Learning to read new words in individuals with Down syndrome: Testing the role of phonological knowledge

CrossMark

Silvana E. Mengoni [a,*], Hannah M. Nash [b], Charles Hulme [c]

[a] Centre for Education and Educational Technology, Faculty of Education and Language Studies, The Open University, Milton Keynes MK7 6AA, UK
[b] Institute of Psychological Sciences, University of Leeds, UK
[c] Division of Psychology and Language Sciences, University College London, UK

A R T I C L E   I N F O

A B S T R A C T

This study examined the effect of word level phonological knowledge on learning to read new words in Down syndrome compared to typical development. Children were taught to read 12 nonwords, 6 of which were pre-trained on their phonology. The 16 individuals with Down syndrome aged 8–17 years were compared first to a group of 30 typically developing children aged 5–7 years matched for word reading and then to a subgroup of these children matched for decoding. There was a marginally significant effect for individuals with Down syndrome to benefit more from phonological pre-training than typically developing children matched for word reading but when compared to the decoding-matched subgroup, the two groups benefitted equally. We explain these findings in terms of partial decoding attempts being resolved by word level phonological knowledge and conclude that being familiar with the spoken form of a new word may help children when they attempt to read it. This may be particularly important for children with Down syndrome and other groups of children with weak decoding skills.

1. Introduction

Although there is variability between individuals, reading accuracy has been identified as a relative strength in Down syndrome in comparison to general ability and reading comprehension (e.g. Boudreau, 2002; Buckley, 1985; Cardoso-Martins & Frith, 2001; Hulme et al., 2012; Laws & Gunn, 2002; Nash & Heath, 2011). Typically individuals with Down syndrome show better reading of words than nonwords (Roch & Jarrold, 2008). Further, they tend to have poor phonological awareness (Lemons & Fuchs, 2010; Næss, Melby-Lervåg, Hulme, & Lyster, 2012), a skill that is important for decoding in typical development (e.g. Byrne & Fielding-Barnsley, 1989; Hulme, Goetz, Gooch, Adams, & Snowling, 2007; Wagner et al., 1997). This relationship is also present in Down syndrome (Fowler, Doherty, & Boynton, 1995; Roch & Jarrold, 2008); indeed a recent meta-analysis found that the deficit in nonword reading in individuals with Down syndrome is moderated by their performance on phoneme deletion tasks (Næss et al., 2012).

The relative difficulties in nonword reading and phonological awareness among individuals with Down syndrome suggests that they may be recruiting compensatory strategies to support the development of word reading, such as visual skills or vocabulary knowledge (Boudreau, 2002; Buckley, 1985; Kay-Raining Bird, Cleave, & McConnell, 2000). A recent

longitudinal study suggested that vocabulary is a stronger predictor of reading development in Down syndrome than in typical development (Hulme et al., 2012). Related to this, Nation and Cocksey (2009) have suggested that phonological (sound-based) aspects of vocabulary knowledge may be particularly important for learning to read when decoding is compromised. The aim of the current study was to investigate the contribution of word level phonological knowledge to reading and orthographic learning in individuals with Down syndrome.

In order to study the mechanisms behind reading development in Down syndrome, it is useful to consider models of reading in typical development. The triangle model of reading (Plaut, McClelland, Seidenberg, & Patterson, 1996) proposes two ways in which the phonology of words can be activated from their orthography: directly or indirectly via semantics. Semantic information (meaning-based knowledge) is argued to be most important when the direct phonological pathway is impaired or compromised such as when reading irregular words (McKay, Davis, Savage, & Castles, 2008; Taylor, Plunkett, & Nation, 2011) or in disorders such as Down syndrome or dyslexia.

Semantic knowledge is not well-specified in the triangle model and was conceptualised as additional input to the phonological representation (Plaut et al., 1996). In studies with children, semantics is typically assessed by vocabulary tasks. However, these tasks often require both phonological and semantic knowledge about a word (Johnson, Paivio, & Clark, 1996; Levelt, Roelofs, & Meyer, 1999). Nation and Cocksey (2009) devised separate measures of phonological knowledge and semantic knowledge and found that at the item-level, phonological, but not semantic, knowledge uniquely predicted variations in children's reading of irregular words. They suggested that irregular words may result in partial decoding attempts, and possession of a whole-word phonological representation allows children to resolve these attempts and produce the correct response. Such a process may well be important for learning to read in individuals who have decoding difficulties, such as individuals with Down syndrome.

One method to determine how existing phonological knowledge affects reading is to conduct training studies with novel words. This controls what phonological information about a word children have been exposed to. In such studies, children are taught to read unfamiliar words or nonwords with or without pre-training. Pre-training can be used to train phonological knowledge of words or nonwords and may involve individuals hearing and saying the items (McKague, Pratt, & Johnston, 2001) or discriminating between the target items and phonologically similar distracters (Duff & Hulme, 2012). It has been found that typically developing children are more accurate when attempting to read words that have received such phonological pre-training (i.e. those they have phonological knowledge about), than those words which have not (Duff & Hulme, 2012; McKague et al., 2001). This supports the idea that knowing the phonological form of a word is causally related to children's ability to learn to read it.

Training studies can also explore how children establish orthographic (written) representations of new words. According to Share's self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) when a child encounters an unknown word, they independently convert the letters into sounds, a process termed phonological recoding. Multiple successful encounters with a word result in the formation of an orthographic representation. Orthographic knowledge can be tested using orthographic choice tasks that assess whether children can discriminate the correct written form of the word from a nonword with the same pronunciation but a different spelling. If familiarising the child with the phonological form of a word supports decoding, this should also promote the creation of an accurate orthographic representation.

The aim of the present study was to examine the effect of phonological knowledge on written nonword learning in individuals with Down syndrome. A group of typically developing children was matched to the individuals with Down syndrome on word reading. A subgroup of the typically developing children was also individually matched to the individuals with Down syndrome on decoding. This two-stage matching procedure was used to investigate whether individuals with Down syndrome learnt to read new words at a rate commensurate with their reading or decoding level. It was predicted that individuals with Down syndrome would show written nonword learning in line with their decoding skill but below the level expected from their word reading ability.

Phonological pre-training was designed to familiarise individuals with the phonological form of the nonwords prior to encountering them in print. It was expected that this would benefit the typically developing children (Duff & Hulme, 2012; McKague et al., 2001). The individuals with Down syndrome would likely have poorer decoding skills than typically developing children at the same level of reading and so make more partial decoding attempts that could be resolved through phonological knowledge. Therefore it was also predicted that individuals with Down syndrome would benefit more from phonological pre-training than the typically developing children matched for word reading but that when the groups were matched for decoding, they would benefit equally from phonological pre-training.

