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Cognitive Correlates of Social Outcomes in Children and Adolescents with ADHD: A PRISMA Systematic Review

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Abstract

Social difficulties are commonly experienced by children and adolescents with ADHD. With a view to informing targeted interventions, this review aimed to: (1) evaluate the literature on cognitive correlates of social outcomes in children and adolescents with ADHD; and (2) investigate the impact of medication use, co-occurring diagnoses, ADHD presentation type, chronological age, and gender on the relationships between cognitive functions and social outcomes. Thirty studies met criteria for inclusion. Data were synthesised according to three social outcomes of interest: interpersonal skills, prosocial behaviours, and peer-group factors. Quality was appraised using the Quality Assessment for Diverse Studies (QuADS) and additional predetermined criteria, specifically, the quality of reporting on variables of interest in Aim (2) above. Results provided preliminary evidence for associations between emotion regulation and social outcomes, and between non-verbal working memory and prosocial behaviours. Present findings should, however, be interpreted cautiously due to inadequate reporting on the impacts of medication use and co-occurring conditions. The results suggest that emotion regulation and working memory are potential avenues for future research and cognitive intervention to assist social functioning for those with ADHD. Future research needs to further delineate the effects of medication status, co-occurring conditions, and ADHD presentation type on the relationship between cognition and social outcomes in ADHD, and longitudinal study designs are needed to better determine causation. The present review calls for consistency in the terminology and operationalisation of social outcomes, the use of consistent, standardised diagnostic tools, and inclusion of multiple informants when using questionnaire measures.

Keywords: ADHD; Social outcomes; Executive functioning; Emotion regulation; Children & Adolescents

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a developmental condition characterised by differences in attention regulation and executive functions. Lesser known, and often overlooked, are the significant social challenges experienced by children and adolescents with ADHD. The underlying neuropsychological mechanisms for these social challenges are poorly understood and, as a result, there is limited evidence for the efficacy of interventions designed to enhance social outcomes. This, in turn, necessitates an improved understanding of the underlying factors contributing to poor social outcomes in children with ADHD, to better inform more suitable and effective interventions. The current study provides a systematic review of the literature on the cognitive correlates of social outcomes in young people with ADHD.

Cognitive abilities such as attention and executive functioning may have direct impacts on the expression of ADHD traits and behaviour and, in turn, indirect impacts on social outcomes. However, a shift in the literature in recent decades has revealed that, although executive functioning challenges tend to be present in ADHD, the extent and nature of executive functioning challenges vary within the ADHD population [1,2]. At present, interventions targeting cognitive skills (e.g., computer-based training) have limited support for their impact on functional outcomes (e.g., academic performance or symptom expression), in part due to interventions failing to address the cognitive functions of importance [3], and due to poor generalisation to real-world functioning [3,4]. There is currently a growing body of research into the associations between cognitive skills and social outcomes in ADHD. There is also wide variability in how cognitive and social factors are operationalised. However, at present, there is no synthesis or systematic review of this research and its methodological quality.

Social outcomes in ADHD

There is no consensus in the ADHD literature about terminology relating to social outcomes that fall outside of the realm of social cognition. In this review, we conceptualise social outcomes by distinguishing between the individual characteristics and peer group factors that shape social outcomes. Individual characteristics that might shape social outcomes include 'social performance' and 'social knowledge.' Social performance refers to *outward, observable, and on-line* social behaviours, such as prosocial or interpersonal skills. This is distinguishable from social knowledge, which reflects more *internal* social processes, such as social cognition or social skills, including theory of mind, social motivation, and social awareness. On the other hand, we use the term 'peer group factors' to refer to the extent to which a child is accepted, rejected, or victimised by their broader peer group, and to consider the presence and quality of their friendships. As such, social performance can be considered as more 'child-specific' (i.e., relating to the behaviours of the individual child) and 'peer-group factors' are peer-group specific (i.e., relating to the attitudes or related behaviours of the broader peer group in relation to the child). We will use the term 'social outcomes' as an umbrella term to capture measures of both the social behaviours of the individual child and the level of acceptance by the broader peer group, as well as the degree of impairment or impact that results from social difficulties. We approach the literature with an understanding that social outcomes can be influenced by both individual characteristics and peer group factors, and that individual characteristics and peer group factors can influence each other bidirectionally. The present study focuses on social outcomes in the domains of social performance and peer-group factors.

Children with ADHD experience significant social challenges compared to their neurotypical peers. The expression of the core ADHD traits of inattentiveness, hyperactivity, and impulsivity reportedly impact social performance in differing ways. For example, higher levels of hyperactivity and impulsivity in primary school aged children with ADHD can manifest as differences with respect to turn taking, interrupting others, breaking rules in games, dominating dyadic interactions or behaving in ways that are interpreted by neurotypical peers as aggressive, overbearing, or dismissive of social boundaries [5-8]. On the other hand, inattention has been associated with more socially withdrawn and shy behaviour [9], lower assertiveness [10], reduced attention to positive behaviours of other people [11], challenges interpreting social cues and losing focus during social interactions, which can be interpreted by peers as disinterest [12]. Interestingly, the impacts of ADHD traits on social outcomes appear to vary over time, such that hyperactivity and impulsivity is more strongly associated with social difficulties in younger children, while inattentiveness becomes more relevant in adolescence [11], suggesting an interplay of developmental processes and context in influencing social outcomes.

Social performance interacts with peer-group factors, such that, compared to their neurotypical peers, children with ADHD tend to experience difficulties establishing [13] and maintaining friendships [14], and experience reduced friendship quality [15]. A common and ecologically valid method for measuring peer regard is sociometric nominations, which involve classmate nominations and ratings of peers that they like and dislike. Children with ADHD are often rated lower on measures of social preference, have fewer reciprocated friendships [12,16,17], and have lower rates of peer acceptance and higher rates of peer rejection [18]. While negative peer group perceptions may be a reaction to child-specific social performance, levels of peer rejection have also been influenced by pre-existing and stigmatising peer perceptions in children [19], and adolescents [20], revealing that peer group attitudes, not just the social behaviours of the individual child, are an important determinant of social challenges in children with ADHD. The overall picture is captured in recent systematic reviews which found that, compared to peers without ADHD, children and adolescents with ADHD had fewer friends, lower quality friendships, and poorer quality friendship interactions [21], as well as reduced 'peer functioning' (i.e., peer status, friendships, social skills and competence, and peer victimisation) [22,23].

Social challenges for children with ADHD persist into adolescence, and are characterised by experiences of rejection, loneliness, and interpersonal conflict [16,24]. Furthermore, these social challenges are associated with broader adverse outcomes. Compared to their peers who have ADHD without social challenges, those with social challenges have been found to experience higher rates of depression [25], negative impacts on identity and self-esteem [26], greater frequency of smoking and delinquency [27], and lower academic achievement in adolescence [28]. This highlights the importance of understanding and addressing the aetiology of these social challenges. Conversely, greater social acceptance has been found to buffer the association between ADHD symptoms and poor grades in adolescents and undergraduates with ADHD [29,30]. Also, the development of dyadic friendships in adolescence can contribute to improved adjustment and belonging [24], and serve as a buffer against the effects of wider peer-group rejection [31]. Given the benefits of social acceptance and inclusion, there have been significant efforts to devise interventions to improve social outcomes for youth with ADHD. However, these interventions have not consistently resulted in improvements in social outcomes, as described in the following section. The limitations of interventions for social outcomes suggests that the underlying reasons behind poor social outcomes are insufficiently understood.

Limitations of interventions for social outcomes

Pharmacological interventions: Executive functioning differences are common in ADHD

[32,33] and related to core symptom expression, such as the difficulties with regulating behaviour and attention to achieve goals. These executive functioning differences are consistent with

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the underlying neurobiology in ADHD, including differences in fronto-striatal, fronto-parietal, and ventral attention networks, as well as dopamine and noradrenergic neurotransmitter systems [33]. Psychostimulant medication, the first line treatment for ADHD, is designed to primarily act on the release of dopamine and noradrenaline to improve prefrontal cortex efficiency in ADHD [34]. A meta-analysis investigating the impact of methylphenidate (MPH) treatment on social outcomes for 6-12-year-olds with ADHD [35], identified moderate to large effect sizes on teacher-report social performance measures, moderate effect sizes for parent-reports, and small effect sizes for child self-reports. This evidence for improved parent- and teacher-rated social performance following stimulant medication alludes to a possible link between medication, its associated impact on cognition and behaviour, and social performance.

However, despite the reported benefits of medication for on-line social performance as rated by teachers and parents, pharmaceutical treatment has not been associated with having more friends or being more accepted or less rejected by peers [16,17]. Although there is evidence that psychostimulant medication is effective in targeting attention, cognitive control, and emotion regulation [36,37], it is less effective in improving executive functioning skills such as working memory [37], which may be important for effective social interactions. The discrepancy between improved social behaviour and continued peer rejection is consistent with evidence that, once established, perceptions of peers are highly resistant to change [12,17,38], and there may be a latency period between pharmaceutical treatment, changed behaviour, and changes in friendships and peer acceptance. The discrepancy across findings also highlights the importance of examining both child-specific social performance factors, as well as broader peer-group factors, such as levels of acceptance and rejection, as well as peer attitudes and stigma. Furthermore, while reviews on the effects of medication often identify protective effects on functional outcomes such as academic achievement, psychological outcomes, substance misuse, motor vehicle accidents, and quality of life [39,40], there is a paucity of reviewed evidence regarding the impact of medication use on longer term social outcomes and, when social outcomes are being examined, they are rarely the main outcome of interest.

Non-pharmacological interventions: While social skills training (SST) has been proposed to

support social functioning in some neurodivergent populations such as the autistic community, several reviews have identified limited evidence to support the effectiveness of SST in improving social outcomes for children or adolescents with ADHD [41-44]. Social skills training involves explicit teaching of social skills (such as turn-taking, emotion recognition, and sportsmanship) in a clinic setting, and often involves role playing of specific skills and receiving peer and clinician feedback [45]. In a comprehensive Cochrane review, Storebø et al. [43], identified 25 randomised controlled trials investigating the benefit of SST for children and adolescents with ADHD, and concluded that there was insufficient evidence to either support or refute the use of SST in ADHD. Storebø et al. [43], report a high risk of bias in the existing evidence and, consequently, a very low level of certainty in current research. The incomplete support for SST in ADHD has been attributed to: (1) social skills training neglecting to address the embedded biases of peers [45], and (2) interventions targeting a lack of social knowledge, despite the literature suggesting that it is most often the on-line *performance* rather than *knowledge* of social skills that is the main contributor to social difficulties in ADHD [41,43,45,46,47].

To address the limitations of SST, other non-pharmacological interventions have sought to mimic naturalistic settings (e.g., summer camp programs) or have been delivered in school settings, rather than a clinic environment. However, in a systematic review and meta-analysis, Morris et al. [42], concluded that there was a lack of high-quality evidence in randomised trials to support the effectiveness of such interventions for adolescent social outcomes, despite interventions using naturalistic settings and including elements of on-line strategies, such as positive reinforcement. Morris et al.'s [42], findings highlight the need to consider the generalisability of interventions by recognising the distinctions between social knowledge and on-line social performance. Overall, the limited evidence for non-pharmacological interventions suggests they may be misdirected and failing to adequately understand the factors underlying social difficulties experienced by individuals with ADHD.

There are no known systematic reviews that have specifically investigated the relationship between cognitive factors (such as attention or executive functioning) and social outcomes. However, one literature review examined the relationships between standardised measures of visuospatial and/or auditory-verbal working memory and functional outcomes, including social functioning, in children, adolescents, and adults [48]. Fried et al. identified mixed evidence for the relationship between working memory and social outcomes, with several studies reporting significant associations between non-verbal spatial working memory and social outcomes, and others failing to find these same associations. The review also noted disparities in the operationalisation of social outcomes. Fried et al. [48], posited that working memory may only indirectly contribute to poor social outcomes, via its impacts on academic performance. The purpose of Fried et al.'s review was to explore how working memory problems in individuals with ADHD impacted several functional outcomes (including academic and psychiatric outcomes) across all ages and, as such, the review did not differentiate studies according to the various ways in which social outcomes were operationalised. The present review, however, focuses specifically on social outcomes for children and adolescents, and casts a wide net to capture a range of cognitive domains as potential correlates of social outcomes, including, for example, working memory, attention, and other executive functions. Given the finding that peer attitudes are established early and resistant

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to change, the present review also attempted to investigate how relationships between cognition and social outcomes may vary depending on the nature of the social outcome being examined (e.g., interpersonal skills, prosocial behaviour, or peer group factors). Findings from this review are intended to help inform the development of suitable interventions to improve social outcomes for those with ADHD.

A PRISMA systematic review was undertaken of peer-reviewed, published literature to investigate the cognitive factors significantly associated with social outcomes in children and adolescents with ADHD. Our primary aims were: (1) to evaluate the literature on the relationship between cognitive factors and social outcomes in children and adolescents (below age 19) with ADHD; (2) to investigate the impact of medication use, co-occurring diagnoses, ADHD presentation type (formerly 'subtype'), chronological age, and gender on the relationships between cognitive functions and social outcomes.

Method

Table 1: Full search strategy including all search terms.

ADHD	Children/Adolescent	Cognitive factor	Social functioning outcome
Attention deficit disorder with hyperactivity/ or (attention deficit adj3 disorder*) or adhd	Adolescent/ or child/ Or (child* or adolescen* or teen* or high school* or primary school* or young adult* or young people) Apply limit to "all child (0 to 18 years)	Cognition/or Neuropsychological Tests/ or Executive Function/or Attention/ or Memory, Short Term/ or Cognitive Dysfunction or Impulsive Behavior/ or exp Self-Control/ Or (neuropsycholog* or executive function* or attention or working memory or short-term memory or inhibit* or disinhibit* or cognitive dysfunct* or impulsiv* or self-monitor* or cognitive flexibility)	Exp Interpersonal Relations/ or Psycho-social functioning or ((psycho-social or psychosocial or social) adj2 (function* or skill* or abilit* or perform* or behavio* or competenc* or impairment)) Or Friends/ or exp Peer group/((Peer* or friend*) adj2 (function* or reject* or isolat* or accept* or conflict*))

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, research methodology was published on PROSPERO prior to data collection (registration number: CRD42021243309). The following electronic databases were searched: Medline, PsycINFO, CINAHL, Scopus, and Embase. Database filters were used to limit the search to articles from January 1994 until September 2023. The keywords that were searched were related to four main topics ('ADHD'; 'child or adolescent'; 'cognitive factors'; 'social factors') combined with 'AND,' which were mapped to medical subject headings. For all database searches, the search terms were mapped to subject headings. and the full search strategy including all search terms can be found in Table 1. EndNote [49], was used for initial import and management of references, and references were then imported into Covidence for title/abstract and full text screening. Screeners were masked to each other's decisions. Microsoft Excel was used to extract data related to each study (i.e., sample characteristics, methods, results, and findings).

