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Orthographic and Phonological Pathways in Hyperlexic Readers with Autism Spectrum Disorders

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Orthographic and Phonological Pathways in Hyperlexic Readers with Autism Spectrum Disoders

Abstract

Children with Autism Spectrum Disorders (ASD) often present poor text comprehension relative to their ability to read individual words. Some of them have been considered hyperlexic because of their oustanding word reading abilities. Although it has been suggested that these children access word reading in an atypical way, there is conflicting evidence on their use of phonological and orthograhic pathways. Fourteen adolescents with ASD with word reading to text comprehension discrepancy and 12 typically developing children, all matched on word reading and chronological age, were administered different lexical and sublexical tasks exploring semantic, orthographic and phonological word representations and processes. No differences were found on any of the tasks between the children with ASD and the typically developing group. The children with ASD were further subdivided into two groups matched on word reading, one with outstanding word reading relative to verbal IQ and another with word reading consistent with verbal IQ. The first group outperformed the second on tasks involving lexical orthographic and phonological representation. However, they were no different on sub-lexical phonological processing, on rapid naming or working and short-term memory tasks.

Orthographic and Phonological Pathways in Hyperlexic Readers with Autism Spectrum Disoders

Readers with Autism Spectrum Disorders (ASD) often show a discrepancy between their ability to read words and comprehend written text (Burd, Kerbeshian, & Fisher, 1985; Grigorenko et al., 2002; Nation, Clarke, Wright, & Williams, 2006; Whitehouse & Harris, 1984). Many of these children have been labelled *hyperlexic readers,* although there is no general consensus as to the actual definition of hyperlexia.

Traditional definitions have required word reading age to be significantly above mental age to consider a child hyperlexic (Richman & Kitchell, 1981; Silberberg & Silberberg, 1971). Pennington, Johnston and Welsh (1987), for example, suggested that the ratio between reading and mental ages, which they termed *Reading Quotient* (RQ), was an adequate measure of this discrepancy. They considered reading to be significantly advanced if the ratio was greater or higher than 1.2. This criterion has subsequently been adopted in many studies (e.g. Cohen, Campbell, & Gelardo, 1987; Glosser, Grugan, & Friedman, 1997; Grigorenko et al., 2002; Temple & Carney, 1996; Welsh, Pennington, & Rogers, 1987). Definitions using the reading quotient are centred on the outstading performance of these children in word reading, and thus consider hyperlexia to reflect a form of "superability" (Grigorenko, Klin, & Volkmar, 2003). However, a word to text reading discrepancy can also be seen to reflect poor performance on text compehension relative to word reading skills. If looked at in this way, it would be more closely related to a "disability" in text comprehension. In order to include this relative lack of text comprehension, various definitions involving different forms of *double discrepancies* that comprise both superior word reading and inferior text comprehension have been suggested (Rispens & Van Berckelaer, 1991; Snowling & Frith, 1986). One of the stricter definitions requires hyperlexic children to present word reading significantly above and text comprehension significantly below mental age (Snowling & Frith, 1986). Nation (1999) has suggested that this criterion may be too stringent, considering the general correlation between IQ and reading comprehension. Instead she proposed that reading comprehension should be lower than expected from word reading and chronological age (for studies using this definition, see for example Richman & Wood, 2002; Sparks, 2001, 2004). Both these definitions would exclude readers with an overall good word reading score that is significantly above an also good text comprehension score, i.e., readers that are generally good at both aspects of reading. However, they do not avoid a certain overlap with the other group of children with a word reading to text comprehension discrepancy, i.e., the *poor comprehenders* (Yuill & Oakhill, 1991). Poor comprehenders are generally defined as readers whose text comprehension is lower than expected and definitional criteria typically involve a discrepancy with word reading and with IQ. Comprehension researchers have naturally concentrated their efforts on explaining why readers do not adequately extract meaning from text, with the assumption that word reading processes are normal in this group. Researchers using the term hyperlexia, on the other hand, assume that it is the unexpectedly outstanding good word reading behaviour that needs explaining.

