ADHD Attention Deficit and Hyperactivity Disorders (2019) 11:325–332
https://doi.org/10.1007/s12402-018-0279-4

SHORT COMMUNICATION

How relevant is higher-order language deficit (HOLD) to children with complex presentations of attention-deficit hyperactivity disorder?

Rebecca Randell[1] · Luke Somerville-Brown[2] · Wai Chen[3,4,5]

Received: 18 May 2018 / Accepted: 23 October 2018 / Published online: 31 October 2018
© Springer-Verlag GmbH Austria, part of Springer Nature 2018

Abstract
Attention-deficit hyperactivity disorder (ADHD) is frequently associated with language impairment, autism spectrum disorder (ASD) symptoms and higher-order language deficit (HOLD); yet, their complex relationship is poorly understood. HOLD encompasses deficits in using language for reasoning, problem-solving, causal and critical thinking. This study evaluates the roles of HOLD in children with ADHD. We hypothesise that both our subgroups (ADHD-only and ADHD + 'ASD traits') will have HOLD difficulties, though to a differing degree, as children with ADHD are compromised by executive function deficits, and those with additional ASD traits are further impaired by pragmatic language deficits. Data were reviewed from 36 children with ADHD (± 'ASD traits'), who attended the tier 4 statewide specialist clinic for ADHD patients non-responsive to community care. HOLD was assessed by the Test of Problem Solving-3 Elementary (TOPS-3). The age of the sample ranged from 6 to 12 years with a male-to-female ratio of 8:1. The rate of HOLD in our sample was 47.2% (published controls = 16%). Likewise, the rates of Making Inferences (50.0%, $p < 0.001$), Sequencing (44.4%, $p < 0.001$), Negative Questions (33.3%, $p = 0.278$), Problem-Solving (38.9%, $p = 0.022$), Predicting (27.8%, $p = 0.022$) and Determining Causes (30.6%, $p = 0.022$) were all elevated. When stratified, the rates in ADHD-only group and ADHD + 'ASD traits' group were 37.5% and 55.0%, respectively. Children with ADHD + 'ASD traits' had greater 'Sequencing' deficit. Our exploratory study confirms that HOLD is more common in children with ADHD, including deficits in Making Inferences, Sequencing, Problem-Solving, Predicting, Determining Causes and understanding Negative Questions. Our findings provide preliminary support for the potentially important role played by HOLD in neurodevelopmental disorders.

Keywords Higher-order language deficit (HOLD) · Attention-deficit hyperactivity disorder (ADHD) · Autism spectrum disorder (ASD) · Language impairment · Sequencing deficit

Introduction

Attention-deficit hyperactivity disorder (ADHD) is characterised by persistent and age-inappropriate levels of inattention, hyperactivity and impulsivity, pervasive across settings causing social, functional, academic or occupational impairments (American Psychiatric Association 2013). Though language impairment is not a cardinal feature of ADHD, there is nevertheless a strong association between ADHD and a range of language deficits, including problems with

✉ Wai Chen
Wai.Chen@health.wa.gov.au

[1] Speech-Language Pathology, Complex Attention and Hyperactivity Disorders Service (CAHDS), Child and Adolescent Mental Health Service, Perth, WA, Australia

[2] Child and Adolescent Mental Health Service, Perth, WA, Australia

[3] Child Psychiatry, Complex Attention and Hyperactivity Disorders Service (CAHDS), Child and Adolescent Mental Health Service, Perth, Australia

[4] Centre & Discipline of Child and Adolescent Psychiatry, Psychosomatics and Psychotherapy, School of Medicine, Division of Paediatrics and Child Health & Division of Psychiatry and Clinical Neurosciences, The University of Western Australia, 35 Stirling Highway (M561), Crawley, Perth, WA 6009, Australia

[5] Complex Attention and Hyperactivity Disorders Service (CAHDS), 4th Floor West Entrance, iiid Building, Discovery Way, Murdoch University, Murdoch, WA 6150, Australia

semantics, coherence, non-verbal communication and pragmatic use of language (Helland et al. 2012, 2014; Jensen and Steinhausen 2015). Interestingly, children with a persistent hyperactive-inattentive developmental trajectory are more likely to have persistent social communication deficits but not vice versa (Pourcain et al. 2011). Furthermore, amongst children with primary specific language impairments (including syntactic and speech abnormalities), ADHD is the most common comorbidity (Cohen et al. 2000). Moreover, there is also an association between ADHD and autism spectrum disorder (ASD) symptoms, identified in both community and clinical samples (Reiersen et al. 2007). Overall, there is a complex relationship between ADHD, ASD and language impairments that is not well understood.