2. Method

2.1. Participants

Sixteen children and adolescents with Down syndrome (mean age of 13;08 (SD = 2;11; range 8–17 years); five males) were recruited through families who were also taking part in a longitudinal study and all individuals completed the study. All individuals also participated in a spoken word learning study approximately 12 months previously (Mengoni, Nash & Hulme, 2013), which trained different nonwords using different methods and none of the background data were re-used in the present study. All individuals had Trisomy 21 according to parental report and were known from previous testing to have a reading age of at least five years. Parental consent was obtained for the individuals to participate in the study.

Table 1
Scores of the individuals with Down syndrome and the typically developing children on all background measures.

	Individuals with Down syndrome[a]		Typically developing children[b]		Between-group differences
	Mean (SD)	Range	Mean (SD)	Range	
Chronological age	13;08 (2;11)	8;07–17;02	6;01 (0;06)	5;03–7;01	$t(15.48) = -10.37$, $p < .001$, $d = 3.83$
Matrices raw score (max. 29)	11.81 (4.93)	5–20	15.63 (4.98)	6–24	$t(44) = 2.49$, $p = .017$, $d = .77$
Matrices age-equivalent score	5;00 (1;03)	4;00–7;03	6;00 (1;02)	4;00–7;03	$t(44) = 2.55$, $p = .014$, $d = .83$
Single word reading raw score (max. 60)	26.44 (13.88)	4–45	21.40 (9.08)	8–39	$t(22.05) = -1.31$, $p = .204$, $d = .43$
Single word reading age-equivalent score	7;05 (1;06)	4;11–10;00	6;10 (0;10)	5;06–8;09	$t(20.30) = -1.43$, $p = .169$, $d = .48$
Nonword reading raw score (max. 20)	6.69 (5.95)	0–17	10.20 (5.49)	1–20	$t(44) = 2.01$, $p = .051$, $d = .61$
Picture naming raw score (max. 30)	22.13 (4.69)	11–27	23.70 (2.93)	17–29	$U = 206.50$, $p = .436$, $d = .40$
Picture naming age-equivalent score	6;00 (1;06)	2;10–7;03	6;06 (1;00)	4;04–7;03	$U = 213.00$, $p = .527$, $d = .39$
Alliteration matching raw score (max. 10)	7.20 (2.11)	4–10	9.40 (0.89)	7–10	$U = 89.00$, $p < .001$, $d = 1.36$
Sound deletion raw score (max. 12)	5.00 (3.16)	0–9	8.67 (2.31)	4–12	$U = 77.00$, $p < .001$, $d = 1.33$
Sound deletion age-equivalent score	5;09 (1;03)	4;00–7;07	7;01 (0;10)	5;04–7;08	$U = 73.50$, $p < .001$, $d = 1.26$
Word recall raw score (max. 42)	11.81 (3.12)	7–18	17.77 (4.34)	12–32	$U = 53.00$, $p < .001$, $d = 1.58$

[a] $n = 16$ except for alliteration matching and sound deletion where $n = 15$.
[b] $n = 30$ for all tasks.

Of the individuals with Down syndrome, ten were in mainstream education: five in primary schools and five in secondary schools. Four individuals were in special education: two in secondary schools and two in college. Two individuals had joint attendance at special and mainstream secondary schools.

Thirty typically developing children (mean age of 6;01 (SD = 0;06; range 5–7 years); 16 males) were recruited from Year 1 and 2 classes in two primary schools. These year groups were chosen to correspond to the reading ability of the group of individuals with Down syndrome, and indeed there was no difference between the two groups on a test of single word reading (see Table 1). This matching procedure means that any differences in word learning cannot reflect overall differences in word reading ability, but it means that the typically developing group are likely to have had more limited reading experience. Consent for the typically developing children to participate was obtained from the headteachers of the schools and from their parents. Children who had been identified with special educational needs were excluded. All participants in both groups were monolingual English speakers.

2.2. Assessment battery

Testing for the longitudinal study in which the individuals with Down syndrome were participating took place at the same time as this study and the tasks reported below were part of the longitudinal study. It was decided to administer the same tasks to the typically developing group to keep the procedure the same and to act as filler tasks before the post-tests. The results of standardised tests are reported later to give an indication of the relative profiles of the two groups.

2.2.1. Nonverbal reasoning

The Matrices subtest from the Wechsler Pre-School and Primary Scale of Intelligence III[UK] (WPPSI-III[UK]; Wechsler, 2003; reliability coefficient .90) was administered to measure nonverbal reasoning skills. In this task, children were asked to look at an incomplete matrix and choose the missing section from four or five options. Testing was discontinued after four incorrect answers on either four or five consecutive items.

2.2.2. Word reading

The Single Word Reading Test from the York Assessment of Reading for Comprehension (YARC) Passage Reading battery (Snowling et al., 2009; reliability coefficient .98) was administered. The test consists of 60 words that increase in complexity from simple words such as 'see' to more complex words such as 'pseudonym'. Individuals were shown all words and asked to read as many as they could.

2.2.3. Nonword reading

The Graded Nonword Reading Test (Snowling, Stothard, & McLean, 1996; reliability coefficient .96) was used to test children's decoding skills. Individuals were presented with nonwords that increased in difficulty from 'hast' to 'sloskon', and were asked to read them aloud. There were five practice trials and 20 test items, and the task was discontinued after six consecutive errors. Individuals were awarded one point for each nonword read correctly.

2.2.4. Expressive vocabulary

The WPPSI-III[UK] Picture Naming subtest (reliability coefficient .88) was administered to test expressive vocabulary ability. Individuals were asked to name a series of 30 pictures ranging from car to thermometer, and the test was discontinued if five consecutive incorrect responses were made.

2.2.5. Phonological awareness

To assess phoneme awareness individuals were given an Alliteration Matching task, adapted from Carroll (2004). All stimuli were presented to children as spoken words and colour pictures. Individuals were asked which word out of a choice of two started with the same sound as a target word. The distracters were matched to the correct answer for global similarity to the target word. There were two practice items and 10 test items, and individuals were administered all items.

The Sound Deletion subtest from the YARC Early Reading battery (Hulme et al., 2009; reliability coefficient .93) was also administered to test phonological awareness. Individuals were presented with spoken words and corresponding colour pictures, asked to repeat the word and then asked to delete a sound. Some of the items resulted in nonwords, e.g. say sheep without the /?/, whereas some items resulted in real words, e.g. say boat without the /t/. There were 12 items, which tapped deletion of syllables and phonemes in initial, medial and final positions and individuals completed all items.

2.2.6. Verbal short-term memory

The Word Recall subtest from the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001; reliability coefficient .72) was used to measure verbal short-term memory skills. The individuals heard a sequence of words and had to repeat them in the same order. The sequence of words increased in length, across trials. The test was discontinued when individuals scored less than four out of six items correct at a given list length. The number of correct trials, rather than span score, was used in analyses as this score had a greater range and therefore was more sensitive to individual differences.

