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The Neuropsychological Profile of Children with Autism Spectrum Disorder and Children with Developmental Language Disorder and its Relationship with Social Communication

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DECLARATION OF INTEREST

All authors formally declare that there is no conflict of interest in this paper.

ABSTRACT

Objective: Probing neuropsychological mechanisms of social communication in children with Autism Spectrum Disorders (ASD) and children with Developmental Language Disorders (DLD). Due to overlap of symptoms that include social dysfunction, diagnostic boundaries between these two developmental disorders remain unclear. This study hypothesizes that these two groups of children differ in the characteristics and in the underlying mechanisms of their social issues.

Method: This study examines a wide range of neuropsychological domains in search of a relationship with social communication. A total of 75 children with ASD and 26 children with DLD are included. A cross-battery assessment of neuropsychological functions is conducted, and social communication is evaluated using the Social Responsiveness Scale (SRS).

Results: The neuropsychological profile for ASD group differs from the DLD group, with the former demonstrating higher scores on Visual Processing and Comprehension, whereas the DLD group scores higher on Fluid Reasoning, Visual Processing and Processing Speed. Correlation analysis reveals that the association between neuropsychological domains and social communication differs between the groups.

Discussion: Children with ASD and DLD clearly have distinctive neuropsychological profiles - their strengths and weaknesses are not equivalent. Such results motivate broad assessment of neuropsychological functions, as this assists in differentiating ASD from DLD for theragnostic purposes.

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by persistent deficits in social communication, in combination with restricted, repetitive behavioral patterns, interests, or activities (American Psychiatric Association, 2013), covering a large spectrum of symptoms, skills, and severity (Brentani et al., 2013). However, a lack in social skills is universal in children with ASD, across ages and ability levels, regardless of variations in language abilities (Tager-Flusberg, Joseph, & Folstein, 2001). Although social communication impairments are a hallmark of ASD, the underlying mechanisms driving such deficits remain unclear.

Social communication deficits are also observed within individuals who have Developmental Language Disorder (DLD) (Cantwell, Baker, Rutter, & Mawhood 1989; Howlin, Mawhood, & Rutter 2000). DLD is a neurodevelopmental disorder characterized by language deficits, resulting in issues with comprehension, production, or language use. When a language disorder is the primary disability, with no comorbidities (such as sensory impairment, intellectual disability, or motor dysfunction), it is deemed a DLD (American Psychiatric Association, 2013). Social communication skills of children with DLD are recognized to be lower than expected for their age (Norbury, Nash, Baird, & Bishop, 2004). In addition, Leyfer et al. (2008) report that 41% of DLD children meet diagnostic thresholds for ASD in social and communication domains, based upon gold-standard measures for ASD. Unlike ASD children, core challenges in DLD are centered around structural language (phonology, morphology, syntax). Although language difficulties have an impact upon social communication, the extent of social difficulties in this group can be challenging to define. Social difficulties in children with DLD have been described as mild, and secondary to their language impairment.

Neuropsychological profile of children with ASD and DLD

In terms of intelligence, a discrepancy between the verbal intelligence quotient (VIQ) and performance intelligence quotient (PIQ) is prevalent in children with ASD, skewing towards a higher PIQ (Charman et al., 2011b; Ryland, Hysing, Posserud, Gillberg, & Lundervold 2014; Minshew, Goldstein, Muenz, & Payton 1992; Szatmari, Tuff, Finlayson, & Bartolucci 1990; Mouga et al., 2016).

Furthermore, when applying a broad-spectrum of neurocognitive domains into consideration, the neuropsychological profile of children with ASD includes higher scores on the (verbal) Comprehension Index and on Visual Processing, when compared to the Freedom from Distractibility Index (FDI) and the Processing Speed Index (PSI) (Mayes & Calhoun, 2003, 2008; Nyden, Billstedt, Hjelmquist, & Gillberg 2001; Wechsler, 2003b). The FDI is an index score composed of the sum of scores on the Arithmetic and Digit Span subtests. The FDI is interpreted as a measure of attention and concentration, and is referred to in this study as the 'Working Memory Index'. The PSI measures a child's ability to efficiently scan and quickly identify visual information and ability in executing quick and accurate decisions. Processing Speed is more than a basic reaction to visual stimuli. Both visual-motor coordination and sustained focus are required to perform well in this area. Mayes and Calhoun (2003) identify children with high-functioning ASD that had obtained low-grade results in FDI and PSI Indexes, with 73 % accuracy. Relative weaknesses in working memory have also been reported in several studies (Rosa et al. 2017; Schaeffer, 2018; Williams, Minshew, Goldstein and Mazefsky, 2017). Within such investigations, both verbal and non-verbal working memory impairments were reported, with emphasis on verbal memory. While studies have demonstrated intact semantic memory in ASD, issues arise when linguistic material becomes more complex. Issues with memory could also be long term (Williams, Minshew, Goldstein and Mazefsky, 2017).

In summary, the neuropsychological profile of high-functioning children with ASD seems to consist of a selection of relative strengths, namely Visual Processing and Verbal Comprehension, together with several relative weaknesses in Processing Speed, Working Memory and Long Term Memory. Whether such relative weaknesses are directly associated with social communication, or otherwise, is yet to be investigated. Several authors report correlations between processing speed issues and social communication issues in children with ASD (Oliveras - Rentas et al. 2012), while others find no direct link (Black, Wallace, Sokoloff, & Kenworthy, 2009). Malhi and Singhi (2015) demonstrate that global IQ positively correlates to adaptive social functioning.