An implicit hypothesis has often been that the level of word reading in children with hyperlexia is indicative of reading processes qualitatively different from those of the average reader. This view has been supported by a number of studies showing that hyperlexic readers often have difficulties in solving phonological tasks and could therefore be relying mostly on direct-visual access pathways. Sparks (1995; 2001), for example, studied three hyperlexic children over an 8 year period and concluded that their phonemic awareness was low compared to their word reading level. Richman and Wood (2002) found a higher percentage of phonetic errors in a subgroup of 19 of their 30 participants with hyperlexia. This group, which they labelled language disorder hyperlexics, showed good visual memory compared to the remaining 11, which they called non-verbal disorder hyperlexics, that presented poor visual memory and a smaller proportion of errors on the phonological tasks. Cohen, Hall and Riccio (1997) found that children with Specific Language Impairment (SLI) and hyperlexia outperformed non-hyperlexic children with SLI on visuospatial memory tasks, arguing that this was the main factor contributing to their outstanding reading abilities. Although rote holistic visual learning of word forms does not seem to be a plausible explanation (see Cobrinik, 1982), since hyperlexic children are able to read distorted words (Goldberg & Rothermel, 1984), some researchers have concluded that orthographic processing and/or representations are stronger than phonological processing and/or representations in these children. Therefore, their main reading pathway could be the direct orthographic route, as opposed to phonological mediation in typically developing readers (Glosser, Friedman, & Roeltgen, 1996; Glosser et al., 1997; Kennedy, 2002; Sparks, 2004; Talero-Gutierrez, 2006).

However, hyperlexic children also seem capable of reading non-words (Aram, 1997; Goldberg & Rothermel, 1984; Snowling & Frith, 1986) and read regular words more easily than irregular words (Aram, 1997; Frith & Snowling, 1983; Goldberg & Rothermel, 1984). This would imply that, although their word reading is superior to matched controls, the processes by which this is achieved are not particularly different.

A recent study involving one of the largest groups of hyperlexic participants seems to point in this direction (Newman et al., 2007). Forty-one children with ASD and hyperlexia and 21 with ASD and non-hyperlexic were tested on visual memory and phonological processing tasks. The hyperlexic children demonstrated strong phonological processing, particularly in the Non-word Reading tasks. In a pseudoword decoding task the hyperlexic ASD participants performed significantly better than the non-hyperlexic children with ASD, with no differences found with respect to a typically developing sample. No superiority of the hyperlexic group on the visual processing tasks was found. Interestingly, the hyperlexic children in this study were identified on the basis of the discrepancy between their word and text reading scores. It could be argued that using the term hyperlexia in this broad sense could include both children with poor comprehension and those with truly hyperlexic profiles. Since there is no reason to expect differences in word processing between poor comprehenders and typically developing children, the non-significant differences in phonological or visual processing found in the hyperlexic group do not directly adress the possibility of qualitatively different reading in these children. Also, although visual memory was tested in this study, no measure of semantic or orthographic word representation was included that allowed explicit assessment of other direct-visual word reading pathways.

In the present study, we aim to further explore the processes involved in hyperlexic reading using tasks that directly address the orthographic, semantic and phonological processes required for reading. We include children with ASD who present a word reading to text comprehension discrepancy and compare their performace to word reading and age-matched typically developing children. This should allow us to provide relevant data on the possibility of qualitative differences in hyperlexic reading. In addition, children in the ASD group were adscribed to one of two sub-groups, depending on whether their word reading was superior to or commensurate with their verbal IQ. It was expected that this analysis of individual differences would help to clarify whether additional criteria to the word to text reading discrepancy are actually useful.

Method

Participants

Fourteen children with ASD (13 boys and one girl) and 12 typically developing boys took part in the study. The participants with ASD all had a minimum difference of 10 points between their standardized word reading and text reading comprehension scores on the

Weschler Objective Reading Dimensions test (WORD) (Rust, Golombok, & Trickey, 1993) and could therefore broadly be considered hyperlexic. The test involves reading individual words aloud and responding to comprehension questions on increasingly complex short texts,which remain visible to participants, minimizing memory demands. The WORD has internal and test-retest reliability scores above .90. Its comprehension scale has been considered to be less demanding to poor comprehenders than other tests (Bowyer-Crane & Snowling, 2005). The word reading to text comprehension discrepancy obtained here can therefore be considered a conservative estimate.

ASD pupils were recruited from special schools or autism units within mainstream schools in London, Surrey or Kent (United Kingdom). These units are only accessed with educational statements of special needs that explicitly include an ASD-related diagnosis. All of the typically developing participants had text comprehension and word reading scores within 10 points of the standardization population mean. They were recruited from mainstream secondary schools in London, and no diagnosis of ASD or other disorders was reported.

