Published article:

Nash, H and Heath, J (2011) *The role of vocabulary, working memory and inference making ability in reading comprehension in Down syndrome.* Research in Developmental Disabilities, 32 (5). 1782 - 1791. ISSN 0891-4222

http://dx.doi.org/10.1016/j.ridd.2011.03.007

Running head: Reading comprehension in DS

The role of vocabulary, working memory and inference making ability in reading comprehension in Down syndrome

Published as:

Nash, H., & Heath, J. (2011). The role of vocabulary, working memory and inference making ability in reading comprehension in Down syndrome. *Research in developmental disabilities, 32*(5), 1782-1791.

Elsevier

http://dx.doi.org/10.1016/j.ridd.2011.03.007

Abstract

Thirteen children and young adults with Down syndrome (DS) completed tests of language and reading and their performance was compared to that of three control groups. Reading comprehension was confirmed to be a specific deficit in DS and found to be strongly correlated with underlying language skills. Although reading comprehension was more strongly related to language ability in the DS group, this was shown to be a function of more advanced word recognition rather than a characteristic of DS per se. Individuals with DS were found to have greater difficulty with inferential comprehension questions than expected given their overall comprehension ability and the reading profile associated with DS was found to be similar to that of children known as poor comprehenders. It is recommended that oral language training programs, similar to those that have been shown to improve reading comprehension in poor comprehenders, be trialed with children who have DS.

The role of vocabulary, working memory and inference making ability in reading comprehension in Down syndrome

1. Introduction

Down syndrome (DS) is the most common genetic cause of learning disability with a prevalence of 1 in 700 (Roizen, 1997). Reading is a critical skill for individuals with learning disabilities as it may open up vocational opportunities, facilitate increased independence and help improve language and communication skills (Buckley, 1985). The cognitive profile observed in DS is typically uneven with language ability being more affected than nonverbal ability (e.g., Laws & Bishop, 2003) and reading accuracy (Cardoso Martins, Peterson, Olson & Pennington, 2009). Most children with Down syndrome can learn to read, although levels of attainment vary considerably (Sloper, Cunningham, Turner, & Knudsen, 1990; Kay-Raining Bird, Cleave, & McConnell, 2000; Laws & Gunn, 2002). Published research focusing on reading comprehension in DS is more limited than that on reading accuracy, but the available evidence has identified reading comprehension as an area of significant difficulty (e.g., Carr, 1995).

Studies have shown that reading comprehension is correlated with measures of language (e.g., Boudreau, 2002; Laws & Gunn, 2002), and data from a recent study in Italian (Roch & Levorato, 2009) suggest that language comprehension may in fact be a more important determinant of reading comprehension in this population. On this view, the reading comprehension deficit in DS is the result of underlying language difficulties. Alternatively, or additionally, the reading comprehension deficit could be caused by weaknesses in higher level processes; the process of making inferences during reading was identified as a potential difficulty in DS in a case study by Groen et al. (2006). The current study tested the hypotheses that reading comprehension in DS is more strongly related to language skills than in typically developing (TD) children and that inferential comprehension questions pose a particular problem for individuals with DS.

In order to understand the reading comprehension difficulties associated with DS it is useful to consider models of reading comprehension and relationships between reading comprehension and underlying skills in typical development. Theoretical models typically conceptualise reading comprehension as the product of two skills or sets of skills. In the 'Simple View of Reading' (SVR) Gough and Tunmer (1986) proposed that reading comprehension is the product of decoding (word reading) and linguistic comprehension. Linguistic comprehension is seen as a complex process, involving the ability to access lexical information and derive sentence and discourse interpretations. In support of the SVR, word recognition skills and components of linguistic comprehension (vocabulary and grammar) have been found to be significant predictors of reading comprehension in typically developing children (e.g., Catts, Adlof, Hogan & Weismer, 2005, Kendeou, Savage & van Den Broek, 2009; Muter, Hulme, Snowling, Stevenson, 2004). According to the convergent skills model proposed by Vellutino et al. (2007) the relative contribution of word reading and language skills to reading comprehension are not stable across development; word reading is the best predictor of reading comprehension in the early stages of reading development, while language skills become the dominant predictor once accurate word identification has been achieved.

Recent models of reading comprehension emphasize the role of lower level language skills, such as knowledge of word meanings and syntax. The convergent skills model (Vellutino et al. 2007) views semantic and syntactic knowledge as key skills that feed into language comprehension and hence into reading comprehension. The lexical quality hypothesis (Perfetti & Hart, 2002) also emphasizes the role of language skills in reading comprehension; placing word meanings at the interface between word identification and reading comprehension. While semantic and syntactic knowledge enable the reader to compute the meanings of individual words and sentences, other processes must be brought to bear to integrate the meanings of successive sentences and incorporate background knowledge to create a representation of the text. Inferences are necessary to establish links between events in the text and establish connections between what is presently being read and existing knowledge (Graesser, Singer & Trabasso, 1994). There are many different forms of inferences, such as pronoun resolution, bridging, elaborative and evaluative inferences. Of these, bridging inferences are considered to be of particular importance, as according to Haviland and Clark (1974) they serve to establish connections between events in the text. For example, to fully understand the statement ‘The man threw his paper on the fire. The ashes rose up the chimney’. The listener/reader must remember the two sections of text and integrate them to understand the relationship between the two events; that the first event caused the second (Singer, 1993). Without this connection coherence would be lost. Inference making takes place within the constraints of working memory, as noted in models such as the Landscape model (van Den Broek, Risden, Fletcher & Thurlow, 1996). Therefore, limitations in working memory may affect a reader’s ability to make inferences while reading. In support of this, verbal working memory has been found to correlate with performance on inferencing tasks and directly with reading comprehension (e.g., Oakhill, Cain & Bryant, 2003a).