Within the use of language for communication, there are three essential but distinct components: (1) content, (2) form and (3) social use—corresponding with vocabulary, grammar and pragmatics, respectively (Geurts and Embrechts 2008). Pragmatics refers to the appropriate and effective use of language in interpersonal contexts and is of central importance for children's social function at home, at school and with peers (Green et al. 2014). Pragmatic difficulties can manifest as excessive talking; not taking turns in a reciprocal manner; misreading non-verbal interactions; literal use of language (failures to understand humour, sarcasm, metaphors and figurative speech); failure to contextualise the content, not accounting for the listener's perspective; and deficits in rephrasing a message to accommodate a listener's needs (Green et al. 2014).

Children with ASD can have pragmatic communication deficits, despite having adequate command of vocabulary and grammar. These communication difficulties can lead to impaired social functioning and difficulty in building friendships appropriate to their age, and at times, peer rejection, social isolation and bullying. In addition, children with ASD may be pedantic, overly dependent on stereotype routines, stock phrases as well as over-focusing on minor or irrelevant details.

On the other hand, children with ADHD also have pragmatic communication difficulties (Bishop and Baird 2001), presenting with more stereotyped conversations, poorer conversational rapport and impaired social relationships when compared to typically developing children. They also have excessive talking, poor conversational turn-taking and deficits in coherence and organisation in elicited speech. These deficits are thought to be consistent with deficits in executive function (Green et al. 2014). Indeed, verbal working memory deficits have also been found to correlate with narrative comprehension impairments in children with ADHD, who also recall less information from read stories, in addition to having deficits in grammar comprehension and sentence recall (Papaeliou et al. 2015). The model proposed by Cohen et al. (2000) suggests that working memory and executive function deficits are closely associated with language impairment, more than ADHD itself, and could potentially mediate the relationship between ADHD and the observed pragmatic language difficulties in children with ADHD.

Pragmatics is a multidimensional construct (Green et al. 2014): one aspect of pragmatic difficulties can be evaluated by assessing *higher-order language skills* (Geurts and Embrechts 2008). Higher-order language skills are those elements of language which are involved in reasoning and critical thinking, such as determining causal relationships as well as making inferences and predictions. These language skills exert greater cognitive demands, taxing language capacities beyond those involved in processing syntax, semantics and grammatical structures. To be considered to have a higher-order language deficit (HOLD), a patient must have difficulties in their language application for thinking, reasoning as well as higher levels of information processing, such as problem-solving (Bowers et al. 2005). The majority of past research on pragmatics in ADHD samples utilise parental reports on different aspects of language deficits (Geurts et al. 2009; Green et al. 2014). To date, to our knowledge, no study has used an age-standardised test to quantify HOLD by directly evaluating the performance of children with ADHD on a set of validated tasks which systematically capture different subdimensions of HOLD.

The Test of Problem Solving-3 (TOPS-3) (Bowers et al. 2005) directly measures six domains of higher-order language skills in children: *Making Inferences, Sequencing, Negative Questions, Problem-Solving, Predicting and Determining Causes*. These domains represent different aspects of the functional application of language in daily life and are explained in more detail below. In essence, children with HOLD lack crucial skills: to read conflicting information, understand unspoken and implied subtexts as well as to deal with the subtlety and fluidity of language. Fluidly negotiating all these elements is essential in rapid social exchanges during interpersonal interactions. Furthermore, these children cannot use language to represent the outer world and to verbalise their internal thinking and feelings; therefore, they cannot use self-talk effectively to resolve conflicts between the inner and outer worlds, thereby leading to social and emotional difficulties.

Making Inferences is about deductive reasoning; it combines existing knowledge or past experiences to make an informed guess about the future, which may include unfamiliar and novel situations not yet encountered. Being cognisant of why one makes these guesses and how accurate they would be is characteristic of more thoughtful inferential thinking.

Sequencing is about organising information in a logical order, such as a temporal sequence (past–present–future) or a hierarchical order (size or shape) or sequentially ordering several logical steps best to accomplish a complex task.