Titles and abstracts were reviewed independently by two reviewers to determine eligibility of studies for inclusion. Studies were included based on all the following inclusion criteria being met:

1) The primary neurotype of interest was ADHD. Studies were included if children were formally diagnosed with ADHD or if they scored above cut-off criteria on a standardised ADHD screening measure (i.e., interview or checklist), e.g., Conners 3, Conners 4, Disruptive Behaviour Disorders Rating Scale (DBDRS), Children's Interview for Psychiatric Syndromes (P-ChIPS), Vanderbilt Assessment Scale. This was intended to increase the applicability of the review's findings to clinical samples.

2) Participants of interest were children and adolescents up to 18 years and 11 months of age. No lower age limit was specified. This age range was selected to incorporate children of all ages and across preschool, primary, and high school.

3) The authors reported specifically on social outcomes for children with ADHD (i.e., if there were multiple populations in the sample, findings related to children with ADHD needed to be reported separately).

4) Co-occurring conditions were acceptable; however, studies were included only if the research was focused primarily on social outcomes in relation to the ADHD diagnosis.

5) The authors examined cognitive factors in relation to their impact on social outcomes, such as interpersonal skills, peer acceptance or rejection, and reciprocal friendships.

6) Cognitive abilities were measured using standardised measures (e.g., neuropsychological or psychometric assessment tools or standardised questionnaires) or experimental paradigms.

7) Social outcomes were measured using standardised questionnaires, observational or experimental paradigms, or sociometric methods.

The systematic review excluded:

1) Review articles; dissertations; editorials; case studies; conference papers.

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2) Studies with samples containing adults ≥19 years of age.

3) Studies where it was apparent that the sample did not include children or adolescents with ADHD (e.g., studies where participants are described as having 'attention problems,' or 'ADHD symptoms' that are below a symptom cut-off). Studies whose participants had 'sluggish cognitive tempo' (SCT) were excluded, based on SCT not being established as a formal diagnosis (e.g., in the DSM-5-TR).

4) Studies that were investigating social knowledge factors, such as social perception, theory of mind, or social cognition, as a predictor of social outcomes.

5) Studies that only investigated *either* cognitive abilities *or* social outcomes in ADHD, but not each in relation to the other.

Full texts were read critically and screened for inclusion/exclusion by two independent researchers (AB & and a trained research assistant). A third reviewer was available to resolve potential discrepancies. Discrepancies were discussed between reviewers to achieve 100% consensus. Key data were extracted by researcher AB, and a research assistant verified the extracted information to ensure accuracy. Data were sought on which cognitive domains and social outcomes were being investigated, the tools used to measure these constructs, and the relationships between these cognitive and social factors. To explore potential sources of heterogeneity among results, data were also sought on the breakdown of ADHD presentation types, age range and gender distribution of the sample, presence and types of co-occurring diagnoses, medication status, and the methods used to diagnose or screen for ADHD. Data were also sought on whether these variables were controlled for in statistical analyses and/or if there were findings relating to potential moderating or mediating effects of these variables on study outcomes.

Quality was evaluated independently by the first author (AB) and a trained research assistant using the Quality Assessment for Diverse Studies (QuADS) tool [50]. The QuADS is a 13-item tool used to review multi-method or mixed methods research. Although it does not employ cut-off scores, the questions are used to determine which studies have more or less comprehensive reporting. Twelve of the original 13 items from the QuADS were used for quality appraisal, as item 12 ("evidence that the research stakeholders have been considered in research design or conduct") was not addressed in any of the articles and therefore did not differentiate the studies. Each item was rated on a scale from 0 to 3 (with 3 indicating higher quality). Therefore, each article could score up to 36 points on this rating scale. The QuADS and its precursor (the QATSDD) have been used in medical and allied health research and, following conventions in health science and psychology systematic reviews [51,52], the final QuADS score was converted into a percentage for each article using the formula ([rating]/36)*100.

Data were synthesised according to the social outcomes being investigated: Interpersonal skills, prosocial behaviours, and peer-group attitudes. A qualitative synthesis was conducted to evaluate the relationships between cognition and social outcomes. Quantitative synthesis was not possible for this review due to the varying ways in which cognition and social outcomes were conceptualised, operationalised, and measured. For instance, social outcomes may refer to child-specific factors, such as prosocial and interpersonal skills, or peer-group outcomes, such as peer acceptance and rejection, or number of friendships. Similarly, many studies measured cognitive factors using neuropsychological tests, standardised questionnaires, or other behavioural measures such as observation and coding of emotion regulation skills, and were therefore unsuitable for quantitative synthesis.

Results

Study Selection

Figure 1 depicts the selection process in a PRISMA flow diagram. The electronic search returned 15,231 papers and an additional nine papers were identified from hand-searching. Duplicates were removed using EndNote, Covidence, and by scanning through the references. After removing duplicates, the titles and abstracts of 9,280 articles were screened. There were 13 conflicts in the title and abstract screening stage and consensus was achieved by reading and discussing the full text. The first author and a trained research assistant considered 88 articles for full text review and discrepancies (n=4) were discussed to reach consensus. Some studies [10,53], examined the relationship between ADHD presentation type and social functioning, however these were excluded for not directly investigating a *cognitive* correlate of social functioning. Overall, 30 articles met the inclusion criteria. We report on 30 papers that were deemed eligible for inclusion.

Operationalisation of social outcomes

Data from the included studies were grouped and synthesised according to the social outcomes measured. To determine broad social outcome categories, two reviewers (AB, MP) read the items and/or the user manuals for each outcome measure and discussed how they would best be categorised. Social measures were categorised according to whether they measured: interpersonal skills, prosocial behaviours, or peer-group attitudes. The cognitive correlates of interpersonal skills, prosocial behaviours, and peer-group attitudes are shown in Tables 2-4, respectively. Several studies investigated a combination of different social outcomes (e.g., both prosocial behaviours and peer group attitudes), and these are shown in Table 5. Studies in each table are arranged from strongest to weakest quality rating on the QuADS.

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Table 2: Summary of studies investigating cognitive correlates of interpersonal skills

Author (year)	Sample size by group	% Boys [a]	ADHD Presentations	Age Range in years (M)	Medication status	Co-occurring conditions/ Excluded conditions	Cognitive domain(s) Cognitive measure(s) of interest	Social measure(s)	Analyses used & Main findings	QUADS quality rating (%)
Melegari et al. (2019)	Total: 190 ADHD: 86 Control: 104	81.10%	Not reported	Range not reported. (4.68)	Not reported	Comorbidities: ODD; Anxiety. Excluded: Neurological sensory-motor disorder; IQ < 70; autism.	Emotion regulation *CBCL-TRF: Anxiety/ Depression, Aggression behaviours, & Attention problems (DESR profile)*	PAPA (PR) [+]	ROC analyses: ADHD group with deficient emotional self-regulation (DESR) were sig more impaired in social functioning (relationships with peers, parents and teachers) compared to ADHD group without DESR ($p = 2.23 \times 10^{-5}$).	83.3
Tamm et al. (2021)	ADHD: 159	79.10%	Not reported	5-12 (7.64)	Not reported	Comorbidities: ODD; Anxiety disorder; Depressive disorder; adjustment disorder	Executive functioning (Cognitive flexibility, inhibition, working memory) *MEFS*	VAD (PR & TR) performance ratings on individual impairment items	Multivariate regression: MEFS was not uniquely associated with any parent or teacher social performance ratings. Symptom severity (β= .25, p<.05) and younger age (β= -.20, p<.05) were sig associated with PR relationships with peers. Symptom severity (β= .18, p<.05) and younger age (β= -.22, p<.05) were sig associated with TR relationships with peers.	83.3
Happe et al. (2006)	Total: 94 ADHD: 30; Autism: 32; Control: 32	100.00%	Not reported	8-16 (11.6)	Methylphenidate: 90%* (medicated for IQ testing, but unmedicated for experimental tasks)	Comorbidities: Reading disorder; CD; anxiety disorder Excluded: PDD; Tourette syndrome; OCD; ADD without hyperactivity; IQ<70.	Response selection *Go-No Go Task; Cognitive Estimates; Letter Fluency; Category Fluency; Design Fluency.* Cognitive flexibility *Letter Fluency; Category Fluency; Design Fluency; CANTAB ID/ED.* Planning/Working memory *CANTAB SOC; CANTAB SWM*	VABS: Socialisation domain (Interactive & Active sociability) (PR)	Correlation: No sig correlation between executive functioning and the socialisation factors (interpersonal, play, and leisure) on the VABS for the ADHD group (r and p values not reported for n.s. outcomes). Socialisation was significantly related to planning/ working memory in the control group and to all executive functioning domains for the autistic group.	77.8
Tseng & Gau (2013)	Total: 452; ADHD: 279; Control: 173	52.20%	Not reported	11-17 (12.94)	Not reported	Comorbidities: ODD; CD; MDD; GAD Excluded: Autism; psychosis; learning disability; IQ<80.	Working memory *CANTAB: Spatial Span CANTAB: SWM.* Cognitive flexibility *CANTAB: ID/ED.* Planning *CANTAB: SOC*	Composite score of 'social problems' created by averaging the summed scores on the following measures: YSR: Social Problems subscale (SR) CBCL (PR)	Mediation model analyses: Spatial working memory span (B= -0.51, p < .001), spatial working memory errors (B= 7.90, p < .001) and planning (B=0.64, p<.01) (but not set shifting and response inhibition) significantly mediated the effect of ADHD symptoms on social problems, independent of age, gender, IQ. General Linear Model analyses: ADHD group with social problems had significantly more spatial working memory errors compared to ADHD group without social problems (p<.05, d=0.87). ADHD social problems were not significantly associated with ADHD severity or comorbidities.	69.4

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Ayyildiz et al. (2014)	Total: 109; ADHD: 37; Autism: 33; Control: 39	69.90%	C: 62.1%; I: 27.02%; HI: 10.8%	6-17 (10.54)	Drug-naïve sample	Comorbidities: ODD; Separation Anxiety disorder; specific phobia; tic disorder Excluded: IQ<70; history of psychotropic drug use, neurological illness or head injury involving loss of consciousness	Executive functioning: Metacognition & behaviour regulation *BRIEF (PR)*	SRS (PR)	Hierarchical linear regression: BRI and MCI explained 52.6% of the variance in SRS scores (sig). In the final model, only the BRI value was significant. Gender and Verbal IQ did not significantly predict SRS score. ODD was not a significant predictor of SRS score.	66.7
Ng et al. (2021) ≈	Total: 94; ADHD: 27; Autism: 23; ADHD+ASD: 44	85.10%	C: 62.96%; I: 22.22%; HI: 3.70%	7-18 (10.78)	ADHD Medication: ADHD: 63.0%; ASD: 17.4%; ASD+ADHD: 68.2%	Comorbidities: Anxiety disorder; Mood disorder. Excluded: History of neurological disorders; Intellectual disability.	Attention Inhibition Sustained Attention *CPT-II Omissions and Commissions.* Symptom severity *Conners 3 Parent Report inattention and hyperactivity/ impulsivity*	SRS Total Score (PR)	Correlations: Among the ADHD group, greater social impairment was associated with greater inattentive symptoms (parent report) and greater hyperactive/impulsive symptoms (parent report(=). Regression: Parent-report hyperactivity/impulsivity was a significant predictor of social outcomes, whereas CPT omissions and commissions, and parent-report inattentiveness were not significant in the overall model.	66.7
Chiang & Gau (2014)	Total: 635 ADHD: 511 Control: 124	82.70%	C: 54.6%; I: 39.92%; HI: 5.48%	8-18 (12.09)	Unspecified medication 60.1%*	Comorbidities: Not reported. Excluded: Serious medical illness, IQ<80, history of bipolar, psychosis, epilepsy, PDD, or learning disorders.	Working memory *CANTAB: SWM* Planning *CANTAB: SOC mean moves*	SAICA (PR): Domains of interest: School social interactions; Peer social relationships; Peer problems.	Multivariate analysis: Children with ADHD (with and without executive functioning impairment) had poorer school social interactions, poorer peer social interactions and greater peer problems than neurotypical peers (all *ps* < .001), controlling for age, sex, IQ, comorbidity, and current medication use. Hierarchical multiple linear regressions: Poor spatial working memory was significantly associated with more severe problems in peer social relationships (β=.005, *p* = .024). Poor spatial planning (β=.03, *p* = .011) and spatial working memory (β=.003, *p* = .015) were significantly associated with more peer problems. Spatial working memory (β=.004, *p*=.037), age (β=.05, *p* <.001), and comorbidity (β=0.25, *p* <.001) was significantly associated with poorer social interactions at school. Covariates: Older age was associated with worse social function generally, except peer interactions. Psychiatric comorbidity had a negative effect on most social functions.	66.7

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[a]The binary of boys and girls was used in all studies.

∫ Longitudinal Design; ≈ Retrospective design

C: ADHD-Combined Presentation; I: ADHD-Predominantly Inattentive Presentation; HI: ADHD-Predominantly Hyperactive/Impulsive Presentation.

ODD: Oppositional defiant disorder; CD: Conduct disorder; MDD: Major depressive disorder; SLD: Specific learning disorder; GAD: Generalised anxiety disorder; OCD: Obsessive Compulsive disorder; PDD: Pervasive Developmental Disorders; NOS: Not otherwise specified.