2.3. Design and procedure

All individuals were taught to read 12 nonwords, and there was phonological pre-training for six of these nonwords. Individuals were then tested on their phonological and orthographic knowledge of the taught nonwords. The phonological pre-training condition and control condition (no pre-training) took place in two separate sessions on different days. All children were seen individually and the testing sessions lasted 20–30 min each. All typically developing children were seen at school and the individuals with Down syndrome were either seen at home or school. In the pre-training condition, the phonological pre-training occurred first, followed immediately by written nonword learning. In the control condition, the written nonword learning was the first activity. The background tasks were then administered, followed by the phonological choice post-test and the orthographic choice post-test.

2.4. Nonword learning procedure and materials

2.4.1. Training materials

Twelve pairs of nonwords were created that had two different but homophonic vowel digraphs (e.g. 'nirp' and 'nurp'). All nonwords had four graphemes and three phonemes and are shown in Appendix. Within the nonword pairs, there were no significant differences between the number and frequency of orthographic neighbours of the nonwords according to the ARC database (Rastle, Harrington, & Coltheart, 2002). The nonword pairs were separated into two lists ensuring that similar vowel patterns were not all in the same list. Within each pair, nonwords were randomly assigned to be either a target nonword or pseudohomophone distracter, which would be used in the orthographic choice post-test. These assignments were the same for all individuals.

2.4.2. Learning procedure

The individuals were introduced to the training procedure by being told they were going to learn some words from an alien planet. The two conditions (phonological pre-training vs. control) occurred on different days and the training procedure is depicted in Fig. 1. The two lists of target nonwords were counterbalanced across the two conditions, as was the order of conditions resulting in four versions of the experiment. The learning procedure lasted approximately 5–10 min and the children generally enjoyed it and attended well.

2.4.3. Phonological pre-training

There were four trials in the phonological pre-training procedure, each of which consisted of a repetition activity and a phonological consolidation activity. These activities were spoken and individuals did not see any written material. First, the individuals heard the nonword and repeated it. This was the same across each trial. They then did a phonological consolidation activity that was designed to familiarise individuals with the sound of the nonword. This increased in difficulty throughout the training. For the first trial the individuals heard the nonword segmented into its constituent phonemes and repeated this and they also heard the first and last sound isolated. The second trial was the same as the first but the individuals sounded out the nonword independently. For the third and fourth trial, individuals independently isolated the initial sound and the final sound, respectively. The six nonwords appeared in a fixed random order within each trial and corrective feedback was given, which was either "well done" or "that's not quite right" followed by the correct answer.

2.4.4. Written nonword learning (reading aloud)

There were four trials of written nonword learning, in which the individuals saw the written nonwords individually and read them aloud. Individuals were permitted one attempt at the answer and were then given corrective feedback, which was
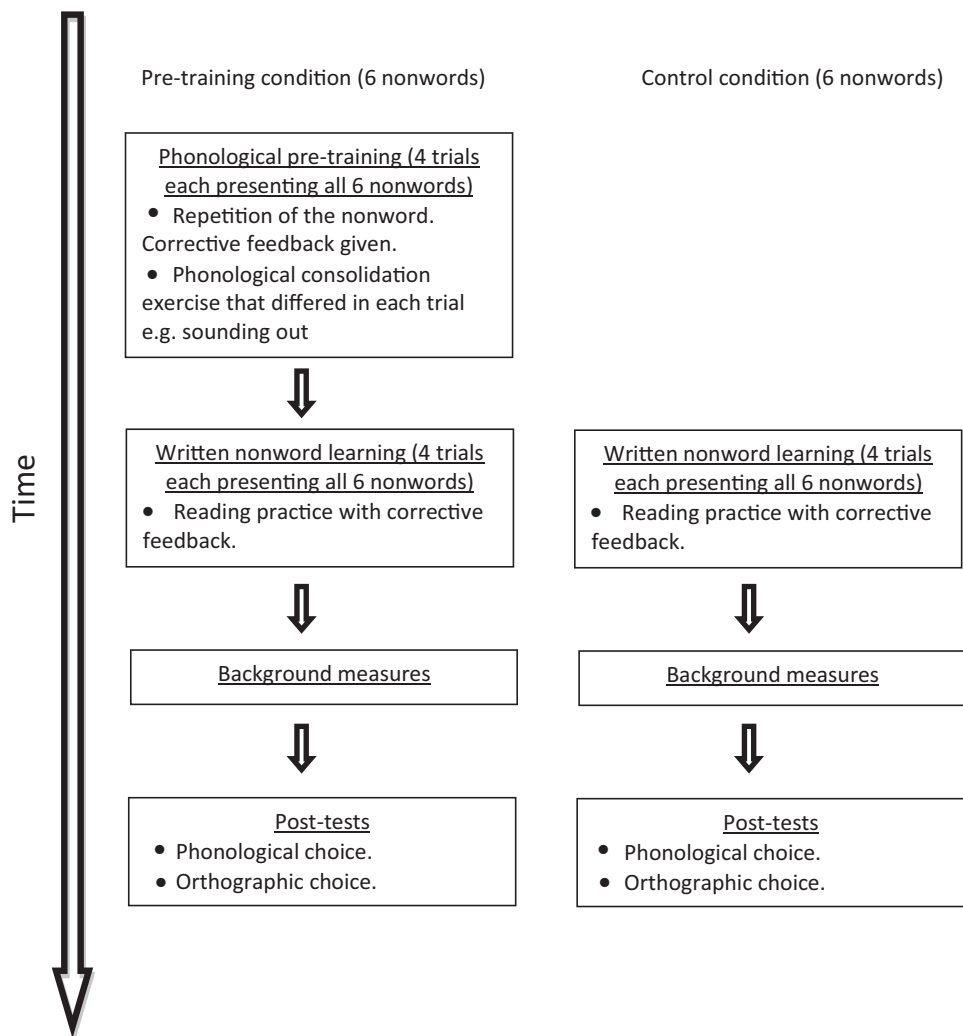
Fig. 1. The training procedure for each condition.

either "well done" or "that's not quite right" followed by the correct answer. The nonwords were printed in size 36 Century Gothic lower-case font-type on sheets of A4 paper. All six nonwords appeared in a fixed random order within each trial. Individuals were awarded one point for each nonword they read correctly.

Problems with articulation are common in children with Down syndrome (Kumin, Councill, & Goodman, 1994; Roberts et al., 2005) and if a phoneme was pronounced incorrectly but with a consistent realisation then this pronunciation was accepted as correct in the nonword learning task.

2.5. Experimental post-tests

Two computerised post-tests, a phonological choice task and an orthographic choice task, were administered approximately 10–15 min after the training procedure. The phonological choice task assessed whether individuals could recognise the phonological forms of the trained nonwords. The orthographic choice post-test assessed individuals' recognition of the nonwords' spelling.