Negative Questions demand attention to the negative components in a sentence, e.g. 'won't' and 'shouldn't', and to hold these in one's mind in order to manipulate multiple pieces of information mentally. Both cognitively and linguistically, it is harder for children to handle negative questions than positive questions, especially double-negatives.

Problem-Solving requires solution-focused thinking, as well as holding a mental framework to select the best strategies while weighing up different outcomes to make the best choice.

Predicting includes cause-and-effect thinking in order to anticipate what will happen; it is a fundament component in scholastic, academic and life skills. It also includes the understanding of the probabilistic odds embodied in each line of prediction and thus their accuracy.

Determining Causes is another application of causal thinking in understanding the relationship between an action and its consequences. This differs from predicting in that causal analysis focuses on something that has already occurred, whereas predicting is more about imagining several competing consequences in different hypothetical futures generated by different actions to be taken.

To address the gap in the literature, this study applied TOPS-3 to evaluate empirically the association between ADHD and different aspects of HOLD in a sample of children with complex ADHD (i.e. cases non-responsive to community treatments). We hypothesise that both ADHD and ADHD + 'ASD traits' groups will have HOLD difficulties, though to a different degree, as ADHD children are compromised by executive function deficits, and those with additional ASD traits are further impaired by pragmatic language deficits. More specifically, this study also explores the rates and patterns of HOLD in children with ADHD-only and with ADHD + 'ASD traits'. We evaluated whether:

1. There will be a higher rate of HOLD amongst children in this study when compared with published rates of the population controls;
2. Children with ADHD + 'ASD traits' will have a higher burden of HOLD than children with ADHD-only.

Method

Participants

The clinical data were retrospectively analysed as a clinical audit for children who attended the Complex Attention and Hyperactivity Disorders Service (CAHDS) for assessment, between the months of July 2015 and March 2016. CAHDS is a tier 4 statewide, subspecialty service offering specialist multidisciplinary assessment for children with complex presentations of ADHD, who have not responded to ADHD treatments and management in the community. Parents or carers of the participants gave informed consent for their de-identified data to be analysed for audit, and the permission to conduct this audit was granted by the local governing research ethics committee, the Perth Children Hospital Human Research Ethics Committee.

A diagnostic status of ADHD was determined by clinical and semi-structured diagnostic interviews and evaluations by child and adolescent psychiatrists, according to DSM-5 diagnostic criteria. Marked ASD traits and associated pragmatic language difficulties in this analysis were captured using the Children's Communication Checklist 2 (CCC-2) (Bishop 2003) and designated as the ADHD + 'ASD traits' group. TOPS-3 formed part of the standard multidisciplinary speech–language pathology assessment and was used to capture HOLD. Exclusion criterion included children with IQ below 70 and an age outside the range 6–12 years and 11 months (the age cut-offs for TOPS-3, see below). This analysis was conducted as a part of a clinical audit on the clinical utility of TOPS-3 in our service.

The patterns of medication prescribed for the children at referral and initial assessment were mixed. Of the 36 children, 8 (about 22%) did not take any medication at all due to community treatment failures or previous adverse reactions. For the remaining 28, 3 took non-ADHD medications for anxiety control: 1 took escitalopram (20 mg); 1 took fluoxetine (20 mg); and 1 took risperidone (0.5 mg). In the remaining 25 children who took ADHD medications, 2 took atomoxetine (daily dosage of 40 mg); 5 took Concerta (daily dosage of 36–54 mg); 4 took short-acting dexamfetamine (daily dosage of 10–25 mg); 5 took lisdexamfetamine (daily dosage of 30 mg); 6 took short-acting Ritalin (daily dosage of 20–30 mg); and 3 took long-acting Ritalin (daily dosage of 20–30 mg). Some of these children took more than one medication: 4 also took risperidone (daily dosage of 0.5–1 mg); 1 also took aripiprazole (10 mg); 1 also took melatonin; and 4 also took clonidine 50–100 mcg.