ASD and control group means were matched on age (*M* = 13.9*, SD* = 1.3 and *M* = 13.7*, SD* = 1.9, respectively) and word reading scores (*M* = 99.4*, SD* = 7.9 and *M* = 102.7*, SD* = 6.2). Reading comprehension scores and verbal IQ, as measured through the British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, & Whetton, 1997) were both within the normal range for the typically developing children (*M* = 101.1*, SD* = 8.2 and *M* = 99.2*, SD* = 14.4). However, the ASD group mean reading comprehension score (*M* = 75.7*, SD* = 11.5) was significantly lower than the control group, t (24) = - 6.39, p < .001. Groups were not matched on verbal IQ (*M* = 86.1*, SD* = 18.7, for the ASD group), t (24) = - 1.98, p = .060.

Two sub-groups were distinguishable within the ASD group when the relationships among word reading, reading comprehension and verbal IQ were considered. In one group, each individual's word reading standardized score (*M* = 98.9, *SD* = 8.9) was at least 10 points above their verbal IQ (*M* = 72.9, *SD* = 13.4). For the participants in this group, reading comprehension and verbal IQ were similar, with a difference of less than 10 points (*M* = 70.4, *SD* = 11.3), and it is the unusually high word reading that stands out. Due to this profile, the group was labelled as a *Reading-VIQ Discrepant* group. In the second group (*Reading-VIQ Consistent group*), word reading scores (*M* = 99.9, *SD* = 7.4) were non-discrepant from BPVS scores (*M* = 99.3, *SD* = 12.9), with a difference of less than 10 points for every individual, whereas the difference between word reading and text comprehension (*M* = 81.0, *SD* = 9.6) was greater than 10 points. The two groups defined in this way and the control group all remained matched on standardized word reading scores and age (*M* = 14.4, *SD* = 0.6 and *M* = 13.4, *SD* = 1.0, for ages in both ASD groups respectively). In addition, sentence reading times, as measured with a self-paced computerized reading task involving two-sentence stories, were obtained for all except one participant in each of the Reading-VIQ Consistent and control groups (Saldaña & Frith, 2007). No significant differences were found on reading speed. Figure 1 provides a clear picture of the relative scores on word reading, text reading and verbal IQ in all three groups.

INSERT FIGURE 1 HERE

Instruments and procedure

Children were tested individually in a quiet room in their schools over a maximum of three sessions. In addition to text comprehension, word reading scores and the BPVS, various lexical and sublexical processing tasks were administered:

Lexical representation tasks.

- Semantic Choice (Olson, Forsberg, Wise, & Rack, 1994): subjects had to choose between two words with identical phonological representation but different meanings (homophones) (e.g. "bear" and "bare"), in response to an orally presented question ("Which one is an animal?"). The computer screen was blank during the presentation of the question, which was followed by a fixation cross for 500 milliseconds and the two written words, side by side. The participants had to indicate whether the chosen word was on the right or the left of the screen by pressing the "m" or "z" key (appropriately labelled) respectively. Feedback on accuracy of the response was provided after each question, together with the reaction time for correct responses. The instructions were followed by a practice block of 5 items and, once the task was clearly understood by the subject, 61 test items. The order of presentation was randomized and the left or right placement of words was counterbalanced across participants and items.
- Orthographic Choice (Olson et al., 1994): this was a task in which participants were given the instructions to decide whether the item presented on screen "was a word or not". Stimuli were only actual words ("pole") and pseudohomophones ("poal"). Two equivalent lists were prepared by randomly drawing a word or its corresponding homophones, in such a way that in each one half of the items were words and half were homophones. Presentation of each list was counterbalanced across subjects, with the order of items randomized for each individual. As in the previous task, an initial training block known to the participants (9 items) was followed by the test items (40 items). Each trial was initiated with a 500 ms. fixation cross and

finalized with feedback on accuracy and reaction times for correct responses. The "p" and "q" keys, appropriately marked, were used for "yes" and "no" responses, respectively.

- Phonological Choice (Olson et al., 1994): three different words were presented on screen, two of which were pseudowords (e.g. "jile", "nule") and one a pseudohomophone (a word incorrectly written, but with a pronunciation equivalent to an existing one, e.g. "rale"). The instructions were to select the one that "sounded like a real word". Five practice trials followed by 60 test items were used. The trials were, as in both of the other tasks, preceded by a fixation cross and followed by feedback. The words were presented side by side on the screen, and subjects had to choose the word on the left, centre or right by pressing the "z", "b" or "m" keys, respectively. The position of the correct response was counterbalanced across subjects and items.

