such information for exploring possible explanations on informant agreement/disagreement.

Moreover, the generalisation of the current results might be affected by ADHD subtypes. The ADHD diagnosis in Chapters Three and Four was restricted to ADHD without subtype specifications due to issues in the selected datasets. Although limited in number, previous research suggested that ADHD subtypes could vary depending on the method of combing information source and low levels of parent-teacher agreement among subtypes have been observed (Gadow et al., 2004; Valo & Tannock, 2010) and group differences in executive functions were also associated among ADHD subtypes (Willcutt et al., 2005). How the current study might be generalised to the ADHD subtypes categorisation will be of interest to future investigations.

The last but not least limitation concerns executive functions in Study Three. Executive functions have been concerned about the diverged definitions across scholars and researchers. The measurements included in the current study do not include all aspects of executive functions but only those relating to ADHD, i.e., the inhibitory control. Inclusion of the full executive functions spectrum in future study might be concurrent with suggestions of comorbidity and provide a full understanding of the clinical diagnostic process. The parent-rated executive functions adapted in the current study, and ADHD diagnosis from Study Three, may be under common method variance with the ADHD screening results while they are all obtained from the parent report. Information from the other informants, or diagnosis from clinician, would be remedial to such possible risk but may be difficult for reality practice. Yet assistance from objective measures like executive function performance tasks would be expected to provide insights in such a diagnosis process.

Future research

Numerous directions for future research would help extending the theory. First, including more detailed characteristics of the informants would be useful. This includes characteristics of teacher raters such as their gender, ethnicity, and stress level. This might establish further understanding of informant discrepancy in ADHD diagnosis. Including teacher-rated executive function rating would also be useful not only to extend further exploration of the role of executive functions in ADHD screening accuracy but also to avoid possible common method variance problems. This might be relevant in the current studies due to parents providing both ADHD and executive function ratings.

Furthermore, research on psychometric conversions (Mansolf et al., 2022) between screening tools especially in the ADHD domain might aid in providing more accurate interpretation of their screening accuracy. This might also enhance the generalisation of the results from all three studies included in this thesis. In addition, determination of converging cut-offs, whether in scoring form or in terms of percentile, among these screening tools might be explored and hence the categorisation tested for screening accuracy. As Study Three demonstrated, executive function measures may provide different indications in the context of different patterns of informant agreement. It would be expected that further categorisation divisions might help to reflect more complex scenarios similar to real life practice. Study Three has found that among informant-agreement scenarios, executive function ratings facilitate true positives (i.e., both informants report at risk and receiving a diagnosis) while executive functions performance facilitates true negatives (i.e., both informants report not at risk and not receiving a diagnosis). Identifying how these patterns might exhibit in the 3×3 categorisation of children based on informants' SDQ and/or CBCL scores in future research might produce more informative results on how executive functions might contribute differently among various informant agreement patterns. Applying different cut-offs from the screening tools in future studies would also simulate real-life ADHD screening scenarios and exploration of the effectiveness of executive function measures within those scenarios.

Including other clinical conditions, such as ASD, might extend the understanding of the screening accuracy from ADHD screening tools. Further work on comparing ADHD only, ADHD with comorbid condition, other clinical conditions, and typically developed children would simulate the clinical diagnostic process for ADHD and would provide opportunities to improve current theoretical understanding. For example, some false discoveries might be due to other psychiatric conditions that were mis-attributed to ADHD risks. At the same time, executive functions might be found to aid in differentiating these comorbidities from ADHD (Duff & Sulla, 2015). Up-to-date research exploring the clinical utility of different executive function domains in identifying ADHD and discriminating ADHD from other conditions is limited (Moura et al., 2017). Further research should continue to investigate other executive function domains using both performance tasks and informant ratings to enrich the current understanding of their role in ADHD screening accuracy.