Measures used

1. Children's Communication Checklist 2 (CCC-2) (Bishop 2003).

   The CCC-2 was developed to measure various aspects of communication impairment. The questionnaire consists of 70 items, which can be grouped into 10 subscales (with 7 items each). In addition to subscale scores, a general communication composite (GCC) score can also be computed, yielding an overall measure of communication skills. CCC-2 also yields a second composite score, the Social Interaction Deviance score (SIDC), which aims to capture and identify significant ASD traits and associated pragmatic language difficulties. This score is a reflection of the mismatch between the

sums of the scales exploring the social elements of communication and the sum of the scales that explore the more basic elements of language. Children with marked ASD traits and associated pragmatic language difficulties were designated as having 'ASD traits' according to the algorithm described by Bishop (2003): that is, if (1) a SIDC score less than 0 and (2) a GCC score < 55. The internal consistency of CCC-2 has been reported to range from 0.66 to 0.80.

2. Test of Problem Solving-3 Elementary (TOPS-3) (Bowers et al. 2005).

   TOPS-3 was used to evaluate the higher-order language skills of the participants. The age range for this measure is 6 years to 12 years 11 months. The *TOPS-3 Elementary* measures discrete skills in language-based thinking, reasoning and problem-solving abilities. This test consists of 18 pictures for which the children are asked questions that examine six higher-order language tasks. The six higher-order language tasks evaluated were: Making Inferences, Sequencing, Negative Questions, Problem-Solving, Predicting and Determining Causes. TOPS-standardised scores were dichotomised and designated as 'a case' at 15th percentile, i.e. if total or subscale standardised scores < 85, which is equivalent to 1 standard deviation below the mean or z-scores of minus 1. Each subtest yields respective raw scores, and these were converted to standardised scores according to age and gender, representing 'a statistic that describes the raw score's distance from the population mean in terms of the standard deviation of the distribution of the scores'. (Bowers et al. 2005) Similarly, the total scores were converted. We used the standardised score of 85 to represent the 1 standard deviation threshold, in line with the guidance from a gold standard instrument in speech and language assessment—*Clinical Evaluation of Language Fundamentals* (CELF5) (Wiig et al. 2017)—which presents 1 SD below and above the means, as 'the lower and upper limits of the average range of performance' (Wiig et al. 2017), given that there is no definitive study to validate the clinical cut-off threshold for HOLD. Furthermore, CCC-2 also recommends this threshold, stating that 'scores at or above the 15th percentile should be regarded within normal limits' (CCC-2 Manual 2nd edition, Bishop 2003, page 20). Therefore, all subtest scores were dichotomised accordingly. This threshold was chosen to reflect 'difficulties' instead of 'a disorder'. The test–retest reliability for the TOPS-3 ranges from 0.64 to 0.95 (Bowers et al. 2005).

Data analysis

HOLD caseness was reported as frequencies and percentages for categorical variables and with means and standard deviations (SD) for continuous variables. Chi-square (χ^2) analyses for contingency tables were used for the categorical comparison. The significance level for tests was established at $p \leq 0.05$. For comparison between ADHD and ADHD + 'ASD traits' groups, logistic regression was conducted to compute odd ratios and statistical significance. For continuous variables, their standardised scores were also compared using ANOVA. Analyses were carried out using STATA (version 15.1). Due to the small sample size and multiple comparisons, Bonferroni correction for 14 comparisons was provided as a guide, which would test each individual hypothesis at $\alpha = 0.05/14 = 0.004$. The corrected p value was included in the relevant tables.