Sub-lexical representation tasks.

- Non-word Reading Test (Frederikson, Frith, & Reason, 1997): participants were asked to read 10 two-syllable non-words and 10 three-syllable non-words, following three one-syllable practice trials. Each type of non-word was presented on a different A-4 size sheet. Accuracy and total reading times were recorded.
- Spoonerisms (Frederikson et al., 1997): this test consisted of two parts of 10 items. In the first one, subjects were asked to replace the initial sound of a word with a different one presented to them orally (e.g. "cat with a /f/" was to be responded "fat"). In the second half, they were asked to exchange the initial sounds of two different words (e.g. "sad cat" required a response of

"cad sat"). Each section was preceded by a three-item practice block. Accuracy and total response times were registered.

- Non-word Repetition: a computerized version of the Children's Test of Non-word Repetition was used (Gathercole & Baddeley, 1996). Participants were presented 40 pre-recorded Non-words. They are asked to repeat each one after listening to it through the computer's headphones. Total response time and accuracy are registered.

Rapid naming

- Picture and Digit Naming (Frederikson et al., 1997): participants were instructed to name as fast as possible 50 pictures representing five objects (hat, ball, table, door, box), on two occasions with different orderings. For the digit naming, they were asked to do the same with two lists of 50 digits. Total naming time for each of the tests was recorded.

Working and short-term memory

- Forward and Backward Digit Span (Wechsler, 1992). In the Forward Digit Span task, participants are orally presented with a sequence of digits and are asked to repeat it in the same order. In successive trials the number of digits in the sequence is increased and a score reflecting the maximum number of the list successfully recalled is registered. In the Backward Digit Span the participant must respond with the same digits in the reverse sequence to the one presented.

Results

Lexical Processing and Phonological Mediation in ASD versus typical readers

Mean accuracy scores on the lexical semantic, orthographic and phonological tasks across all participants were respectively .78 (SD = .09), .80 (.08) and .73 (.14), F (2, 24) =

7.45, p = .003, partial $\eta 2$ = 0.383. Bonferroni corrected pairwise comparisons showed that subjecs were less accurate on the phonological task than on the orthographic task, t (25) = 3.64, p = .004. Median reaction times to correct responses were 1330 milliseconds (435), 991 (325) and 3315 (1020), respectively. Normality checks showed an excessive positive skew for reaction times for the three tasks. These data were consequently transformed with an inverse function. Repeated-measure ANOVAs showed that differences in reaction times among all three tasks were significant, F (2, 24) = 115.45, p < .001, partial $\eta 2$ = 0.906, (p < .001 for all Bonferroni corrected pairwise comparisons).

Correlation among relevant variables are included in table 1. There were significant correlations among the accuracy, on the one hand, and reaction time scores, on the other, of the lexical semantic, orthographic and phonological tasks. Although the accuracy scores did not correlate with the BPVS scores, reaction time data did. Raw BPVS scores were therefore included as a covariate in all tests with lexical processing in order to take account of group differences on this variable.

INSERT TABLE 1 HERE

Mean accuracy scores for ASD and typical readers were .78 (*SD* = .10) and .78 (*SD* = .09), respectively on the semantic choice task, .79 (*SD* =.09) and .81 (*SD* = .05) on the orthographic choice task, and .74 (*SD* =.16) and .72 (*SD* =.12) on the phonological choice task. Group means for median reaction time for the ASD and typical participants on these same tasks were respectively 1405 ms (*SD* = 518) and 1240 ms (*SD* = 313) (semantic choice task), 942 ms (*SD* = 253) and 1048 ms (*SD* = 398) (orthographic choice task), and 3239 ms (*SD* = 741) and 3404 ms (*SD* = 1304) (phonological choice task). Accuracy and reaction time data were standardized across the whole of the sample. One-way ANOVAs were performed on both accuracy and median reaction time scores, with no significant differences among groups (*F*s < 1.6).

