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# Current Profiles and Early Predictors of Reading Skills in School-Age Children with Autism Spectrum Disorders: A longitudinal, retrospective population study

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# Current Profiles and Early Predictors of Reading Skills in School-Age Children with Autism Spectrum Disorders: A longitudinal, retrospective population study

This study explores current reading profiles and concurrent and early predictors of reading in children with ASD. Before the age of 3 years, the study cohort underwent a neurodevelopmental assessment following identification in a population-based autism screening. At age 8 years, reading, language and cognition were assessed. Approximately half of the sample (n=25) were "poor readers" at age 8 years, meaning that they scored below the normal range on tests of single word reading and reading comprehension. Eighteen were "skilled readers" performing above cut-offs. The final subgroup (n=10) presented with a "hyperlexic/poor comprehenders" profile of normal word reading, but poor reading comprehension. The "poor readers" scored low on all assessments, as well as showing more severe autistic behaviors than "skilled readers". Group differences between "skilled readers" and "hyperlexics/poor comprehenders" were more subtle: These subgroups did not differ on autistic severity, phonological processing or nonverbal IQ, but the "hyperlexics/poor comprehenders" scored significantly lower on tests of oral language. When data from age 3 were considered, no differences were seen between the subgroups in social skills, autistic severity or IQ. Importantly, however, it was possible to identify oral language weaknesses in those that five years later presented as "poor readers" or "hyperlexics".



## Introduction

Literacy skills are important for lifelong learning, employment and independence in our society and studies exploring the reading profiles and reading difficulties of children with

autism spectrum disorders (ASD) has grown in recent years. Much of this research has focused on the mismatch between stronger single word reading/decoding and weaker reading comprehension observed in some children with ASD (e.g., Huemer & Mann, 2010), with the term "hyperlexia" sometimes being used to describe an extreme version of this profile (c.f., Aaron, 2012; Grigorenko, Klin, & Volkmar, 2003; Nation, 1999; Ostrolenk, d'Arc, Jelenic, Samson, & Mottron, 2017). Other studies have, however, noted a very considerable heterogeneity in reading capacity among children with ASD (Åsberg, Kopp, Berg-Kelly, & Gillberg, 2010; Brown, Oram-Cardy, & Johnson, 2013; Nation, Clarke, Wright & Williams, 2006; Norbury & Nation, 2011; White et al, 2006).

Nation et al. (2006) utilized a subgrouping procedure to characterize this heterogeneity. In a sample of 41 children (aged 6-15 years, M=10.33), 21 children scored either below the normal range (i.e. standard score below 85), at floor levels or were non-readers in terms of single word reading/decoding skills. Another subgroup (n = 10) were classified as skilled in word reading/decoding and reading comprehension on the basis of their performance on age-referenced tests scores. Finally, another ten children displayed the "hyperlexic"-profile described above. Of particular interest to Nation et al. (2006) were the differences (and similarities) between the two latter subgroups; results showed that participants with the "hyperlexic/poor comprehender"-profile had difficulties not only with *reading* comprehension but also with *language* (*listening*) comprehension more generally, relative to "skilled readers" with ASD. In contrast, the "skilled readers" and the "hyperlexic" subgroups were not differentiated by nonverbal cognitive ability. These cross-sectional results fit well with the generally accepted conclusion in non-ASD reading research: reading comprehension builds on a foundation of oral language (i.e. listening) comprehension (Hoover & Gough, 1990; Hulme & Snowling, 2013). In particular, the so-called "Simple view of Reading" proposes that reading comprehension is the product of decoding skills and oral language/listening

comprehension; deficits in oral language therefore place a primary constraint on reading comprehension in fluent word readers (Hoover & Gough, 1990).

Previous research has also explored the extent to which word reading development in ASD is coupled with phonological processing capacity, a lower level linguistic skill often impaired in poor word readers without ASD (i.e. dyslexics) (Hulme & Snowling, 2013; White et al., 2006). Conversely, phonological processing capacity is well developed in skilled word readers, with a presumed causal influence on word reading development (Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012), although the influence between phonology and word reading is likely bidirectional (Nation & Hulme, 2011; Peterson et al., 2018). Nation et al. (2006) did not explicitly assess phonological processing in their participants with ASD, but suggested that the "hyperlexic" group may not present with phonological difficulties despite being weak in non-phonological language domains (e.g., semantic processing). A dissociation between phonological and non-phonological language skills may therefore explain why these children were able to develop skilled word reading while failing to develop age appropriate reading comprehension. This hypothesis is also in line with the two-dimensional model of language and reading difficulties proposed by Bishop and Snowling (2004). This model extends the Simple view of reading in the sense that both phonological and broader language (listening) skills are put forward as differentially important factors in children's literacy development. Children with impaired phonological and listening comprehension capacity will accordingly be challenged in both single word reading/decoding and reading comprehension, whereas some children with language comprehension difficulties without phonological difficulties will have relatively more selective deficits in reading comprehension. Studies have empirically confirmed that phonology underpins word reading/decoding capacity in ASD as it does in non-ASD individuals (Åsberg & Dahlgren Sandberg, 2012; Newman et al., 2007;

White et al., 2006) but it is less clear if this is the case when comprehension difficulties are also evident (Bishop & Snowling, 2004).