2.5.1. Phonological choice task

The phonological choice task was presented on a laptop computer using e-Prime version 1.0 (Schneider, Eschman, & Zuccolotto, 2002). Pictures of three children were shown sequentially, each accompanied by a spoken nonword that was either the target nonword or a distracter. The three pictures of the children then appeared simultaneously on the computer screen and the individual was asked who had said an alien word that they had learnt earlier. They could respond verbally or non-verbally by pointing.

For each target nonword, two distracters were devised (see Appendix). The first differed by one phoneme; for half of the nonwords, the initial phoneme was changed and for the remaining half, the final phoneme was changed. The second distracter differed by two phonemes and was based on the first distracter but the remaining consonant was also changed, for example the distracters for 'nirp' were 'nirt' and 'mirt'. Prior to the experimental trials, two practice trials with real target words were administered to familiarise the individuals with the task demands. These presented the real word 'bird' with the distracters 'mird' and 'mirg' and the real word 'ball' with the distracters 'borz' and 'morz'.

2.5.2. Orthographic choice task

The orthographic choice task was also presented using e-Prime. Three written nonwords appeared on the computer screen simultaneously and individuals were asked to pick the alien word that they had learnt that day. They could respond verbally or non-verbally by pointing.

As outlined in Section 2.4.1, all target nonwords had a pseudohomophone distracter. A visual distracter was also created by changing the last consonant of the target nonword to a visually similar one. Therefore, the target nonword 'nirp' had the pseudohomophone distracter 'nurp' and the visual distracter 'nirg'. All distracter items are shown in Appendix. Prior to the experimental trials, two practice trials with real words and pictures were administered. These presented the real word 'bird' with the distracters 'berd' and 'birg' and the real word 'door' with the distracters 'doar' and 'doof'.

3. Results

Raw scores and a significance level of .05 were used for all analyses. One child with Down syndrome did not score on the alliteration matching and sound deletion tasks for behavioural reasons therefore N was reduced for these tasks.

3.1. Performance on background measures

To examine the distribution of scores within the groups the Shapiro–Wilk test was used and histograms were examined. If the distribution of scores for a task were non-normal for either or both groups then a Mann–Whitney U test was used to test the differences between the groups. If the distributions were normal in both groups, then an independent samples t-test was used. The mean scores, standard deviations and between-group test results are reported in Table 1. Where possible age-equivalent scores are also reported to indicate the developmental level of the two groups. As can be seen the two groups were matched on word reading and from previous research it would be expected that the typically developing children would perform significantly better than the individuals with Down syndrome on all other tasks. This was the case for matrices, alliteration matching, sound deletion and word recall, and there was also a trend for a difference on nonword reading. However the two groups performed similarly on the picture naming task.

3.2. Phonological learning

In order to investigate whether the phonological pre-training improved written nonword learning, it must first be established that it resulted in increased phonological knowledge in both groups. The mean scores for the correct response in the phonological choice post-test are shown in Table 2. For both conditions and both groups, the correct answer was chosen above chance levels (score of two). The two distracters were chosen at similarly low levels across groups and conditions.

A mixed 2×2 ANOVA was conducted for the correct answer on the phonological choice post-test with condition (control vs. phonological pre-training) as a within-subjects variable and group (Down syndrome vs. typically developing) as a between-subjects variable. Partial eta squared effect sizes are reported for all ANOVAs, where 0.01 represents a small effect, 0.06 represents a medium effect and 0.14 represents a large effect (Cohen, 1988). There was a main effect of condition with a

Table 2
Scores on the written nonword learning, phonological choice and orthographic choice post-tests.

	Control condition				Phonological pre-training condition			
	Written nonword learning mean score (SD)[a]	Written nonword learning range	Phonological choice mean score (SD)[b]	Orthographic choice mean score (SD)[b]	Written nonword learning mean score (SD)[a]	Written nonword learning range	Phonological choice mean score (SD)[b]	Orthographic choice mean score (SD)[b]
Individuals with Down syndrome	9.50 (6.83)	0–21	3.13 (1.31)	4.06 (1.57)	15.75 (7.96)	0–24	3.56 (1.50)	4.06 (1.44)
Typically developing group matched on word reading	15.20 (7.54)	0–24	3.40 (1.45)	3.70 (1.32)	18.87 (6.01)	7–24	4.30 (1.34)	3.97 (1.56)
Typically developing subgroup matched on target decoding	10.13 (6.60)	0–20	3.13 (1.59)	3.25 (1.29)	15.63 (6.09)	7–24	4.00 (1.37)	3.38 (1.59)

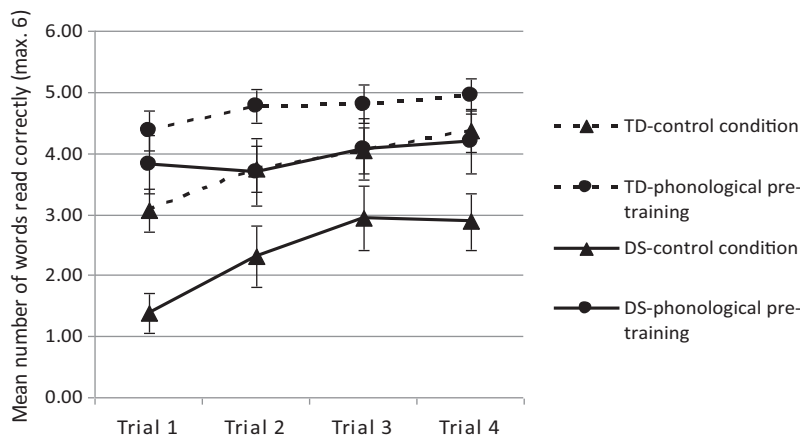[a] max. score = 24.
[b] max. score = 6.

Fig. 2. Performance of the typically developing children and children with Down syndrome during written nonword learning with standard error bars.

large effect size, $F(1, 44) = 7.85$, $p = .008$, $\eta_p^2 = .15$, due to better performance in the phonological pre-training condition. The main effect of group, $F(1, 44) = 1.95$, $p = .170$, $\eta_p^2 = .04$, and the group by condition interaction, $F(1, 44) = 0.94$, $p = .338$, $\eta_p^2 = .02$, were not significant and had small effect sizes. These results confirm that both groups had significantly better knowledge of the phonological form of the taught nonwords after the phonological pre-training.

3.3. Written nonword learning

The written nonword learning scores for both groups in the control and phonological pre-training conditions across the four learning trials are shown in Fig. 2 and the overall means are in Table 2. Individuals with Down syndrome generally performed at a lower level than the typically developing children, with both groups doing better in the phonological pre-training condition than the control condition. Learning increased across trials, although this appeared to be greater in the control condition.