5.4 Conclusion

This thesis aimed to investigate the role of informant discrepancy in identifying ADHD, with a specific interest of executive function informant rating and performance-based measures as a remedial measure. The studies illustrated in the thesis in general suggested for factors that bring into parent-teacher discrepancy in rating ADHD symptoms (Study One), how the informant discrepancy could have influenced prediction of ADHD diagnosis (Study Two and Three), and how executive functions both in rating and performance-based measure could improve such prediction (Study Three). The thesis has brought insights of interpretation of the informant discrepancy in ADHD rating and included executive functions as remedial measures for such discrepancy. The discovery of varying implications of executive functions under agreed and disagreed conditions has provided clinical implications in real practice. The thesis has also provided insights for future research to explore how screening accuracy could be improved for delivering more accurate screening to assist children and families which are in need.

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Appendix A.

Values of variance information factor on each variable.

Variable		VIF	1/VIF
Child	Male	1.00	1.00
	Age	1.30	.77
Parent	Male	1.05	.95
	Age	1.42	.70
	Positive for emotional issue	1.04	.96
	Without a formal degree	1.16	.86
Family	Lone parent	1.50	.67
	Neither parent working	1.44	.69
	Below average income	1.46	.69
	No. of children in household	1.17	.86
	Ethnicity as Non-White	1.04	.96
Mean VIF		1.23	

VIF: variance information factor

Appendix B

Correlation table amongst covariates in Pearson's r.

		Child		Parent				Family				
		Male	Age	Male	Age	Positive for emotional issue	Without a formal degree	Lone parent	Neither parent working	Below average income	No. of children in household	Ethnicity as Non-White
Child	Male	--	--	--	--	--	--	--	--	--	--	--
	Age	.00	--	--	--	--	--	--	--	--	--	--
Parent	Male	.02	.03*	--	--	--	--	--	--	--	--	--
	Age	.44*	-.00	.14*	--	--	--	--	--	--	--	--
	Positive for emotional issue	.05*	.00	-.03*	-.01	--	--	--	--	--	--	--
	Without a formal degree	.06*	.00	.06*	-.02	.06*	--	--	--	--	--	--
Family	Lone parent	.02	.00	.03*	-.12*	.14*	.15*	--	--	--	--	--
	Neither parent working	-.03*	.00	.06*	-.13*	.15*	.29*	.46*	--	--	--	--
	Below average income	-.02	.00	.03*	-.22*	.11*	.29*	.47*	.39*	--	--	--
	No. of children in household	-.24*	-.02	.00	-.29*	.02	.08*	-.07*	.13*	.08*	--	--
	Ethnicity as Non-White	-.03*	-.01	.16*	-.01	.01	.11*	0.02	.10*	.10*	.12*	--

Figures with * denote statistically significance at: $p < .05$.

Appendix C

Descriptive statistics of the risk factors among the eight groups of informant agreement patterns.

Factors		Mean (s. d.)/Rate[a]							
		P0T0Dx0 (n^b=4200)	P0T0Dx1 (n^b=1)	P0T1Dx0 (n^b=501)	P0T1Dx1 (n^b=7)	P1T0Dx0 (n^b=598)	P1T0Dx1 (n^b=9)	P1T1Dx0 (n^b=406)	P1T1Dx1 (n^a=59)
Child	Male	44.79%	100%	73.05%	85.71%	60.03%	55.56%	72.66%	91.53%
	Age	10.43 (3.35)	11.00 (-)	9.90 (3.42)	10.57 (4.43)	9.90 (3.31)	11.44 (3.84)	9.61 (3.25)	10.20 (3.33)
	Ethnicity minority	10.93%	.00%	14.20%	14.29%	9.87%	.00%	8.37%	5.08%
Parent	Male	4.45%	100%	7.19%	.00%	5.02%	.00%	3.94%	.00%
	Age	39.32 (6.24)	31.00 (-)	38.15 (7.09)	36.86 (6.44)	37.75 (6.30)	41.33 (6.89)	36.76 (6.41)	37.73 (7.16)
	Ethnicity minority	9.55%	.00%	12.60%	14.29%	8.19%	.00%	5.91%	5.08%
	Positive for emotional issue	19.99%	.00%	22.15%	71.43%	29.51%	33.33%	33.08%	33.90%
	Without degree	82.69%	100.00%	87.50%	85.71%	90.36%	88.89%	95.21%	91.53%
Family	Lone parent	20.71%	100.00%	28.34%	28.57%	25.25%	11.11%	34.73%	35.59%
	Neither parent working	11.29%	100.00%	20.36%	14.29%	16.36%	22.22%	26.49%	35.59%
	Below average income	44.53%	100.00%	56.92%	14.29%	55.43%	44.44%	67.39%	70.00%
	Number of children in household	2.12 (1.02)	2.00 (-)	2.21 (1.08)	1.71 (.76)	2.20 (1.07)	1.78 (1.39)	2.25 (1.02)	2.03 (.95)