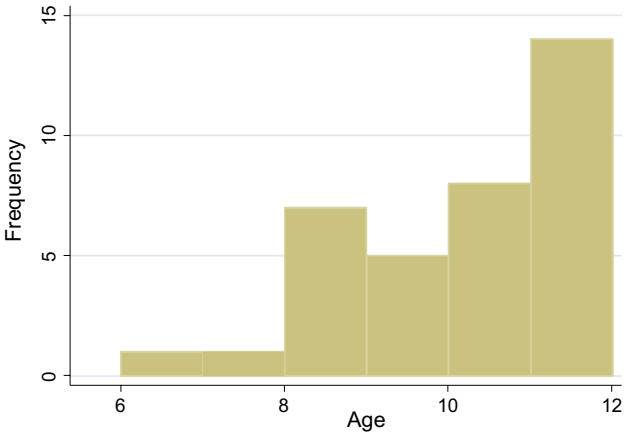

Fig. 1 Age distribution of the sample

Results

The study sample consisted of 36 children, with 32 males (a M:F ratio of 8:1). The ages ranged from 6 to 12 years, conforming to the age range of TOPS-3. Age distribution of the study sample participants is given in Fig. 1. Between the two groups (i.e. ADHD-only and ADHD + 'AS traits'), there were no significant differences in gender distribution, age distribution or GCC scores. But the groups significantly differed, as expected, for SIDC scores (see Table 1). Bartlett's test for equal variance was non-significant for both parameters, indicating no threat to ANOVA assumptions: chi2(1) = 2.722, $p = 0.099$ for GCC scores and chi2(1) = 0.260, $p = 0.610$ for SIDC scores. For age, Bartlett's test for equal variance was again non-significant: chi2(1) = 0.941, $p = 0.332$. IQ scores were available in 29 participants; there was no significant difference between ADHD-only and ADHD + 'ASD traits' groups (ADHD-only group = 92.45 (SD 9.14); ADHD + 'ASD traits' group = 88.83 (SD 11.33); F = 0.80, $p = 0.379$).

Table 1 Basic characteristics of participants

	ADHD-only ($n=16$)	ADHD + 'ASD traits' ($n=20$)	Statistics	p value
Gender (male)	93.75% ($n=15$)	85% ($n=17$)	$Chi_{(1)}=0.689$	0.406
Age	9.25 (SD 1.69)	10.25 (SD 1.33)	$F_{1, 26}=3.94$	0.055
GCC score:mean	40.81 (SD 18.05)	36.5 (SD 12.01)	$F_{1, 26}=0.74$	0.397
SIDC score:mean	− 1.81 (SD 6.49)	− 8.8 (SD 7.37)	$F_{1, 26}=8.86$	0.005

Table 2 Comparing the rates of HOLD in ADHD-only and ADHD + 'ASD traits' cases with published controls (HOLD caseness threshold at 15th percentile, i.e. < 85 standardised scores)

	HOLD in published controls ($n=1406$)	ADHD-only ($n=16$)	Chi2(1)	p value	ADHD + 'ASD traits' ($n=20$)	Chi2(1)	p value
HOLD (based on total TOPS score)	16% ($n=225$)	37.5% ($n=6$)	5.37	**0.020**	55% ($n=11$)	21.71	**< 0.001**
Making Inferences	16%	37.5% ($n=6$)	5.37	**0.020**	60% ($n=12$)	27.56	**< 0.001**
Sequencing	16%	25% ($n=4$)	0.95	0.330	60% ($n=12$)	27.56	**< 0.001**
Negative Questions	16%	37.5% ($n=6$)	5.37	**0.020**	25% ($n=5$)	1.18	0.278
Problem-Solving	16%	43.8% ($n=7$)	8.92	**0.003**	35% ($n=7$)	**5.22**	**0.022**
Predicting	16%	18.8% ($n=3$)	0.09	0.760	35% ($n=7$)	**5.22**	**0.022**
Determining Causes	16%	25% ($n=4$)	0.95	0.330	35% ($n=7$)	**5.22**	**0.022**

p value corrected for 14 tests = $p < 0.004$; bold for p-value of 0.05 or below

Is there a higher rate of HOLD in children in this study (with ADHD-only and ADHD + 'ASD traits') compared with published rates of the population controls?

The published prevalence rate of HOLD is 16%[1]: There were 225 cases of HOLD in 1406 subjects in the published standardisation sample of TOPS-3 (Bowers et al. 2005). In our study, the overall rate of HOLD in our whole sample, unstratified by 'ASD traits' status (i.e. ADHD-only and ADHD + 'ASD traits' together), was 47.2% ($n = 17/36$), which is significantly higher than the published rate of the normative sample at 16% ($chi_{(1)}=24.497$; $p < 0.001$). Likewise, the rates of Making Inferences (50.0%), Sequencing (44.4%), Negative Questions (33.3%), Problem-Solving (38.9%), Predicting (27.8%) and Determining Causes (30.6%) were all elevated.

When stratified by 'ASD traits' status, the rates of HOLD were 37.5% and 55.0% for ADHD-only and ADHD + 'ASD traits' cases, respectively, see Table 2, while the rates of HOLD (total, Making Inferences and Sequencing) in the ADHD + 'ASD traits' group were about 1.5–2 fold that of ADHD-only, see Table 2.