A third research strand has addressed the association(s) between autistic symptom severity and different reading skills. A few studies have reported an association between increased autistic symptoms and reduced reading comprehension (Åsberg et al., 2010; McIntyre et al., 2017; Ricketts, Jones, Happé, & Charman, 2012; Westerveld, Paynter, Trembath, Webster, Hodge, & Roberts, 2017). Researchers have suggested that poor reading comprehension in ASD might reflect underlying social-communicative difficulties that by definition are integral to ASD. For instance, impaired coherence making and inferencing skills (e.g., Ricketts et al., 2013) and/or difficulties in identifying author intentions and tracking the mental states of characters in the texts (cf., Hulme & Snowling, 2013) could affect reading comprehension beyond the role of oral language comprehension. However, another study showed that this influence of autistic severity on reading comprehension attenuated when considered in addition to the contributions of word reading/decoding and language capacity in a multifactorial analysis (Lucas & Norbury, 2014). Yet another study only found an association between increased social impairment and alphabetic knowledge (but not with reading comprehension) (Davidson & Ellis Weismar, 2014). Hence, existing results are mixed to date, and may reflect differences in samples in terms of age, sample size, and population representativeness. Elucidating the extent to which reading comprehension difficulties in ASD can be explained by word reading/decoding and/or language (listening) comprehension difficulties, as stipulated by the Simple View (Hoover & Gough, 1990) is of both practical and theoretical importance.

Drawing any causal conclusions based on the cross-sectional results should be approached with caution. Longitudinal studies provide evidence of developmental primacy that can inform causal theories. Davidson and Ellis Weismer (2014) assessed various cognitive, linguistic and autism severity measures at mean age 2 ½ years in 101 children with ASD, all of which were longitudinally related to early literacy skills when the children entered kindergarten. In keeping with previous research, the sample tended to perform better on tasks tapping alphabetic and early decoding skills than on comprehension and meaning. Moreover, the results showed that the best longitudinal prediction model of reading comprehension (the "Meaning subtest") at age 5.5 years was multifactorial. Of these 2.5 year variables, nonverbal cognition and expressive language stood out as the most significant contributors to later reading comprehension. Similarly, Miller et al. (2017) demonstrated that language ability at age 2 years predicted school-age reading comprehension in 26 children with ASD. Both of these studies concluded that oral language skills provide a foundation for later reading comprehension, although there appeared to be additional influences of other early predictors, including nonverbal cognitive ability and autistic severity. Neither of these two longitudinal studies applied a subgrouping procedure; instead, they predicted the full variation of reading skills in collapsed convenience samples.

Although dimensional approaches are typically preferred because they increase statistical power, it is more difficult to identify cases in which reading comprehension and word reading/decoding capacity are decoupled. Consequently, the current paper considers early precursors to qualitatively different reading profiles, including the hyperlexic/poor comprehender profile (e.g., Nation et al., 2006).

Furthermore, with the exception of the population-based sample from the SNAP study (Jones et al., 2009; Ricketts et al., 2013), previous research on reading and ASD has utilized convenience and/or clinical samples, making it hard interpret how common different reading profiles are within the ASD population. Therefore, the current study employed a population-based sample and a longitudinal, retrospective study design to examine concurrent reading profiles and their early predictors based on assessment at the age of 3 years. Children had been identified via population-based screening (Kantzer, Fernell, Gillberg, & Miniscalco, 2013; Kantzer, Fernell, Westerlund, Hagberg, Gillberg, & Miniscalco, 2018). At age 8 years, we used a subgrouping procedure based on individual children's scores on standardized tests of word reading and reading comprehension to determine the prevalence of different reading profiles. The identified subgroups were then compared both concurrently and retrospectively on a range of linguistic, cognitive and social skills/autistic severity data.

Three research questions were posed:

1. Which reading profiles can be identified within the sample?
2. To what extent are the reading profiles associated with concurrent measures of language, phonological processing, nonverbal cognitive ability and autistic severity?
3. To what extent are the reading profiles associated with language, cognition, communication and social functioning, and autistic severity measures taken at age 3 years?

## Methods

***Participants***

More than 100 children in Gothenburg, Sweden, were identified as having a suspected autism spectrum disorder (ASD) by a population screening at 2.5 years of age (Nygren, Sandberg, et al., 2012), at child health care centers. According to Magnusson (1997), 97.5% of all Swedish children participate in screening at these centers.The project was called *AUtism Detection and Intervention in Early life* (AUDIE) and ran from 2009-2011. Of the children who screened positive for ASD, parents of 107 children gave their consent to participate in the current research project. These children were assessed in depth by a multi-disciplinary team at the Child Neuropsychiatry Clinic (CNC) around 3 years of ages (Kantzer et al., 2013; Kantzer et al., 2018) focusing on autism diagnostics/assessment, language ability, cognitive level, and adaptive functioning. All involved professionals then met and made a consensus diagnosis based on all available information i.e. test results, observation data, parental questionnaires and interviews.