Stemming from delayed language skills, children with DLD obtain lower scores on verbal tasks in neuropsychological assessments. Consequently, typical VIQ-PIQ discrepancies - in favor of the PIQ - are commonplace (Finnish Association of Phoniatrics and Finnish Association of Pediatric Neurology, 2010). Above all, impairment of verbal working memory and auditory processing - more precisely, phonological short-term memory (PSTM) - on tasks such as sentence and nonword repetition, are deemed as risk markers of DLD (Archibald & Gathercole, 2006). Therefore, auditory processing (including PSTM), working memory indexes and verbal comprehension indexes are expected to be relative weaknesses in the neuropsychological profile of children with DLD.

Spaulding (2014) stated that non-linguistic deficits can also be associated with DLD. Across two meta-analyses, children with DLD obtained lower PIQ scores than age-matched control children (Earle, Gallinat, Grela, Lehto, & Spaulding, 2017; Gallinat & Spaulding, 2014).

Social Communication in ASD and DLD

Social communication is a complex activity, relying on both linguistic skills and pragmatic competence. Within ASD, social impairments can be more prominent than they are for individuals with DLD. Children with ASD tend to have persistent deficits in social-emotional reciprocity, in non-verbal communicative behaviors, and in developing, maintaining, and understanding relationships (American Psychiatric Association, 2013).

It is well-established that impairments in theory-of-mind and social perception have an impact on social functioning in ASD (Kimhi, 2014; Mazza et al., 2017), as do deficits in executive functioning (especially concerning initiation, working memory and planning). In addition, visual motor integration issues could be another foundation for deficit in social functioning. Specifically, non-verbal communication (hand gestures, posture, body positioning, facial expressions) relies on motor cues. Consequently, mirroring, planning and performing physical movements could be problematic in ASD (Chien et al., 2015).

Social impairments in DLD children are considered to be mainly associated with poor expressive language skills and delayed comprehension development (Marton, Abramoff, & Rosenzweig, 2005). More specifically, communicative deficits in DLD tend to consist of atypical word choices, literal interpretation of figurative language, poor topic maintenance and turn- taking, together with conversational inadequacies, leading to interaction challenges (Hughes & Leekam, 2004; Andrés-Roqueta, Adrian, Clemente, & Katsos, 2013). Moreover, Griffiths (2007) reports correlations between pragmatic skills, phonological short-term memory and working memory scores, suggesting reduced abilities in automatized language processing in children with DLD.

In essence, social communication issues in DLD have been defined through language difficulties, a limited working memory and phonological processing capacity, together with limited acquisition of social skills, and delayed or impaired social cognition. Although overlap exists between individuals with ASD and DLD regarding social communication challenges, there could be variability in the underlying mechanisms driving these challenges. This opposes Bishop's (2010) suggestion, that both disorders are part of the same spectrum. Bishop takes the 'above-chance' co-occurrence of symptoms in ASD and DLD, as an indication that both share a common etiology. Consequently, it is paramount to investigate the extent and nature of these co-occurring social impairments across both groups.

The present study

This study investigates neuropsychological profiles of children with ASD and DLD, using a large and diverse analytical battery. Children of 6-16 years, without intellectual disability, are included. The aim is to assess whether specific neuropsychological abilities could distinguish children with ASD from DLD children, and whether such abilities are related to social communication skills. If the neuropsychological profile for children with ASD severely differs from profiles of children with DLD, this would suggest that such disorders do not share a common continuum. This study hypothesizes that the neuropsychological profile for ASD and DLD pediatric groups differs considerably and that distinct underlying mechanisms exist for ASD and DLD manifestations.

This study is expected to act as a validating investigation for previous findings (Rosa et al. 2017; Mouga et al. 2016; Williams et al. 2017), where children with ASD have relatively lower processing speed and working memory (in relation to their global intellectual functioning), as well as reduced long-term memory. Conversely, this current study expects to observe higher scores for comprehension and visual processing skills. Within the DLD group, reduced working memory or auditory processing are predicted, compared to other functions, as previously identified by Archibald and Gathercole (2016). This current study also expected higher scores for visual processing and fluid reasoning in relation to indexes requiring language skills, in accordance with previously reported discrepancy findings between VIQ and PIQ in children with DLD (Finnish Association of Phoniatrics and Finnish Association of Pediatric Neurology, 2010).

Socially, this current study predicts an association between social communication, processing speed and working memory within the ASD pediatric group (Chien et al. 2015;

Oliveras-Rentas et al. 2012). It is also expected that children with higher overall intelligence have fewer issues in interpreting social situations. Consequently, the current study expects an inverse correlation between general intelligence and social communication scores (measured through SRS) within the ASD group (Malhi and Singhi, 2015). Within DLD, this study expects inverse correlations between the comprehension index and SRS social communication scores, as deficits in structural language (eg., syntax) or language comprehension could impact negatively on social communication skills (Milligan et al. 2007). Finally, this study also expects inverse correlations between social communication scores (SRS-based) and both auditory processing and working memory – expecting corroboration with Bishop's (1997) previous findings.

METHODOLOGY

Procedure

The data used for this study stem from a database harboring archival research of a multidisciplinary center for children with neurodevelopmental disorders in Flanders, the Dutch-speaking region of Belgium. To be included in this study, all participants underwent a broad neuropsychological assessment, and participants' primary caregivers had completed the Social Responsiveness Scale (Constantino & Todd, 2005) survey form. All parents or caretakers of participating children gave written consent for utilizing such data for research purposes.

The neuropsychological test data and SRS interview scores come from those children in the database that were assessed and diagnosed with ASD or DLD during the 2015 – 2019 timeframe. A total of 101 records of school-aged children, ranging from 6 to 16 years and 11 months, met the inclusion criteria and are included in this study. Participants are divided into two clinical groups: children with ASD (n = 75; mean age = 9.8 years; 57 male/18 female) and children with DLD (n = 26; mean age = 8.5 years; 16 male/10 female).