The ADHD + 'ASD traits' group showed significant differences from controls in five out of six subdomains of HOLD (i.e. all domains except Negative Questions), while the ADHD-only group showed differences in only three subdomains (Making Inferences, Negative Questions and Problem-Solving). However, the significance levels were much reduced after Bonferroni correction for multiple comparisons.

Do children with ADHD + 'ASD traits' have a higher burden of HOLD than children with 'ADHD-only'?

We found a significantly higher rate of Sequencing deficit in the ADHD + 'ASD traits' group when compared with the ADHD-only group in our sample, as shown in Table 3. Three other subdomains—Making Inferences, Predicting and Determining Causes—also showed a trend of differences but did not reach statistical significance. Exploratory analyses using HOLD scores as dimensional traits by ANOVA detected the same pattern of results and did not improve statistical power. However, after Bonferroni correction, the difference in Sequencing was not significant in both continuous measure and categorical measure analyses.

Discussion

There are two key findings of this study. Firstly, children with ADHD have higher rates of HOLD than the published population controls. Within this sample, children with ADHD-only have elevated risks in three domains: Making

[1] HOLD diagnostic threshold is at 1 standard deviation below the population mean or at 16th percentile.

Table 3 Comparing the rates of HOLD by subdomain between ADHD-only and ADHD + 'ASD traits' (HOLD caseness threshold at 15th percentile, i.e. < 85 standardised scores)

	ADHD-only ($n=16$)	ADHD + 'ASD traits' ($n=20$)	Chi2(1)	p value	OR (95% CI)
HOLD (based on total TOPS score)	37.5% ($n=6$)	55% ($n=11$)	1.09	0.296	2.04 (0.53–7.79)
Making Inferences	37.5% ($n=6$)	60% ($n=12$)	1.80	0.179	2.50 (0.65–9.65)
Sequencing	25% ($n=4$)	60% ($n=12$)	4.41	**0.036**	**4.50*(1.06–19.04)**
Negative Questions	37.5% ($n=6$)	25% ($n=5$)	0.66	0.418	0.56 (0.13–2.32)
Problem-Solving	43.8% ($n=7$)	35% ($n=7$)	0.29	0.593	0.69 (0.17–2.67)
Predicting	18.8% ($n=3$)	35% ($n=7$)	1.17	0.280	2.33 (0.49–1.06)
Determining Causes	15% ($n=4$)	35% ($n=7$)	0.42	0.517	1.62 (0.38–6.94)

p value corrected for 14 tests = $p < 0.004$

*$0.05 > p > 0.005$; bold for p-value of 0.05 or below

Inferences, Negative Question and Problem-Solving; in contrast, children with ADHD + 'ASD traits' have elevated risks in five domains: Making Inferences, Sequencing, Problem-Solving, Predicting and Determining Causes. Secondly, ADHD + 'ASD traits' children have significantly greater deficits in Sequencing when compared with ADHD-only children.

Our findings are in line with previous studies. Geurts and Embrechts (2008) and Purvis and Tannock (1997) have found higher risks of communication and language disorders in children with ADHD, but such risks are often overlooked. The rates of language pragmatic and processing difficulties were reported to be at 45% by Tirosh and Cohen (1998), 55.2% by Purvis and Tannock (1997) and 63.6% by Cohen et al. (2000). Studies using parental report measures also identified elevated scores in pragmatic impairments (Helland et al. 2012, 2014; Green et al. 2014). Our findings (37.5% for ADHD-only, 55% for ADHD + 'ASD traits' and 47.2% for our unstratified sample) were broadly in line with these studies. However, previous studies did not utilise a standardised test specifically designed to measure HOLD directly in children, and they also did not stratify their ADHD cases by comorbid 'ASD traits' status.

Two studies (Geurts and Embrechts 2008; Demopoulos et al. 2013) have reported that children with ASD and those with ADHD have similar patterns of social deficits, suggesting more similarity than previously considered. However, when stratifying the children by 'ASD traits' status in our study, we detected different levels of risks between the ADHD-only and ADHD + 'ASD traits' groups in relation to HOLD.

One of our preliminary novel findings is the significant association of Sequencing deficit with the ADHD + 'ASD traits' group when compared with ADHD-only children. Sequencing requires a mental representation of the whole in relation to its parts; such a deficit appears consistent with the weak central coherence theory in ASD children (Frith 1989; Happé 1996). The sample of our study is small and may have low statistical power to detect other differences. If replicated, this finding may have clinical implication in that Sequencing may need to be specifically targeted in therapy for these children, such as how to use planners, organisers and outlines to complete tasks.