The current follow-up assessment took place when the children were between 5.9 and 9.8 years old ($n$=85) (15 girls; 70 boys) and included measures of oral language, non-verbal functioning, and literacy. Assessments were made by two speech and language pathologists (SLP) during one or two sessions at the CNC. Inclusion criteria stipulated that children were in the first or second grade of school (7-8 years of age); 27 children of the 85 were excluded since they had either not started first grade (n =24) or entered third grade at the time for assessment (see supplementary online material for further information). Another five participants were excluded because reading assessments were not completed due to time constraints and/or errors during administration. Thus, the total number of participating children was 53 with a mean age of 8.0 (6.6 – 9.8) years old (8 girls; 45 boys).

Of these 53 children, there were five who did not meet full DSM-IV criteria for an ASD diagnosis at their latest full autism assessment, but all were identified with autistic traits. We

chose to include all participants in the current study, due to 1) the unique recruitment procedure and 2) that the eventual influence of "autistic severity" (measured both dimensionally and categorically) on reading was one of the main issues we wished to explore.

***Tests and material***

**Data from the assessment at school age follow-up**

Oral language skills (comprehension and production)

Language comprehension was assessed using the Test for Reception of Grammar-2 (TROG-2) (Bishop, 2003; Swedish version, 2009) and receptive vocabulary using the Peabody Picture Vocabulary Test-, PPVT-III (Dunn & Dunn, 1997). TROG-2 involves matching orally presented sentences to the correct picture of a choice of four. The results are presented as both raw scores (number of correctly solved blocks out of a maximum of 20), and standard scores (M = 100, SD = 15) based on Swedish norms. The Cronbach's alpha is reported to be .89. On the PPVT, the child listens to a word uttered by the assessor and then selects one of four pictures that best describes the word's meaning. The test is not standardized for Swedish children, and therefore the original American norms were used. The Cronbach's alpha is reported to be .95 in the manual.

We indexed language production (Klem, et al., 2015) using the "Recalling Sentences" subtest from the Clinical Evaluation of Language Fundamentals – 4 (CELF 4; Semel, Wiig, & Secord, 2003; Swedish version, 2013). "Recalling sentences" consists of 24 sentences which are repeated verbatim by the child and scored on a 4-point scale depending on the number of errors present in the child's repetition. We present the results as both raw scores and scaled

scores (around a normative M = 10, SD = 3 based on Swedish norms). The Cronbach's alpha is reported to be .89.

Phonological processing/non-word repetition

Non-word repetition was assessed with 30, one to five syllable non-words that conform to Swedish phonotactics (Radeborg, Barthelom, Sjöberg, & Sahlén, 2006). The children repeated the non-words after the SLP's oral presentation. Norms are available for children aged 4-6 years. The SLP marked the responses online using broad phonetic transcription according to the International Phonetic Alphabet (IPA, 2005). Each repeated non-word was immediately scored as correct or incorrect. Radeborg et al. report a Cronbach's alpha of 0.74.

Letter knowledge

The child was asked to name the letters of the Swedish alphabet (which includes three letters besides those represented in English), written on two sheets of paper in both uppercase and lowercase form. The max score for each form is 24.

Single word reading/decoding

The LÄST test (Elwér, Fridolfsson, Samuelsson & Wiklund, 2009) was used to examine participants' single word reading/decoding ability. The task is to read as many words as possible in 45 seconds, from two lists of words. A total score is created by summarizing the number of correctly read words. Such efficiency measures – rather than separate accuracy and fluency measures – are typically used in Sweden and other semi-consistent orthographies. Swedish norms are available in the manual based on the stanine scale (i.e., around a mean of

M = 5, SD = 2) for each grade year. The test-retest reliability is reported to be $r$ = .93 for both lists in the Swedish manual.

Reading comprehension

The DLS Bas test (Järpsten, 2004) was used in order to assess the child's reading comprehension. The test comprises 20 sentences intertwined into a small story. For each sentence, there are five pictures and the child should mark the picture that best can be linked with the written content. The child is asked to read as many items as possible in 7 minutes (for 7 year-old children, i.e. school year one in Sweden) or in 5 minutes (for 8 year-old children, i.e. school year two in Sweden), with a maximum possible score of 20. Swedish norms are available in the manual based on stanine scores for each grade year. The test-retest reliability is reported to be $r$ = .78.

Non-verbal cognitive ability

The matrix reasoning subtest of Wechsler abbreviated scales of intelligence (WASI) was used as a measure of nonverbal cognitive ability (WASI: Wechsler, 1999). Results are expressed in raw and T-scores (M = 50, SD = 10) based on American norms. No Swedish norms are available.

Autism symptomatology

The Autism Spectrum Screening Questionnaire (ASSQ, Ehlers, Gillberg, & Wing, 1999) uses parent ratings on 27 items with a three-point Likert scale to measure autistic symptomatology. Test-retest reliability is reported to be high ($r$ = .96), and validity was established by Ehlers et al. (1999) and by Posserud, Lundervold, and Gillberg (2009), showing a clear correspondence

between total score on the ASSQ and a clinical consensus diagnosis of ASD. A screening cut-off for ASD of > 18 has been suggested (Ehlers et al., 1999).