Psychiatric classifications were performed according to DSM-5 criteria, by a multidisciplinary team that includes an experienced neuropsychiatrist and psychologists, on the basis of clinically structured and semi-structured interviews, child observations, questionnaires, and neuropsychological assessments.

Participants

i) *Children with ASD.* The ASD diagnosis was assigned on the basis of gold-standard instruments: a parental or caregiver interview using Autism Diagnostic Interview – Revised, ADI-R (Lord et al. 1994), together with the direct-structured assessment, the Autism Diagnostic Observation Schedule, ADOS-2 (Lord et al., 2012). All children with ASD had positive results in the ADI-R and ADOS-2 for ASD, and met the criteria for ASD from DSM-5. Exclusion criteria for children were evaluated through the anamnesis carried out with the families. These included neurological or genetic diseases, comorbidity with ADHD, brain lesions, sensory and auditory or motor deficits. Children with a global intelligence score (g-score) < 80 are excluded from the current study. This exclusion criterion was determined through data in the archival dataset.

ii) *Children with DLD.* All children in the DLD group met the criteria of a communication disorder by the DSM-5 (APA, 2013). They all speak Dutch as their primary language, passed a hearing screening (performed at 20dB) and achieved mean standard scores >80 on global intelligence (g-score). Use of non-verbal intelligence in the diagnosis of DLD is debated, though it remains a commonly utilized diagnostic criterion for DLD, and is important in this study since children with DLD are assessed in the same way as children with high-functioning ASD. Language abilities are assessed for all participants via core language subtests (Dutch version) of the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4-NL) (Kort, Schittekatte & Compaan, 2010). All participants achieve standard scores at least 1.25 SD below the mean of age-matched children's language scores on the Core Language Score (CLS), or at least two sub-index scores, or exhibit a severe deficit (e.g., 2SD or more below the mean) on any language measure. Exclusion criteria include hearing or visual impairment, neural-motor impairment and psychiatric or behavioral disorders other than deficits in learning. Children with concurrent ADHD or ASD are excluded from the current study.

Materials

Participant datasets all contain data of the neuropsychological assessments and the Social Responsiveness Scale survey form (Constantino & Todd, 2005). Both assessments are discussed below.

A *neuropsychological assessment*, according to the Cattell–Horn–Carroll model (CHC-model), is used to compare neuropsychological domains for pediatric ASD and DLD groups (inter-/intra-group analyses). The CHC-model is widely accepted as the most comprehensive and empirically supported investigation of neuropsychological abilities (Flanagan & McGrew, 1997; Kaufmann, 2009; Schneider & McGrew, 2012). The Cattell-Horn-Carroll (CHC) theory emphasizes multidimensional intelligence rather than IQ scores. This framework consists of the three-stratum model and uses multiple cognitive domains to provide a more accurate cognitive profile (see figure 1). The model consists of three levels or strata of cognitive abilities: specific cognitive abilities (the subtests), broad cognitive abilities (the cognitive domains), and general intelligence, which provides a richer knowledge of an individual's cognitive strengths and weaknesses compared to a single IQ score. Clinical and educational neuropsychological tests benefit from including a broad spectrum of cognitive domains. A deeper knowledge of an individual's cognitive profile can guide targeted interventions and support strategies, improving outcomes. In conclusion, the CHC theory's use of numerous cognitive domains improves the accuracy of cognitive potential assessment. In clinical and educational contexts, this method yields a more accurate and informative profile than IQ alone.

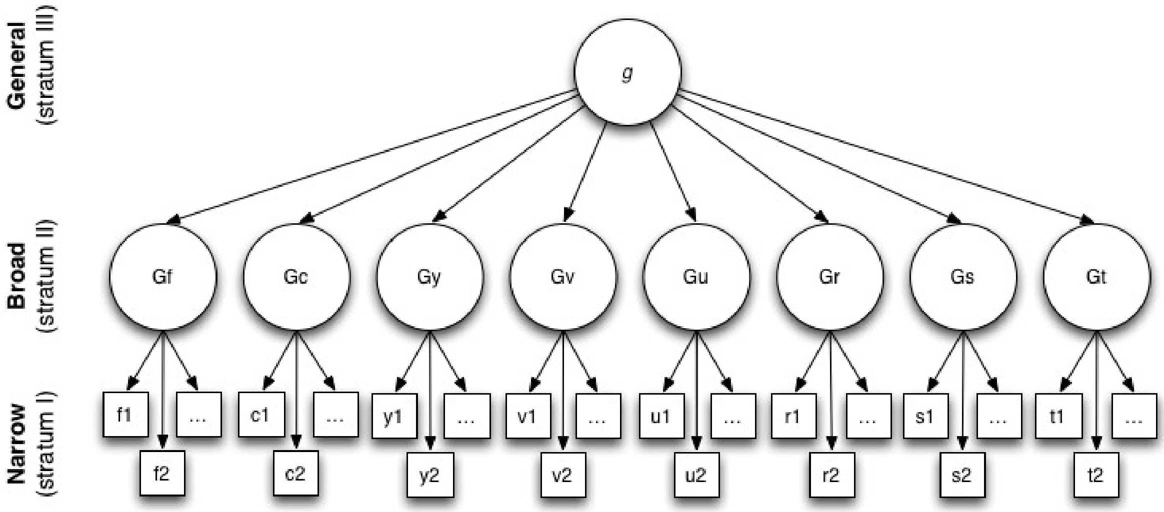

Figure 1. Cattell-Horn-Carroll (CHC) three-stratum model of human cognitive abilities.