The most obvious cause of reading comprehension failure is a word reading difficulty. If an individual is unable to read with sufficient accuracy and fluency then the information extracted from the text may not be sufficient for comprehension. According to the reading comprehension models presented above, language difficulties provide another source of reading comprehension failure. Children referred to as ‘poor comprehenders’ are children who experience comprehension difficulties despite having age appropriate word recognition and decoding skills (Nation & Snowling, 1998; Cain & Oakhill, 1999). Research with this group of children allows the exploration of the role of factors other than word recognition in reading comprehension. Studies have reported that poor comprehenders exhibit deficits in lower level language processes such as vocabulary knowledge (Catts, Adlof & Weismer, 2005) and morphosyntactic skills (Nation & Snowling, 2000; Nation, Clarke, Marshall & Durand, 2004). Evidence for a causal role for poor vocabulary knowledge in reading comprehension difficulties comes from a randomised control trial by Clarke et al (in press), which showed that an oral language program led to greater gains in vocabulary, which led to gains in reading comprehension. There is also evidence for deficits in higher level processes such as verbal working memory (Nation, Adams, Bowyer-Crane & Snowling, 1999), comprehension monitoring (Oakhill, Hartt & Samols, 2005) and inference generation (Cain, Oakhill, Barnes & Bryant, 2001). Cain and Oakhill (1999) argue that a difficulty making inferences is causally related to the reading comprehension deficit as such difficulties are poorer than expected given overall comprehension level.

Reading comprehension has been found to be an area of particular difficulty for individuals with DS. Carr (1995) found that the average lag between reading accuracy and reading comprehension was 11 months in a group of adults. It has been suggested that underlying language weaknesses contribute to the reading comprehension deficit found in individuals with DS and in support of this studies have found significant correlations between measures of language and reading comprehension (e.g., Boudreau, 2002; Laws & Gunn, 2002). However, the measures of reading comprehension used in these earlier studies focussed on the comprehension of single written words, phrases or sentences rather than passages of text, and floor effects were evident in the DS groups. Data from a recent study in Italian (Roch & Levorato, 2009) suggest that language comprehension may in fact be a more important predictor of reading comprehension in DS than in TD children. Roch and Levorato (2009) went on to hypothesize that individuals with DS show an uneven reading profile similar to that exhibited by poor comprehenders and propose that an investigation of factors found to influence reading comprehension in poor comprehenders, such as inferential skills, working memory and meta-comprehension skills, could prove fruitful.

The findings of a case study by Groen et al. (2006) suggest that individuals with DS may have particular difficulties making inferences during reading, a difficulty that could be causally related to the reading comprehension deficit as has been proposed in poor comprehenders. An 8 year old girl with DS (KS) was found to have a level of reading comprehension significantly below her reading accuracy level when assessed using The Neale Analysis of Reading Ability – Revised (NARA II, form II, Neale, 1997) but not when assessed using the WORD (Wechsler, 1993). Critically, the NARA II includes questions assessing both memory for information presented in the text (literal questions) and questions that require an inference to be made, while the WORD (Wechsler, 1993) contains mainly literal questions. Inferential questions have been shown to pose greater difficulties than literal questions for typically developing readers (Priya & Wagner, 2009) and it has been reported that poor comprehenders have greater difficulty with inference based questions than literal ones (e.g. Cain & Oakhill, 1999; Bowyer-Crane & Snowling, 2005).

The present study compared the reading and related cognitive skills of a group of children and adolescents with DS to that of three groups of children, typically developing children matched on single-word reading ability, typically developing children matched on reading comprehension ability and a group of ‘poor comprehenders’ matched on reading accuracy and reading comprehension ability. Matching groups on reading accuracy (reading age, RA) ensures that any resulting difference in reading comprehension is not the product of difference in reading accuracy and must therefore reflect differences in other underlying skills. The use of a comprehension age matched comparison (CAM) group means that differences in underlying skills, such as vocabulary, working memory or inferencing skill, are not a result of differences in reading comprehension and likely to be associated with the cause of difficulties. The poor comprehender group was included to investigate the extent of the similarity between the two developmental disorders as highlighted by Roch & Levorato (2009).

1.1 Research questions

1. Do individuals with DS have a difficulty with inferential questions that goes beyond their general comprehension level? Based on the Groen et al (2006) study we predicted that the DS group would have greater difficulty with the inferential comprehension questions than the RA and CAM control groups.

2. What are the contributions of word reading and language skills to reading comprehension in DS? Roch and Levorato (2009) found that underlying language skills made a greater contribution to reading comprehension in Italian children with DS compared to a comprehension-age matched control group. On the basis of this we predicted that this would be the case in our sample, when the DS group was compared to the CAM group. We included measures of vocabulary and verbal working memory as these have been found to be related to reading comprehension in typically developing children (Muter et al.

2004; Oakhill, Cain & Bryant, 2003a) and found to be impaired in poor comprehenders (Catts, et al. 2005; Nation et al. 1999). A verbal working memory measure such as listening recall requires both the processing and storage of verbal information. The processing component of this task requires language comprehension and so this task can be considered to be a measure of higher level language ability.

3. Do individuals with DS have a similar reading profile to poor comprehenders? It has been hypothesized that there is overlap in the reading profiles of the two groups, but this has not been tested empirically.

All groups were assessed using a range of standardised tests measuring single word reading, decoding, passage reading accuracy and comprehension, vocabulary, non-verbal ability, and verbal working memory. An experimental passage reading task was created with literal and inferential comprehension questions.