PR: Parent-report; SR: Self-report; TR: Teacher-report

* 24+ hour washout period; **<24-hour washout period; ***Washout period length unspecified

^ Observational measure; + Interview

B = unstandardised beta co-efficient; β = standardised beta coefficient

Cognitive measures abbreviations: BASC-2: Behavior Assessment System for Children: Second Edition; BRI: Behaviour Regulation Index (of the BRIEF); BRIEF: Behaviour Rating Inventory of Executive Function; CANTAB: Cambridge neuropsychological test automated battery; CASL: Comprehensive Assessment of Spoken Language; CBCL: Child Behaviour Checklist; CCC-2: Children's Communicative Checklist, Second Edition; CELF-4: Clinical Evaluation of Language Fundamentals - 4th Edition ; CPT-II: Conners Continuous Performance Test, 2nd Edition; CPT: Conners Continuous Performance Test; CUL: Cancel Underline; DERS : Difficulties in Emotion Regulation Scale; ERICA: Emotion Regulation Index for Children and Adolescents ; ERQ-CA: Emotion Regulation Questionnaire for Children and Adolescents; GEC: Global Executive Composite (of the BRIEF); ID/ED: Intra- or Extra-dimensional set shifting (of the CANTAB); MEFS: Minnesota Executive Function Scale ; MI: Metacognition Index (of the BRIEF); MSVA : Magallanes Scale of Visual Attention; NAP: Narrative Assessment Profile ; OSARI: Open-Source Anticipated Response Inhibition Task; PERCI: Perth Emotion Regulation Competency Inventory; PHWM: Computerised Phonological Working Memory Task (Rapport et al., 2009); PPVT-R: Peabody Picture Vocabulary Test-Revised; ROCF: Rey-Osterrieth Complex Figure Copy Task; SIDAC: Structured Interview for Diagnostic Assessment of Children ; SNAP-IV: Swanson, Nolan, and Pelham Rating Scale, Fourth Edition; SOC: Stockings of Cambridge Task (of the CANTAB); SSRT : Stop-Signal Reaction Time task; SWM: Spatial Working Memory Task (of the CANTAB); TEIQue-CF: Trait Emotional Intelligence Questionnaire - Child form, Low Impulsivity subscale; ToH: Tower of Hanoi; TOPL-2: Test of Pragmatic Language - 2nd Edition; TRF: Teacher Report Form (of the CBCL); VCI: Verbal Comprehension Index (from Wechsler scales; Comprising of the Similarities, Vocabulary & Comprehension subtests); VSWM: Computerised Visuospatial Working Memory Task (Rapport et al., 2009); WASI: Wechsler Abbreviated Scale of Intelligence; WISC-III: Wechsler Intelligence Scale for Children, Third Edition; WISC-IV: Wechsler Intelligence Scale for Children, Fourth Edition; WISC-V: Wechsler Intelligence Scale for Children, Fifth Edition.

Social measures abbreviations: ASS: Active Sociability Scale; BASC-2: Behaviour Assessment System for Children - 2nd Edition; CABS: Children's Assertive Behaviour Scale; CBCL: Child Behaviour Checklist; DSAS: Dishion Social Acceptance Scale; DSPS: Dishion Social Preference Scale; FQQ: Friendship Quality Questionnaire; GBS: Gatehouse Bullying Scale; IRS: Impairment Rating Scale; ISS: Interactive Sociability Scale; PAPA: Paediatric Interview with Preschool Age Psychiatric Assessment; PedsQL: Paediatric Quality of Life; PR: Parent-report questionnaire; QOP: Quality of Playdates Questionnaire; SAICA: Social adjustment inventory for children and adolescents; SDQ: Strengths & Difficulties Questionnaire; SR: Self-report questionnaire; SRQ: Social Relationships Questionnaire; SRS: Social Responsiveness Scale; SSIS: Social Skills Improvement System; SSRS: Social Skills Rating System; TR: Teacher-report questionnaire; TRF: Teacher Report Form from the CBCL; VABS: Vineland Adaptive Behaviour Scales; VAD: Vanderblit ADHD Diagnostic Rating Scales; YSR: Youth Self-Report parallel to the parent-report CBCL.

Table 3: Summary of studies investigating cognitive correlates of prosocial skills.

Author (year)	Sample size by group	% Boys [a]	ADHD Presentations	Age Range in years (M)	Medication status	Co-occurring conditions/ Excluded conditions	Cognitive domain(s) *Cognitive measure(s) of interest*	Social measure(s)	Analyses used & main findings	QUADS quality rating (%)
Kofler et al. (2017)	ADHD: 44	70.50%	C: 40.91%; I: 52.27%; HI: 6.82%	8-13 (10.31)	Psychostimulants: 50%*	Comorbidities: ODD; Depressive disorders; anxiety disorders. Excluded: Autism; IQ<80; history of seizure disorder; gross neurological, sensory, or motor impairment.	Working memory *PHWM Task; VSWM Task* Inhibition Processing speed *Stop-Signal Task (Stop-signal delay; Mean choice reaction time)*	BASC-2 - Social skills (PR & TR)	Cohen's d group differences: Children with PR social impairment demonstrated slower processing speed (d = 0.53, *p* = 0.4) and had medium magnitude but n.s. impairments in PHWM (d = 0.53, *p* = .12). Children with TR social impairment had small-medium but n.s. reductions in inhibitory control (d = 0.44, *p* = .2). Linear regressions: Better VSWM (*B* = 4.02, *p* = .03) and processing speed (*B* = 4.53, *p* = .03) predicted better teacher reported social functioning. Inhibition, PHWM, and IQ did not predict TR social functioning. PHWM was reported to predict parent-reported social functioning (*B* = 3.07, *p* = .06), but the omnibus test for PR social functioning was non-sig. (*p* = .44).	94.4

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Kofler et al. (2018)	Total: 117; ADHD: 77; Control: 40	63.20%	C: 54.55%; I: 38.96%; HI: 6.49%	8-13 (10.45)	Psychostimulants: 40.3%*	Comorbidities: ODD; autism; Depressive disorders; anxiety disorders. Excluded: Intellectual disability; history of seizure disorder; gross neurological, sensory, or motor impairment	Working memory *PHWM Task; VSWM Task.* Inhibition Processing speed *Stop-Signal Task (Stop-signal delay; Mean choice reaction time)*	SSIS (PR & TR)	Bayesian linear regressions: PR: Better VSWM (β = .17) and fewer TR hyperactive symptoms (β = -0.18) were associated with better PR social skills (overall model BF_{10} = 3.20). Evidence supported a lack of an effect of processing speed, PHWM, and TR attention problems. TR: Better-developed VSWM (β = .19), PHWM (β = .19), IQ (β = .20), and fewer inattentive behaviours (β = -.34) were associated with better developed TR social skills (Overall model BF_{10} = 7.92 x 10^5). There was a lack of an effect for processing speed and socio-economic status. No evidence was found for a role of inhibition or processing speed in social skills. Covariates on PR-based analysis: Evidence for *lack of* an effect of age, gender, SES, and IQ. Covariates on TR-based analysis: Evidence for *lack of* an effect of PR hyperactivity symptoms, age, and gender. No differences in findings based on the presence of comorbidities.	91.7
Cleminshaw et al. (2020)	ADHD: 174	81.40%	C: 49.7%; I: 49.7%; HI: 0.53%	Range not reported. (*M*=14.51)	Unspecified medication: 43%	Comorbidities: ODD; CD; GAD; MDD; Social anxiety disorder. Excluded: IQ<75; bipolar disorder; OCD; psychotic disorder; at high risk for substance abuse disorder.	Emotion regulation *ERICA SR: Self-awareness & emotional control subscales. DERS SR: Impulse subscale.*	SSIS (PR)	Simple mediation: Emotional self-awareness significantly mediated the relationship between ADHD symptom frequency and social skills (R^2=0.383, p <.001, 95% CI [-0.215, -0.069]). Emotion control significantly mediated the relationship between ADHD symptom frequency and social skills (R^2= 0.33, *p*<.001; 95% CI [0.408, 0.166]). Impulse control was not a significant mediator. Moderated mediation model: Depression did not moderate the negative indirect effect of ADHD on parent-rated social skills with ERICA self-awareness, emotional control, or DERS impulse as mediators.	88.9
Bunford et al. (2015)	ADHD: 171	76.00%	C: 48.85%; I: 51.15%	10-14 (12.15)	Not reported	Comorbidities: ODD; MDD; Any anxiety. Excluded: IQ<80; PDD; Bipolar disorder; Psychosis; substance dependence other than tobacco; OCD.	Emotion regulation *DERS-SR - Impulse subscale ERICA-SR: Emotional Control & Emotional self-awareness subscales*	SSIS (PR)	Simple mediation: Emotional self-awareness mediates the negative association between ADHD symptoms and social skills (B=.045, CI [.004, .135], overall model R^2*=.352,* p<.001). Emotional control and impulse control were not significant mediators of the relationship between ADHD symptom frequency and social skills. Moderated mediation analysis: Self-awareness mediated the relationship between ADHD symptom frequency and social skills at non-clinical but not at sub-clinical or at clinical levels of depression (R^2 = .341, p < .001). Emotional Control mediated the relationships between ADHD and social skills at non-clinical and sub-clinical but not at clinical levels of depression (R^2 = .340, p < .001).	80.6

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Staikova et al. (2013)	Total: 63; ADHD: 28; Control: 35	74.60%	C: 67.86%; I: 28.57%; HI: 3.57%	7-11 (8.88)	Stimulant medication: 7.1%**	Comorbidities: Not reported. Excluded: Autism; neurological disorders; severe expressive/receptive language delays; WISC-IV VCI<80; IQ<80; Chronic illness requiring medication.	Pragmatic language *CCC-2 CASL TOPL-2* Discourse analysis *NAP* Receptive & expressive language *CELF-4*	SSIS (PR)	Multiple linear regression: After controlling for receptive language difficulties, ADHD was a sig predictor of social skills (β = -.626, p < .001), contributing to 40% of the variance in social skills. However, when discourse management was added to the model, the association between ADHD and social skills was no longer significant (β = -.241, p = .097), i.e., Discourse Management (an aspect of pragmatic language) fully mediated the relationship between ADHD and social skills.	75.0
Al-Yagon et al. (2020)	Total: 100; ADHD: 50; Control: 50	49.00%	Not reported	11-12 (11.45)	Not reported	Comorbidities: SLD.	Executive functioning: Metacognition & behaviour regulation *BRIEF (TR) - MI, BRI, GEC*	SSIS (SR)	Linear regression: Executive functions did not contribute significantly to overall social skills score (p >.05). However, affiliation to the ADHD group (β = -.28, p < .01) and an insecure attachment with mother (β = .32, p < .01) and father (β = .28, p < .01) were related to poorer social skills in the overall model (R^2 = .34, p < .001).	72.2
Fernandez-Jaen et al. (2012) ≈	ADHD: 170	75.90%	C: 55.3%; I: 43.5%; HI: 1.2%	6-12 (8.4)	Not reported	Comorbidities: ODD; antisocial disorder; GAD; MDD/ Dysthymia. Excluded: Motor or perceptive disorders; IQ<70; diagnosis of generalised development disorder, OCD, bipolar disorder, schizophrenia, and/or psychosis; known neurological diseases (e.g., epilepsy, drug dependence); previous ADHD diagnosis.	FSIQ *WISC-IV* Attention Visual discrimination *The Face Perception Test* Attention Inhibitory control *The D2 Test* Sustained visual attention *MSVA* Attention (vigilance) Inhibitory control Reaction time *CPT-II omissions, commissions, reaction time*	BASC-2 (PR & TR)	Correlation analysis: Mother-rated social skills were not significantly correlated with any attention tests (Faces test, D2 Test, MSVA, or CPT-II). Mother-rated social skills were significantly associated with WISC-IV Perceptual Reasoning (r=0.32, p<.05), Working Memory (r=0.22, p<.05), and Processing Speed (r=0.21, p<.05) indices. Father-rated social skills were not significantly correlated with any of the cognitive skills. Teacher-rated social skills were significantly correlated with attention measured by CPT omission errors: More attention errors were significantly associated with poorer social skills (r= -0.19, p=.02).	58.3

[a] The binary of boys and girls was used in all studies.

∫ Longitudinal Design; ≈ Retrospective design

C: ADHD-Combined Presentation; I: ADHD-Predominantly Inattentive Presentation; HI: ADHD-Predominantly Hyperactive/Impulsive Presentation.

ODD: Oppositional defiant disorder; CD: Conduct disorder; MDD: Major depressive disorder; SLD: Specific learning disorder; GAD: Generalised anxiety disorder; OCD: Obsessive Compulsive disorder; PDD: Pervasive Developmental Disorders; NOS: Not otherwise specified.

PR: Parent-report; SR: Self-report; TR: Teacher-report

* 24+ hour washout period; **<24-hour washout period; ***Washout period length unspecified

^ Observational measure; + Interview

Cognitive measures abbreviations: BASC-2: Behavior Assessment System for Children: Second Edition; BRI: Behaviour Regulation Index (of the BRIEF); BRIEF: Behaviour Rating Inventory of Executive Function; CANTAB: Cambridge neuropsychological test automated battery; CASL: Comprehensive Assessment of Spoken Language; CBCL: Child Behaviour Checklist; CCC-2: Children's Communicative Checklist, Second Edition; CELF-4: Clinical Evaluation of Language Fundamentals - 4th Edition ; CPT-II: Conners Continuous Performance Test, 2nd Edition; CPT: Conners Continuous Performance Test; CUL: Cancel Underline; DERS : Difficulties in Emotion Regulation Scale; ERICA: Emotion Regulation Index for Children and Adolescents ; ERQ-CA:

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Emotion Regulation Questionnaire for Children and Adolescents; GEC: Global Executive Composite (of the BRIEF); ID/ED: Intra- or Extra-dimensional set shifting (of the CANTAB); MEFS: Minnesota Executive Function Scale ; MI: Metacognition Index (of the BRIEF); MSVA : Magallanes Scale of Visual Attention; NAP: Narrative Assessment Profile ; OSARI: Open-Source Anticipated Response Inhibition Task; PERCI: Perth Emotion Regulation Competency Inventory; PHWM: Computerised Phonological Working Memory Task (Rapport et al., 2009); PPVT-R: Peabody Picture Vocabulary Test-Revised; ROCF: Rey-Osterrieth Complex Figure Copy Task; SIDAC: Structured Interview for Diagnostic Assessment of Children ; SNAP-IV: Swanson, Nolan, and Pelham Rating Scale, Fourth Edition; SOC: Stockings of Cambridge Task (of the CANTAB); SSRT : Stop-Signal Reaction Time task; SWM: Spatial Working Memory Task (of the CANTAB); TEIQue-CF: Trait Emotional Intelligence Questionnaire - Child form, Low Impulsivity subscale; ToH: Tower of Hanoi; TOPL-2: Test of Pragmatic Language - 2nd Edition; TRF: Teacher Report Form (of the CBCL); VCI: Verbal Comprehension Index (from Wechsler scales; Comprising of the Similarities, Vocabulary & Comprehension subtests); VSWM: Computerised Visuospatial Working Memory Task (Rapport et al., 2009); WASI: Wechsler Abbreviated Scale of Intelligence; WISC-III: Wechsler Intelligence Scale for Children, Third Edition; WISC-IV: Wechsler Intelligence Scale for Children, Fourth Edition; WISC-V: Wechsler Intelligence Scale for Children, Fifth Edition.