Tasks tapping processes essential for phonological mediation in visual word reading were analysed separately. Accuracy scores for Non-Word Reading (*M* = .85, SD = .15 for ASD participants and M = .92, SD = .08 for typical readers), Spoonerisms (*M* = .68, *SD* = .21, and *M* = .74, *SD* = .14), and Non-Word Repetition (*M* = .84, *SD* = .09, and *M* = .84, *SD* = .09) were obtained. Due to excessive negative skew, these accuracy scores were transformed using an arcsine of square-root function. Group means for the ASD and the control groups were respectively 32.4 seconds (*SD* = 10.8) and 35.3 sec. (*SD* = 17.6) for Non-word reading total reaction time, 203 sec. (*SD* = 67) and 215 sec. (*SD* = 98) for Spoonerisms total reaction time, and 435 sec. (*SD* = 150) and 325 sec. (*SD* = 90) for Non-word Repetition median reaction time. Median reaction times were obtained for Picture (*M* = 85.6 sec., *SD* = 18.2, for the ASD group and *M* = 75.9, *SD* = 16.8 for typical readers), and Digit Naming (*M* = 47.3, *SD* = 15.8, and *M* = 39.3, *SD* = 12.7, respectively). An inverse function was used for transformation of the reaction time scores for Non-word Repetition and Non-word Reading to adjust for positive skew. The resulting data, together with non-transformed Picture and Digit Naming times and Forward (*M* = 5.4, *SD* = 2.0, for the ASD group and *M* = 5.3, *SD* = 2.1 for typical readers) and Backward (*M* = 8.2, *SD* = 1.9, for the ASD group and *M* = 9.8, *SD* = 2.0 for typical readers) Digit Span scores, were standardized across the whole of the sample. No differences among groups were found on one-way ANOVAs with BPVS raw scores as covariate on any of these variables (*F*s < 1.2, except for Forward Digit Span, *F* = 1.7, and Non-Word Repetition, *F* = 3.8).

Lexical processing in Reading-VIQ Discrepant Group

Following analyses of the ASD and control groups, the Reading-VIP Consistent and Discrepant groups, as well as the typically developing children were compared. Figure 2 shows the standardized accuracy scores for all three groups on each of the semantic, orthographic and phonological tasks. Univariate analyses showed that there were no significant differences among groups on the standardized accuracy scores of the semantic choice task ($F < 1$). However, differences on the orthographic task did reach significance, F (2,22) = 4.78, $p = 0.005$, partial η2 = 0.383. Here, post-hoc Bonferroni corrected analyses showed that the Reading-VIQ Discrepant readers ($M = 0.58$, $SD = 0.86$) outperformed the poor Reading-VIQ Consistent readers ($M = -0.88$, $SD = 1.11$), t (22) = 3.56, $p = 0.005$, $d = 2.06$, with the the control group mean accuracy scores ($M = 0.17$, $SD = 0.67$) between both ASD groups. The mean scores of the control group were, however, not significantly different from either the Reading-VIQ Discrepant readers, or the Reading-VIQ Consistent readers.

Differences among groups were also significant on the phonological choice task, F (2,22) = 7.08, $p = .004$, partial η2 = 0.392. Once again the Reading-VIQ Discrepant group was more accurate ($M = 0.88$, $SD = 0.37$) than the Reading-VIQ Consistent group ($M = -0.75$, $SD = 1.06$), t (22) = 3.76, $p = .003$, $d = 2.17$, although the differences with the control group were non-significant ($M = -0.07$, $SD = 0.86$), t (22) = 2.57, $p = .053$.

INSERT FIGURE 2 HERE

The analyses of individual scores showed that profiles across participants were consistent with group means' comparisons. Performance on the phonological task was uniformly outstanding in the Reading-VIQ Discrepant group, with accuracy scores higher than .75 in all cases (range .77 to .93). All members of the Reading-VIQ Discrepant group showed positive standardized scores, over one standard deviation above the group mean in three of the cases, and between 0.70 and 1.0 standard scores in another two. Four of the seven Reading-VIQ Consistent group showed standard scores lower that -1.0, with the remaining three having scores of – 0.01, 0.14 and 0.73. The control group included two individuals with scores one standard deviation above the group mean and another two with 0.73 standard scores, and two underperforming individuals with scores of -1.85 and -0.96.

On the orthographic choice task, three individuals in the Reading-VIQ Consistent group, and one in the control group had accuracy scores one standard deviation below the group mean, whereas this was not the case for any of the children in the Reading-VIQ Discrepant group. Three participants of this group did show scores at least one standard deviation above group mean. This also occurred in one of the participants of the control group. In addition, three participants of the control group showed standardized scores above 0.70. No participant from the Reading-VIQ Consistent group had positive scores above 0.10.