2. Method

2.1 Participants

Seventeen participants with Down syndrome (DS) were initially recruited to this study. However, four were not able to read sufficiently well to complete all the reading tasks and the final sample size for the DS group was thirteen (aged 11 years 4 months to 19 years 3 months). Twelve participants had full trisomy 21, while one individual had translocation DS. Furthermore, 12 participants attended mainstream education and only one participant attended a school specialising in learning difficulties. All participants were recruited with full parental consent. Thirty nine typically developing children from three local mainstream schools were assessed. Thirteen were then selected to serve as reading ability (RA) match controls and another 13 to serve as comprehension ability match (CAM) controls. All achieved a standard score of above 80 or above the 10th percentile with the exception of one RA and one CAM child on the nonverbal task. Informed consent was obtained from the parents of each child. None of the children were reported as experiencing any difficulties by their teacher.

Thirteen children classed as ‘poor comprehenders’ (PC) completed a reduced task battery (which included all the measures except the test of nonverbal ability and verbal working memory) as they were taking part in a different study of reading comprehension that had some overlapping measures. All had a single-word reading accuracy standard score greater than 92 and each participant’s reading comprehension score was more than 10 points below their single word reading accuracy score. Ten of the 13 had discrepancies greater than 15 standard score points (1 standard deviation). In terms of age equivalent scores all the children had a reading comprehension age that was more than 12 months below their single word reading age, in-line with the criteria used by Nation and Snowling (1999) to identifiy poor comprehenders.

The DS and RA participants were matched for reading as measured by the British Ability Scales-II Single Word Reading Test (BAS – II, Elliott, Smith & McCulloch, 1996). The DS and CAM participants were matched for reading comprehension ability as measured by the NARA II, form II (Neale, 1997). The DS and PC groups were also matched for reading comprehension as measured by the NARA II, form II. Group descriptives are displayed in Table 1 in the results section. The data were analysed using separate ANOVAS and significant group differences are indicated. The DS group were significantly older than the 3 other groups.

2.2 Materials

2.2.1 Single word reading. All the participants were administered the British Ability Scales-II Test of Word Reading (BAS-II, Elliott et al., 1996). Total number of words read correctly formed the raw score.

2.2.2 Reading accuracy and comprehension. The Neale Analysis of Reading Ability – Revised (NARA II, form II, Neale, 1997) was used to assess passage reading accuracy and reading comprehension. In this test, children read aloud a series of short stories and answer questions about them. The stories get progressively harder and testing stops once a prescribed number of reading errors have been made. A reading accuracy score is obtained from the number of errors made during reading and comprehension score is obtained by summing the total number of questions answered correctly. The NARA-II has high test-retest reliability (correlation co-efficients above .81) and high internal reliability (correlation co-efficients above .82).

2.2.3 Decoding ability. The Graded Non Word Reading Test (GNWRT; Snowling, Stothard & McLean, 1996) was administered in which the testee is asked to read aloud 20 nonwords varying in phonological difficulty. The test score is the number of nonwords read correctly. The GNWRT has high validity and high internal and test-retest reliability (reliability coefficients ranging from .90 to .96).

2.2.4 Vocabulary knowledge. The British Picture Vocabulary Scale – II (BPVS-II; Dunn, Dunn, Whetton & Burley, 1997) was used to assess receptive vocabulary. During the test the child is asked to choose a picture from a possible four that best illustrates the meaning of a word said by the experimenter. The BPVS has high validity and reliability (r = .86).

2.2.5 Verbal working memory. The listening recall test from the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001) was administered. In this test the child must answer true/false to sentences read aloud by the tester and then recall the final word of each sentence, in the order the sentences were presented, once all the sentences have been responded to. The test starts with single sentences, and then the number of sentences increases by one after every correct block of trials. A trial is correct if all the final words have been recalled in the correct order. The WMTB-C has been reported as having high internal and external validity (Pickering & Gathercole, 2001). While the listening recall measure has high test-retest reliability for children aged 6 to 7 years old (r = .83). The test-retest reliability is considerably lower for children aged 10 to 11 years old (r = .38). However, at present this is one of the most widely used tests of verbal working memory ability.

2.2.6 Nonverbal ability. The Pattern Construction subtest of the BAS-II (Elliot, Smith & McCulloch, 1996) was used to assess non-verbal ability. The test requires the child to make two dimensional patterns from blocks that are two or, three dimensional when given a target pattern. The test possesses high overall reliability (r = .91)

2.2.7 Literal and inferential reading comprehension. This task assesses the ability to extract literal information and to make inferences to connect different parts of text. Each participant read aloud four short stories of similar lengths (M = 146 words, SD = 18 words). Each story had a word equivalent reading age between 7 years, 0 months to 7 years, 6 months, as measured by the Hatcher Book Grading Formula (Hatcher, 2000). If any errors were made, the examiner prompted the child with the correct word or pronunciation. At the end of each passage, the examiner read aloud six open-ended questions, three literal questions and three inferential questions, which the participant had to answer verbally. The text was available to the participant during the questions.

The literal questions assessed memory for facts presented in the text. For example: “Mum was in the kitchen looking through her diary”. Literal question: Where was mum? The inference questions assessed the individual’s ability to integrate information between two sentences (to make a bridging inference). The sentences were either adjacent in the text or separated by one intervening sentence. For example: “Mum had promised she would make Daisy’s costume. When Daisy got home, she rushed upstairs to get changed but she couldn’t see the cat costume anywhere”. Inference question: What costume did mum promise she would make daisy? An example passage is shown in the Appendix.