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Table 4: *Summary of studies investigating cognitive correlates of peer factors*

Author (year)	Sample size by group	% Boys [a]	ADHD Presentations	Age Range in years (M)	Medication status	co-occurring conditions/ Excluded conditions	Cognitive domain(s) *Cognitive measure(s) of interest*	Social measure(s)	Analyses used & Main findings	QUADS quality rating (%)
Zendarski et al. (2020)	ADHD: 121	89%	Not reported	12-15.7 (13.62)	Unspecified medication: 69%	Comorbidities: Autism; Other comorbidities not reported. Excluded: IQ<70; severe medical condition (e.g., cerebral palsy) or sleep apnoea.	Working memory *WISC-IV Digit Span Backwards*	SDQ - Peer Problems subscale (latent variable including SR, PR, & TR) GBS (SR)	Correlation: Sig but weak correlation between working memory and peer victimisation (r=.25, p<.01), and no sig relationship between WM and SDQ peer problems (TR/SR/PR); Sig correlation between WM and SR peer connectedness (r=.19, p<.05); Sig correlations between WM and academic measures. Regression model: Significant but weak associations between working memory and bullying frequency (β = -.18, *p* = .02) and between working memory and distress caused by bullying (β = -.20, *p* = .02). Significant moderate associations between peer relationship problems and bullying frequency (β = .55, *p* < .001 and distress (β = .44, *p* < .001).	86.1
Lee & Hinshaw (2006) [f]	Total: 228; ADHD: 140; Control: 88	0% (all female)	C: 66.43%; I: 33.57%	11.3 - 18.2 (14.1)	~50%*** Data reflect unmedicated behaviour patterns	Comorbidities: ODD; CD. Excluded: IQ<70; neurological disorders or psychosis; autism or other PDD; other medical or psychological conditions that prevented participation.	Inattention Hyperactivity/Impulsivity *SNAP-IV (PR or TR, whichever had more severe rating)*	DSPS (TR)	Hierarchical linear regressions: Neither Time 1 inattention nor Time 1 hyperactivity/impulsivity predicted negative social preference at 5yr follow up (*ps* > .05). Only peer status at Time 1 predicted follow-up social preference (β = -.36, *p* < .001). Age and family income were entered as covariates.	75.0

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McKay et al. (2023)	ADHD: 30	70%	C: 30 %; I: 33%; HI: 17%; Not stated: 20%	13-18 (15.4)	Stimulant medication: 83.3%	Comorbidities: Mood-related; anxiety-related; borderline personality disorder. Excluded: Neurodevelopmental disorders (other than ADHD); history of neurological impairment; physical or mental impairment that prevented participation.	Inhibition *OSARI* Emotion regulation *PERCI (SR)* Emotion recognition *NEPSY-II Emotion Recognition*	Conners 3: Peer Relations subscale (PR)	Correlation: Sig positive correlation between positive emotion regulation and social difficulties (r = -.44, *p* = .014). No sig correlation between negative emotion regulation and social difficulties. No sig correlation between response inhibition and social difficulties. Linear regression & cross-sectional mediation: The regression model including response inhibition (β = .13, *p* =.465), emotion recognition (β = -.36, *p* =.029), and positive emotion regulation (β = .38), *p* =.039) significantly predicted social skills (R^2 = .29, *p* = .007). Emotion regulation did not significantly mediate the relationship between inhibition and social difficulties (i.e., no indirect effect of inhibition on social difficulties through positive emotion regulation). Inhibition significantly predicted positive emotion regulation (*p* = .023). Difficulties regulating positive emotions, rather than difficulties regulating negative emotions, are related to social difficulties in ADHD, and proactive inhibition plays a role in this process.	75.0
Berenguer et al. (2017)	Total: 72; ADHD: 35; Control: 37	ADHD: 91.42% Control: 67.56% Total sample: 79.2%	C: 77.14%; I: 22.86%	7-11 (8.83)	Psychostimulants: 71.4%	Comorbidities: Not reported. Excluded: IQ<80.	Executive functioning: Behaviour regulation *BRIEF – BRI (TR)* Executive functioning: Metacognition *BRIEF – MI (TR)*	SDQ - Peer Problems (PR)	Partial correlation: Peer problems sig correlated with BRI (r=.39, *p* = .022) & ADHD symptoms (r=.46, *p* < .001). Simple mediation analyses: BRI is a partial mediator in relationship between ADHD symptoms and peer problems. ADHD symptoms predicted BRI (R^2 = .2, *p* =.006). Higher BRI (i.e., poorer behaviour regulation) was associated with more peer problems, controlling for ADHD symptoms, (R^2 = .18, *p* =.037). ADHD symptoms did not predict problems with peers above & beyond what was predicted by BRI (*p* = .271). Covariates: sex and age.	72.2

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Sjowall et al. (2014)	Total: 204; ADHD: 102; Control: 102	45.10%	C: 70%; I: 26%; HI: 4%	7-13 (10.38)	Stimulant medication: 62%. Non-stimulant: 8%	Comorbidities: ODD; CD; GAD/Anxiety NOS; OCD; Tourette syndrome. Excluded: IQ<70.	Working memory *Find The Phone Task; Children's Size Ordering Task; WAIS Digit Span Backwards* Inhibition Shifting Reaction time variability *Go-No Go Task; The Navon-like task* Delay aversion *Choice Delay Task* Emotion regulation *Emotion Questionnaire (PR)* Emotion recognition *Identifying emotions from photographs*	SDQ - Peer Problems Subscale (PR & TR mean scores)	Partial correlations: Neuropsychological variables (working memory, inhibition, shifting, reaction time variability) were not significantly correlated with peer problems. Regulation of anger significantly correlated with peer problems ($r=.20$, $p < .01$) after controlling for multiple comparisons. Regulation of sadness, fear, and happiness did not remain significant after controlling for multiple comparisons. Simple mediation: Regulation of anger was a significant mediator of the relationship between ADHD symptoms and peer problems, when controlling for IQ and multiple comparisons. Neither gender nor symptoms of ODD/CD moderated these findings.	72.2.

a The binary of boys and girls was used in all studies.

∫ Longitudinal Design; ≈ Retrospective design

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PR: Parent-report; SR: Self-report; TR: Teacher-report

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Table 5: Summary of studies investigating cognitive correlates of multiple social outcomes

Author (year)	Sample size by group	% Boys [a]	ADHD Presentations	Age Range in years (M)	Medication status	co-occurring conditions/ Excluded conditions	Cognitive domain(s) *Cognitive measure(s) of interest*	Social measure(s)	Analyses used & Main findings	QUADS quality rating (%)
Bunford et al. (2018)	ADHD: 180	75%	C: 48.89%; I: 51.11%	12-16 (13.5)	Not reported	Comorbidities: ODD; MDD/Dysthymia; Any anxiety. Excluded: IQ<80; PDD; bipolar disorder; psychosis; substance dependence (other than tobacco); OCD.	Emotion regulation *DERS-SR* *ERICA-SR*	CBCL- Social problems (PR) SSIS (PR & SR) IRS (PR)	Multivariate linear regression: Controlling for gender, social impairment was significantly predicted by ODD (p < .001), DERS Impulse (p < .001), ERICA Emotional Control (p < .001) and ERICA Self-Awareness (p = .001).	88.9
Kouvava, Antonopoulou, Kokkinos, et al. (2022)	Total: 192; ADHD: 64; SLD: 64; Control: 64	50%	Not reported	8-13 (9.77)	Not reported	Excluded comorbidities.	Emotion regulation *ERQ-CA (SR)* Emotional intelligence *TEIQue-CF (SR): Low Impulsivity subscale*	Sociometric peer nominations FQQ (SR)	Correlation: Aspects of emotion regulation (Low Impulsivity and Cognitive Reappraisal) positively correlated with all self-reported positive friendship qualities. Overall Positive Friendship Quality Total correlated with Low Impulsivity (r=.34, p <.01) and Cognitive Reappraisal (r=.36, p < .01). Low impulsivity negatively correlated with conflict and betrayal in friendships. There were no significant associations between emotion understanding and positive friendship qualities. Hierarchical regressions: Emotion regulation variables (Emotion understanding, low impulsivity, cognitive reappraisal) explained 13% of the variance in number of best friends (R^2 = .13, p <.05). Emotion regulation variables (Emotion understanding, low impulsivity, cognitive reappraisal, expressive suppression) explained 18% of the variance in positive friendship qualities (R^2 = .18, p <.05). Emotion regulation variables (Emotion understanding, low impulsivity, cognitive reappraisal) explained 20% of the variance in conflict and betrayal (R^2 = .20, p <.01).	86.1

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Miller & Hinshaw (2010) [∫]	Baseline: Total: 288; ADHD: 140; Control: 88 FU: Total: 209 (Sample breakdown not reported)	0.00% (all female)	C: 66.43%; I: 33.57%	Baseline: 6-12 (9.6) 5-yr FU: 11-18 (14.2)	Not reported*** Psychotropic medication: 52%	Comorbidities: Reading disorder; CD; ODD.	Executive functioning (Planning, attention, working memory, efficiency) *ROCF Organisation score* *ROCF Error proportion score* Attention Response inhibition *CPT Omissions & Commissions* Inhibitory control Visual discrimination *CUL*	DSPS (TR) Non-standardised Positive Adjustment (PA) measure	Correlations: Baseline cognitive measures all correlated significantly but weakly with follow-up social preference (*rs* range from 0.15 to 0.23; *ps* < .05). Linear regression: When controlling for diagnostic group status, social preference was predicted by CPT omissions (β = 17, *p* =.028) and commissions (β = 16, *p* =.045). Diagnostic group status did not moderate these relationships. Binary logistic regression: When controlling for group status, follow-up Peer Acceptance PA was significantly predicted by (a) ROCF EPS (*p* = .006), (b) baseline CPT omissions (*p* = .012), (c) baseline CPT commissions (*p* = .041).	86.1
Huang-Pollock et al. (2009)	Total: 92; ADHD: 56; Control: 36	64.10%	C: 41.07%; I: 58.93%	8-12 (9.55)	Psychostimulants: 8.9%.* Non-stimulant: 1.8%	Comorbidities: ODD; CD; GAD; MDD. Excluded: Autism; sensorimotor impairment; neurological disorder; psychosis; IQ<80.	A single 'executive functioning' variable based on 3 domains: Response inhibition *SSRT* Working memory *WISC-IV Digit Span* Planning *ROCF Copy time & accuracy*	SSRS (PR) – Total Social Skills scale PRS (TR) Chat Room Task ^	Regression (mediation analysis): EF did not mediate the relationship between ADHD and parent/teacher ratings of social adjustment (all R^2 change <.01, all *p* > .20) or observed behaviours in the Chat Room Task (i.e., off-topic, hostile, or prosocial comments made) (all R^2 change <.02, all *p* > .23), over and above what was accounted for by ADHD diagnostic status. EF predicted some Chat Room task behaviours, i.e., the ability to pick up on subtle social cues (R^2 = .15, *p* =.01) and memory for conversation (R^2 = .22, *p* =.008). Results were primarily driven by inattentive symptoms. Results were not subtype dependent.	83.3
Kouvava, Antonopoulou, Ralli, et al. (2022)	Total: 192; ADHD: 64; SLD: 64; Control: 64	50%	Not reported	8-12 (9.77)	Unmedicated	Comorbidities: SLD.	Receptive vocabulary *PPVT-R* Expressive vocabulary *WISC-III Expressive Vocabulary subscale*	Sociometric peer nominations Best friendship duration (SR)	Correlations: Receptive vocabulary correlated with no. of mutual close friends (r=.35, *p* <.01) and best friendship duration (r=.37, *p* <.01). Expressive vocabulary correlated with number of mutual close friends (r=.23, *p* <.05) and best friendship duration (r=.27, *p* <.05) in the ADHD group. Significant correlations were also present for the control and SLD groups. Hierarchical regression (*authors collapsed ADHD & SLD into one group*): Having ADHD/SLD predicted 15% of the variance in the number of close mutual friends (p<.05); and receptive and expressive vocabulary explained a further 23% of the variance (p<.01). Age and gender were not significant predictors. Having ADHD/SLD predicted 12% of the variance in friendship duration (p<.01); Receptive and expressive vocabulary explained an additional 21% of variance in friendship duration (p<.01). Age and gender were not significant predictors.	83.3