Our findings suggest HOLD as a relevant and potentially important clinical component in children with complex presentations of ADHD. As some children may have normal acquisition of language and basic language skills, they may nevertheless experience difficulties in applying language for social and pragmatic use, especially within the areas of sequencing, making inferences and determining casual relationships. This in turn may impact their ability for solving problems encountered in daily life. Leonard et al. (2011) found that pragmatic language impairments fully mediated the relation between hyperactivity and social skills problems, and partially mediated the relation between inattention and social skills problems. Our findings are preliminary and should be interpreted with caution, but can stimulate further research in this area. If replicated by other studies and in larger samples, the association when confirmed could inform clinical management and how best to provide education support. Given that ADHD is strongly associated with emotional dysregulation (Liu et al. 2016, 2017), given that social skills problems increase the risks of peer rejection, bullying, frustration, externalising disorders and emotional disorders, given that there are significant roles played by non-pharmacological treatment of children with ADHD (Hodgson et al. 2014), these findings suggest potential important roles in (1) assessing HOLD in children with ADHD and (2) providing remedial intervention which can target HOLD. From a practical point of view, language impairment and HOLD should be assessed and taken into account when planning therapies for patients with complex ADHD presentations.

The interaction between HOLD, ADHD and ASD communication characteristics is complex. The risks may be additive or multiplicative, and while our study shows a general trend of elevated risks in certain domains, further

studies with sufficient statistical power are needed to elucidate fully the mechanisms of their relationship.

Several limitations should be considered, and our results should be interpreted with caution. Parental rating of their children using the CCC-2 may not capture the full extent of the child's ASD traits. Second, this is a pilot study with small sample size; therefore, lacking statistical power, replication in larger samples would validate our preliminary findings. Due to the small size of our sample and multiple comparisons (i.e. we performed the maximum of 14 tests), we accordingly provided corrected α at 0.004 ($\alpha = 0.05/14$) in the relevant tables. Our results should be interpreted with caution. Third, while the SIDC scores are sensitive to detect 'the pattern of communication difficulties characteristic of autistic spectrum disorders' (page 12, CCC-2 manual), the association detected may not solely capture HOLD construct in the subjects with ADHD + 'ASD traits', but may also reflect an inter-method correlation between the CCC-2 and TOPS-3, as both measures potentially evaluate pragmatic language skills. Therefore, construct overlap in measurement may contaminate the detected association, and such effects could not be fully disentangled. Future study using more ASD-specific measures such as Social Communication Questionnaire, Autism Diagnostic Interview, 3DI or ADOS may overcome this limitation. Fourth, our study participants attended a statewide subspecialty service, consisting of a selected sample with patients non-responsive to community care, and their recruitment and information ascertainment could be subjected to referral bias.

Conclusion

Our findings have replicated some of the previous findings of significant risks of language deficits in ADHD children; more specifically, we isolated specific domains of deficits in HOLD by using TOPS-3. ADHD children regardless of 'ASD traits' have difficulties in Making Inferences, Sequencing, Problem-Solving, Predicting and Determining Causes. Another novel but preliminary finding is the specific association of Sequencing deficit with the ADHD + 'ASD traits' group, which may have clinical implications.

Our findings offer preliminary evidence to support that HOLD may play an important role in the clinical presentation and impairments of children with ADHD and complex neurodevelopmental disorders. HOLD may represent a potential mechanism which mediates between neuropsychiatric deficits and socio-emotional impairments in complex neurodevelopmental disorders, thus a potentially fruitful area for further research.

Acknowledgement The authors would like to express their thanks to the children and families who gave consent for their data analysed, and also to Mrs. Kym Shortte and Dr. Daniel Rudaizky for their inputs.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this clinical audit study, formal research consent and formal research ethnics committee's approval are not required, but the permission to conduct this audit was granted by the local governing research ethics committee.