2.3 Procedure

Participants were tested individually within their schools or at home and the test battery was administered in one session. The administration of the tests was fixed in the order: BPVS-II, BAS-II Word Reading, GNWRT, experimental reading comprehension task, Pattern Construction, NARA-II, and Listening recall.`

3. Results

3.1 Group profiles on the standardised measures of language and reading

Descriptive data for the standardised measures are shown in Table 1, presented as mean raw scores. Separate between subject ANOVAS were run for each variable. Significant main effects were followed up with Tukey’s HSD post hoc test and significant group differences are indicated. To explore the relative contributions of word reading and language skills to reading comprehension in the DS group performance will first be compared to that of the RA group and then to the CAM group. Correlational analyses were also conducted to address this question and are presented following the data from the literal and inferential reading comprehension task.

Insert Table 1 about here

Despite being matched on word reading accuracy the DS group scored significantly lower than the RA group on reading comprehension. This indicates that the reading comprehension difficulties associated with DS are not solely due to reading accuracy weaknesses; other factors are limiting reading comprehension in this group of individuals. Further, the DS group scored significantly lower than the RA group on the measures of decoding nonverbal ability and listening recall. The difference was not significant for vocabulary but in the same direction**.** When compared to the CAM group the DS group were matched for vocabulary, had better word reading ability and poorer verbal working memory and nonverbal ability. Given the use of the CAM design, the group differences in verbal working memory are not the result of poorer overall reading comprehension ability and may well be causally related to it. Receptive vocabulary knowledge appears to be in-line with reading comprehension ability.

3.2 Do individuals with DS have particular difficulty answering literal comprehension questions?

In terms of reading accuracy for the stories the CAM group made, on average, more reading errors than the three other groups. There was a main effect of group on number of reading errors (F (3,48) = 4.540, p<0.05, $\eta^2_{p\,=}$ .22), however, the difference was only significant when the CAM group was compared to the RA group. Turning to the comprehension questions; inspection of the data revealed a ceiling effect for the literal questions in the RA group and so comparisons involving this group should be interpreted with caution. As can be seen in Figure 1, children in all four groups found literal questions easier to answer than inferential questions; however, the relative difficulty of inferential questions was greater for the DS group. Differences between the groups appear to be greater for the inferential questions although it is clear that the DS group have difficulty with both question types relative to the comparison groups.

Insert Figure 1 about here

In the analysis of the comprehension question data there were main effects of question type (F (1,48) = 53.154, p<0.05, $\eta^2_{p\,=}$ .53), group (F (3,48) = 11.633, p<0.05, $\eta^2_{p\,=}$ .42) and a significant interaction of question type by group (F (3,48) = 8.211, p<0.05, $\eta^2_{p\,=}$ .34). The interaction was followed up with separate between groups ANOVAS for the literal and inferential questions.

For the literal questions there was a significant main effect of group (F (3,48) = 6.476, p<0.05, $\eta^2_{p\,=}$ .29). Tukeys HSD post hoc comparisons revealed that the DS group answered significantly fewer literal questions than the RA group but compared similar number to the CAM and PC groups. For the inferential questions there was also a significant main effect of group (F (3,48) = 12.899, p<0.05, $\eta^2_{p\,=}$ .45). This time the DS group answered significantly fewer inferential questions than all three other groups. This analysis shows that the ability to answer literal questions is in-line with general reading comprehension level in DS but that the ability to answer inferential questions is not. This suggests that a difficulty making inferences during reading could be causally related to reading comprehension difficulties in DS.

To test whether inferential questions were significantly more difficult than literal questions within the groups, paired-samples t-tests were used with the Bonferroni correction for multiple comparisons which increased the alpha level to 0.017 (as the RA group were at ceiling on the literal questions they were not included in this analysis). The difference was significant in the DS (t (12) = 6.470, p<0.017, r = .57 and PC groups (t (12) = 3.266, p<0.017, r = .46) but not in the CAM group (t (12) = 2.412, p>0.017, r = .25). Therefore, inferential questions are not of particular difficulty for typically developing children of this reading comprehension level but pose a challenge for children with DS and specific comprehension difficulties.

3.3 Are underlying language skills more strongly related to reading comprehension in DS?

In this section the relationships between reading comprehension and age, reading accuracy, vocabulary, verbal working memory and inferencing ability will be compared across the groups. The question of whether language skills are more strongly correlated with reading comprehension in individuals with DS compared to children matched for reading comprehension ability will be addressed. The correlation matrices for the RA and CAM groups are shown in Table 2 and the DS and PC matrices are shown in Table 3[1].

Table 2 about here

Table 3 about here

Age iss correlated with NARA II reading comprehension only in the PC group. In the RA and CAM groups, age is significantly correlated with scores on the literal and inferential questions in the experimental task, in the PC group it is only significantly correlated with the

[1] The participants in the PC group did not complete the measures of nonverbal ability or verbal working memory.

inferential questions. It should be noted that the range of ages is restricted in the RA and CAM groups, and this could account for the lack of a correlation between age and NARA II reading comprehension. Age is not significantly correlated with any of the measures of reading comprehension in the DS group.

In the DS group and all three comparison groups, NARA II reading comprehension is significantly correlated with reading accuracy and decoding. The pattern of correlations between the measures of reading comprehension and the language measures is more complex. NARA II reading comprehension is significantly correlated with vocabulary knowledge in the DS and RA group and moderately but not significantly in the PC group.   However, the correlation between vocabulary and reading comprehension in the CAM group is non-significant and relatively small compared to the correlation in the other groups. In fact, the difference in the size of the correlation between vocabulary and reading comprehension is significant between the DS and CAM group ($p<.05$). NARA II reading comprehension is significantly correlated with verbal working memory in the DS but not in the RA or CAM groups[2]. It should be noted that although the correlations between reading comprehension and verbal working memory differ in size between the groups, these differences are not statistically significant. The correlation between the ability to answer inferential questions and the more general measure of reading comprehension (NARA II) is significant in the DS and PC groups, and moderate but not significant in the CAM group. The lack of a correlation in the RA group is most likely due to ceiling effects for the comprehension questions in the experimental task.