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Mikami et al. (2018) - Study 1	Total: 124; ADHD: 62; Control: 62	67.70%	Not reported	6-10 (8.25)	Unspecified medication: 64.5%	Comorbidities: ODD; CD; Depression; Anxiety. Excluded: PDD; Verbal IQ <75; IQ<70	Verbal IQ *WISC-IV VCI*	SSRS (TR) – Cooperation & Assertiveness subscales DSPS (TR) QOP (PR) Sociometric interviews with peers [+]	Hierarchical multiple regressions: Across all children (with or without ADHD) higher verbal ability was associated with higher teacher-rated socially skilled behaviour (i.e., assertion & cooperation) (β = .230, p < .01). The main effect of higher verbal ability and lower parent-rated conflict and disengagement on playdates was reported "significant at p = .05." After controlling for ADHD status, gender, and comorbidity, verbal ability was unrelated to *peer* sociometric ratings of liking (p > .05) or teacher-rated peer liking (p > .05). ADHD diagnostic status & gender were not significant moderators of any of the relationships.	83.3
Mikami et al. (2018) – Study 2	Total: 137; ADHD: 24; Control: 113	48.20%	Not reported	6-9 (7.35)	Unspecified medication: 41.7%	Comorbidities: ODD; CD; Depression; Anxiety. Excluded: IQ<80;	Verbal IQ *WASI- VCI*	SSRS (TR) – Cooperation & Assertiveness subscales DSPS (TR) QOP (PR) Sociometric interviews with peers [+]	Hierarchical multiple regressions: Across all children (with or without ADHD) higher verbal ability was associated with higher teacher-rated assertion & cooperation (β = .146, p = .03), and lower parent-rated conflict and disengagement on playdates (β = -.18, p = .04), but not with peer- or teacher-rated peer liking, after controlling for ADHD status, gender & comorbidity. Moderation (ADHD status): For children with ADHD, verbal ability predicted higher teacher-rated peer liking (β = .038, p = .016), but lower peer-rated liking on sociometric measures (β = -.361, p = .028). These effects were n.s. for comparison children. Moderation (Gender): Verbal ability may have a beneficial association with TR, PR, and peer-rated peer functioning for boys, but no effect or a potential detrimental association for girls.	83.3
Rinsky & Hinshaw (2011) [ƒ]	Baseline: Total: 228; ADHD: 140; Control: 88 FU: Total: 209 (Sample breakdown not reported)	0.00% (all female)	C: 66.43%; I: 33.57%	Baseline: 6-12 (9.6) FU: 11.3-18.2 (14.2)	Not reported in present study	Comorbidities: Disruptive behaviour disorders; Anxiety disorders; Depression. Excluded: IQ<70; PDD; overt neurological damage; psychosis.	Planning *ROCF Error proportion score* Response inhibition *CPT Commission errors* Working memory *WISC-III Digit Span Forward & Backward subtests* Fine motor control *Grooved Pegboard*	Authors created a composite score of 'social functioning' by finding z score and summing the below measures: DSPS (TR) SSRS (PR) – Total Social Skills scale SRQ (PR) CBCL (PR) Total Competence & Social Problems scales TRF 'Behaving Appropriately' scale	Linear regressions: Significant predictive association between baseline response inhibition and follow up social functioning (β = .158, p = .022), and between baseline planning and follow-up social functioning (β = .150, p = .038), controlling for group (ADHD) status. There was no sig association between baseline working memory and follow-up social functioning (p = .082). ADHD status did not moderate predictive associations between baseline inhibition or planning and follow-up social functioning, indicating that poorer scores on EF measures predicted poorer social functioning in all girls, independently from ADHD. Adolescent comorbidity partially mediated the effect of childhood planning on adolescent social functioning (p = .002)	80.6

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Charman, et al. (2001)	Total: 44; ADHD: 22; Control: 22	100.00%	Not reported	6-10 (8.7)	Psycho-stimu-lants: 90.9%*	Excluded comorbidities. Excluded: IQ outside average range; CD.	Planning *ToH* Response inhibition *Go-No Go Task*	VABS (PR) ASS (PR); ISS (PR)	Correlations: No significant correlations between any measures of social competence planning (all *ps* > .05) or inhibition (all *ps* > .05), controlling for IQ.	75.0
Graziano et al. (2011)	ADHD: 62	75.80%	C: 59.68%; I: 37.10%; NOS: 3.23%	6-18 (11.3)	Unspeci-fied med-ication: 64%	Comorbidities: Not reported. Excluded: Intellectual disability; psy-chotic disorders.	Inattention *Conners 3 Inattention T-Score (PR)* Behaviour regulation & emotion *BASC-2*	A single social functioning factor based on the vari-ables below: PedsQL social functioning quality of life (PR) Conners 3: Peer Relations Subscale (PR) BASC-2 social skills and adaptability subscales (PR)	Correlations: Poorer social functioning was correlated with higher levels of inattention (r = -.39, p < .01) and hyperactivity/impulsivity (r = -.44 p <.001). Hierarchical regression: After controlling for ADHD symptom severity, externalizing symptoms (β = -.23, p < .05) and atypical behaviours (β = -.51, p < .01) were significant predictors of social functioning.	69.4
Melnick & Hin-shaw (2000)	Total: 82; ADHD: 48; Control: 34	100.00%	Not reported	6-12 (9.11)	Stimulant medi-cation: 100%	Comorbidities: Not reported. Excluded: Verbal IQ<70; overt neurological impair-ment.	Emotion regulation *Behavioural observa-tion of reactivity and regulation* ^	Behaviour Ob-servation System (non-compliance, verbal aggress-sion) ^ Sociometric inter-views with peers +	Multiple regression: After controlling for ADHD symp-tomatology, some emotion regulation strategies, 'accommodates' (coef-ficient = .18, p < .05) and 'negative responses' (coefficient = -.24, p < .05) were marginally significant predictors of social preference. Other emotion regulation strategies (e.g., problem-solves, shuts down, vents, seeks help) were not significant predictors of social preference. Diagnostic status does not moderate the relationship between emotion regulation and social outcomes. There was a specific vulnerability to poor emotion regulation among the boys with ADHD who were classified as 'highly aggressive.'	69.4
Maedgen & Carlson	Total: 47; ADHD: 30; Control: 17	63.20%	C: 53.33%; I: 46.67%	8-11 (10.19)	Methyl-phenidate: 66.7% Dextro-amphet-amine: 6.7% Clonidine: 6.7%**	Comorbidities: ODD; CD; Learning disabil-ities.	Emotion regulation *Emotion Regulation Task (Prize Para-digm)* ^	CABS (PR & TR) DSPS (PR & TR) CABS (SR)	Simultaneous regression: Regardless of ADHD status, emotion regulation ('negative behaviour following disappointment') (β = -.22, p = .04) and parent-report social performance (β = -.12, p < .01) were significant predictors of parent-rated peer social preference.	61.1

[a]The binary of boys and girls was used in all studies.

∫ Longitudinal Design; ≈ Retrospective design

C: ADHD-Combined Presentation; I: ADHD-Predominantly Inattentive Presentation; HI: ADHD-Predominantly Hyperactive/Impulsive Presentation.

ODD: Oppositional defiant disorder; CD: Conduct disorder; MDD: Major depressive disorder; SLD: Specific learning disorder; GAD: Generalised anxiety disorder; OCD: Obsessive Compulsive disorder; PDD: Pervasive Developmental Disorders; NOS: Not otherwise specified.

PR: Parent-report; SR: Self-report; TR: Teacher-report

* 24+ hour washout period; **<24-hour washout period; ***Washout period length unspecified

^ Observational measure; + Interview

Cognitive measures abbreviations: BASC-2: Behavior Assessment System for Children: Second Edition; BRI: Behaviour Regulation Index (of the BRIEF); BRIEF: Behaviour Rating Inventory of Executive Function; CANTAB: Cambridge neuropsychological test automated battery; CASL: Comprehensive Assessment of Spoken Language; CBCL: Child Behaviour Checklist; CCC-2: Children's Communicative Checklist, Second Edition; CELF-4: Clinical Evaluation of Language Fundamentals

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- 4th Edition ; CPT-II: Conners Continuous Performance Test, 2nd Edition; CPT: Conners Continuous Performance Test; CUL: Cancel Underline; DERS : Difficulties in Emotion Regulation Scale; ERICA: Emotion Regulation Index for Children and Adolescents ; ERQ-CA: Emotion Regulation Questionnaire for Children and Adolescents; GEC: Global Executive Composite (of the BRIEF); ID/ED: Intra- or Extra-dimensional set shifting (of the CANTAB); MEFS: Minnesota Executive Function Scale ; MI: Metacognition Index (of the BRIEF); MSVA : Magallanes Scale of Visual Attention; NAP: Narrative Assessment Profile ; OSARI: Open-Source Anticipated Response Inhibition Task; PERCI: Perth Emotion Regulation Competency Inventory; PHWM: Computerised Phonological Working Memory Task (Rapport et al., 2009); PPVT-R: Peabody Picture Vocabulary Test-Revised; ROCF: Rey-Osterrieth Complex Figure Copy Task; SIDAC: Structured Interview for Diagnostic Assessment of Children ; SNAP-IV: Swanson, Nolan, and Pelham Rating Scale, Fourth Edition; SOC: Stockings of Cambridge Task (of the CANTAB); SSRT : Stop-Signal Reaction Time task; SWM: Spatial Working Memory Task (of the CANTAB); TEIQue-CF: Trait Emotional Intelligence Questionnaire - Child form, Low Impulsivity subscale; ToH: Tower of Hanoi; TOPL-2: Test of Pragmatic Language - 2nd Edition; TRF: Teacher Report Form (of the CBCL); VCI: Verbal Comprehension Index (from Wechsler scales; Comprising of the Similarities, Vocabulary & Comprehension subtests); VSWM: Computerised Visuospatial Working Memory Task (Rapport et al., 2009); WASI: Wechsler Abbreviated Scale of Intelligence; WISC-III: Wechsler Intelligence Scale for Children, Third Edition; WISC-IV: Wechsler Intelligence Scale for Children, Fourth Edition; WISC-V: Wechsler Intelligence Scale for Children, Fifth Edition.

Social measures abbreviations: ASS: Active Sociability Scale; BASC-2: Behaviour Assessment System for Children - 2nd Edition; CABS: Children's Assertive Behaviour Scale; CBCL: Child Behaviour Checklist; DSAS: Dishion Social Acceptance Scale; DSPS: Dishion Social Preference Scale; FQQ: Friendship Quality Questionnaire; GBS: Gatehouse Bullying Scale; IRS: Impairment Rating Scale; ISS: Interactive Sociability Scale; PAPA: Paediatric Interview with Preschool Age Psychiatric Assessment; PedsQL: Paediatric Quality of Life; PR: Parent-report questionnaire; QOP: Quality of Playdates Questionnaire; SAICA: Social adjustment inventory for children and adolescents; SDQ: Strengths & Difficulties Questionnaire; SR: Self-report questionnaire; SRQ: Social Relationships Questionnaire; SRS: Social Responsiveness Scale; SSIS: Social Skills Improvement System; SSRS: Social Skills Rating System; TR: Teacher-report questionnaire; TRF: Teacher Report Form from the CBCL; VABS: Vineland Adaptive Behaviour Scales; VAD: Vanderblit ADHD Diagnostic Rating Scales; YSR: Youth Self-Report parallel to the parent-report CBCL.

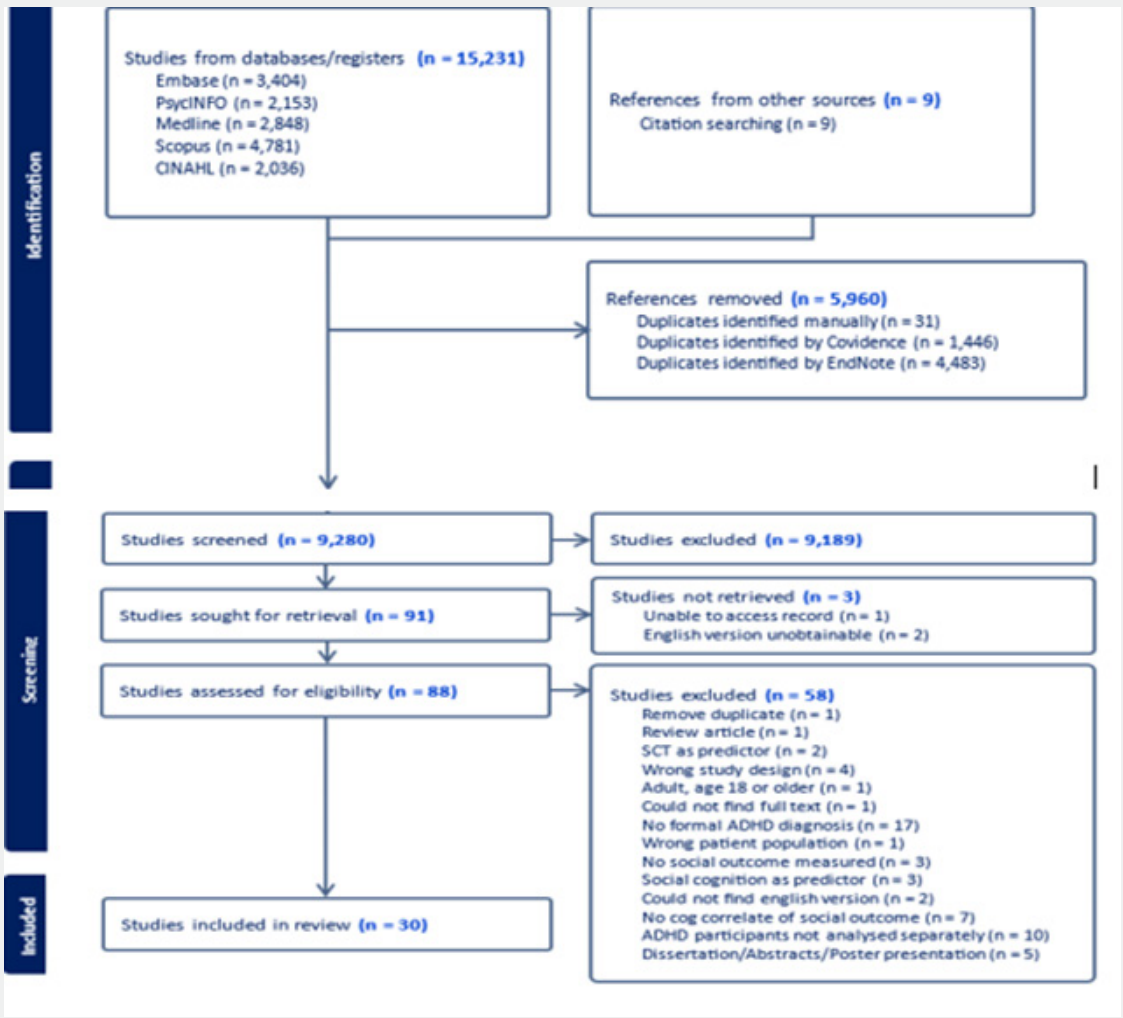

Figure: PRISMA Flow Diagram

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Each table contains study characteristics that were deemed relevant for the analysis, such as reporting on medication, ADHD presentation type, and co-occurring diagnoses, gender and age, as well as the measures used and the key findings.