Phonological processing in the Reading-VIQ Discrepant group

Mean accuracy scores for the Reading-VIQ Discrepant and Consistent groups were .90 (SD = .11) and .80 (SD =.18) respectively on the Non-word Reading task, .66 (SD =.27) and .71 (SD = .13) on the Spoonerisms and .80 (SD = .11) and .88 (SD = .05) on the Non-word Repetition. Mean total reaction times for these groups were 34.9 (SD = 13.9) and 30.0 seconds (SD = 6.7), respectively, for Non-word Reading and 196 (SD = 46.7) and 209 seconds (SD = 85.6) for Spoonerisms, 83.7 (SD = 17.0) and 87.4 seconds (SD = 20.4) for Picture Naming and 45.1 (SD = 17.5) and 49.4 seconds (SD = 14.8) for Digit Naming. Group means for median reaction times on Non-word Repetition were 415 (SD = 151) and 455 ms (SD = 158). Multivariate analyses of Spoonerisms, Non-word Repetition and Non-word Reading accuracy standardizes scores, on the one hand, and reaction times, on the other, with raw BPVS scores as a covariate, showed no significant differences among groups ($F < 1.5$). No differences were found either on univariate ANOVA's of total time for Picture Naming, Digit Naming or the total score for Backward Digit Span (M = 5.0, SD = 1.8 for the Reading-VIQ Discrepant group and M = 5.9, SD = 2.2 for the Reading-VIQ Consistent group) or the Forward Digit Span (M = 8.0, SD = 2.2 and M = 8.5, SD = 1.7, respectively)..

Discussion

At first glance our results suggest that the participants with ASD read words in exactly the same way as typically developing readers, in terms of semantic, phonological and orthographic access. This is contrary to the hypothesis that these readers may not use a phonological access route. In fact, the lack of differences in the present battery of tests related to diverse aspects of phonological processing is striking. Non-word reading, non-word repetition, ability to produce spoonerism, and verbal short-term memory all reflected equally good phonological processing in the three groups that had been matched on word reading ability, but differed on verbal IQ and comprehension. These data are in line with a number of earlier studies (e.g. Aram, 1997, Newman et al., 2007), while studies which have found serious impairments in phonological awareness tasks (Kennedy, 2002; Sparks, 1995, 2001, 2004) have used participants with much lower IQs, and also did not include typically developing controls.

Our results are also contrary to the hypothesis that readers with poor comprehension may have difficulties with semantic access to words. We found instead that performance was good for all participants on the homograph semantic identification task which we used to test access to the semantic pathway. This has important implications for our understanding of the accessibility of semantic representation versus orthographic knowledge of words. It has been hypothesized that, since children with hyperlexia find it hard to disambiguate homographs from sentence context (Happé, 1997; Snowling & Frith, 1986), their outstanding orthographic representations may not be adequately related to semantic content (Ehri & Snowling, 2004; Nation, 1999). The fact that ASD participants, whether considered jointly or in sub-groups perform equally well on the semantic-orthographic task seems to disprove this possibility and supports the idea that the problems behind homograph disambiguation difficulties are related to text representation processes. The clues for disambiguation in our case were included in a specific question ("which is an animal?" bare/bear), that requires very little inferential processing at the discourse level. Prior research has found impairments in different kinds of inferences in poor comprehenders when reading text passages (Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001; Oakhill, 1984) and this might be the case also for the hyperlexic readers. These results would thus seem to strengthen the view that componential processes in word reading and text comprehension are not necessarily the same (Landi & Perfetti, 2007; Oakhill, Cain & Bryant, 2003; Stothard & Hulme, 1995). Our participants show word reading that is adequate or even outstanding, with sufficient semantic, orthographic and phonological access, although their text comprehension does not reach the same level of proficiency.

However, although serious impairments in semantic, orthographic or phonological lexical processing are not apparent from our data, a closer look at individual variability within the ASD group pointed to subtle and interesting differences in these pathways to word reading. The children with surprisingly good word-reading with respect to verbal IQ, i.e. those we have called Reading-VIQ Discrepant group, turn out to have more secure phonological and orthographic representations than the other children with ASD. The results are particularly striking given that these are children who scored an average of nearly 30 standardized points below these other readers on the verbal IQ test.