Implementing a cross-battery approach, including subtests of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 2005), the Clinical Evaluation of Language Fundamentals-4-NL (CELF-4-NL; Kort, Schittekatte & Compaan, 2008), the Snijders-Oomen Nonverbal Intelligence Test (SON-R 6-40, Tellegen & Laros, 2011), the NEPSY-II (Korkman, Kirk, & Kemp, 2007a) and the Children Memory Scale (CMS; Cohen, 1997) the following seven broad neuropsychological domains were analyzed across both groups: Comprehension, Fluid Reasoning, Working Memory, Long Term Memory, Visual and Auditory Processing, and Processing Speed. Indexes and confidence intervals (CI) for neuropsychological domains were registered following guidelines based upon Flanagan et al. (2000, 2013), described on the CHC platform of Thomas More University College (Thomas More, 2016; VCLB De Wissel, 2014a, 2014b; Magez & De Jonghe, 2015).

Within this model, all (sub)test and index scores are based upon the same standardized normal distribution. We use standardized scaled scores (M= 10, SD= 3) on the subtest level. These subtest scores are summed to obtain index scores (again standardized scores with M = 100 and SD = 15), which are translated into norm scores using the normative table of either WISC-III, SON 6-40 IQ or CELF-4-NL: For the Fluid Reasoning index, the normative table for IQ-scale of SON 6-40 is used. For Visual processing and Processing Speed indexes, normative tables for WISC-III – namely, Perceptual Organization and the Processing Speed Index – is used. Regarding other indexes – namely Auditory Processing, Long-Term Memory and Working Memory – we use normative tables of CELF-4. If a significant scatter exists between scaled subtest scores (i.e. if the difference between the highest and lowest scaled score was > 3 points) compromising an index, then this index score is considered as uninterpretable and is not calculated. This leads to a large amount of missing data points within study datasets for both groups.

Next, the Global Intelligence index is determined through the sum of 10 scaled subtest scores; Categories (SON-R 6-40), Analogies (SON-R 6-40), Information (WISC-III-NL), Vocabulary (WISC-III-NL), Similarities (WISC-III-NL), Digit Span (CELF-4-NL), Recalling Sentences (CELF-4-NL), Block design (WISC-III-NL), Picture completion (WISC-III-NL) and Coding (WISC-III-NL), using the normative table of WISC-III Total IQ. See Table 1 for an overview of the CHC-model we use in the current study.

Table 1: Overview of Neuropsychological Assessment Tools

Index and subtests	Description subtests
Fluid Reasoning	**Abstract reasoning, logical thinking skills and problem solving abilities, which do not require verbal language production and comprehension**
Categories (SON-R 6-40)	The subject is shown three drawings of objects or situations that have something in common and must discover the concept.
Analogies (SON-R 6-40)	The subject is required to discover the principle behind the transformation A : B and apply it to figure C
Comprehension	**A person's breadth and depth of acquired knowledge of the language, information and concepts of a specific culture, and the application of this knowledge.**
Information (WISC-III-NL)	The subject has to give answers to a broad range of general-knowledge topics
Vocabulary (WISC-III-NL)	The subject is required to define orally presented words in this subtest.
Similarities (WISC-III-NL)	The subject has to describe how two given concepts are alike.
Working memory	**Memory span and working memory.**
Digit Span (CELF-4-NL)	The subject is asked to perform relatively simple manipulations, in particular to name the digits backwards.
Recalling Sentences (CELF-4-NL)	The subject has to listen to spoken sentences of increasing length and complexity, and have to repeat the sentences without changing the sentence structure.

Auditory processing	**A wide range of abilities involved in the interpretation and organization of phonological or verbal information**
Nonsense Words (NEPSY-II)	The subject has to repeat nonsense words, with increasing complexity, aloud.
Logical Memory (CMS)	This test consists of two short stories, which are verbally presented by the examiner. Immediately following each story, the subject is asked to repeat what they remember, as accurately as possible
Visual processing	**The ability to make use of mental imagery to solve problems. It includes the ability to rotate, reverse and manipulate spatial configurations**
Block design (WISC-III-NL)	The subject has to rearrange blocks that have various color patterns, to match a pattern.
Picture completion (WISC-III-NL)	The subject is shown a picture in which there is a significant part missing, and is required to say what is missing.
Long-term memory	**The ability to store and consolidate new information in long-term memory and later fluently retrieve the stored information.**
Word associations (CELF-4-NL)	The subject has to produce isolated words from a specific semantic category.
Logical Memory Delayed Response (CMS)	The subject is asked to recall the story (of the subtest Logical Memory) again after thirty minutes delay (delayed recall).
Processing speed	**The ability to rapidly and accurately search, compare for visual similarities.**
Coding (WISC-III-NL)	The subject is presented with a key in which numbers 1 to 9 are each connected with a different symbol, and have to use this key to put in the correct symbols for a list of numbers.
Symbol search (WISC-III-NL)	The subject has to look at two target symbols and then has to examine a group of symbols to see if the target symbols are repeated.

Note. SON-R 6-40 = Snijders-Oomen Nonverbal Intelligence Test, WISC-III-NL = Wechsler Intelligence Scale for Children 3th edition, ,CELF-4-NL= Clinical Evaluation of Language Fundamentals-4-NL, CMS = Children Memory Scale.