**Data from the first assessment at age 3 years**

Not every child could participate in all tasks described below, therefore the *n* on each task is presented in table 2.

Assessment of cognitive/developmental level

A psychologist assessed children's general cognitive and developmental level using the Griffiths' developmental scales (GDS) (Alin-Åkerman & Norberg, 1991). The test includes six subscales; the total score (M = 100, SD = 15) from the subscales provides a developmental quotient (DQ) which is used here. McLean, McCormick and Baird (1991) reports adequate psychometric properties, both in terms of internal consistency reliability (Cronbach's alpha > .96) and construct validity according to correlation patterns with other tests of cognitive functioning.

Autism symptomatology

The Autism Diagnostic Observation Schedule – Generic (ADOS) (Lord, Risi, Lambrecht, Cook, Leventhal, & DiLavore, 2000) is a standardized, semi structured play-based assessment of communication, reciprocal social interaction, play, and behaviour. Either module 1 or 2 was administered, based on the expressive language level of the child. From these data calibrated severity scores were calculated (scores from 1-10) (Hus, Gotham & Lord, 2014). Higher scores indicate increased autistic symptom severity.

Adaptive communicative and social functioning

The Communication and Socialization domains of the Vineland Adaptive Behaviour Scales (VABS) (Sparrow, Cicchetti, & Balla, 2005) was administered by a child neuropsychologist in a face-to-face interview with one or both parents. Results are expressed in standard scores around a normative $M = 100$, $SD = 15$.

Oral comprehension and production language skills

Language comprehension was assessed with the Reynell Developmental Language Scales III (RDSL) (Edvards, Fletcher, Garman, Hughes, & Letts, 1997) which has Swedish norms (Eriksson & Grundström 2000; Lindström & Åström, 2000). The Kuder-Richardsson reliability coefficient is reported to be .97 in the manual from Great Britain. In addition, the expressive language level of each child was rated by the SLP on a scale from 1-to-5 using the PARIS scale (Philippe, Martinez, Guilloud-Bataille, Gillberg, Råstam et al., 1999): 1 = no words at all; 2 = a few single words; 3 = a few communicative sentences; 4 = talks a great deal, mostly echolalia, or 5 = talks a great deal, mostly in a communicative fashion.

***Statistical analyses***

The variables were subject to normality checks. First, the reading scores (single word reading/decoding, and reading comprehension) analysed dimensionally in the full group were found to diverge from the normal distribution (with many scores at floor); for this reason, we cannot complement the following results based on subgrouping with dimensional analyses across the full range of abilities. The other variables that were compared across subgroups displayed kurtosis and skewness statistics indicative of approximately normally distribution (values < 1.2), with the possible exception of the PARIS scale. A histogram inspection revealed that this variable seemed to be bimodal, with few scores of 3. Therefore, we chose to

transform the PARIS scale into a dichotomous variable, with the scores 1 and 2 representing less/minimally verbal, and 3, 4 and 5 representing relatively more verbal.

## Results

### *Attrition from intake at age 3 years to the current school-age follow-up*

In order to evaluate the population representativeness of the sample, we compared those who participated in the reading assessments at school-age follow-up with the rest of the screen positive cohort on the assessments of interest from intake. Those who did not participate were on average three months younger when they were assessed for the first time ($p = .023$). On all other assessments – for the Griffiths' developmental scales (DQ total score), the RDLS test of language comprehension, the ADOS (severity total score), the Vineland socialization, and the Vineland communication scores – no significant differences were observed (all $p > .20$) (see supplementary online material for details).

### *RQ1: Which reading profiles can be identified within the sample?*

Subgrouping were performed based on a cut off of a stanine score of ≤ 2 on standardized assessments on single word reading/decoding and reading comprehension (which corresponds to the ~ $10^{th}$ percentile); this is a common cut off in both research and in Swedish schools to identify children with reading difficulties. Results showed that almost half of the sample (25/53) were classified into a subgroup that will henceforward be called "poor readers", meaning that they scored below cut off on both single word reading/decoding ($M_{stanine} = 1.0$; $SD = 0.2$) and reading comprehension ($M_{stanine} = 1.0$, $SD = 0.2$). Another 10 participants were assigned in the "hyperlexics/poor comprehenders" group, meaning that they scored above cut

off in word reading/decoding ($M_{stanine}$ = 5.9, *SD* =1.0) but below cut off in reading comprehension ($M_{stanine}$ 1.7, *SD* = 0.5). For all "hyperlexics/poor comprehenders" there was a substantial discrepancy in the word reading versus reading comprehension performance of at least 3 stanine scores. Finally, 18/53 was assigned as belonging to a "skilled readers" subgroup since they performed above cut off on both word reading/decoding ($M_{stanine}$ = 7.1, *SD* = 1.3) and reading comprehension ($M_{stanine}$ = 5.8, *SD* = 1.6). Note that none showed the profile of poor word decoding and relatively better reading comprehension (that sometimes is seen in higher-functioning samples of dyslexic readers); hence, only three subgroups of interest were identified here.

The letter knowledge task was not used for subgroup assignment, but demonstrated that the majority of children in the "poor readers" groups were preliterate. As a group, they were only able to identify half of the letters in the alphabet, with 11 children not being able to recognize any letters at all (see table 1 descriptive data).