Regarding orthography, the readers from this group show a greater ability to distinguish real words from pseudohomophones than the participants with ASD and word reading consistent with their verbal IQ, and are as good as typical readers. This confirms the results of previous case studies showing the solid orthographic representations in hyperlexic readers over and above their limited oral vocabulary (Glosser et al., 1997; Kennedy, 2002; Sparks, 1995, 2001, 2004).

Interestingly, the differences among groups extended to the task assessing phonological lexical representations. The children with ASD and Reading-VIQ discrepancies outperformed the participants of the Reading-Verbal IQ Consistent group and showed particularly high scores, all above 75 % accurate. This was not so in any of the other tasks or groups. This is a particularly hard task for all children, as can be seen from lower accuracy rates and much higher reaction times for the sample as a whole. The children with Reading-VIQ Discrepant scores were not any faster at it, but their accuracy was clearly unaffected by the interference of the conflicting incorrect orthographic presentation when identifying the pseudohomophone.

These results are similar to those of Newman et al. (2007). In their study, the group of hyperlexic participants was superior to the non-hyperlexic ASD readers on phonological tasks. It must be noted, however, that the non-hyperlexic ASD readers were not matched to the hyperlexic sample on word reading age, and therefore the differences were to be expected. The Reading-Verbal IQ consistent readers in our study are matched on word reading to the other two groups and, none-the-less, still underperform with respect to the participants of the reading discrepancy group. Also, Newman et al.'s hyperlexic readers were chosen on the basis of a word reading to text comprehension discrepancy, which could be ignoring the individual differences within the ASD group that were found here.

Surprisingly, no differences have been found in any of the other tasks tapping phonological mediation in word reading. Digit span, in particular, was found to be a relative strength in some previous case studies (e.g. Richman & Kitchell, 1981), and it has been suggested that it is a necessary skill for strong phonological processing (Nation, 1999). Our results do not support the view that short-term verbal memory is outstanding in the hyperlexic children and could be explaining these differences.

A possible explanation for these differences on the lexical phonological task and the lack of differences on the other phonological tests might be their different processing demands. The former requires access to phonological word representations. The other tasks require sublexical processing. It appears that hyperlexic participants cannot draw on superior sublexical representations, at least when tested orally, but can draw on stronger lexical representations. Orthographic representations are likely to be linked to lexical representations especially in English, where many words are so irregularly spelled that they have to be stored as complete letter strings, and these representations are also relatively strong.

The expertise of the hyperlexic readers is therefore unlikely to derive from superior abilities in any of the sublexical phonological abilities necessary for word learning and/or reading. These sublexical abilities may well have reached a ceiling. Only the lexical abilities of hyperlexic readers were increased. Why should this be so? We speculate that increasingly stronger lexical representations could be due to a special interest in print and extensive practice with word decoding. It is plausible that children with ASD and truly outstanding word reading abilities read more, if they have a specific and obsessive interest in written material (Tirosh & Canby, 1993). This interest does not depend on a high verbal IQ. Unfortunately, because data relative to reading precociousness and obsession with words were not available for our sample, we cannot directly test this hypothesis. Future studies should include measures of exposure to print and practice that would be helpful in clarifying the role of repeated practice in the development of hyperlexic profiles in children.

Our findings have clear implications for the definitional criteria for hyperlexia. Both our ASD groups show a word reading to text comprehension discrepancy, with reading comprehension below chronological age expectations. They also present adequate phonological and orthographic access, since they are no less accurate or slower than typically developing children, and no differences have been found on other processes related to or necessary for phonological access. However, readers with a reading score discrepant from their verbal IQ can be distinguished in terms of the strength of the lexical representation of words, and should probably be considered to be truly hyperlexic. Including them in the same group as children with a reading score that is consistent with their verbal IQ, as those in our second ASD group, does not adequately reflect the fact that they are "experts" specifically in word-reading.