[a]All numbers correspond to rates, except for age given in mean number of years and for numbers of children in household given in mean number of children.
[b]Numbers vary depending on occasional missing data in each risk factor.

Appendix D

Wald test and chi-squares between relative risk ratios of informant pairs.

Risk factors	Agreement patterns		
	Parent only vs Teacher only	Parent only vs Both agreed at risk	Teacher only vs Both agreed at risk
Parent characteristics			
Male	.01	2.72	3.07
Age	.31	1.20	.59
Positive for emotional issue	**21.31*** **	.04	**14.61*** **
Without qualifications	1.57	1.20	.03
Family characteristics			
Lone parent	.15	.01	.04
Neither parent working	.25	1.15	.74
Below average income	.37	.00	.30
Number of children in household	1.09	.49	2.70
Ethnicity minority	.03	.16	.34

Bold figures denote statistically significance at: *p < .05; **p < .01; ***p < .001.

Appendix E

Descriptive statistics of the risk factors and executive function measures among the eight groups of informant agreement patterns.

Factors		Mean (s. d.)/Rate[a] Coefficient (base: P0T0Dx0)							
		P0T0Dx0 (n^b=3355)	P0T0Dx1 (n^b=89)	P0T1Dx0 (n^b=67)	P0T1Dx1 (n^b=66)	P1T0Dx0 (n^b=256)	P1T0Dx1 (n^b=28)	P1T1Dx0 (n^b=32)	P1T1Dx1 (n^b=36)
Parent	Male	12.40%	3.37%	11.94%	7.58%	10.55%	3.57%	.00%	5.56%
	Age	42.64 (6.31)	42.63 (5.97)	43.16 (7.55)	42.88 (7.83)	41.31 (7.28)	42.00 (8.43)	41.59 (9.22)	42.28 (8.23)
	Positive for emotional issue	7.03%	22.47%	23.88%	30.30%	6.64%	10.71%	18.75%	25.00%
	Without qualification	29.09%	25.84%	43.28%	34.85%	52.73%	32.14%	46.88%	47.22%
Family	Lone parent	19.28%	11.24%	32.84%	28.79%	37.50%	28.57%	46.88%	22.22%
	Neither parent working	.95%	.00%	1.49%	.00%	1.95%	.00%	3.13%	2.78%
	Below average income	27.63%	22.47%	34.33%	37.88%	48.05%	35.71%	46.88%	36.11%
	Number of children in household	2.64 (1.28)	2.61 (1.47)	2.30 (.92)	2.54 (1.55)	2.64 (1.38)	2.68 (1.12)	2.13 (1.04)	2.67 (1.24)
	Ethnicity minority	24.50%	20.22%	46.27%	19.70%	38.67%	28.57%	31.25%	30.56%
EF	Performance	100.82 (7.03)	101.08 (6.60)	96.52 (9.76)	98.83 (7.78)	97.65 (9.18)	100.43 (7.99)	95.87 (10.95)	98.46 (6.50)
	Rating	13.09 (2.14)	13.76 (1.99)	14.55 (2.55)	14.05 (2.56)	13.41 (2.53)	12.96 (2.33)	13.86 (2.74)	14.06 (2.33)

EF, executive functions.

[a]All numbers correspond to rates, except for age given in mean number of years and for numbers of children in household given in mean number of children.

[b]Numbers vary depending on occasional missing data in each risk factor.