[2] The PC group did not complete the measure of verbal working memory and so the correlation between this and reading comprehension cannot be reported for this group.

As the sample sizes are too small to carry out hierarchical regressions, partial correlations are computed to explore the unique contributions of reading accuracy and language ability to reading comprehension. BAS II single word reading was used as the measure of reading accuracy rather than NARA II passage reading accuracy as the latter can be influenced by comprehension. To assess the unique contribution of accuracy to comprehension, a partial correlation was computed controlling for BPVS II vocabulary scores (with vocabulary acting as a proxy for general language ability). The correlation between BAS single word reading and NARA II reading comprehension is marginally significant (r=.54, p=.07) in the DS group, significant (r =.64, p<0.05) in the RA group and the PC group (r =.90, p<0.05) and marginally significant in the CAM group (r =.57, p=.05). To assess the unique contribution of language ability and higher level skills to reading comprehension, partial correlations were computed between NARA II reading reading comprehension and BPVS II vocabulary, inferencing ability and verbal working memory controlling for BAS II scores. The partial correlation with vocabulary is only significant in the DS group (r =.83), although it is of a moderate size (r =.43) in the RA group (CAM r=.06, PC r=-.01). The partial correlation with verbal working memory does not reach significance in any of the groups, although it is of a moderate size in all three groups (RA r =.30, CAM r =.41, DS r =.51)[3]. The partial correlation between inferential questions and NARA II comprehension is significant in the DS group (r =.58), moderate in the PC group (r =.38) but negligible in the RA (r =-.09) and CAM (r =-.04) groups.

3.4 Do individuals with DS have a similar reading profile to poor comprehenders?

[3] The PC group did not complete the measure of verbal working memory.

When using a discrepancy of greater than 12 months between reading comprehension and reading accuracy, all except one of the DS participants could be classified as a ‘poor comprehender’. The thirteenth participant had the lowest scores on all three tests and therefore was not able to read a sufficient amount of text for the difference to emerge.

On the standardised measures of language and literacy the DS and PC groups were well matched for receptive vocabulary, reading accuracy and reading comprehension, although the PC group did have significantly higher decoding scores. In addition, both groups experienced particular difficulty with the inferential questions on the experimental passage reading task. This pattern of performance was not found in the CAM group, suggesting that is not a function of overall reading comprehension level. In terms of correlates of reading comprehension ability the two groups were similar, with reading accuracy, vocabulary and inferencing ability all correlating to a moderate degree. However, the relationship between vocabulary and reading comprehension remained significant when reading accuracy was controlled in the DS group but not in the PC group. The relationship between inferencing ability and reading comprehension remained in both groups.

4. Discussion

Previous studies have identified reading comprehension as an area of particular difficulty for individuals with DS and shown that it is related to language ability. However, these earlier studies were limited both by the low levels of reading comprehension of their DS participants and by the measures used. The current study sought to extend previous work by including individuals with DS who had measurable levels of passage reading comprehension, measures of both lower and higher level language skills and a number of different comparison groups. Three hypotheses were tested. First, individuals with DS have a difficulty with inferential questions that goes beyond their general comprehension level. Second, language skills make a greater contribution to reading comprehension in DS. Third, individuals with DS have a similar reading profile to poor comprehenders.

In the current study reading comprehension was confirmed to be out of line with reading accuracy and estimates of the lag between context free word recognition and reading comprehension ranged from 6 months to 67 months, with an average of 33 months. In comparing the DS and reading age matched groups we are able to conclude that the reading comprehension difficulties in the DS group are not solely the result of below age level word recognition ability and thus that other factors are limiting reading comprehension. The comparison with the comprehension age matched control group elucidated these factors; vocabulary knowledge was similar in the two groups, but verbal working memory and inferencing skill were significantly poorer in the DS group. This suggests that underlying language weaknesses play a causal role in the reading comprehension difficulties seen in DS.

A novel aspect of the study was the inclusion of the experimental task to investigate whether individuals with DS have particular difficulties forming inferences during reading. We found that the individuals with DS had difficulty answering inferential questions that was unexpected given their overall reading comprehension level, a pattern also seen in the group of poor comprehenders. This could be taken as evidence that individuals with DS have a difficulty making inferences during reading that is causally related to their reading comprehension difficulties, as has been proposed to be the case for poor comprehenders (Cain & Oakhill, 2009). This leads to the question of why individuals with DS have difficulty generating inferences. Making an inference is a complex process. Consider the example used earlier; 'The man threw his paper on the fire. The ashes rose up the chimney'. In order to understand these sentences the reader must decode or recognise each word, they must then access the meaning of each word whilst holding the words in order in memory to extract the syntactic structure necessary to understand the relations between the objects (see Perfetti, Landi & Oakhill, 2005 for a more detailed discussion). Therefore, variations in word reading, vocabulary knowledge, memory, understanding of syntax and attention will all contribute to the ability to successfully make an inference. Vocabulary knowledge, memory and syntactic knowledge are known to be areas of weakness in DS and the correlational data from this study showed that in the DS group the ability to answer the inferential questions was highly correlated with vocabulary knowledge and verbal working memory.

In their study of Italian children with DS, Roch & Levorato (2009) found a stronger relationship between language and reading comprehension in the DS group compared to a comprehension age matched control group. This led us to predict that we would find stronger correlations between measures of language and reading comprehension in our DS sample. When comparing the DS and comprehension age matched groups we found that vocabulary and verbal working memory were significantly correlated with reading comprehension only in the DS group. In fact, the correlation between vocabulary and reading comprehension was significantly larger in the DS group. This supports the hypothesis that reading comprehension is more strongly related to language ability in DS. However, a large correlation between vocabulary and reading comprehension was not unique to the DS group, but was also present in the reading age matched control group. This suggests that a greater role for language ability is a function of more advanced word recognition ability.