A $2 \times 4 \times 2$ mixed ANOVA with condition (control vs. phonological pre-training) and trial (1–4) as within-subject variables and group (Down syndrome vs. typically developing) as a between-subjects variable was conducted. There was a main effect of condition with a large effect size due to higher scores in the phonological pre-training condition, $F(1, 44) = 59.44$, $p < .001$, $\eta_p^2 = .58$. There was also a main effect of group, with a medium effect size, as the typically developing children scored significantly better than the individuals with Down syndrome, $F(1, 44) = 4.50$, $p = .040$, $\eta_p^2 = .09$, and a main effect of trial, with a large effect size, as scores improved during the training, $F(3, 132) = 25.71$, $p < .001$, $\eta_p^2 = .57$. The interaction between trial and group was not significant, $F(3, 132) = 0.70$, $p = .552$, $\eta_p^2 = .02$ nor was the three-way interaction between condition, trial and group, $F(3, 132) = 1.28$, $p = .283$, $\eta_p^2 = .03$, and both these effect sizes were small.

There was a significant interaction between condition and trial, $F(3, 132) = 6.89$, $p < .001$, $\eta_p^2 = .26$, due to greater improvement across trials in the control condition. The effect size for this interaction was large. This was followed up with a Tukey's HSD test, with means collapsed across groups, which showed on each trial there were significantly more correct responses in the pre-training condition compared to the control condition and that the only significant difference between trials in the same condition was between trial 1 and trial 2 in the control condition (HSD = 0.51).

The predicted condition by group interaction was marginally significant, $F(1, 44) = 4.03$, $p = .051$, $\eta_p^2 = .08$ with a medium effect size; therefore this was followed up with a Tukey's HSD test. The difference between the two conditions was significant in both groups (HSD = 0.86). However there was clearly a trend towards greater effect of pre-training for the individuals with Down syndrome; for the typically developing children Cohen's $d = 0.54$, and for the individuals with Down syndrome Cohen's $d = 0.84$.

3.4. Orthographic knowledge

The orthographic choice post-test was conducted after the written nonword learning procedure to investigate whether the written form of the nonwords had been learnt. Table 2 shows the mean number of correct responses for the two groups in each condition. It can be seen that the correct answer was consistently chosen at above chance levels (score of two). Both the pseudohomophone and visual distracter were chosen at similarly low levels by both groups and in both conditions. A 2×2 mixed ANOVA on correct answers with condition (control vs. phonological pre-training) as a within-subject variable and group (Down syndrome vs. typically developing) as a between-subjects variable was conducted. Neither the main effect of condition, $F(1, 44) = 0.39$, $p = .536$, $\eta_p^2 = .01$, the main effect of group, $F(1, 44) = 0.33$, $p = .570$, $\eta_p^2 = .01$, nor the interaction between condition and group, $F(1, 44) = 0.39$, $p = .536$, $\eta_p^2 = .01$, were significant. Further, all these effect sizes were small.

3.5. Summary of results

The phonological pre-training resulted in better performance on the phonological choice post-test and improved ability to read the taught nonwords. In comparison to the typically developing group, the individuals with Down syndrome performed more poorly when reading the nonwords and there was a marginally significant trend for them to benefit more from phonological pre-training. However there was no effect of phonological pre-training or group on orthographic knowledge.

3.6. Matching for target nonword decoding skill

To test the prediction that individuals with Down syndrome would show written nonword learning performance and benefit from phonological pre-training at a level equivalent to their decoding skill, a subgroup of children from the typically developing group were individually matched to the individuals with Down syndrome on their scores on the first written nonword learning trial (first reading aloud attempt) in the control condition. This criterion was chosen as it reflects ability to decode the nonwords with no previous exposure to the spoken or written form. This resulted in 16 typically developing children (seven males) being selected who had a mean age of 6;02 matched to the 16 individuals with Down syndrome.

3.6.1. Performance on background measures

The performance of the typically developing subgroup on the background cognitive measures is shown in Table 3 along with the individuals with Down syndrome for comparison purposes. Matching on target decoding also resulted in the groups having similar scores on the standardised nonword reading test. Due to the uneven profile in individuals with Down syndrome, with word reading generally being a strength compared to nonword reading, the individuals with Down syndrome performed significantly better on the word reading measure than the typically developing subgroup. The two groups had similar scores on the picture naming task, but the typically developing subgroup performed significantly better on the remaining tasks of alliteration matching, sound deletion, matrices and word recall.

3.6.2. Phonological learning

Table 2 shows the scores for the phonological choice post-test. The mean score for the correct answer was above chance (score of two) across both conditions and groups, and was higher in the pre-training condition in both groups. Indeed a mixed ANOVA showed a main effect of condition with a large effect size, $F(1, 30) = 5.77$, $p = .023$, $\eta_p^2 = .16$, due to higher scores in the pre-training condition, but the main effect of group, $F(1, 30) = 0.26$, $p = .616$, $\eta_p^2 = .01$, and group by condition interaction, $F(1, 30) = 0.64$, $p = .430$, $\eta_p^2 = .02$, were not significant and had small effect sizes. The results from this post-test confirmed that the pre-training resulted in better knowledge of the phonological form of the nonwords in both groups.

3.6.3. Written nonword learning

The scores in the control and phonological pre-training conditions during written nonword learning are shown in Fig. 3 for both groups and the overall means can be seen in Table 2. Levels of learning were similar in the two groups in both conditions and there was a clear benefit from pre-training in both groups. As with the data from the whole sample of typically developing children, learning occurred over the training procedure but this appeared to increase at a faster rate in the control condition.

In a mixed ANOVA, there was a main effect of condition due to higher scores in the phonological pre-training condition, $F(1, 30) = 56.84$, $p < .001$, $\eta_p^2 = .66$, and the main effect of trial was also significant, $F(3, 90) = 22.06$, $p < .001$, $\eta_p^2 = .63$. Both

Table 3
Scores on all background measures for the individuals with Down syndrome and the typically developing subgroup pairwise matched on target decoding.