The *Social Responsiveness Scale* (SRS; Constatino & Todd, 2005) (SRS) is a validated, widely-used questionnaire that assesses behavioral and social-communicative traits. The SRS form contains 65 questions concerning a child's behavior and is completed by a parent or caretaker. The questions can be answered on a four-point Likert-scale with answer possibilities ranging from 0 (never true) to 3 (almost always true). An elevated total score indicates increased social issues or autistic traits that the child is believed to exhibit. The SRS manual divides T-scores (M=50, SD =10) into four levels: (0) high level of social responsiveness (T-scores < 40), (1) normal level of social responsiveness (T-score between 40 - 60), (2) mild-to-moderate deficits in social responsiveness (T-scores between 61 - 75) and (3) severe deficits in social responsiveness (T-scores > 75). When children score < 60, this suggests that their social responsiveness does not demonstrate any deficits. Differing scoring measures exist for boys and girls. Five subscales are provided: Social Awareness, Social cognition, Social Communication, Social Motivation, and Autistic Mannerisms. The subscale 'Social Communication' includes expressive social communication (reciprocal communication in social situations) and social understanding. The T-score from the subdomain 'Social Communication' is used in this study.

Data analysis

Statistical analyses are performed with Statistical Package for Social Sciences® software (SPSS® for MS™ Windows® v.24, Chicago, IL, USA). Initially, this study explores differences between neuropsychological domains within each group (i.e., ASD pediatric group and DLD pediatric group separately), analyzing standard scores (i.e., the neuropsychological indexes) through a repeated-measures mixed-model analysis.

However, the large amount of missing data points within neuropsychological measurements does not permit repeated-measures ANOVA analysis. The default approach for missing data in repeated-measures analysis is typically the Listwise Deletion, which drops all observations with any missing data on any variable involved in the analysis. This would have led to a negligible cohort size. Within a mixed approach, only the missing data points are dropped, while remaining data is retained. Consequently, variations within the neuropsychological profiles of children with ASD or DLD are tested using repeated-measures mixed-models, with an unstructured covariance structure. Due to the missing data, cohort size (n) varies in analyses (between 41 – 46) within the group of children with ASD, and between 6 - 21 within the group of children with DLD. The fixed factors 'group (ASD or DLD)', 'Neuropsychological profile' (Fluid Reasoning, Comprehension, Working Memory, Visual Processing, Auditory Processing, Long-Term Memory, Processing Speed) and the interaction between group and neuropsychological profile are used to perform this analysis.

Secondly, this study compares the neuropsychological indexes between both groups, using a Mann Whitney U-test. A measure of size effect, in particular Hedges' g, is performed and indicates the level of variation between both study groups. Since only a minimal population size is within the DLD group, Hedges' g is selected over Cohen's d as size effect. Finally, Spearman correlations are calculated to determine if a correlation exists between the seven neuropsychological domains (using the index scores) and SRS subscale 'Social Communication' (T-score) for both groups.

Descriptive statistics

Mean index scores and standard deviations of the neuropsychological domain / SRS subscale 'Social Communication' are reported in Table 2. A Kolmogorov–Smirnov test with Lilliefors correction is performed to verify normality assumptions, indicating that each neuropsychological domain or SRS – subscale 'Communication' follows a normal distribution.

Table 2: Mean Index and Subtest Scores of Neuropsychological Abilities for ASD and DLD Groups

	ASD			DLD		
	N	M	SD	N	M	SD
Fluid Reasoning	**64**	**101**	**15.6**	**19**	**98**	**4.9**
Analogies (SON-R 6-40)	50	10	1.6	12	9	2.3
Categories (SON-R 6-40)	50	9	1.8	12	10	1.1
Comprehension	**63**	**106**	**17.2**	**21**	**93**	**7.6**
Knowledge						
Information (WISC-III-NL)	51	10	1.5	13	8	1.2
Vocabulary (WISC-III-NL)	52	10	2.1	17	7	1.2
Similarities (WISC-III-NL)	47	12	1.7	15	8	1.3
Working Memory	**64**	**97**	**14.2**	**16**	**86**	**8.7**
Digit Span (CELF-4-NL)	51	9	2.2	7	7	1.2
Recalling Sentences (CELF-4-NL)	49	9	1.4	12	7	1.3
Visual Processing	**64**	**106**	**22.1**	**21**	**98**	**9.5**
Block Design (WISC-III-NL)	52	11	1.2	19	10	1.1
Picture Completion (WISC-III-NL)	52	11	0.9	17	11	1.1
Auditory Processing	**41**	**100**	**14.6**	**11**	**86**	**8.4**
Nonsense Words (NEPSY-II)	46	11	1.5	6	7	1.4
Logical Memory (CMS)	46	10	1.6	7	8	1.3

Long Term Memory	**43**	**100**	**18.0**	**10**	**89**	**5.4**
Word Associations (CELF-4-NL)	48	11	2.1	9	8	1.3
Logical Memory Delayed Response (CMS)	46	8	1.5	12	6	1.4
Processing Speed	**64**	**96**	**17.4**	**19**	**98**	**12.1**
Coding (WISC-III-NL)	52	9	1.4	20	8	1.2
Symbol Search (WISC-III-NL)	52	10	1.4	22	9	1.2
General intelligence	**75**	**102**	**13.1**	**26**	**93**	**8.4**
Social communication (SRS)	64	76	17.5	15	73	16.6

Note. ASD = Autism Spectrum Disorder, DLD = Developmental Language Disorder, N = number of participant, M = mean, SD = standard deviation, SON-R 6-40 = Snijders-Oomen Nonverbal Intelligence Test, WISC-III-NL = Wechsler Intelligence Scale for Children 3th edition ,CELF-4-NL= Clinical Evaluation of Language Fundamentals-4-NL, CMS = Children Memory Scale, SRS = Social Responsiveness Scale (T-scores), ADI-R = Autism Diagnostic Interview-Revised.