***RQ2: Are the reading profiles associated with concurrent measures of language, phonological processing, nonverbal cognitive ability and autistic severity?***

Table 1 present the descriptive data for each of the three reading groups on all measures of interest from the school-age follow-up assessment. Since the groups differed on age ($F$ [2, 50] = 8.36, $p$ = .001, $\eta_p^2$ = .251) with post hoc showing that the "skilled readers" subgroup was somewhat older ($p < .01$) than the other two subgroups (who in turn did not differ from one another, $p$ = .616), we use ANCOVA with control for chronological age in all subsequent group comparisons. Raw-scores rather than age-standardized scores were used in these

analyses in order not to control for age at multiple times; however, for descriptive purposes age-standardized scores values are also reported in Table 1.

>>Table 1. Insert about here<<

In terms of oral language, there were significant group differences on TROG-2 ($F$ [2, 49] = 17.95, $p < .001$, $\eta_p^2 = .423$), PPVT III ($F$ [2, 49] = 9.24, $p < .001$, $\eta_p^2 = .274$.) and Recalling Sentences (repetition) results ($F$ [2, 49] = 13.87, $p < .001$, $\eta_p^2 = .361$). Post hoc comparisons on TROG-2 showed that the "skilled readers" performed significantly better than both the "hyperlexics/poor comprehenders" ($p < .01$) and the "poor readers" ($p < .001$). In turn, "hyperlexics/poor comprehenders" performed better than the "poor readers" ($p = .032$). A slightly different pattern was obtained on PPVT III and Recalling Sentences tasks, in which "skilled readers" performed significantly better than both the "hyperlexics/poor comprehenders" (both $p \leq .01$) and the "poor readers" (both $p < .001$), who in turn did not differ from one another on either measure ($p = .201$ and $p = .786$, respectively). Mean scores in the different groups revealed that the "skilled readers" scored within the normal range on the standardized measures, whereas the "poor readers" and the "hyperlexics/poor comprehenders" scored substantially below the normal range.

Turning to phonological processing, a significant group difference was found on the non-word repetition task ($F$ [2, 48] = 18.85, $p < .001$, $\eta_p^2 = .440$). Post hoc tests showed that the "skilled readers" and the "hyperlexics/poor comprehenders" did not differ from one another ($p = .786$) while both these groups outperformed the "poor readers" (both $p < .001$). There are no norms available for the current age group, but a comparison with norms for four-to-six year-olds shows that the "poor readers" perform below the 25$^{th}$ percentile for the four-year olds. By contrast, the "hyperlexic/poor comprehenders" and the "skilled readers" scored equivalent to the 95$^{th}$ percentile for six-year olds.

Comparing the groups on the Matrix reasoning subtest of nonverbal cognitive ability revealed a significant group difference ($F$ [2, 48] = 12.00, $p < .001$, $\eta_p^2 = .333$), with post hoc analyses showing no significant difference between the "skilled readers" and the "hyperlexics/poor comprehenders" ($p = .604$), while the "poor readers" scored lower than both the "skilled readers" ($p < .001$) and the "hyperlexics/poor comprehenders" ($p < .01$). Mean scores in the different groups revealed that "skilled readers" and "hyperlexics/poor comprehenders" scored within the normal range, whereas the "poor readers" approx. scored 1.5 standard deviations below the normative mean.

With regard to autistic severity, the groups differed on ASSQ total scores ($F$ [2, 47] = 7.49, $p < .01$, $\eta_p^2 = .242$), with post hoc comparisons revealing that "poor readers" had higher symptom severity scores than either of the other groups (both $p < .01$), who did not differ from one another ($p = .807$). Although the mean scores on the ASSQ fell below the suggested screening cut-off for ASD in the "hyperlexics/poor comprehenders" ($\bar{x} = 14.6$) and the "skilled readers" ($\bar{x} = 16.9$), it should be stressed that these scores were well over 2 standard deviations above the population mean for 7-9 year olds as described by Posserud, Lundervold and Gillberg (2006). We also analyzed whether the prevalence of a clinical autism spectrum diagnosis differed between the subgroups, with the results revealing a possible trend ($\chi^2 = 5.01$, $p = .082$). The five participants who did not receive an ASD diagnosis were all classified as "skilled readers" ($n = 3$) or as "hyperlexics/poor comprehenders" ($n = 2$).

***RQ3: Are the reading profiles associated retrospectively with language, cognition, communication and social functioning, and autistic severity at age 3 years?***

Descriptive data for reading subgroups based on means and standard deviations taken when the children were aged 3 are reported in table 2. Chronological age at the 3-years assessment did not differ across the subgroups ($F$ [2, 50] = 2.03, $p$ = .143, $\eta_p^2$ = .075).

>>Table 2. Insert about here<<

Groups did not differ on cognitive ability assessed with Griffiths' developmental scales ($F$ [2, 43] = .097, $p$ = .908, $\eta_p^2$ = .005), degree of autistic severity (as assessed with the ADOS-2 severity scores ($F$ [2, 49] = 2.22, $p$ = .119, $\eta_p^2$ = .083) nor on the Vineland socialization scores ($F$ [2, 47] = 1.15, $p$ = .324, $\eta_p^2$ = .047)). Mean scores indicated equal levels of impairment in all groups.