The convergent skills model (Vellutino et al, 2007) hypothesizes that language comprehension and the semantic and syntactic skills that underlie language comprehension are more strongly related to reading comprehension in older, more advanced readers. This is based on the assumption that language processes do not become fully operative until the child is able to identify the printed versions of the vast majority of the words they are able to comprehend in spoken language. When a child has gained enough facility in word recognition, language comprehension processes can then play the dominant role in accounting for variability in reading comprehension. In the convergent skills model, word identification is the strongest predictor of reading comprehension in younger, less advanced readers. The comprehension age matched group in our study were younger and less advanced readers than the children in the three other groups and in support of the model, reading comprehension was significantly correlated with measures of reading accuracy but not with measures of language.

Roch & Levorato (2009) noted the potential overlap in reading profiles between children with DS and poor comprehenders and the current study tested this directly. We found that nearly all of the individuals with DS met the criteria for being a poor comprehender and that when the two groups were matched for reading comprehension they were also well matched for reading accuracy, vocabulary and inferencing making ability. The presence of a significant correlation between vocabulary and reading comprehension in the DS group but not in the PC group suggests that vocabulary weaknesses may play a greater role in DS. Both groups had particular difficulty answering the inferential comprehension questions, compared to the comprehension age matched group, and in both groups inference making ability was correlated with the more general measure of reading comprehension. This suggests that weaknesses in making inferences may be causally related to the reading comprehension difficulties that these children experience.

This study is the first step in applying research methods used with poor comprehenders to individuals with DS, but there are other abilities known to be weak in poor comprehenders, such as morpho-syntactic skills and comprehension monitoring, which provide opportunities for future research with children with DS. In addition, inferencing ability in the current study was measured in the context of reading and so the next step would be to investigate the ability of individuals with DS to make inferences while listening to spoken language.

In summary, this study has shown that reading comprehension lags reading accuracy by between 2-3 years on average in individuals with DS. This has implications for reading instruction; both accuracy and comprehension levels need to be assessed so that material can be selected that is at an appropriate level to focus on accuracy or understanding. The findings of this study confirm that reading comprehension in DS is limited by the understanding of individual words, the ability to process and hold sentences in memory and to make inferences during reading. In this respect, individuals with DS resemble children known as poor comprehenders. Reading comprehension was found to be strongly related to underlying language skills in DS, but this was also true of reading age matched controls and so likely reflects the increased role of language skills when word recognition becomes sufficiently advanced. Recent research (Clarke, Snowling, Truelove & Hulme, in press) has demonstrated that intervention focusing on improving oral language is successful in ameliorating reading comprehension difficulties in poor comprehenders. On the basis of the findings from the current study a similar approach is recommended for children who have DS. Such an intervention would also allow the hypothesis that the reading comprehension deficit is caused by underlying language difficulties to be more fully tested.

Acknowledgements

We would like to thank Alexandra Petrov and Lisa Henderson for their assistance with data collection and of course the children, families and schools for their time. The preparation of this manuscript was supported by Wellcome Programme Grant 082036 and we would like to thank Maggie Snowling and Paula Clarke for their helpful comments.

References

Boudreau, D. (2002). Literacy skills in children and adolescents with Down syndrome. *Reading and Writing: An Interdisciplinary Journal*, 15, 497-525.

Bowyer-Crane, C., & Snowling, M.J. (2005). Assessing children's inferencing generation: what do tests of reading comprehension measure? *British Journal of Educational Psychology*, 75, 189-201.

Buckley, S. (1985). Attaining basic educational skills: reading, writing and number. In D. Lane & B. Stratford (Eds.), *Current Approaches to Down's Syndrome* (pp. 315-334). London: Holt, Rinehart, & Winston.

Cain, K., & Oakhill, J.V. (1999). Inference making and its relation to comprehension failure. *Reading and Writing*, 11, 489-503.

Cain, K., & Oakhill, J.V. (1999). Reading comprehension development from 8 – 14 years: The contribution of component skills and processes. In R. K. Wagner, C. Schatschneider & C. Phythian-Sence (Eds.), *Beyond Decoding: The Behavioural and Biological Foundation of Reading Comprehension*. The Guilford Press.

Cain, K., Oakhill, J.V., Barnes, M.A., & Bryant, P.E. (2001). Comprehension skill, inference making ability, and their relation to knowledge. *Memory & Cognition*, 29, 850-859.

Cardoso-Martins, C., Peterson, R., Olson, R., & Pennington, B. (2009). Component reading skills in Down syndrome. *Reading and Writing*, 22, 277 – 292.

Carr, J. (1995). *Down's Syndrome: Children Growing Up.* Cambridge: Cambridge University Press.

Catts, H.W., Adlof, S.M., & Weismer, S.E. (2005). Language deficits in poor comprehenders: a case for the simple view of reading. *Journal of Speech, Language and Hearing Research*, 49, 278-293.

Clarke, P. J., Snowling, M. J., Truelove, E., & Hulme, C. (in press). Ameliorating children's reading comprehension difficulties: A randomised controlled trial. *Psychological Science*.

Dunn, L.M., Dunn, L.M., Whetton, C., & Burley, J. (1997). *British Picture Vocabulary Scale II.* Windsor: NFER-Nelson.

Elliott, C.D., Smith, P., & McCulloch, K. (1996). *British Ability Scales II (BAS-II).* Windsor: NFER-Nelson.

Gough, P.B., & Tunmer, W.E. (1986). Decoding, reading and reading disability. *Remedial and Special Education*, 7, 6-10.

Graesser, A., Singer, M., & Trabasso, T. (1994). Constructing inferences during text comprehension. *Psychological Review*, 101, 371-395.