	Individuals with Down syndrome [a]		Typically developing children [b]		Between-group differences
	Mean (SD)	Range	Mean (SD)	Range	
Age	13;08 (2;11)	8;07-17;02	6;02 (0;07)	5;04-7;01	$t(16.15) = -10.22$, $p < .001$, $d = 3.56$
Matrices raw score (max. 29)	11.81 (4.93)	5–20	15.69 (4.84)	6–23	$t(30) = 2.24$, $p = .032$, $d = 0.79$
Matrices age-equivalent score	5;00 (1;03)	4;00-7;03	6;00 (1;02)	4;00-7;03	$t(30) = 2.24$, $p = .033$, $d = 0.83$
Single word reading raw score (max. 60)	26.44 (13.88)	4–45	16.31 (7.74)	8–37	$t(23.52) = -2.55$, $p = .018$, $d = 0.90$
Single word reading age-equivalent score	7;05 (1;06)	4;11-10;00	6;04 (0;09)	5;06-8;03	$t(21.74) = -2.52$, $p = .020$, $d = 0.92$
Nonword reading raw score (max. 20)	6.69 (5.95)	0–17	6.50 (3.03)	1–14	$U = 123.00$, $p = .850$, $d = 0.04$
Picture naming raw score (max. 30)	22.13 (4.69)	11–27	23.75 (2.89)	18–29	$U = 110.50$, $p = .507$, $d = 0.42$
Picture naming age-equivalent score	6;00 (1;06)	2;10-7;03	6;06 (0;11)	4;07-7;03	$t(24.83) = 1.09$, $p = .285$, $d = 0.40$
Alliteration matching raw score (max. 10)	7.20 (2.11)	4–10	9.25 (1.06)	7–10	$U = 51.50$, $p = .005$, $d = 1.23$
Sound deletion raw score (max. 12)	5.00 (3.16)	0–9	7.56 (2.31)	4–11	$U = 65.50$, $p = .030$, $d = 0.93$
Sound deletion age-equivalent score	5;09 (1;03)	4;00-7;07	6;09 (0;11)	5;04-7;08	$t(29) = 2.56$, $p = .16$, $d = 0.92$
Word recall raw score (max. 42)	11.81 (3.12)	7–18	18.25 (4.73)	12–32	$t(30) = 4.55$, $p < .001$, $d = 1.61$

[a] $n = 16$ except for alliteration matching and sound deletion where $n = 15$.
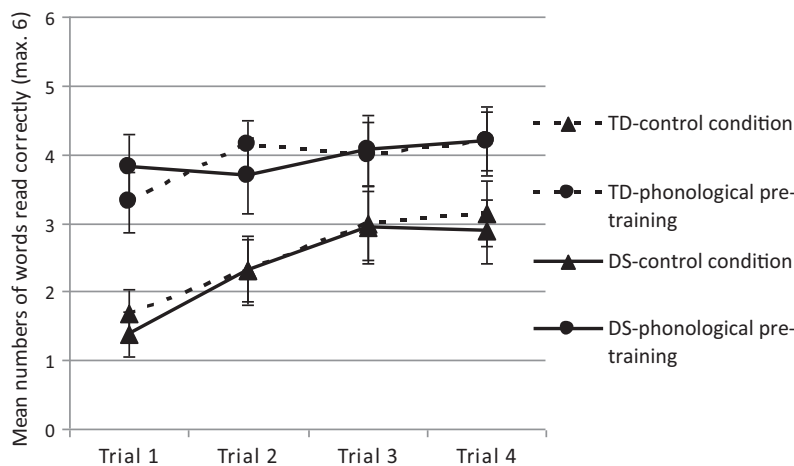[b] $n = 16$ for all tasks.

Fig. 3. Performance of the children with Down syndrome and typically developing subgroup during written nonword learning with standard error bars.

these effect sizes were large. The main effect of group was not significant and had a small effect size, $F(1, 30) = 0.01$, $p = .915$, $\eta_p^2 = .00$. The interaction between condition and trial was significant and the effect size was large, $F(3, 90) = 4.38$, $p = .006$, $\eta_p^2 = .24$, but the interactions between condition and group, $F(1, 30) = 0.23$, $p = .634$, $\eta_p^2 = .01$, trial and group, $F(1, 30) = 0.46$, $p = .711$, $\eta_p^2 = .02$, and condition, trial and group, $F(3, 90) = 1.50$, $p = .220$, $\eta_p^2 = .05$, were not significant and had small effect sizes.

The significant interaction between condition and trial was followed up with a Tukey's HSD test, with means collapsed across groups. The only significant difference either across trials within conditions or between conditions on each trial was the difference in favour of the phonological pre-training condition compared to the control condition on trial 1 (HSD = 0.93).

3.6.4. Orthographic knowledge

The results for the orthographic choice post-test are shown in Table 2. The mean number of correct answers was above chance (score of two) for both groups in both conditions, and the pseudohomophone and visual distracter were both selected at low levels. The individuals with Down syndrome appeared to be performing at a slightly higher level than the typically developing subgroup. In a 2×2 mixed ANOVA there was no significant main effect of group, $F(1, 30) = 2.55$, $p = .121$, $\eta_p^2 = .08$, although this effect size was medium. There was also no significant effect of condition, $F(1, 30) = 0.08$, $p = .786$, $\eta_p^2 = .00$, or interaction between group and condition, $F(1, 30) = 0.08$, $p = .786$, $\eta_p^2 = .00$. Both these effect sizes were small.

3.6.5. Summary of results: matching for target decoding

Phonological pre-training led to similar increases in phonological knowledge in the individuals with Down syndrome and the subgroup of typically developing children matched on decoding. The two groups were also equally accurate when reading the nonwords aloud and benefitted from the phonological pre-training to a similar extent. There was no significant difference between the two conditions or groups when individuals were required to identify the correct spelling pattern of nonwords they had learnt.

4. Discussion

Vocabulary knowledge has been proposed to play an important role in reading development for individuals with Down syndrome (Hulme et al., 2012). The present study built on these findings and findings from studies with typically developing children, which suggest that the phonological aspects of vocabulary knowledge are related to word reading skill, particularly when decoding is compromised (Duff & Hulme, 2012; McKague et al., 2001; Nation & Cocksey, 2009). Specifically this study investigated whether word level phonological knowledge provides a benefit to individuals with Down syndrome when reading new words. Compared to typically developing children matched on word reading, the individuals with Down syndrome performed more poorly during written nonword learning. Although both groups benefitted from phonological pre-training, there was a trend for this benefit to be greater for individuals with Down syndrome. When the individuals with Down syndrome were matched to a subgroup of the typically developing children on target decoding skill, written nonword learning was equated in the two groups and both groups benefitted equally from phonological pre-training. However, there was no effect of phonological pre-training on a measure of orthographic knowledge in either set of analyses.

During written nonword learning, individuals with Down syndrome were less accurate than typically developing children matched on word reading. However, as there was a trend for the typically developing children to perform better on the standardised measure of nonword reading, the two groups were not equated for baseline performance. Therefore 16 of the typically developing children were pairwise matched to the individuals with Down syndrome for target decoding. This

also resulted in the two groups being well matched on the standardised measure of nonword reading. There were no significant differences between this subgroup and the individuals with Down syndrome during written nonword learning. Thus as predicted, on the task of written nonword learning the individuals with Down syndrome performed in line with their existing decoding skill but more poorly than would be expected from their existing word reading level. This is also in line with studies with children with dyslexia (Bailey, Manis, Pedersen, & Seidenberg, 2004; Ehri & Saltmarsh, 1995).

The phonological pre-training exposed individuals to the spoken nonwords and required them to engage in activities that emphasised the individual phonemes within the nonwords. Familiarised nonwords were subsequently better recognised in a phonological choice post-test by both typically developing children and individuals with Down syndrome and as predicted, they were also read more accurately. Nonwords in the control condition were also recognised at above chance levels in the phonological choice post-test; this is likely to be because individuals had also been exposed to the phonological form of the nonwords during the written nonword learning. Phonological pre-training is argued to support reading by providing individuals with a whole-word phonological representation of the new word. This can resolve competition between the correct pronunciation and pronunciations derived from decoding the letter-sound mappings and therefore provide a pronunciation match for partial decoding attempts (Nation & Cocksey, 2009).