As predicted, however, when comparing language ability at intake, significant differences were evident on RDLS language comprehension ($F$ [2, 49] = 14.47, $p$ < .001, $\eta_p^2$ = .371), the Vineland communication scale ($F$ [2, 47] = 3.36, $p$ < .05, $\eta_p^2$ = .125), and the SLP rating of expressive language using the PARIS scale ($\chi^2 = 13.52$, $p = .001$). Post hoc (Tukey) tests showed that the "poor readers" and the "hyperlexics/poor comprehenders" did not differ on the RDLS or Vineland communication ($p$ = .520 and $p$ = 1.00, respectively). By contrast, the "skilled readers" outperformed the "poor readers" on both measures (all $p$ < .05). In terms of PARIS ratings, inspection of adjusted standardized residuals showed that "skilled readers" were more likely to be verbal as toddlers relative to children with poor reading skills who were less/minimally verbal. The skilled readers also outperformed the "hyperlexics/poor comprehenders" on the RDLS comprehension test ($p$ < .01), whereas scores from the Vineland communication subscale was not significantly different ($p$ = .139).

## Discussion

This study aimed to address the heterogeneity present among children with ASD in their early reading skills. Specifically, we investigated individual differences in language comprehension and production, phonological deficits, cognitive level and autistic symptom severity in subgroups identified by different profiles of word reading/decoding skills and reading comprehension. The study allowed us to identify factors related to reading ability profiles both concurrently (mean age 8 years) and retrospectively (around the age of 3). In addition, our participants were identified by screening and are thus population representative to a greater extent than is the case in previous research, reducing ascertainment bias in establishing reading profiles.

The most common reading profile in our sample was that of generally poor reading skills. By contrast, the "hyperlexic/poor comprehenders" profile was relatively less common, whereas a sizable minority (ca 20%) performed age-adequate on both single word reading/decoding and reading comprehension. Hence, our results replicate in a Swedish population sample the great heterogeneity of reading skills and profiles within ASDs (e.g., Åsberg et al., 2010; Jones et al., 2009; Nation et al., 2006).

Our study also confirms the close relationship between reading comprehension and oral language comprehension skills. The "poor readers" subgroup was found to score low on most assessment, including nonverbal cognitive ability, as well as showing a more severe autistic presentation. Hence, the poor reading and language abilities of this group occur in the context

of more general delay. This means that their reading comprehension and oral language weaknesses were accompanied by greater impairments across several developmental domains, making it difficult to propose a distinct relation between reading comprehension and language comprehension deficits in ASD if only this subgroup is considered. By contrast, in the "hyperlexics/poor comprehenders" the difficulty in oral language and reading comprehension was much more selective when compared to the "skilled readers", pointing more clearly to a distinct association (cf., Nation et al., 2006). This finding is in keeping with the "Simple View of Reading" (Hoover & Gough, 1990).

Another important feature of this study was the longitudinal (retrospective) study design. Only two previous studies (Davidson and Ellis Weismer, 2014; Miller et al., 2017) have included analyses of developmental precursors to reading ability in ASD. However, neither of these distinguished between different reading profiles. Hence, it has not been fully clear to what extent identified predictors are important for reading comprehension per se, as opposed to aspects of reading comprehension difficulties accompanied by single word reading/decoding difficulties. Nonetheless, our results are broadly in line with these previous studies, demonstrating that before the age of 3 it may be possible to identify oral language weaknesses in both of the subgroups that presented five years later with poor reading comprehension. This result suggests that supporting oral language skills in ASD could be one way to support reading comprehension in children with ASD, similar to intervention approaches targeting poor reading comprehenders without ASD (e.g., Clarke, Snowling Truelove, & Hulme, 2010). Interestingly, preliminary intervention studies including children with ASD lends initial support for this idea (Bailey, Arciuli, & Stancliffe, 2017).

Consistent with Nation et al. (2006), our results demonstrate that children with the "hyperlexic/poor comprehender" profile had age appropriate phonological processing (as measured by the non-word repetition task), even though they performed poorly on tests of oral language comprehension. Our results are thus in line with the suggestion by Bishop and Snowling in their two-dimensional model of language and reading difficulties (2004), stating that the dissociation between (intact) phonological and (poor) non-phonological (semantic and syntactic) language skills might explain why some children are able to develop skilled word reading/decoding but poor reading comprehension. However, we need to highlight that in this study we were only able to measure this association cross-sectional. Indeed, whereas phonology traditionally has been interpreted as a "predictor" of word reading development, recent work (e.g., Nation & Hulme, 2011; Peterson et al., in press) has shown that phonology, including non-word repetition and related skills, may be causally dependent on word reading level, not only vice versa. It is fully possible that this is the case also in readers with ASD, and hence the causal mechanism in the phonology-word reading link observed here needs to be specified in future research. Nevertheless, disentangling the complex relation between letter knowledge, phonological skills and single word reading might not be critical for being able to provide effective interventions for poor word readers with ASD, at least if intervention approaches used in dyslexia can be transferred to poor word readers with ASD. Indeed, phonics-based training – where the reading intervention includes both letter-sound and phonological knowledge training – has been shown to be effective, whereas a pure phonological approach has gained less clear effects (SBU, 2014). Hence, phonology and word reading seems developmentally intertwined, and this fact also affects efficient teaching/intervention practices.