Groen, M. Laws, G., Nation, K., & Bishop, D. (2006). A case of exceptional reading accuracy in a child with Down syndrome: underlying skills and the relation to reading comprehension. *Cognitive Neuropsychology*, 23, 1190-1214.

Hatcher, P. (2000). Predictors of reading recovery book levels. *Journal of Research in Reading*, 23, 67- 77.

Haviland, S.E., & Clark, H.H. (1974). What's new? Acquiring new information as a process in comprehension. *Journal of Verbal Learning & Verbal Behaviour*, 18, 91-108.

Kay-Raining Bird, K., Cleave, P. L., White, D., Pike, H., & Helmkay, A. (2008). Written and oral narratives of children and adolescents with Down syndrome. *Journal of Speech, Language and Hearing Research*, 51, 436-450.

Kendeou, P., Savage, R., & van Den Broek, P. (2009). Revisiting the simple view of reading. *British Journal of Educational Psychology*, 79, 353-370.

Laws, G., & Bishop, D. V. M. (2003). A comparison of language abilities in adolescents with Down syndrome and children with Specific Language Impairment. *Journal of Speech, Language and Hearing Research*, 46, 1324-1339.

Laws, G., & Gunn, D. (2002). Relationship between reading, phonological skills and language development in individuals with Down syndrome: a five year follow-up study. *Reading and Writing: An Interdisciplinary Journal*, 15, 527-548.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes and language skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology, 40,* 665–681.

Nation, K., Adams, J. W., Bowyer-Crane, C. A., & Snowling, M. J. (1999). Working memory deficits in poor comprehenders reflect underlying language impairments. *Journal of Experimental Child Psychology*, 73, 139-158.

Nation, K., Clarke, P., Marshall, C.M., & Durand, M. (2004). Hidden language impairments in children: parallels between poor reading comprehension and specific language impairment? *Journal of Speech, Language and Hearing Research*, 47, 199-211.

Nation, K., & Snowling, M.J. (1998). Semantic processing and the development of word recognition skills: evidence from children with reading comprehension difficulties. *Journal of Memory and Language,* 39, 85-101.

Nation, K., & Snowling, M.J. (2000). Factors influencing syntactic awareness in normal readers and poor comprehenders. *Applied Psycholinguistics*, 21, 229-241.

Neale, M.D. (1997). *Neale Analysis of Reading Ability – Revised* (2nd ed.). Windsor: NFER-Nelson.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of single-word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes, 18,* 443_468.

Oakhill, J., Hartt, J., & Samols, D. (2005). Levels of comprehension monitoring and working memory in good and poor comprehenders. *Reading and Writing*, 18, 657-686.

Perfetti, C. A. and L. Hart (2002). The lexical quality hypothesis. In L. Vehoeven. C. Elbro and P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189‑213). Amsterdam/Philadelphia: John Benjamins.

Perfetti, C., Landi, N., & Oakhill, J. (2005). The acquisition of reading comprehension skill. In M.J. Snowling & C. Hulme (Eds.), *The Science of Reading*. Oxford: Blackwell Publishing.

Pickering, S.J., & Gathercole, S.E. (2001). *Working Memory Test Battery for Children.* Hove: Psychological Corporation.

Priya, K., & Wagner, R. K. (2009). The roles of fluent decoding and vocabulary in the development of reading comprehension. In R. K. Wagner, C. Schatschneider & C. Phythian-Sence (Eds.), *Beyond Decoding: The Behavioural and Biological Foundation of Reading Comprehension*. The Guilford Press.

Roch, M., & Levorato, M. C. (2009). Simple view of reading in Down's syndrome: the role of listening comprehension and reading skills. *International Journal of Language and Communication Disorders,* 44, 206-223.

Roizen, N. J. (1997). Down syndrome. In M. L. Batshaw (Ed.), *Children with disabilities* (4th ed., pp. 361-376). Baltimore: Brookes.

Singer, M. (1993). Causal bridging inferences: validating consistent and inconsistent sequences. *Canadian Journal of Experimental Psychology,* 47, 340-359.

Sloper, P., Cunningham, C., Turner, S., & Knussen, C. (1990). Factors related to the academic attainments of children with Down's syndrome. *British Journal of Educational Psychology*, *60*(3), 284–298.

Snowling, M.J., Stothard, S.E., & McLean, J. (1996). *Graded Nonword Reading Test.* Bury St Edmunds: Thames Valley Test Company.

van den Broek, P., Risden, K., Fletcher, C. R., & Thurlow, R. (1996). A "landscape" view of reading: Fluctuating patterns of activation and the construction of a stable memory representation. In B. K. Britton & A. C. Graesser (Eds.), *Models of understanding text* (pp. 165–187). Mahwah, NJ: Erlbaum.

Vellutino, F. R., Tunmer, W. E., Jaccard, J. J., & Chen, R. (2007). Components of reading ability: Multivariate evidence for a convergent skills model of reading development. *Scientific Studies of Reading*, 11, 3–32.

Wechsler, D. (1993). *Wechsler Objective Reading Dimensions.* London: The Psychological Corporation.