There was a marginally significant trend for the individuals with Down syndrome to benefit more from phonological pre-training than the typically developing children matched for word reading. In the context of the triangle model, when the phonological pathway is compromised, such as with irregular words that cannot be decoded, existing phonological knowledge is considered to have a stronger effect on reading (Nation & Cocksey, 2009). This may also be the case for children who have an impaired phonological pathway and thus may apply to all words regardless of regularity for individuals with Down syndrome. Specifically, as the individuals with Down syndrome were less able to decode the words, they would be more likely to produce partial decoding attempts that phonological knowledge could then help resolve. This between-group difference was no longer present when the individuals with Down syndrome were matched to the typically developing subgroup for target decoding. This is argued to be because the two groups now made an equal number of partial decoding attempts, therefore resulting in similar opportunities for phonological knowledge to aid performance.

Our findings support the suggestion of Taylor et al. (2011) that existing phonological knowledge about a word could be incorporated within the triangle model as item-specific phonological representations. To assess whether semantic knowledge also contributes to reading when decoding is compromised, such as with individuals with Down syndrome, the effect of semantic pre-training could be compared to phonological pre-training.

Both typically developing children and individuals with Down syndrome showed increased scores across the trials during the written nonword learning. However this improvement was greater in the control condition than the phonological pre-training condition, particularly at the beginning of the training procedure. The nature of the corrective feedback during written nonword learning may have contributed to this difference between the two conditions. For the feedback, individuals heard the correct pronunciation of the target nonword and, as suggested by the lexical quality hypothesis, this may have provided more benefit to the control nonwords as it added new phonological information to the lexical representation (Perfetti & Hart, 2002).

Previous studies that have examined the effect of phonological pre-training on written nonword learning in typically developing children have not included post-tests that specifically tested orthographic learning (Duff & Hulme, 2012; McKague et al., 2001). In the present experiment the target item was selected at relatively high levels of accuracy in an orthographic choice post-test by both groups in both conditions. Therefore the same level of orthographic knowledge was demonstrated for nonwords that received phonological pre-training and those that did not. Furthermore despite showing poorer learning, the individuals with Down syndrome showed the same level of orthographic knowledge as the typically developing sample matched on word reading. The self-teaching hypothesis posits a central role for phonological recoding, or decoding skill, in forming orthographic representations. Therefore it would predict that better performance during training (i.e. in the pre-training condition and for the typically developing children) would result in a stronger orthographic representation that would enhance performance in an orthographic choice task. It could be that the task was not sensitive enough to capture this; alternatively, repeated exposure to the orthography of the target word may have resulted in individuals creating and storing an orthographic representation of the nonword, regardless of whether they read it correctly. To test this, the orthographic choice task could be administered after the first trial of written nonword learning, when in the control condition participants will have had minimal exposure to the phonology of the word.

It should be noted that the present study assessed written nonword learning immediately after training and not in the longer term. It is clearly important both theoretically and practically to know if learning is maintained, particularly as there is some evidence that points to impairments in consolidating newly learnt skills and on verbal, visual and spatial long-term memory tasks in Down syndrome (Carlesimo, Marotta, & Vicari, 1997; Pennington, Moon, Edgin, Stedron, & Nadel, 2003; Visu-Petra, Benga, Ţincaş, & Miclea, 2007; Wishart, 1993). In a written nonword learning study with typically developing children by Bowey and Muller (2005), an orthographic choice task was administered immediately after learning and six days later, and there was significantly better performance on the immediate post-test than the delayed post-test. In future, there is a need for studies with individuals with Down syndrome to include a delayed test of written nonword learning.

There are a growing number of studies evaluating reading accuracy interventions for children with Down syndrome. Training phonological awareness, letter-sound knowledge and new vocabulary results in improvements of the directly taught skills and the reading of untaught words, although there is less evidence that this training extends to nonwords (Cologon, Cupples, & Wyver, 2011; Goetz et al., 2008; Lemons & Fuchs, 2010). In a randomised controlled trial, Burgoyne et al.

(2012) found that an intervention combining both phoneme awareness and broader oral language skills, with a large emphasis on vocabulary instruction, had a significant effect on word reading. The present study provides evidence that the phonological aspect of vocabulary knowledge may help promote reading achievement and therefore being presented with the spoken form of a new word before seeing it in print could be a valuable part of reading instruction for children with Down syndrome.

Acknowledgements

Appendix. Nonwords used in the training procedure and orthographic choice post-test

	Target nonwords	Phonetic transcription	Phonological distracter with one phoneme change	Phonological distracter with two phoneme changes	Homophone distracter	Visual distracter
Word group A	keve	/ki?v/	geve	geze	keav	kewe
	nirp	/n3?p/	nirt	mirt	nurp	nirg
	vabe	/vaIb/	vame	zame	vaib	vade
	kewf	/kju?f/	pewf	pewv	kufe	kewk
	roak	/r??k/	loak	loag	roke	roaf
	gorn	/g??n/	gord	dord	gawn	gorm
Word group B	rorb	/r??b/	lorb	lorp	rawb	rorp
	nawg	/n??g/	nawp	mawp	norg	nawy
	zale	/zaIl/	zade	vade	zail	zafe
	lirg	/l??g/	lird	dird	lurg	lirp
	joat	/j??t/	choat	choap	jote	joaf
	neam	/ni?m/	zeam	zean	neme	nean

References

Bailey, C. E., Manis, F. R., Pedersen, W. C., & Seidenberg, M. S. (2004). Variation among developmental dyslexics: Evidence from a printed-word-learning task. *Journal of Experimental Child Psychology, 87*, 125–154.

Boudreau, D. M. (2002). Literacy skills in children and adolescents with Down syndrome. *Reading and Writing, 15*(5/6), 497–525.

Bowey, J. A., & Muller, D. (2005). Phonological recoding and rapid orthographic learning in third-graders' silent reading: A critical test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 92*(3), 203–219.

Buckley, S. (1985). Attaining basic educational skills: Reading, writing and number. In D. C. Lane (Ed.), *Current approaches to Down syndrome* (pp. 315–343). London: Holt, Rinehart and Winston.

Burgoyne, K., Duff, F., Clarke, P., Buckley, S., Snowling, M. J., & Hulme, C. (2012). Efficacy of a reading and language intervention for children with Down syndrome: A randomized controlled trial. *Journal of Child Psychology and Psychiatry, 53*(10), 1044–1053.

Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisition of the alphabetic principle. *Journal of Educational Psychology, 81*(3), 313–321.