The association between ASD severity and reading profile varied depending on the time point considered. In early school-age, we found evidence of more severe autistic symptoms in the "poor readers" subgroup, which we interpret as an additional sign that this group has more pervasive developmental challenges. However, at age 3 years these differences in autistic severity were not obvious in the ADOS, nor in parent report of social skills. These results suggest that it is probably hard or impossible to predict early reading skills from autistic behaviours/social difficulties observed in toddlers alone.

A related issue is to what extent autistic severity impacts reduced reading comprehension. Several authors (e.g., Åsberg Johnels, Gillberg, & Kopp, 2017; Jones et al., 2009; Ricketts et al., 2013; Westerveld, et al., 2017) have suggested that impairments in social-communicative functioning and flexibility, on the one hand, and reading comprehension, on the other, may be coupled, possibly independently of basic language and cognitive skills. For instance, failing to understand social and communicative norms may hamper a reader's ability to make inferences and, consequently, constrain the processing of the text content (e.g., Ricketts et al, 2013). The results presented here do not easily support this idea, since we could not find any difference in autistic severity between the skilled and the "hyperlexic/poor comprehenders" subgroups. This might mean that we need to reconsider the hypothesis that ASD characteristics "per se" influence text comprehension negatively. In terms of theoretical implications, the results thus suggest that the Simple View of Reading can be applied to explain the reading comprehension difficulties in this cohort of readers with ASD. Still, we believe that the age of the study sample needs to be considered more in future research. Our participants attended first or second grade; during these first years in school, the texts and tasks used in reading comprehension assessment are typically quite basic, and this was arguably the case in the current study. One possibility is that with increasing age, the child meets more complex texts and assessment procedures, which place greater demands on the

flexible usage of both language and social knowledge and strategies, such as making coherence inferences and interpretations of author intentions (cf., Norbury & Nation, 2011). Hence, we propose that future research should consider whether the association between reduced reading comprehension and autistic severity is modulated by age, as well as the text type/context that is used in assessment.

***Limitations and conclusions of the current study***

There are a number of weaknesses of the current study. First, although the sample size is fairly large for a population-based study of autism, it is nonetheless clearly the case that the subgroups are small. Hence, the results should be further corroborated in larger samples. Another weakness is that no assessment of phonology was done at age 3 years. That would have allowed us to assess the predictive value of early phonological skills on single word reading/decoding. Finally, the current study only focused on reading whereas writing skills were not assessed. It has been argued that spelling performance and analyses of error patterns provide important insight into the mechanisms of literacy acquisition (Perfetti & Hart, 2002).

Despite these caveats, the results of this unique population-based study of children with ASD confirm a high degree of heterogeneity in reading skills in ASD. Given the importance of literacy for lifelong learning, employment and independence, it is important that practitioners in the field of ASD are aware of these various profiles of strengths and difficulties. Results also show that the profiles appeared to be predictable from and align well with established findings in general reading research: that word reading is strongly associated with phonological skills, whereas reading comprehension builds on a foundation of oral language skills. By age 3 years it appears to be possible to identify oral language weaknesses in children with ASD that five years later present as “poor readers” or “hyperlexics/poor comprehenders”.

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**Table 1.** Outcome measures for the three groups: "poor readers", "hyperlexic/poor comprehenders", and "skilled readers" at the school-year assessment

| | **Mean (SD)** [min-max] | | | |
|---|---|---|---|---|
| | **Poor Readers** *n* = 25 | **Hyperlexic/ Poor Comprehenders** *n* = 10 | **Skilled readers** *n* = 18 | Group differences using ANCOVA with correction for age |
| **Age** (years) | 7.8 (0.7) | 7.6 (0.4) | 8.4 (0.5) | Poor Readers = Hyperlexic < Skilled Readers |
| **Language ability** | | | | |
| PPVT III (raw score) | 51.9 (38.9) [0-126] | 70.1 (12.7) [41-91] | 103.7 (39.5) [0-172] | Poor Readers = Hyperlexic < Skilled Readers |
| PPVT III (ss) [1] | 63.5 (26.8) [40-125] | 74.1 (9.0) [59-91] | 94.4 (26.8) [40-150] | |
| TROG-2 (block score) | 3.9 (4.7) [0-15] | 7.4 (3.8) [3-13] | 13.5 (4.4) [6-19] | Poor Readers < Hyperlexic < Skilled Readers |
| TROG-2 (ss)[1] | 61.6 (14.1) [55-110] | 68.3 (15.1) [55-93] | 89.7 (21.4) [58-116] | |
| Recalling Sentences CELF-4 (raw score) | 10.1 (13.3) [0-39] | 19.6 (11.0) [6-21] | 32.8(14.8) [1-60] | Poor Readers = Hyperlexic < Skilled Readers |
| Recalling Sentences CELF-4 (scs)[2] | 3.5 (4.3) [1-16] | 6.1 (4.3) [1-14] | 10.1 (5.0) [1-19] | |
| Non word repetition (max 30) (raw score) | 7.9 (8.8) [0-23] | 21.0 (3.6) [15-26] | 21.1 (8.2) [0-30] | Poor Readers < Hyperlexic = Skilled Readers |
| **Autism symptomatology** | | | | |
| ASSQ [a] (raw score) | 25.1 (9.4) [11-50] | 14.6 (9.1) [2-35] | 16.9 (7.2) [5-28] | Poor Readers < Hyperlexic = Skilled Readers |
| **Non- verbal ability** | | | | |
| Matrix reasoning (raw score) | 5.0 (5.6) [ 0-20] | 12.4(6.3) [7-25] | 14.9 (6.6) [0-26] | Poor Readers < Hyperlexic = Skilled Readers |
| Matrix reasoning (t-score)[3] | 35.0 (10.1) [23-66] | 49.0 (9.2) [40-67] | 48.7(10.5) [28-68] | |

