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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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

1

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

2

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;

3

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.

4

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).

5

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

7

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

8

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

9

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

10

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

11

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

12

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 ~ 10th 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

13

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, η_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

14

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 25th percentile for the four-year olds. By

contrast, the "hyperlexic/poor comprehenders" and the "skilled readers" scored equivalent to

the 95th percentile for six-year olds.

15

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" ($n = 2$).

16

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, η_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, η_p^2 = .005), degree of autistic severity (as assessed with the ADOS-2 severity scores (F [2, 49] = 2.22, p = .119, η_p^2 = .083) nor on the Vineland socialization scores (F [2, 47] = 1.15, p = .324, η_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, η_p^2 = .371), the Vineland communication scale (F [2, 47] = 3.36, p < .05, η_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).

17

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

18

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

21

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".

22

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24

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25

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26

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)			Group differences using ANOVA
	Poor Readers	Hyperlexic/Poor Comprehenders	Skilled readers	
	$n = 25$	$n = 10$	$n = 18$	
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.