RESULTS

Inter-/Intra-group Comparisons of Neuropsychological domains

To probe whether the strengths and weaknesses within neuropsychological domains vary between ASD and DLD pediatric cases, a repeated-measures mixed-models analysis is carried out. More precisely, differences within the neuropsychological profiles of each group are tested, and the obtained relationships between neuropsychological domains are compared between both groups. Since it is assumed that effects would be constant among all children within a group, only fixed effects are estimated within the model. Since differing neuropsychological domains are compared, it is assumed that variances and covariances between domains differ. Consequently, an unstructured covariance matrix is used. The fixed factors Group (ASD or DLD), Neuropsychological profile (Fluid Reasoning, Comprehension, Working Memory, Visual Processing, Auditory Processing, Long Term Memory and Processing Speed) and the interaction between Group and Neuropsychological Profile are included in the model.

A significant main effect is found of the fixed factor Group, F (1, 100.70) = 13.64, $p < 0.001$, η^2 p <0.001, as well as a within-subject effect of Neuropsychological Profile, F(6,78.36)

= 13.64, $p < 0.001$, $\eta^2 p < 0.001$. Consequently, the interaction between Neuropsychological Profile and Group is significant, $F(6,78.36) = 3.15$, $p < .001$, $\eta^2 p = .01$. This effect indicates that the relationship between neuropsychological domains in children with ASD differs significantly from the relationship between neuropsychological domains in children with DLD. These results confirm that children with ASD have a different neuropsychological profile in comparison to children with DLD. Figure 2 depicts mean index scores, the neuropsychological domain, and group, showing interaction between Group and Neuropsychological Profile. To verify interpretation of the interaction effect, post-hoc analyses of repeated-measures mixed-model results are performed.

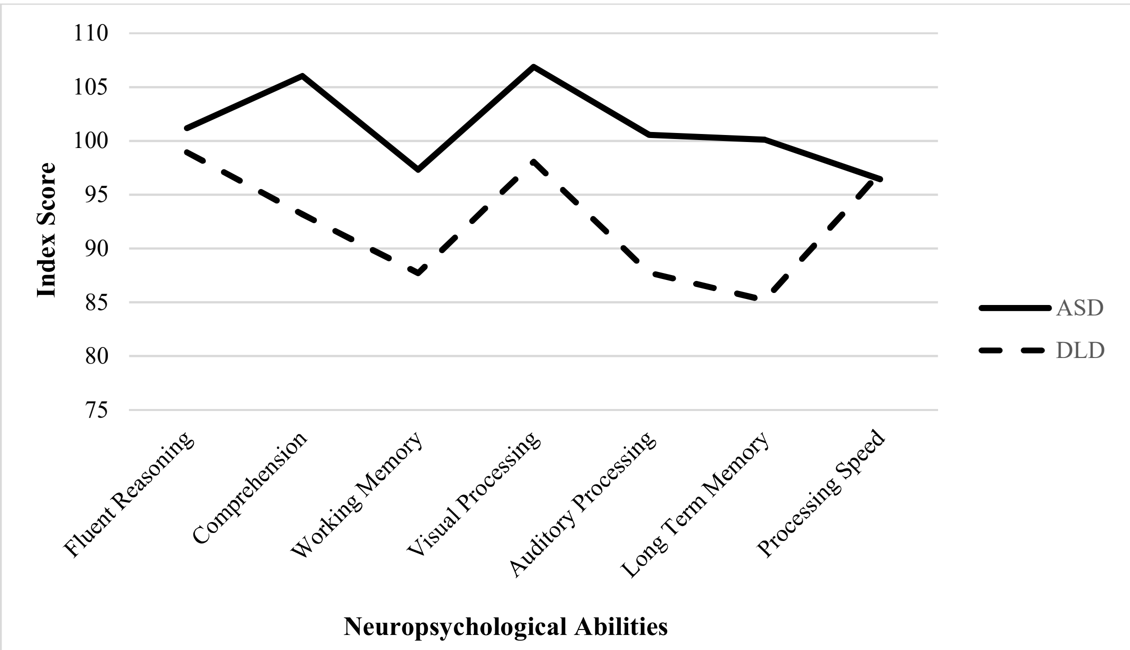

Figure 2. Mean index scores for each neuropsychological ability within ASD and DLD groups; ASD= Autism Spectrum Disorder, DLD= Developmental Language Disorder, Index Score (M=100, SD=15).

Post-hoc analyses

Post-hoc pairwise comparisons (with Bonferroni correction) between neuropsychological domains for the ASD pediatric group are carried out. The results indicate that, typically, children diagnosed with ASD have higher scores for Comprehension than for Working Memory ($p < 0.01$). The scores for Comprehension are also higher than scores for Processing Speed abilities ($p < 0.01$). A 'same-score' pattern is observed when comparing Visual Processing abilities with Working Memory. For Processing Speed abilities, higher scores are obtained on Visual Processing in comparison with Working Memory ($p <0.01$), and also in comparison with Processing Speed ($p < 0.01$).

For children with DLD, significant differences are found between neuropsychological domains. These children obtain higher scores for Fluid Reasoning in comparison with Working Memory ($p < 0.01$), and in comparison with Auditory Processing ($p = 0.02$). Likewise, scores for Visual Processing are higher than Working Memory ($p < 0.01$) and Auditory Processing ($p < 0.01$). Higher scores are also obtained for Processing Speed, when compared with Working Memory ($p = 0.02$) and with Auditory Processing ($p = 0.05$). In summary, scores for Fluid Reasoning, Visual Processing and Processing Speed are - individually - significantly higher than scores for Working Memory and Auditory Processing. Table 3 illustrates these results.