Table **1**

Mean raw scores (standard deviations) for the standardised measures in each of the four groups

	DS (N=13)	RA (N=13)	CAM (N=13)	PC (N=13)	*F*
Gender [1]	12F	11 F	7 F	9 F	
Age (mths)	185.92 (31.53)[b]	109.92 (8.35)[a]	103.23 (7.41)[b]	114.00 (8.80)[b]	65.078
BPVS II [2]	83.92 (14.63)[a]	91.31 (10.35)[a]	85.92 (11.25)[a]	86.54 (8.05)[a]	0.993
BAS [3]	62.85 (11.44)[a]	63.85 (9.53)[a]	50.85 (10.20)[b]	63.31 (7.45)[a]	5.336
GNWRT [4]	11.00 (4.34)[b]	17.31 (2.66)[a]	14.46 (3.43)[ab]	17.69 (3.43)[a]	10.11
NARA II accuracy	56.23 (20.00)[ab]	58.92 (15.89)[a]	41.54 (11.68)[b]	54.15 (14.38)[ab]	3.098
NARA II comprehension	12.08 (6.46)[a]	26.38 (5.75)[b]	14.92 (4.92)[a]	14.23 (3.35)[a]	19.531
Pattern construction	31.23 (10.24)[b]	52.85 (13.95)[a]	45.62 (14.66)[a]	N/A	9.179
Listening recall [5]	5.62 (3.80)[b]	11.15 (2.38)[a]	12.08 (3.43)[a]	N/A	14.975

Notes: [1] number of females in the group; [2] receptive vocabulary; [3] single word reading; [4] nonword reading; [5] total number of trials correct
Means with different superscripts are significantly different, those with the same superscript are not significantly different ($p<0.05$), combined superscript characters indicate that the mean does not differ significantly from the means represented by each character
The PC group did not complete the pattern construction or listening recall tests

Table 2

Correlation matrix for the RA group (N=13) above the diagonal and the CAM group (N=13) below the diagonal

	CA	BAS	BPVS	GNWRT	NARA Acc	NARA Comp	Patt Con	Lit	Inf	List recall
CA		.10	.25	.05	.06	-.17	-.04	.60*	.70*	.27
BAS	.77*		.66*	.66*	.84*	.81*	.07	.37	.17	-.09
BPVS	.13	.28		.35	.67*	.73*	.43	.39	.52	.06
GNWRT	.47	.72*	.15		.54	.55	.33	.19	.22	-.61
NARA Acc	.66*	.79*	.11	.70*		.89*	.29	.12	.03	.20
NARA Comp	.43	.60*	.21	.61*	.88*		.35	.03	.09	.10
Patt Con	.35	.38	.36	.67*	.50	.66*		-.04	.15	.45
Literal Qs	.74	.81*	.07	.60*	.66*	.53	.24		.70*	.30
Inferential Qs	.78*	.69*	.03	.50	.52	.39	.29	.79*		.29
Listening recall	-.42	.08	-.01	.29	.26	.37	.22	-.00	-.24	

Note: Correlation coefficients are Pearson's r and * indicates a significant correlation ($p<0.05$)

Table 3

Correlation matrix for the PC (N=13) group above the diagonal and the DS group (N=13) below the diagonal

	CA	BAS	BPVS	GNWRT	NARA Acc	NARA Comp	Patt Con	Lit	Inf	List recall
CA		.82*	.53	.80*	.73*	.74*	N/A	.28	.63*	N/A
BAS	.28		.51	.69*	.88*	.92*	N/A	.32	.46	N/A
BPVS	.08	.31		.53	.57*	.46	N/A	.05	.06	N/A
GNWRT	.07	.61*	.54		.66*	.63*	N/A	.08	.44	N/A
NARA Acc	.20	.84*	.39	.77*		.74*	N/A	.20	.37	N/A
NARA Comp	.20	.54	.83*	.78*	.70*		N/A	.34	.56*	N/A
Patt Con	.51	.22	.31	.34	.36	.43		N/A	N/A	N/A
Literal Qs	-.15	.41	.82*	.52	.31	.65*	-.10		.38	N/A
Inferential Qs	-.17	.38	.72*	.74*	.43	.66*	-.09	.86*		N/A
Listening recall	.23	.41	.65*	.48	.42	.61*	-.03	.61*	.69*	

Note: Correlation coefficients are Pearson's r and * indicates a significant correlations (p<0.05)

Table 4

Chronological age, reading ages and the difference between accuracy and comprehension in months for the participants in the DS group

Participant	Chronological age	BAS II reading age	NARA acc age	NARA comp age	BAS II / NARA comp difference	NARA acc - NARA comp difference
DS1	136	99	96	82	17	14
DS2	147	105	96	73	32	23
DS3	153	171	154	104	67	50
DS4	159	123	124	92	31	32
DS5	166	91	88	85	6	3
DS6	179	111	106	79	32	27
DS7	187	129	93	85	44	8
DS8	201	141	128	91	50	37
DS9	209	129	113	97	32	16
DS10	210	94	93	77	17	16
DS11	215	111	97	79	32	18
DS12	224	141	154	133	8	21
DS13	231	141	133	77	64	56

Note: all ages are presented in months

Appendix

Example passage from the experimental test of reading comprehension

Ernie the hamster loved food. He was very fat. Everyday, Ernie watched his owner Sarah put her packed lunch in her bag before she went to school. One day the cage door was left open. When no one was looking Ernie decided to escape and headed straight for Sarah’s bag. He climbed in and found her sandwiches at the bottom of the pencil case. He was so happy. Sarah came in and picked her bag up. She didn’t see Ernie. Sarah said goodbye to her Mum and set off for school. As Sarah walked, she couldn’t remember if she’d packed her maths book. Sarah stopped to check in her bag. When she opened the bag Sarah got a huge surprise. Ernie was in there eating her sandwiches. She told him off and said: “They’ll make you poorly”. Sarah took Ernie straight home and put him safely back in the cage. Sarah made sure she shut the door this time.

1. (literal) What type of animal was Ernie?
2. (literal) What did Ernie watch Sarah do everyday?
3. (inferential) How was Ernie able to escape?
4. (literal) Who did Sarah say goodbye to?
5. (inferential) Why did Sarah stop to check in her bag?
6. (inferential) Why did Sarah get a huge surprise?