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Table 1

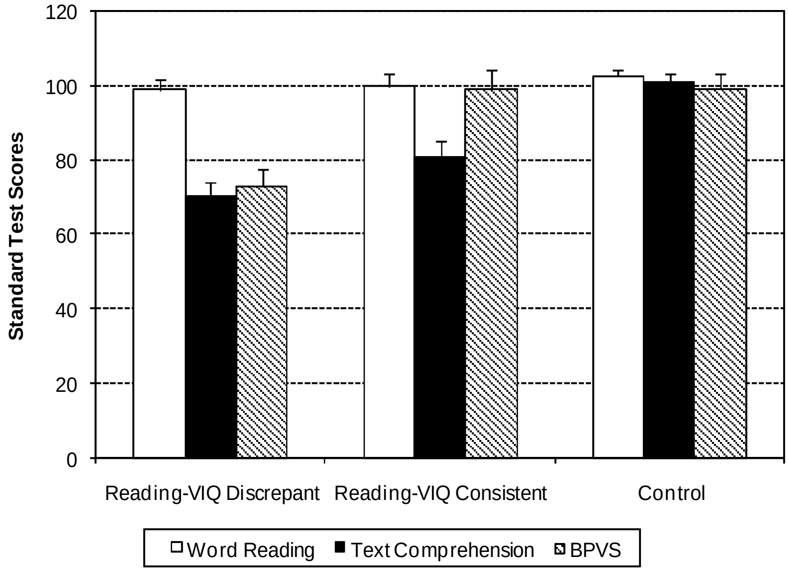
Correlations among standardized semantic, orthographic and phonological tasks, and BPVS standardized raw scores

		Semantic		Orthographic		Phonological	
		Accuracy	RT	Accuracy	RT	Accuracy	RT
Verbal IQ		.262	-.685 (**)	.036	-.268	-.143	-.432 (*)
Semantic	Accuracy	-	-.001	.639 (**)	-.309	.472 (*)	-.013
	RT		-	.179	.496 (*)	.283	.382 (†)
Orthographic	Accuracy			-	-.270	.736 (**)	.013
	RT				-	-.300	.573(**)
Phonological	Accuracy					-	-.060
	RT						-

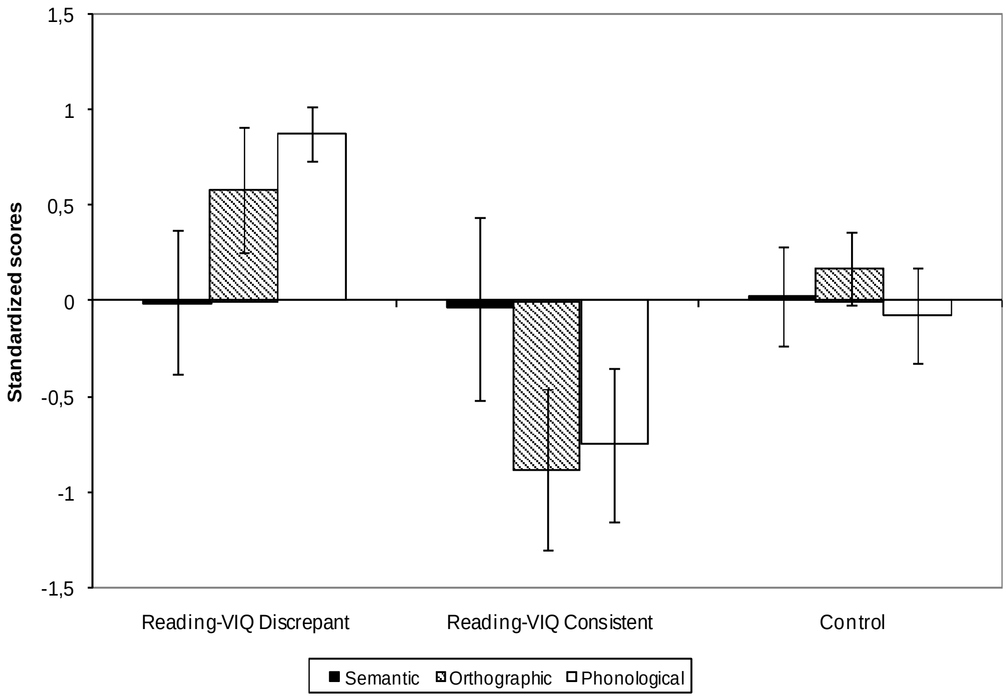
(†) $p = .054$, (*) $p < .01$, (**) $p < .001$

Figure 1. *Standard word reading, text comprehension and BPVS test scores for participants by groups (bars indicate standard error of the mean)*

Figure 2. *Standardized scores for semantic, orthographic and phonological tasks (with standard error)*



120
100
80
60
40
20
0
Standard Test Scores
Reading-VIQ Discrepant
Reading-VIQ Consistent
Control
Word Reading
Text Comprehension
BPVS



1,5
1
0,5
0
-0,5
-1
-1,5
Standardized scores
Reading-VIQ Discrepant
Reading-VIQ Consistent
Control
Semantic
Orthographic
Phonological