Table 3: Pairwise Comparisons of Neuropsychological Profile in ASD and DLD

ASD	DLD
Comprehension > Working Memory	Fluid Reasoning > Working Memory
Comprehension > Processing Speed	Fluid Reasoning > Auditory Processing
Visual Processing > Working Memory	Visual Processing > Working Memory
Visual Processing > Processing Speed	Visual Processing > Auditory Speed
	Processing Speed > Working Memory
	Processing Speed > Auditory Processing

Note. ASD = Autism Spectrum Disorder, DLD = Developmental Language Disorder.

Comparisons of Neuropsychological Domains Between Groups

Within this section, the main effect-of-group id assessed, namely, the presence of a performance variation between ASD and DLD pediatric groups, across the seven neuropsychological index scores (Fluid reasoning, Comprehension, Working memory, Visual spatial processing, Auditory processing, Long-term memory, Processing speed) and on the global intelligence score.

This performance is determined using the Mann Whitney U-test, through median accuracy score of each group, for each neuropsychological domain. The Mann Whitney U-test indicates that ASD participants score differently (by large margins) for neuropsychological index scores, compared to DLD participants.

Index scores are significantly higher within the ASD group, when compared to the DLD group: Comprehension, U = 284.5, p = 0.00, g = 0.96, Working memory, U = 283.00, p = 0.006, g = 0.98, Long-term memory, U = 126.00, p = 0.042, g = 0.81, and Global intelligence U = 493.00, p = 0.001, g = 0.81.

Correlations between Neuropsychological profile and Social Communication

Spearman correlations are performed to determine if a relation exists between the seven neuropsychological domains (using index-scores) and the SRS subscale 'social communication' (using a T-score). Table 4 depicts correlations among subscales within the ASD group. DLD group correlations are reported in Table 5.

Table 4: Spearman Correlation Analysis Between Neuropsychological Abilities and SRS Scores Within ASD Group (N=63)

		Social Communication
Fluid Reasoning	r_s	-.16
Comprehension	r_s	-.13
Working Memory	r_s	-.17
Visual Processing	r_s	-.13
Auditory Processing	r_s	-.15
Long Term Memory	r_s	-.01
Processing Speed	r_s	-.05
General intelligence	r_s	-.16

Note. N = number of participant,* = Correlation is significant at the 0.05 level, **= Correlation is significant at the 0.01 level, r_s = Spearman's correlation coefficient.

Concerning the ASD group, there are no significant correlations between neuropsychological outcome measures and the SRS subscale.

Table 5: Spearman Correlation Analysis Between Neuropsychological Abilities and SRS Scores within DLD Group (N= 17)

		Social Communication
Fluid Reasoning	r_s	-.67*
Comprehension	r_s	-.61*
Working Memory	r_s	-.30
Visual Processing	r_s	-.31
Auditory Processing	r_s	-.20
Long Term Memory	r_s	.57
Processing Speed	r_s	.27
General intelligence	r_s	-.04

Note. N = number of participant, * = Correlation is significant at the 0.05 level, **= Correlation is significant at the 0.01 level, r_s = Spearman's correlation coefficient.

Within the DLD group, the neuropsychological domain 'Fluid Reasoning' correlates significantly with the SRS subscale 'Social Communication'. This suggests that increased scores by DLD children for Fluid Reasoning are associated with reduced scores for Social communication, which indicates that there are fewer issues with social communication. Furthermore, this study finds a weak negative correlation between 'Social Communication' and 'Comprehension' subscales, suggesting that increased comprehension in children with DLD can be linked to reduced Social Communication scale scores on SRS, thus having fewer issues in this domain.

DISCUSSION

The current study corroborates previous studies documenting variations in neuropsychological profiles between ASD- or DLD-harboring pediatric cases. This study has investigated the strengths and weaknesses for neuropsychological profiles among such groups of children through a neuropsychological assessment, according to the CHC-framework, comparing each neuropsychological domain across both groups. In addition, this study looks into associations between social communication (measured through the SRS sub-scale 'Social Communication') and seven neuropsychological domains across both groups.

Corroborating previous studies, the ASD pediatric group demonstrates poor performance across tests designed to measure processing speed and working memory, in comparison with their performance in other neuropsychological domains (Rosa et al. 2017; Mouga et al. 2016; Mayes & Calhoun, 2008; Nyden et al. 2001; Wechsler, 2003a). Mouga and colleagues (2016) have noted that processing speed aspects, including visual-motor coordination, planning and associative non-verbal learning, are core deficits in children with ASD. It remains unclear, however, whether the nature of their difficulties is cognitive, visuo-motor or a combination of both etiologies. While working memory has been widely studied in the ASD population, findings are rather inconsistent (Wallence et al. 2016). A study by Russel and colleagues (1996) reveals intact working memory in children with ASD. However, the relative lower working memory scores obtained in the current study corroborate the findings described by Rosa and colleagues (2017).

Relative weaknesses in verbal working memory, and weaknesses in auditory processing, especially phonological short-term memory, can be considered core deficits in children with DLD. Reduced capacity in both skills serve as risk markers for DLD (Archibald & Gathercole, 2006). In line with earlier studies, the DLD pediatric group in the current study displays worse performances than peers with ASD in tests evaluating comprehension, working memory, long-term memory, and global intelligence (Coady & Evans, 2008; Petrucelli, Bavin, & Bretherton, 2012), with all such abilities being verbal-based. This indicates that language comprehension and/or production issues, possibly combined with a poor working memory in children with DLD, could drive such low-scoring results for the DLD group, in comparison to the ASD group. Consequently, it would be preferable to use the Fluid Reasoning Index score as a baseline for intelligence grading of children with DLD, rather than the Global Intelligence factor, since the latter includes a high proportion of verbal-based tasks in its assessment protocol.