References

American Psychiatric Association (2013) Diagnostic and statistical manual of mental disorders, 5th edn. American Psychiatric Publishing, Arlington

Bishop DVM (2003) The children's communication checklist, 2nd edn. Harcourt Assessments, New York

Bishop DV, Baird G (2001) Parent and teacher report of pragmatic aspects of communication: use of the children's communication checklist in a clinical setting. Dev Med Child Neurol 43(12):809–818

Bowers L, Huisingh R, LoGiudice C (2005) Test of problem solving 3 elementary. Lingui Systems, East Moline

Cohen NJ, Vallance DD, Barwick M, Im N, Menna R, Horodezky NB, Isaacson L (2000) The interface between ADHD and language impairment: an examination of language, achievement, and cognitive processing. J Child Psychol Psychiatry Allied Discip 41(3):353–362

Demopoulos C, Hopkins J, Davis A (2013) A comparison of social cognitive profiles in children with autism spectrum disorders and attention-deficit/hyperactivity disorder: A matter of quantitative but not qualitative difference? J Autism Dev Disord 43(5):1157–1170

Frith U (1989) Autism: explaining the enigma. Basil Blackwell, Oxford

Geurts HM, Embrechts M (2008) Language profiles in ASD, SLI, and ADHD. J Autism Dev Disord 38(10):1931

Geurts HM, Broeders M, Nieuwland MS (2009) Thinking outside the executive functions box: theory of mind and pragmatic abilities in attention deficit/hyperactivity disorder. Eur J Dev Psychol 7(1):135–151

Green BC, Johnson KA, Bretherton L (2014) Pragmatic language difficulties in children with hyperactivity and attention problems: an integrated review. Int J Lang Commun Disord 49(1):15–29

Happé FG (1996) Studying weak central coherence at low levels: children with autism do not succumb to visual illusions. A research note. J Child Psychol Psychiatry 37(7):873–877

Helland WA, Biringer E, Helland T, Heimann M (2012) Exploring language profiles for children with ADHD and children with Asperger syndrome. J Atten Disord 16(1):34–43

Helland WA, Helland T, Heimann M (2014) Language profiles and mental health problems in children with specific language impairment and children with ADHD. J Atten Disord 18(3):226–235

Hodgson K, Hutchinson AD, Denson L (2014) Nonpharmacological treatments for ADHD: a meta-analytic review. J Atten Disord 18(4):275–282

Jensen CM, Steinhausen HC (2015) Comorbid mental disorders in children and adolescents with attention-deficit/hyperactivity disorder

in a large nationwide study. ADHD Atten Deficit Hyperact Disord 7(1):27–38

Leonard MA, Milich R, Lorch EP (2011) The role of pragmatic language use in mediating the relation between hyperactivity and inattention and social skills problems. J Speech Lang Hear Res 54(2):567–579

Liu L, Chen W, Vitoratou S, Sun L, Yu X, Hagger-Johnson G, Wang Y (2016) Is emotional lability distinct from "angry/irritable mood," "negative affect," or other subdimensions of oppositional defiant disorder in children with ADHD? J Atten Disord. https://doi.org/10.1177/1087054715624228

Liu L, Chen W, Sun L, Cheng J, Su Y, Rudaizky D, Wang YF (2017) The characteristics and age effects of emotional lability in ADHD children with and without oppositional defiant disorder. J Atten Disord. https://doi.org/10.1177/1087054717745594

Papaeliou CF, Maniadaki K, Kakouros E (2015) Association between story recall and other language abilities in schoolchildren with ADHD. J Atten Disord 19(1):53–62

Pourcain BS, Mandy WP, Heron J, Golding J, Smith GD, Skuse DH (2011) Links between co-occurring social-communication and hyperactive-inattentive trait trajectories. J Am Acad Child Adolesc Psychiatry 50(9):892–902

Purvis KL, Tannock R (1997) Language abilities in children with attention deficit hyperactivity disorder, reading disabilities, and normal controls. J Abnorm Child Psychol 25(2):133–144

Reiersen AM, Constantino JN, Volk HE, Todd RD (2007) Autistic traits in a population-based ADHD twin sample. J Child Psychol Psychiatry 48(5):464–472

Tirosh E, Cohen A (1998) Language deficit with attention-deficit disorder: a prevalent comorbidity. J Child Neurol 13(10):493–497

Wiig EH, Semel E, Secord WA (2017) Clinical evaluation of language fundamentals (CELF5) Australian and New Zealand standardised edition, examiner's manual. Pearson Clinical and Talent Assessment, Sydney, Australia