*Note* [1)] standard scores (M=100, SD=15), [2)] scaled scores (M=10, SD=3), [3)] T -scores (M=50, SD=10), [a)] $n$ =17 of the "skilled readers" parents completed the ASSQ.

**Table 2.** Results from the age 3 year assessment in the three subgroups: "poor readers", "hyperlexic/poor comprehenders" and "skilled readers"

| **Results from the 3 year assessment** | **Mean (SD)** Poor Readers | Hyperlexic/Poor Comprehenders | Skilled readers | **Group differences** using ANOVA |
|---|---|---|---|---|
| | *n* = 25 | *n* = 10 | *n* = 18 | |
| **Age** (months) | 35.4 (5.9) | 36.1 (6.2) | 38.8 (4.8) | Poor Readers = Hyperlexic = Skilled Readers |
| **Language ability** | | | | |
| RDLS (raw score) | 8.0 (11.3) | 14.0 (11.2) | 32.6[2] (20.0) | Poor Readers = Hyperlexic < Skilled Readers |
| PARIS level (no verbal 3-5 [%]) | 10 (40%) | 5 (50%) | 17 (94%) | Poor Readers < Skilled Readers |
| **Autism symptomatology** | | | | |
| ADOS severity total (raw score) | 6.1 (2.9) | 4.7 (2.4) | 4.4 [2] (2.7) | Poor Readers = Hyperlexic = Skilled Readers |
| **Developmental Quotient** | | | | |
| Griffiths' developmental scales [1] | 79.7[3] (18.5) | 80.1[3] (11.2) | 82.5 [3] (21.8) | Poor Readers = Hyperlexic = Skilled Readers |
| **Adaptive functioning** | | | | |
| VABS Socialization[1] | 73.2 [4] (7.9) | 74.9 (14.3) | 78.5 [4] (12.4) | Poor Readers = Hyperlexic = Skilled Readers |
| VABS Communication[1] | 70.9[4] (13.4) | 71.0 (12.7) | 81.8[4] (15.2) | Poor Readers < Skilled Readers |

*Note* [1)] standard scores (M=100; SD=15). Not all children had been assessed with the instrument

[2)] n= 1 of "skilled readers" did not provide a score, [3)] *n*=3 of "poor readers", *n* = 2 of

hyperlexic/poor comprehenders, and $n = 4$ of "skilled readers" did not provide a score, [4] $n = 1$ of "poor readers" and $n = 2$ of "skilled readers" did not provide a score.

# Supplementary material

Group comparisons on baseline measures for assessments at age 3 using *t*-tests and ANCOVA between the current study sample and the remainder of the AUDIE cohort

| | **Mean (SD)** | | **Test statistic** | **Group differences** |
|---|---|---|---|---|
| | Current sample | Remainder of the AUDIE cohort | *t*-value / F-value | *p-value* |
| | *n*=53 | *n*=54 | | |
| Age (months) | 36.70 (5.73) | 33.91 (6.71) | -2.31 | * |
| Developmental Quotient (GDS) | 80.67 (18.23) | 82.78 (18.37) | .56[1] | .577 |
| Language comprehension (RDLS) | 17.17 (18.19) | 13.35 (14.71) | -1.19[1] | .236 |
| ADOS (severity total) | 5.29 (2.82) | 5.39 (2.88) | -.18[1] | .861 |
| Vineland socialization | 75.22 (10.94) | 77.33 (9.50) | .30[1] | .302 |
| Vineland communication | 74.42 (14.48) | 76.08 (12.78) | .61[1] | .543 |

[1] Corrected for age (ANCOVA result). * p <.05

A relatively large proportion of the original cohort could not be included in the analyses since they had not yet started 1st grade. However, in fact n = 24 of these children were administered the tests of literacy, even though they had only received very little or no formal reading instruction. A look at their data revealed that there several cases that displayed some reading ability. When their performance was related to norms for grade 1, six of them could classified as "hyperlexics/poor comprehenders" and one as a "skilled reader. In the hyperlexic group there was one case with particularly precocious reading, obtaining a stanine score of 7 using grade 1 norms.