Study Characteristics

Study characteristics are displayed in Tables 2-5. Of the studies that were included, samples tended to have more male participants, reflecting the disproportionately higher rates of ADHD diagnosis in males compared to females [54]. Six studies had samples comprising of *only* girls [55-57], or *only* boys [58-60]. It is notable that approximately 30% of the studies that were considered in the title/abstract and full text screening stages were excluded due to a lack of an ADHD screening measure or formal diagnostic process for ADHD, highlighting that a sizeable proportion of the research pertains to individuals without an ADHD diagnosis. Eighteen (60%) studies provided a breakdown of the ADHD presentation types within their samples. Of the studies that reported on ADHD presentation type, the hyperactive/impulsive presentation was the least represented.

Twenty-two studies (73.3%) reported on medication status (i.e., whether participants in their samples were currently taking medication). Of these, two included unmedicated samples, five included samples where only a minority (i.e., <50%) were medicated, 13 included samples where a majority (>50%) of the sample were medicated, and two reported that 50% of their sample were medicated. Twenty-four papers (80%) reported on the presence of at least one co-occurring diagnosis in their samples or reported that they had excluded participants with co-occurrences. Fifteen studies excluded individuals with autism, formerly 'pervasive developmental disorders' (PDD), while 14 studies did not report on whether their sample included or excluded participants with co-occurring autism. Sixteen (53.33%) studies included participants with a diagnosis or elevated features of Oppositional Defiant Disorder (ODD), and this was the most common co-occurrence noted across studies, consistent with the literature that ODD occurs in approximately 50% of children with the Combined presentation, and 25% of children with the Inattentive presentation [54]. Fifteen (50%) studies included participants with co-occurring anxiety disorders or elevated anxiety symptoms and 11 (36.67%) studies included participants with depressive disorders or elevated depressive symptoms.

Most studies were cross-sectional in design. Three studies (10%) were longitudinal (Lee & Hinshaw, 2006; Miller & Hinshaw, 2010; Rinsky & Hinshaw, 2011) [55-57], and all based on the same dataset.

Cognitive functioning was measured with standardised performance-based tests (n= 19; 63.3%), standardised questionnaires (n=14; 46.7%), laboratory observation (n= 2; 6.7%), or parent interviews (n= 1; 3.3%). Five papers employed a combination of these techniques. The most frequently investigated cognitive skills were working memory (n=10; 33.3%), emotion regulation (n=9; 30%), inhibition (n=6; 20%), and planning (n=6; 20%). Many papers investigated a combination of cognitive factors.

All except one study examined social outcomes with standardised self-, parent-, and/or teacher-report questionnaires. The remaining study [61], measured social outcomes using sociometric peer nominations to gauge peer acceptance. Thirteen studies (43.3%) drew conclusions about social outcomes based on responses from only a single informant, most often a parent- or self-report. Fewer than half (n=14, 46.7%) incorporated a teacher report of social outcomes. A handful of studies additionally employed the use of laboratory-based observational or experimental tasks (n=2; 13.3%), sociometric peer nominations (n=5; 16.7%), or structured parent interviews (n=1; 3.3%).

Methodological Quality

Quality ratings identified on the QUADS are shown in Tables 2-5. In summary, the included studies varied considerably in quality, with quality ratings ranging from 58.3%-94.4%, however most studies were generally sound in quality when measured against QuADS criteria alone. Most studies provided a strong theoretical and conceptual background for their research and stated their research aims clearly. Common limitations with studies included: failure to provide sufficient detail about how participants were recruited; limited justifications for analytic methods selected, and incomplete descriptions of data collection procedures. Only three studies [47,62,63], provided evidence of a power calculation to determine an appropriate sample size.

An often-unavoidable source of bias in this literature was that the assessors (e.g., parents and teachers) could not be masked to the child's ADHD diagnosis, and there was a heavy reliance on questionnaire-based research. However, included papers that used performance-based tests [64], and laboratory observation [65], were able to mask their assessors and coders to participants' diagnostic status. In one naturalistic observational study involving observations of behaviour at a summer camp [58], it was unclear if the behavioural coders were masked during all phases of the study. None of the studies included in this review clearly indicated whether participants were masked to the research question and, therefore, the potential for reporting bias could not be ascertained.

Data on other measures of study quality were also extracted, including whether authors reported on ADHD presentation type, participant gender, co-occurring diagnoses, and medication status and type (i.e., stimulant, non-stimulant). These are shown in Tables 2-5. In most studies, the ADHD diagnosis was confirmed by a psychologist or other mental health professional. One study re-affirmed ADHD diagnosis using standardised parent and teacher report questionnaires, and three studies did not provide detail on how the reported ADHD diagnosis was confirmed.

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Although most studies provided data on medication status and the breakdown of ADHD presentation types within the sample, it was rare to control for the effects of these variables on the relationship between cognitive factors and social outcomes. Of the 22 studies that reported on medication status, six considered its effects on outcomes and three reported that samples were either all medicated (n=1), all unmedicated for the duration of the study (n=1), or all drug naïve (n=1). Of the 18 studies that reported on ADHD presentation type, only three (16.67%) considered ADHD presentation type as a potential covariate.

In contrast, of the 24 studies that reported on comorbidities, half considered co-occurring conditions as a potential covariate, moderator, or mediator in the relationship between cognition and social outcomes. ODD was the most commonly reported co-occurrence in the reviewed literature (n = 16 articles, 53.33%), followed by anxiety (n = 15 articles, 50%) and depressive disorders (n = 11, 36.67%). However, of the articles that reported on co-occurrences, it was not always clear whether rates of co-occurrence in their samples reflected formal diagnoses or elevated symptomatology. In the few reviewed studies that examined covariance, mediation, and/or moderation of co-occurring conditions, there was some evidence that co-occurring conditions may influence relationships between cognitive factors and social outcomes.

Key Findings

Cognitive correlates of interpersonal skills

Seven studies investigated a relationship between cognition and interpersonal skills (i.e., relationships with peers and friends) (Table 2). These studies were cross-sectional in design. Only two of these studies included multiple informants on social measures (either a parent- and teacher-report, or a parent- and child self-report) [66,67]. One study (Tseng & Gau, 2013) [66], created a single composite score of 'social problems' by averaging across parent- and self-report measures.

All seven of these studies examined an aspect of executive functioning as the cognitive correlate of interest. Five studies used standardised performance-based measures of executive functioning, including measures of working memory (n=3), planning (n=3), inhibition (n=1), set shifting (n=1), flexibility (n=1), and response selection (n=1). None of these studies found evidence to support a significant relationship between interpersonal skills and aspects of executive functioning (i.e., inhibition, set-shifting, flexibility, or response selection) in children and adolescents with ADHD [59,67]. Two of these studies reported evidence for a significant relationship between interpersonal skills and non-verbal (spatial) working memory and spatial planning [67,68], whereas another study [59], did not find significant support for these same associations. Tamm et al. [66], did not find evidence for a significant association between performance on a card sorting task measuring cognitive flexibility, inhibitory control and working memory, and parent- or teacher-rated interpersonal skills.

Two studies examined the relationship between aspects of emotion regulation and interpersonal skills. In a preschool sample, Melegari et al. [69] compared children with ADHD who had poorer teacher-reported emotion regulation with children with ADHD who did not have emotion regulation challenges. Melegari et al. found that children with higher levels of emotion dysregulation scored significantly lower on parent-reported measures of interpersonal relationships. Ayyildiz et al. [70], examined relationships between parent-reported executive functioning and social reciprocity. Ayyildiz et al. reported that parent-reported behaviour regulation (on a composite measure of emotion control, behavioural inhibition, and mental flexibility) was the only predictor of social reciprocity in their model, whilst metacognitive skills (e.g., working memory and planning) were non-significant.

Gender was not a significant covariate in the relationship between executive functions and interpersonal skills, as assessed in three studies [21,67,70]. There was some evidence that chronological age and the presence of comorbidities influenced the relationship between cognition and interpersonal skills in ADHD. On the one hand, Tamm et al. [66], found that younger age was significantly associated with poorer interpersonal skills, over and above executive functioning problems for children with ADHD. On the other hand, Chiang and Gau [21], found that older age contributed significantly but weakly to interpersonal problems in a hierarchical multiple linear regression. Chiang and Gau also reported that psychiatric comorbidity significantly impacted social outcomes, however, they did not specify which co-occurring diagnoses were present in their sample. Of note, medication status was reported in only two studies, and only one of these [21], controlled for medication use in their analysis.

In studies where data were analysed using regression analyses, and ratings of ADHD symptom severity were included in their regression models, levels of ADHD traits (i.e., inattention and/or hyperactivity/impulsivity) were consistently the strongest predictors of social outcomes, over and above executive functioning [66], non-verbal working memory and planning (Chiang & Gau, 2014), and attention and inhibition [71].

Cognitive correlates of prosocial behaviours

Seven studies examined the relationship between cognition and prosocial skills (Table 3). In these studies, social outcomes were measured using one of two standardised questionnaires – the Social Skills Improvement System (SSIS) or the Behaviour Assessment System for Children 2nd Edition (BASC-2). Studies used either cross-sectional (n=6) or retrospective (n=1) designs. Most studies reported on ADHD presentation types (n=6) and

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co-occurring diagnoses (n=6), with most samples including participants with co-occurring ODD. Four studies reported on medication status. However, only one of these [47], statistically controlled for medication use in their analysis.

There was some convincing evidence that prosocial behaviours were significantly related to both better emotion regulation and working memory ability. Aspects of emotion regulation were significantly associated with prosocial behaviours in two high quality studies which were similar in sample size, distribution of gender and ADHD presentation types, and measures used [62,72]. Both studies reported that self-reported poorer 'emotional self-awareness' [i.e., "emotional inflexibility and slow return to emotional baseline]" [73], mediated the relationship between ADHD symptom frequency (i.e., how often the behaviour or symptom occurred over the last 6 months) and parent-reported prosocial behaviour. However, of these two studies, Bunford et al. [72], found that this association was moderated by depressive symptoms, whereas Cleminshaw et al. (2020)[62], did not identify a moderating effect of depressive symptoms. Cleminshaw et al. reported that emotion control was a significant mediator in the relationship between ADHD symptom frequency and prosocial behaviour, but Bunford et al. [72], failed to find a significant relationship in this regard. Together, these studies were suggestive of an association between emotion regulation and prosocial behaviour outcomes, but revealed the importance of additional research into the impacts of co-occurring mental health conditions.

Better working memory was significantly associated with more prosocial behaviours in three studies [63,74,75]. Two methodologically high-quality studies [63,75], differentiated between phonological and visuospatial working memory. Both studies reported that better developed visuospatial working memory was significantly associated with more teacher reported prosocial behaviours, however phonological working memory was not consistently linked with prosocial behaviours across parent and teacher ratings and between studies. When examining covariates, Kofler et al. (2018) [75], found no significant effect of age, gender, or socioeconomic status on parent- or teacher-reported prosocial behaviours. However, the impact of some covariates differed between informants, such that having greater hyperactivity significantly influenced the relationship between cognition and prosocial behaviours on parent report, whereas having fewer inattentive features and higher IQ was significantly associated with more prosocial behaviours on teacher report. This may reflect the different degrees of importance attributed to higher IQ and attention for teachers compared to the relevance of hyperactivity for parents in the home setting. Furthermore, it may be that the effects of medication tend to wear off after school, and there is less structure in the home compared to the school environment, resulting in parents observing more hyperactive behaviours.

There was insufficient evidence for an association between pragmatic language and prosocial behaviours. Only one study investigated this relationship [76], and found that pragmatic language fully mediated the relationship between ADHD and parent-reported prosocial behaviours. Similarly, only one study investigated the relationship between standardised questionnaire measures of day-to-day executive functioning and prosocial behaviours [77]. In a linear regression, Al-Yagon et al. [77], reported that teacher-reported executive functioning of the child did not explain significant variance in child self-reported prosocial skills, whilst affiliation to the ADHD group and insecure attachment style were significant predictors in their regression model. As this was the only study investigating these relationships, broader conclusions could not be drawn.

Cognitive correlates of peer group factors

Cognitive correlates of peer-group factors were assessed in five studies (Table 4). Studies were either longitudinal (n=1) or cross-sectional (n=4) in design. Most studies (n=4) provided a breakdown of the ADHD presentation types included in their sample. Most studies (n=4) reported on co-occurrences, but only two studies [78,79], controlled for co-occurrences in their analyses. All studies reported on the percentage of participants who were medicated. Across all studies, at least 50% of participants were prescribed medication. One study [55], employed a 'washout period' of unspecified length and reported that their data reflected unmedicated behaviour patterns. Two studies [78,80] did not consider medication use as a covariate. The remaining two studies reported that medication was not statistically related to key variables and therefore did not control for medication use in further analyses [64,79]. In these two studies, the lack of statistical support for a relationship between medication and peer group acceptance aligned with the evidence that pharmaceutical treatment has not been associated with having more friends or being more accepted or less rejected by peers [16,17]. However, this inference should be taken with caution due to the small number of studies that investigated potential medication effects.

Significant associations between emotion regulation difficulties and low peer acceptance were found in all studies investigating this relationship (n=3). However, delineating these results according to types of emotions afforded some interesting findings. Although emotion regulation is not specific to emotional states [81], McKay et al. [64], found that observed difficulties regulating 'positive' emotions were associated with poorer peer relations in adolescents with ADHD, compared to difficulties regulating 'negative' emotions. In contrast, Sjowall and Thorell (2014)[78], found that difficulties regulating anger, but not sadness, happiness, or fear, was significantly related to childrens' peer problems and significantly mediated the relationship between ADHD and more peer problems. These differences are likely due to sample characteristics, such as McKay

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et al.'s (2023) [64], sample being older, comprising of more boys, and having more internalising comorbidities, whilst Sjowell and Thorell's [78], sample was younger, had a relatively even gender distribution, and had more externalising comorbidities. These discrepancies suggest that for adolescents with ADHD, difficulties regulating 'positive' emotions are potentially more detrimental to peer acceptance, whereas for younger children with more externalising comorbidities, poor regulation of anger may have greater consequences for a child's social acceptance. This aligns with existing qualitative findings, which have found that younger neurotypical children were more likely to exclude peers with ADHD based on concerns about disciplinary consequences of befriending a child with ADHD, and adopt beliefs in stereotypes that their peers with ADHD were 'naughty' [20].