Currently, the use of neuropsychological measures as diagnostic tools in neurodevelopmental disorders is still under debate. The present study highlights the importance of employing a large and diverse analytical battery, focusing on both strengths and weaknesses within a neuropsychological profile, in order to add further knowledge for differential diagnoses between ASD and DLD.

Within the ASD group, no associations between social communication and the seven neuropsychological domains could be found. This means that no specific neuropsychological core deficit can be isolated to explain the social deficit observed in ASD children. The rapid integration of abundant and varied linguistic and extralinguistic contextual information in social functioning impose complex demands which are presumably taxing on a wider array of underlying cognitive functions.

Within the DLD group, on the other side, fluid reasoning correlates with social communication. These findings suggest that overall cognitive abilities in children with DLD are associated with symptom severity, especially with inabilities in social communication. This is in line with previous findings by Dethorne and Watkins (2006), who have noted that deficits in non-verbal performance within DLD children are related to issues in verbal processing. Indeed, in their study, the level of non-verbal IQ is associated with semantic and morphosyntactic issues. Within the present study, a relationship is also observed between comprehension and social communication. Consequently, reduced performance in comprehension, reflecting acquired knowledge of language-based information and concepts, are naturally associated with low performance in social communication. In essence, this study finds that social communication in children with DLD appears to correlate with overall intelligence and language skills. Marton and colleagues (2005) state that impairments in social communication are especially associated with a poverty in language skills and delayed comprehension development. These findings are not surprising, considering that comprehension of the discourse, word choice, semantics, and topic maintenance are all essential for social communication.

While Griffiths (2007) and Bishop (1997) suggest that deficits in social communication result solely from poor performance levels in working memory and phonological processing, the current study does not find any relationship across working memory or auditory processing on the one hand, and social communication on the other hand. This does not indicate that relative weaknesses in both indexes, as seen in the neuropsychological profiles of this DLD pediatric group, could not manifest in tandem with weakness in language skills that could affect social communication. The question of what develops first requires additional research efforts.

We have found that social communication deficits (measured through SRS) within the DLD pediatric group are especially related to their language impairments and global intelligence, while social communication deficits in the ASD pediatric group seem unrelated to any specific neuropsychological domain. Therefore, the present study assumes that additional underlying cognitive deficits drive the social communication issues within children with ASD. This could be one of the reasons why none of the neuropsychological domains were related to their social deficits, as observed in the abovementioned results.

In conclusion, the strengths and weaknesses found in the neuropsychological profile for ASD and DLD pediatric groups are dissimilar, consequently opposing the findings of Bishop (2010), who states that these should be considered as variations of common neurodevelopmental disorders on a spectrum. Our results and employed measurements motivate the broad assessment of neuropsychological functions, as this assists in distinguishing ASD from DLD cases, and differential diagnoses. Since differing associations are found between social communication and neuropsychological domains across both groups, this study hypothesizes that there is also a variation in the underlying neuropsychological factors causing social impairments across both groups. Additional research is required for investigating such underlying neuropsychological factors.

A number of limitations are present in this study. The external validity for this study is limited by the inclusion of only relatively high-functioning children with ASD and DLD. Such findings might not hold among lower-functioning children with ASD or DLD. Furthermore, DLD is a heterogeneous disorder - with symptoms in either expressive, or receptive function, or a combination of both functions being identified. A growing body of evidence supports the notion that a sub-group of children with DLD also have deficits in pragmatics. These manifestations could lead to different patterns in the social communication of children with DLD.

When interpreting the findings, it is important to take into account the relatively small sample sizes and missing data in the analyses, especially in the DLD group. A post-hoc analysis of sample size, performed to ascertain the requisite number of participants for appropriate statistical power, indicates that some neuropsychological domains (working memory (n = 16), auditory processing (n = 11) and long term memory (n = 10)) and social communication (n=15) do not meet the threshold of 18 participants. As a result, additional studies using larger samples are necessary to further corroborate these findings. Increasing the sample size would also enable more sophisticated modeling and analyses, allowing for a more comprehensive understanding of the complex relationships between neuropsychological domains and social communication. The inclusion of pediatric control groups with no developmental disabilities would also be helpful in pinpointing the specificity of identified neuropsychological profiles.

Furthermore, aspects of working memory should be examined more deeply, by specifically examining the two relevant storage abilities (phonological and visuospatial working memory, in particular), the domain-general central executive and the episodic buffer. These could add novel information to inconsistent findings concerning working memory processing in ASD. Motor and non-motor processing speed tasks should also be investigated further in children with ASD, in order to examine whether processing speed is relatively weak in this group, or only related to visuo-motor issues.

Finally, additional research is required to identify possible factors that could explain correlations between neuropsychological and social functioning in both groups. Further studies should include two important neurocognitive domains related to social communication, namely executive functions (EF) and social perception. The relationship between EF and social functions is widely recognized in individuals with ASD and DLD (Kimhi, 2014; Mazza et al., 2017). In light of this, even the assessment of social information coding or processing (e.g., with social perception subtests of the NEPSY II) is justified in future studies. Recent advances in social neuroscience have also highlighted the critical role of the cerebellum in social communication (Van Overwalle et al., 2021; Ma, Pu, et al., 2021b) and the association between the Mirror Neuron System and Social Communication in ASD (Chien et al., 2015). More research is needed to explore these possible underlying mechanisms of communication.

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