Cardoso-Martins, C., & Frith, U. (2001). Can individuals with Down syndrome acquire alphabetic literacy skills in the absence of phoneme awareness? *Reading and Writing, 14*(3/4), 361–375.

Carlesimo, G., Marotta, L., & Vicari, S. (1997). Long-term memory in mental retardation: Evidence for a specific impairment in subjects with Down's syndrome. *Neuropsychologia, 35*(1), 71–79.

Carroll, J. M. (2004). Letter knowledge precipitates phoneme segmentation, but not phoneme invariance. *Journal of Research in Reading, 27*(3), 212–225.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New Jersey: Lawrence Erlbaum Associates.

Cologon, K., Cupples, L., & Wyver, S. (2011). Effects of targeted reading instruction on phonological awareness and phonic decoding in Children with Down syndrome. *American Journal on Intellectual and Developmental Disabilities, 116*(2), 111–129.

Duff, F. J., & Hulme, C. (2012). The role of children's phonological and semantic knowledge in learning to read words. *Scientific Studies of Reading, 16*(6), 504–525.

Ehri, L. C., & Saltmarsh, J. (1995). Beginning readers outperform older disabled readers in learning to read words by sight. *Reading and Writing, 7*, 295–326.

Fowler, A. E., Doherty, B. J., & Boynton, L. (1995). The basis of reading skill in young adults with Down syndrome. In L. N. D. Rosenthal (Ed.), *Down syndrome: Living and learning in the community* (pp. 182–196). New York: Wiley-Liss Inc.

Goetz, K., Hulme, C., Brigstocke, S., Carroll, J. M., Nasir, L., & Snowling, M. (2008). Training reading and phoneme awareness skills in children with Down syndrome. *Reading and Writing, 21*(4), 395–412.

Hulme, C., Goetz, K., Brigstocke, S., Nash, H. M., Lervåg, A., & Snowling, M. J. (2012). The growth of reading skills in children with Down syndrome. *Developmental Science, 15*(3), 320–329.

Hulme, C., Goetz, K., Gooch, D., Adams, J., & Snowling, M. J. (2007). Paired-associate learning, phoneme awareness, and learning to read. *Journal of Experimental Child Psychology, 96*(2), 150–166.

Hulme, C., Stothard, S. E., Clarke, P. J., Bowyer-Crane, C., Harrington, A., Truelove, E., & Snowling, M. J. (2009). *York assessment of reading for comprehension: Early reading.* London: GL Assessment.

Johnson, C. J., Paivio, A., & Clark, J. M. (1996). Cognitive components of picture naming. *Psychological Bulletin, 120*(1), 113–139.

Jorm, A. F., & Share, D. L. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics, 4*(2), 103–147.

Kay-Raining Bird, E., Cleave, P., & McConnell, L. (2000). Reading and phonological awareness in children with Down syndrome: A longitudinal study. *American Journal of Speech-Language Pathology, 9*, 319–330.

Kumin, L., Councill, C., & Goodman, M. (1994). A longitudinal study of the emergence of phonemes in children with Down syndrome. *Journal of Communication Disorders, 27*, 293–303.

Laws, G., & Gunn, D. (2002). Relationships between reading, phonological skills and language development in individuals with Down syndrome: A five-year follow-up study. *Reading and Writing, 15*(5-6), 527–548.

Lemons, C. J., & Fuchs, D. (2010). Phonological awareness of children with Down syndrome: Its role in learning to read and the effectiveness of related interventions. *Research in Developmental Disabilities, 31*(2), 316–330.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, 1–75.

McKague, M., Pratt, C., & Johnston, M. B. (2001). The effect of oral vocabulary on reading visually novel words: A comparison of the dual-route-cascaded and triangle frameworks. *Cognition, 80*, 231–262.

McKay, A., Davis, C., Savage, G., & Castles, A. (2008). Semantic involvement in reading aloud: Evidence from a nonword training study. *Journal of Experimental Psychology: Learning, Memory and Cognition, 34*(6), 1495–1517.

Mengoni, S. E., Nash, H., & Hulme, C. (2013). The benefit of orthographic support for oral vocabulary learning in children with Down syndrome. *Journal of Child Language, 40*, 221–243.

Næss, K.-A.B., Melby-Lervåg, M., Hulme, C., & Lyster, S.-A.H. (2012). Reading skills in children with Down syndrome: A meta-analytic review. *Research in Developmental Disabilities, 33*, 737–747.

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

Nation, K., & Cocksey, J. (2009). The relationship between knowing a word and reading it aloud in children's word reading development. *Journal of Experimental Child Psychology, 103*, 296–308.

Pennington, B. F., Moon, J., Edgin, J., Stedron, J., & Nadel, L. (2003). The neuropsychology of Down syndrome: Evidence for hippocampal dysfunction. *Child Development, 74*(1), 75–93.

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. In L. T. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189–213). Amsterdam: John Benjamins Publishers.

Pickering, S., & Gathercole, S. (2001). *Working memory test battery for children*. London: The Psychological Corporation.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*(1), 56–115.

Rastle, K., Harrington, J., & Coltheart, M. (2002). 358, 534 nonwords: The ARC nonword database. *Quarterly Journal of Experimental Psychology, 55A*, 1339–1362.

Roberts, J., Steven, L. H., Malkin, C., Barnes, E., Skinner, M., Hennon, E. A., & Anderson, K. (2005). A comparison of phonological skills of boys with fragile X syndrome and Down syndrome. *Journal of Speech Language and Hearing Research, 48*(5), 980–995.

Roch, M., & Jarrold, C. (2008). A comparison between word and nonword reading in Down syndrome: The role of phonological awareness. *Journal of Communication Disorders, 41*(4), 305–318.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh: Psychology Software Tools Inc.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55*(2), 151–218.

Snowling, M. J., Stothard, S. E., Clarke, P. J., Bowyer-Crane, C., Harrington, A., Truelove, E., & Hulme, C. (2009). *York assessment of reading for comprehension: Passage reading*. London: GL Assessment.

Snowling, M. J., Stothard, S. E., & McLean, J. (1996). *Graded nonword reading test*. Bury St Edmunds, England: Thames Valley Test Company.

Taylor, J. S. H., Plunkett, K., & Nation, K. (2011). The influence of consistency, frequency, and semantics on learning to read: An artificial orthography paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*(1), 60–76.

Visu-Petra, L., Benga, O., Ṭincaş, I., & Miclea, M. (2007). Visual–spatial processing in children and adolescents with Down's syndrome: A computerized assessment of memory skills. *Journal of Intellectual Disability Research, 51*(12), 942–952.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., & Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology, 33*(3), 468–479.

Wechsler, D. (2003). *Wechsler pre-school and primary scale of intelligence* (3rd ed.). Oxford, UK: The Psychological Corporation.

Wishart, J. G. (1993). The development of learning difficulties in children with Down's syndrome. *Journal of Intellectual Disability Research, 37*(4), 389–403.