The remaining studies explored peer group factors in relation to other aspects of executive functioning; however, no firm conclusions could be made due to variable findings. Zendarski et al. (2020) [79], reported that poorer phonological working memory was a significant but weak statistical predictor of self-reported peer victimisation. On the other hand, Sjowall and Thorell [78], did not find any significant relationships between a range of neuropsychological variables (verbal and non-verbal working memory, inhibition, set-shifting, delay aversion, and reaction time variability) and parent- or teacher-rated peer problems. Peer-group attitudes were also not found to be significantly associated with scores on functional, standardised questionnaire measures of executive functioning such as the Behavior Rating Inventory of Executive Function (BRIEF) Metacognition Index [80], or Swanson, Nolan, and Pelham Rating Scale (4th Edition, SNAP-IV) inattention and hyperactivity scores [55].

Cognitive correlates of multiple social outcomes

Eleven studies assessed a combination of social outcome measures, including child-specific social performance outcomes (i.e., prosocial behaviours and interpersonal skills) and peer-group factors (i.e., peer status and dyadic friendships). As shown in Table 5, there was support for a relationship between emotion regulation and social outcomes in all four studies investigating this relationship [60,65,73,82]. There was evidence that emotion dysregulation, including difficulties remaining in control of feelings and behaviours, less flexible emotion management, and having a low threshold for emotional excitability or reactivity, were significantly associated with poorer outcomes on parent- and self-report measures of social performance (including prosocial behaviours and interpersonal skills)[73]. Regarding the association between emotion regulation and peer-group factors, emotion regulation explained significant variance in self-reported friendship quality, the number of mutual friends on sociometric [82], ratings of peer preference on sociometric measures [60], as well as parent- and teacher- reported social preference [65]. Two of these studies reported that the relationship between emotion regulation and social preference was evident regardless of ADHD status [60,65]. Overall, there was consistent support for a significant relationship between emotion regulation and both interpersonal skills and prosocial behaviours. Consistent with this, emotion regulation skills were also significantly related to peer-group factors, such as levels of acceptance and inclusion in their peer group.

In a longitudinal study that explored social outcomes in girls with ADHD from childhood to adolescence, Rinsky and Hinshaw [57], reported that poorer scores on baseline psychometric measures of planning and inhibition, but not phonological working memory, predicted adolescent social outcomes at 5-year follow up for all participants, regardless of ADHD diagnosis. Based on data from the same sample, Miller and Hinshaw [56], also identified significant negative relationships between disinhibition and inattention in childhood and level of peer acceptance in adolescence at 5-year follow up. These were the only two studies that identified a significant relationship between disinhibition and poor social outcomes. In both analyses, CPT commission errors at baseline predicted follow-up peer acceptance [56], as well as follow-up 'social functioning,' which was a composite outcome measure comprising of ratings of peer acceptance well as several social skills and competence-based questionnaires [57]. This significant finding indicates that disinhibition may have a more detrimental effect on social outcomes for girls relative to boys, and that early disinhibition may have longer- rather than shorter-term social consequences.

In contrast, cross-sectional research provided insufficient and conflicting evidence regarding the association between executive functions and social outcomes. There was limited significant support for associations between social outcomes and executive functions measured using objective neuropsychological tests. However, behaviour ratings of the severity of inattentiveness, hyperactivity, and impulsivity were reliably associated with social outcomes. These findings are depicted in Table 5. For example, one study [58], did not find evidence for a significant correlation between planning or inhibition and any measures of prosocial behaviours or interpersonal skills. Another study [47], reported that a composite executive function score (comprising of measures of inhibition, phonological working memory, and planning) did not mediate the relationship between ADHD symptoms and peer rejection or prosocial behaviours. However, Huang-Pollock et al. [47], found that executive functions mediated the ability to detect subtle social cues and remember conversations. Huang-Pollock et al. reported that this finding was primarily driven by severity of inattention and hyperactivity/impulsivity. Consistent with these findings, one study [83], reported that parent-reported behavioural observations of inattention, hyperactivity and impulsivity were significantly related to poorer social outcomes based on a social functioning variable comprised of parent-report measures of interpersonal skills, prosocial behaviours, and peer group acceptance.

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As shown in Table 5, there was some sound evidence for a significant relationship between verbal skills (such as expressive and receptive vocabulary and verbal reasoning) and social outcomes. However, discrepancies based on the nature of the social outcome being measured and across informants were identified. For example, Kouvava, Antonopoulou, Ralli, et al. [61], found that receptive and expressive vocabulary skills were associated with having significantly more mutual close friends and longer duration of best friendship on sociometric and questionnaire measures, respectively. However, Mikami et al. (2018) [84], found that while better verbal skills were associated with significantly stronger socially skilled behaviour when rated by parents and teachers, they were not significantly associated with greater peer or teacher rated social acceptance or peer liking. In a second study published in the same paper, Mikami et al. [84], reported that verbal ability was significantly associated with greater peer acceptance when peer acceptance was rated by teachers, but significantly lower peer acceptance when rated by peers themselves. These findings revealed that positive social behaviour observed by parents and teachers was not consistently linked to improved social inclusion by peers. Mikami et al. [84], also identified gender differences, such that verbal ability was significantly associated with better social outcomes for boys but more detrimental outcomes for girls.

Discussion

Children and adolescents with ADHD commonly experience social challenges that are associated with adverse short- and long-term outcomes. At present, interventions fail to adequately improve social outcomes, indicative of a gap in our understanding of the factors contributing to social difficulties in ADHD. To address this gap, as a first step, a systematic review was conducted to evaluate the literature investigating the *cognitive* factors associated with social outcomes among children and adolescents with ADHD. To facilitate qualitative synthesis, articles were classified according to whether they were measuring child-specific social performance factors (i.e., interpersonal skills or prosocial behaviours) or peer group factors (i.e., peer status and friendship). As a secondary aim, we sought to evaluate the potential influence of ADHD presentation type, co-occurring diagnoses, medication status, chronological age, and gender on the relationships between cognitive factors and social outcomes. Despite some limitations with respect to the quality of the literature, the current review provided preliminary support for associations between social outcomes and both emotion regulation and non-verbal (spatial) working memory. Findings from the review and practical implications are discussed in detail below.

Aim 1 main findings: Cognitive correlates of social outcomes

Emotion regulation: This review provided preliminary support for a relationship between

emotion regulation challenges and poorer social outcomes in children and adolescents with ADHD. In the reviewed literature, emotion regulation was measured with standardised self-, parent-, or teacher-report questionnaires or laboratory observations of behaviour in response to disappointing or frustrating scenarios. A key limitation arose from the failure to mask participants to the research question, as well as inadequate reporting about whether coders were masked during laboratory-based behaviour observations, introducing the possibility of Hawthorne effects and confirmation bias, respectively. With these limitations in mind, across all articles reviewed, difficulties with emotion regulation were significantly associated with lower-rated interpersonal skills and prosocial behaviours, as well as lower levels of broader peer group acceptance. A small portion of the reviewed literature found that the nature of the relationship between emotion regulation and social outcome varied depending on either age, gender, or the presence of co-occurring psychological conditions. However, there was a paucity of literature that assessed sub-group differences, limiting the ability to draw conclusions.

Existing theory suggests that emotion regulation difficulties in ADHD are the outcome of two processes: (1) difficulties inhibiting behavioural responses associated with initial emotional arousal (i.e., emotional impulsivity), and (2) difficulty with self-regulation, which impacts the ability to self-soothe, refocus attention, and behave in a goal-directed manner (sometimes referred to as 'deficient emotional self-regulation') [72,85]. Emotion regulation is a skill that is called upon during times of heightened emotion, and therefore plays a key role in the in-the-moment performance of behaviours such as interpersonal and prosocial skills. Real world social interactions may elicit affective responses and require the regulation of emotion and behaviour to achieve favourable social outcomes. It may be that the ability to regulate a response to emotionally charged situations can enable an individual to behave or respond in more socially accepted ways. These findings align with prior research that has highlighted the on-line, performance-based, rather than knowledge-based, social differences in ADHD (i.e., knowing versus doing), as well as the high frequency of emotion regulation difficulties in this population.

Working memory: The present review also found evidence for: a significant relationship between

non-verbal (spatial) working memory and prosocial behaviour; mixed evidence for a significant relationship between non-verbal working memory and interpersonal skills; and insufficient research about the extent to which non-verbal working memory difficulties in children with ADHD were associated with levels of acceptance or rejection in their peer group. The authors of the reviewed literature posit that poor working memory impacts both the acquisition of prosocial skills [75], as well as the in-the-moment performance of learned prosocial skills, due to the impact on "give and take, listen and wait behaviours" [63]. Additionally, the reduced ability to hold thoughts in mind appears to result in more interruptions during social interactions [63,67]. These

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outward behaviours may be secondary to the working memory demands associated with processing non-verbal cues, planning responses, and filtering environmental distractions. Therefore, consistent with existing research, these findings suggest that working memory may be involved in a top-down executive functioning process that is important for regulating and selecting effective social behaviours to promote better social outcomes [86]. The present review suggests that working memory may not only impact social outcomes via impacts on academic functioning, as indicated by Fried et al. [48], but may also play an important role in the acquisition and on-line performance of behaviours considered to be 'prosocial' in neurotypical contexts. On the other hand, inconsistencies in the relationship between non-verbal working memory and interpersonal skills outcomes indicates that working memory may not consistently translate into better interpersonal interactions, despite its associations with prosocial behaviour. Given that interpersonal interactions are more complex, involving skills, characteristics, and attitudes of both the target child and their interaction partner, working memory may play a relatively smaller role in this social process. Additionally, the present review does not clarify whether the impact of working memory on social behaviour corresponds with secondary reductions in peer-group acceptance.

Inhibition: Most cross-sectional research that was reviewed did not report a significant

relationship between behavioural inhibition and social outcomes. However, longitudinal studies exploring the social outcomes of girls with ADHD [56,57], identified that reduced inhibition at baseline was significantly associated with lower levels of peer acceptance and lower scores on parent ratings of social outcomes at 5-year follow-up. The authors highlighted the importance of executive functions in the development of social abilities, as well as the exacerbating impacts of internalising and externalising psychopathology for adolescent girls on longer-term social outcomes [57]. Aside from early impacts of executive dysfunction possibly emerging over time, this discrepancy in findings between cross-sectional and longitudinal studies may also partially be explained by sample characteristics, namely that Rinsky and Hinshaw's and Miller and Hinshaw's samples comprised entirely of girls. It is possible that disinhibited or impulsive behaviours displayed by girls may be perceived as more incongruent with the social norms and expectations placed on them relative to boys, resulting in greater exclusion from the social group (see Mikami, 2010, for a discussion of the unequal impacts of ADHD symptoms on the friendships of girls and boys) [31].

Aim 2 main findings: Impacts of variables of interest on the relationships between cognitive factors and social outcomes

With respect to our second aim, many studies included in the current review reported on variables such as the presence of select co-occurring diagnosis, frequency of ADHD medication use, ADHD presentation type, chronological age, and gender of the sample. However, most studies failed to statistically control for or even consider the effects of these variables on the relationship between cognitive factors and social outcomes. Failure to comprehensively investigate potential effects of these variables impacted the validity of the findings in the present review, as discussed below, and thereby reduced the ability to draw strong conclusions with respect to both aims.

Only 12 of the reviewed studies adequately controlled for common co-occurring conditions such as ODD, anxiety, or depression. For those studies that did include and control for select co-occurring conditions, it was often unclear whether reported co-occurrences reflected official diagnoses or elevated symptomatology on screening measures. It was also occasionally unclear whether co-occurring neurotypes that were not mentioned were comprehensively and adequately screened out. Fifteen studies explicitly excluded participants with co-occurring autism or PDD, whilst 14 studies did not report on whether they included or excluded participants with co-occurring autism. A recent systematic review reported that the rate of co-occurrence between ADHD and clinically significant autism symptoms was between 15%-64.3% [87]. Given this high rate of co-occurrence, the number of studies in the present review that explicitly excluded participants with autism may have reduced the representativeness of the research and in turn compromised the generalisability of the current findings. On the other hand, the failure of nearly half of the studies in the current review to report on or account for potential co-occurring autism may have inflated the degree of social problems in the reviewed literature. One might expect, for example, that for those with co-occurring autism, poorer social outcomes may be more accurately attributed to social cognitive abilities related to autism, such as theory of mind or emotion recognition, rather than the cognitive abilities explored in this review. In turn, this may have impeded our ability to identify relationships between cognitive factors and social outcomes, due to variance that may be better explained by traits associated with autism. Overall, the inconsistent reporting on the presence and impacts of co-occurring conditions may bring into question the validity of the reviewed findings.

In addition to the above, only six studies considered the impact of medication on the relationships between cognitive factors and social outcomes. In the current review, inadequate reporting and statistical control of medication use, medication type, and medication dose may have accounted for the absence of a significant relationship between many of the neuropsychological factors and social outcomes. For example, in studies that did not account for medication status, it is possible that stimulant medications improved executive functioning skills, which may have in turn diluted the relationships between cognition and social outcomes. Of the studies that considered potential medication effects, most investigated relationships between cognition and peer group

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factors, rather than on the social performance outcomes, such as prosocial or interpersonal skills. In these studies, medication was not found to significantly impact the relationship between cognition and peer group factors. However, by neglecting to directly investigate medication effects on social performance, we cannot know from the reviewed literature if medication may, in fact, be impacting social performance but simply not transferring to peer-group outcomes, or if the medication effects are also not being seen at the level of the child's social performance. Further, without longitudinal research, we are unable to identify potential longer-term benefits of medication. The failure to account for medication effects represents a missed opportunity to investigate a potential role for medication in remediating social challenges via impacts on cognitive skills, especially in the long-term.

Additionally, girls were under-represented in the reviewed literature, with potential impacts on generalisability. As mentioned above, certain cognitive factors, such as disinhibition, were associated with poorer social outcomes in samples comprised only of girls, whereas disinhibition was not significantly associated with social outcomes in mixed samples. This suggests that there may be gender differences in the relationships between domains of cognition and social outcomes. As girls' friendships tend to be characterised by more intimacy, self-disclosure, closeness, and smaller group interactions [88,89], cognitive differences, such as inattention, disinhibition, and emotional regulation challenges, may be more salient and have greater impacts social outcomes. These gendered relationships between cognition and social outcomes may, however, be overlooked due to the under-representation of girls in this literature.

Overall, future research should be stratified according to variables such as presence and type of co-occurring conditions, medication status, dose, and type, chronological age, gender, and ADHD presentation type. Research that considers the potential mediating or moderating impacts of these additional variables will greatly assist in our understanding of the factors underlying poor social outcomes in ADHD, and therefore in the development of targets for intervention.

Limitations of the evidence and pathways for future research

Four key limitations of the reviewed studies were identified which impact on the ability to generalise the study findings and should be considered in future designs: (1) heterogeneous operationalisation of cognitive functioning, (2) heterogeneous operationalisation and labelling of social outcomes, (3) reliance on single-informant questionnaire-based measures of social outcomes, (4) more general methodological issues identified on quality appraisal tools. Each of these study limitations are discussed below.

First, the reviewed studies were heterogeneous in the ways in which they operationalised cognitive functions. Cognitive factors were typically assessed using standardised, performance-based neuropsychological tests, with a predominant focus on executive functioning skills. Some studies operationalised executive functioning by averaging performance across a selection of tasks and, therefore, executive functioning domains. For example, Huang-Pollock et al. [47], created a single executive functioning composite which combined scores across measures of inhibitory control, attention, working memory, and planning. On the other hand, Tamm et al. [66], operationalised executive functioning based on a single card-sorting task. While composite measures may improve reliability of the measure of the overall construct, there is an associated risk that the creation of composite measures can either mask or over-state the significance of the included factors. As such, Huang-Pollock et al. [47], reported that, although creating a single executive functioning factor may be more reliable than the individual variables alone, "some executive functions may be more predictive of social outcomes than others" (p. 688). This is especially relevant, as executive functioning challenges are not universal in ADHD and not all executive functioning skills are equally reduced [2]. In turn, some executive functioning skills, but not others, may impact social outcomes in ADHD, and these distinctions may be missed when using composite measures.

There was also notable heterogeneity in the operationalisation of individual cognitive functions, which impeded the ability to make comparisons across studies measuring the same constructs. To illustrate this variability, across different studies, the construct 'planning' was measured using either the mean number of moves on the CANTAB Stockings of Cambridge (SOC) Task, mean error score on the SOC, Rey-Osterrieth Complex Figure (ROCF) Organisation score, ROCF error proportion score, and Tower of Hanoi task. Similarly, although emotion regulation was the one cognitive factor that was almost exclusively measured with standardised questionnaires and some observational measures, choice of questionnaire or observational method varied across studies. Relatedly, two studies assessed an aspect of cognition using laboratory observation and one used parent interview, presenting less valid measures of cognition relative to neuropsychological measures. Comparison across studies was, therefore, limited in this review and quantitative synthesis was not possible due to heterogeneity in cognitive domains reviewed and the numerous ways in which cognitive factors were operationalised. Nevertheless, the present review intentionally cast a wide net to capture the range of cognitive functions that may be associated with social outcomes in young people with ADHD. This review may provide a starting point for future research to identify specific cognitive functions worthy of further investigation.

Second, social outcomes were labelled and operationalised in heterogeneous ways. When the same measures were used across studies, the labels applied to these measures often differed. For example, the Social Skills Improvement System (SSIS) is a standardised questionnaire that was utilised across

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several of the reviewed studies. Amongst these studies, the SSIS was described as a measure of either 'social problems,' 'social deficits,' 'social skills,' or 'social impairment.' On the other hand, when a consistent label for a social construct was applied, the measurement tools often differed. For example, the label 'social functioning' was used in several studies, but was measured using a variety of different tools across these studies, including various standardised questionnaires and ratings of peer acceptance and rejection. Future research in the field should work towards greater consensus in the terminology used to describe select social functions and social outcomes. This, in turn, may facilitate an improved understanding of the specific social challenges experienced by young people with ADHD, in order to design appropriately targeted interventions.

Third, social outcomes were primarily measured with parent-report standardised questionnaires. Fewer than half (40%) of the reviewed studies incorporated a teacher-report measure, and only seven studies (23.33%) incorporated a self-report measure of a social outcome. Over-reliance on parent-report measures creates a source of bias by limiting the generalisability of these findings beyond the home setting. Furthermore, in adolescence, parents and teachers are less involved in and aware of their teenager's social experiences, highlighting the value of self-report data. In papers that included more than one informant, findings occasionally varied between informants (e.g., Fernandez-Jaen et al., 2012, see Table 3)[74]. These findings are consistent with the cross-informant discrepancies identified in adolescent mental health research [90,91], and reveal the potential bias from single-informant studies. These findings highlight the need for an improved understanding of how social functioning differs across a range of settings, and according to different informants.

Furthermore, very few studies employed sociometric techniques to gauge peer acceptance and rejection and sociometric data was occasionally inconsistent with findings on questionnaires. For example, Mikami et al. [84], found that peer liking as rated by parents and teachers overestimated the degree of peer liking that was observed on actual peer sociometric ratings (see Table 5). This indicates that reliance on parent- or teacher-perspectives alone may not adequately capture the levels of inclusion and exclusion experienced by the child. Although sociometric research is more heavily resource-dependent, it offers a more ecologically valid measure of the extent to which a child is accepted or rejected by their peers. Future research should seek to include a range of measurement techniques across multiple informants. Prioritisation of self-report data is warranted in order to gauge not only the severity of social difficulties, but also the nature and quality of those experiences.

Lastly, several methodological limitations of the reviewed literature were identified using the QuADS quality appraisal tool. These included limited reporting on power calculations, recruitment procedures, and data collection processes, as well as minimal justifications for analytic methods selected. Masking participant diagnoses may not have been possible in this literature due to the reliance on parent and teacher participation. However, none of the included studies reported whether participants were masked to the research question. To minimise the risk of confirmation bias, future research should aim to mask participants to the research question wherever possible. Additionally, none of the reviewed studies reported on engaging with stakeholders in the development of their research designs, reflecting the absence of formal co-design methods in the reviewed literature. From the perspective of the neurodiversity framework, research should be designed and conducted "with" rather than "on" neurodivergent individuals [92]. From this perspective, future research that is co-designed with individuals with ADHD can create opportunities to improve the accuracy with which social experiences are understood and addressed, in turn facilitating more meaningful, effective, and affirming research and clinical outcomes.

The present review was comprised primarily of cross-sectional data. As the reviewed literature was mostly cross-sectional, assumptions about causative relationships between cognitive and social factors could not be made. Unlike cross-sectional research, longitudinal studies can help to identify relationships or effects that take longer to eventuate, and can provide information on causal links between cognition and social outcomes. Given that peer attitudes towards children with ADHD are often established early and resistant to change [12,17,38], there is a need for more longitudinal research to better understand the degree to which certain factors predispose longer term social outcomes, and which factors may be more protective in the longer term.

Strengths and limitations of the current review

A strength of the current review was the scope of the investigation. To our knowledge, this was the first systematic review that evaluated a wide range of cognitive processes that may be associated with social outcomes in children and adolescents with ADHD. However, the inclusion of many heterogeneous studies hindered the ability to conduct a meta-analytic review or quantitative synthesis of the literature. Relatedly, effect sizes were not able to be calculated for all studies, as standard deviations for independent variables were not always reported. It was also not appropriate to compare effect sizes due to methodological differences between studies, including heterogeneous measurement tools and disparate analytical procedures. To address this, we reported on standardised beta coefficients and other measures of magnitude, where possible.

To assist with the qualitative synthesis of the literature, the present review sought to categorise studies according to the social outcomes that they were investigating. This was achieved by classifying papers according to whether they measured child-specific social performance variables (e.g., interpersonal skills and prosocial skills) or peer-group factors. In doing so, we were able to demonstrate the ways in which social outcomes have been operationalised in the broader literature. However, our system of

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classifying the literature was subjective, and alternative methods of classifying the literature may be worth exploring.

Additionally, the present study addressed cognitive factors in isolation to identify how they may be associated with social outcomes. However, potential interactions between different cognitive domains were not explored, partly due to the inability to conduct statistical analyses on the data and the vast number of cognitive domains that were explored. However, it is possible that disinhibition may be associated with emotional regulation challenges, resulting in poorer social outcomes, or that the presence of both working memory and emotion regulation challenges may have compounding social impacts. Future research should consider the interactions between cognitive domains, and how these interactions may impact social outcomes, particularly when developing ecologically valid interventions.

Finally, although a spectrum-based approach to ADHD can be informative in relation to social difficulties, the present review intended to include only clinical samples, with a view to informing clinical interventions. The inclusion criteria were designed to only include studies where participants were reported to have a confirmed diagnosis of ADHD or who scored above cut-off criteria on a symptom checklist. Ideally, we would have only included those with a formal diagnosis of ADHD, however this was hindered by ambiguity regarding how ADHD diagnoses were established and/or confirmed in the included studies. It is, therefore, possible that some studies included children and adolescents without ADHD, which has potential implications for the applicability of the findings to clinical samples. To address this limitation, future studies should use consistent criteria when establishing ADHD diagnoses for research, ideally adhering to the diagnostic criteria from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) or the International Classification of Diseases (ICD-11). Future research could also explore social outcomes for self-diagnosed individuals and those who do not meet diagnostic criteria. This may provide alternative insights into the social outcomes of individuals who face barriers to accessing assessment and diagnosis and individuals who present with 'subclinical' features of ADHD.

Implications and future research

The current review provides preliminary support for an association between emotion regulation and social outcomes. It also provides preliminary support for an association between working memory and prosocial skills, but more limited evidence for a relationship between working memory and other social outcomes, such as interpersonal skills or peer group acceptance. High quality, longitudinal research is needed to better understand the relationship between cognitive factors and social outcomes, and to, therefore, facilitate the development of more effective, targeted interventions. The present review suggests additional criteria that can be used to design and appraise future ADHD research, including controlling for, or evaluating the effects of, medication use, co-occurring diagnoses, differences in ADHD presentation type, age, and gender. As more research emerges that examines the effects of these additional variables, future reviews should conduct more detailed analyses of their effects on the relationships between cognition and social outcomes.

The preliminary support for a relationship between emotion regulation and social outcomes suggests that non-pharmacological interventions designed to improve emotion regulation skills, including both impulsivity and self-regulation, are worthy of further exploration as a means of addressing social challenges at the point of on-line 'performance' rather than off-line 'knowledge.' Psychological therapy involving skill-building related to managing emotional impulsivity and emotion regulation, as well as parent-focused training designed to support emotion regulation, may offer hopeful intervention avenues which should be assessed in future research. The present review also suggests a potential relationship between working memory and prosocial skills. However, more high-quality research into potential functional benefits of cognitive training is needed, as current computer-based cognitive training programs for working memory and executive functioning lack support in their ability to effectively target cognitive functions of importance and to generalise to functional improvements for children with ADHD [3,4]. Findings regarding the associations between other executive functioning domains and social outcomes were inconsistent in this review. As such, the suitability of interventions targeting other specific executive functions, such planning or behavioural inhibition, remains unknown.

The present review subjectively classified studies according to whether they measured child-specific social performance (e.g., interpersonal skills and prosocial behaviours) or peer-group factors. This method reflected the heterogeneous ways in which social outcomes have been operationalised in the existing literature. Future research should ensure that intervention targets are meaningful, in that they translate into improved real-life social inclusion and acceptance. By delineating between child-specific and peer-group factors, the current review highlighted that peer attitudes and social context were also important sources of social difficulties in ADHD that may not be corrected by pharmaceutical interventions or interventions targeting the individual with ADHD alone. Therefore, interventions involving peer- and teacher-training and psychoeducation, as well as whole-classroom based interventions, are worthy of further investigation as possible avenues for reducing stigma and improving the social inclusion of children with ADHD.

Lastly, while this review began to elucidate which aspects of cognition may play a role in social outcomes, it is insufficient in identifying the many social and cultural factors that impact outcomes for children with ADHD. Students who experience additional forms of marginalisation, due to racism, ableism, gender-based discrimination, or socioeconomic disadvantage, may face greater barriers to accessing support, compounding

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the relationship between cognitive differences and poorer social outcomes. As sociometric approaches to this research become more prevalent, researchers in the field must also question the societal perceptions, institutional factors, and stigma that contribute to the rejection of neurodivergent students by their neurotypical peers, and design interventions that promote broader social acceptance, facilitate advocacy, and consider strength-, rather than deficit-based, approaches to research [93].

Conclusion

The current systematic review was conducted to investigate the cognitive correlates of social outcomes in children and adolescents with ADHD. The quality of the literature was impacted by predominantly cross-sectional study designs; lack of masking and power calculations; preponderance of single-informant questionnaire data; and the heterogeneous ways in which cognitive factors and social outcomes were operationalised. Studies to date have failed to adequately investigate the effects of co-occurring diagnoses, medication status and type, ADHD presentation type, gender, and chronological age on the relationships between cognitive factors and social outcomes. With these limitations in mind, emotion regulation and non-verbal working memory were found to be most consistently associated with social outcomes in young people with ADHD, such as prosocial skills and peer-group acceptance. There was limited support for significant associations between other aspects of cognition and social outcomes, but this is not to say that those relationships fail to exist, and more research is warranted. The findings indicate that emotion regulation and non-verbal working memory are potentially advantageous avenues for future research. For example, the provision of emotion regulation skill-building and parent-focused training may be plausible targets for the development of interventions aimed at improving social outcomes in ADHD. However, based on the findings of this review, we recommend that child-focused interventions be complemented with research and interventions that address the role of peer-group factors as well as broader societal attitudes in shaping social outcomes.

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