



Delays in the reading and spelling of children with cerebral palsy: Associations with phonological and visual processes



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ABSTRACT

Background: This investigation addresses the question of whether there exists a significant discrepancy in the cognitive abilities of children with cerebral palsy (CP) who, despite the presence of age appropriate communication and language, have reading and spelling delays.

Aims: We wanted to discover whether there was a relationship between the phonological and visual perceptual abilities of children with CP and their progress in reading and spelling.

Methods and procedures: Fifteen children with CP (aged between 6:9 years and 11:6 years) were assessed on reading and spelling; communication and language; non-verbal reasoning; phonological processing; and visual perception.

Outcomes and results: Ten of the children had very weak reading and spelling skills. Five children had (mostly) age appropriate scores of reading and spelling. No differences were found between these two groups in non-verbal reasoning or communication and language. However, phonological abilities, visual sequential memory and perception of visuospatial relationships were found to be related to reading and spelling.

Conclusions and implications: The findings suggest that children with CP are at risk for reading and spelling delays when they have poor phonological processing, visual sequential memory and perception of visuospatial relationships. The implications of the findings for classroom practice are discussed.

What this paper adds

The study extends knowledge of the literacy development of children with CP who can talk.

The findings about language abilities, phonological processing and visual perception support and extend previous research in children with CP. We provide additional information about the strengths and weaknesses in the children's cognitive profiles which were associated with their reading and spelling abilities.

We suggest teaching approaches which may benefit children with CP who have poor reading and spelling abilities

1. Introduction

Cerebral palsy (CP) encompasses conditions characterised by motor control impairments, paralysis, muscle and posture disorders which are typically diagnosed at birth or within two years of birth. The degree and type of impairment is variable, with the result that the group is heterogenous, and there is a taxonomy of the different types of motor impairment (Nakken & Vlaskamp, 2007). Types of

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cerebral palsy include spastic, athetoid (dyskinetic) and ataxic, and children can sometimes be affected with more than one type of CP depending on the size and location of lesion/s on the brain (Odding, Roebroek, & Stam, 2006; Rosenbaum, Paneth, Leviton, Goldstein, Bax et al., 2007). The number of children with CP is estimated to be 2.0–2.5 per thousand births, and in the majority of the cases the condition is present before birth (MacLennan, Thompson, & Gecz, 2015). Due to increased survival rates for premature and vulnerable infants the incidence may be increasing, but figures differ according to region, with areas of socio-economic deprivation having higher rates of CP per thousand births (Odding et al., 2006).

This investigation was initiated because classroom observations and assessments by the first author over a number of years suggested that many children with CP have delayed progress in reading and spelling, yet have age-appropriate communication, social abilities and progress in most school subjects. Consequently, the first aim of the project was to use several standardised literacy assessments of reading and a standardised assessment of spelling to obtain evidence concerning the existence of this discrepancy.

If a delay in reading and spelling was identified, then the secondary aim was to consider whether, in common with other children with literacy difficulties such as dyslexia (Caravolas, Hulme, & Snowling, 2001; Ehri, 2005; Frith, 1985; Snowling, 2008; Vellutino & Fletcher, 2005), children with CP have impaired phonological abilities that are related to their reading abilities. In addition, we also wished to consider whether visual and spatial perception difficulties, which are common in children with CP, were related to their reading and spelling development (see Dorman, Laatsch & Hurley, 1984).

1.1. Phonological processing abilities

Extensive research has been conducted into the nature of spelling and reading development, both in children with typical abilities and in children with reading and/ or spelling difficulties. Findings from these studies have suggested that children with literacy difficulties often have problems with phonological processing, that is the knowledge and understanding of phoneme (letter sounds) and grapheme (written letters) associations (Caravolas et al., 2001).

Difficulties with grapheme/ phoneme associations and lack of knowledge of, or poor representations of, groups of letters such as morphemes are also likely to affect the development of spelling abilities. Learning to spell may be more problematic for some children as a single letter may have more than one sound, and a number of sounds may be generated by one grapheme, e.g. ...ough (Lee & Al Otaiba, 2017). While children may be able to use context and story comprehension to aid with deciphering text, it is not possible to use these types of strategy when working out spellings. Spelling is often considered more difficult as there is the need to correctly place each letter in a sequence, whereas in reading [de-coding] children do not necessarily need to process all the letters individually (Ehri, Nunes, Stahl, & Willows, 2001; Treiman, 2018). It is argued that some severe spelling impairments can result in difficulties with reading and writing, especially in languages with opaque spelling systems such as English (Bigozzi, Tarchi, Caudek, & Pinto, 2016).

Findings from investigations into children with CP who have communication difficulties suggest that impairments in phonological processing might be related to the children's lack of verbal language, thus affecting their reading and spelling development (Bishop, Byers Brown & Robson, 1990; Card & Dodd, 2006; Hart, Scherz, Apel, & Hodson, 2007; Peeters, Verhoeven, van Balkom & de Moor, 2009; Sandberg, 2001; Sandberg & Hjelmquist, 1997). However, it cannot be assumed that all children with CP and, in particular, children with age appropriate verbal communication, will have the same profile of learning abilities as those who cannot speak, and that their cognitive abilities develop in the same way as children who are unable to speak (Berninger & Gans, 1986; Berninger and Hart, 1992; Pickering & Gathercole, 2004); the position and severity of the original brain damage may affect children in different ways (Odding et al., 2006).

In adolescents with CP (aged thirteen to nineteen years) who can speak, it has been reported that phonological discrimination was significantly, but not highly correlated with reading (Dorman, Hurley, & Laatsch, 1984; Dorman, 1987). It also has been found in a longitudinal study involving children with CP (ages five to seven years), that speech production, phonological awareness and phonological short-term memory were all significant predictors of later reading, with speech production being the strongest predictor (Peeters, Verhoeven, de Moor, & Van Balkom, 2009).

Thus, there is very good evidence that phonological abilities are related to the development of reading in typically developing children. However, there is only limited evidence about this relationship in children with CP who have typical levels of communication and language. It is possible that the use of interventions targeting specific skills may help to improve the children's phonological knowledge, (Ehri et al., 2001). Therefore, it is important to further examine the relationship between language abilities, phonological abilities, and reading and spelling in children with CP.

1.2. Visual and spatial perception

Reading usually involves the visual processing of print so that the phonological form of a word can be identified from the visual stimuli. Consequently, it is possible that delays in the development of reading and spelling could be caused by impairments to the visual system. There is evidence to support this hypothesis, as visual and spatial perception abilities are related to reading in children with typical abilities (Sortor & Kulp, 2003). It also is the case that children with lower reading abilities have a higher occurrence of visual deficits (Eden, Stein, Wood, & Wood, 1995) and perform relatively poorly on visual sequential memory (Kibby et al., 2015). Furthermore, it has been argued that deficits in visual processing impede the development of reading and spelling (Stein & Walsh, 1997), although other researchers have disagreed with these claims (Vellutino & Fletcher, 2005).

Studies of eye movements (Kozeis et al., 2006), and convergence (Jackson, Castleberry, Galli, & Arnoldi, 2006) in children with CP indicated that 81% and 45% respectively had problems with visual coordination. A high percentage of these disturbances appears

to involve the muscles in and around the eye which can affect fixation, convergence and focusing (Kozeis & Jain, 2018). Related to this issue, many children with CP have impaired visual perception (Ego, Lidzba, Brovedani, Belmonti, Gonzalez-Monge et al, 2015).

There also is evidence of impairments to the perception of visual orientation being related to reading. Adolescents with CP who can speak were found to have quite severe impairments in visuospatial organisation involving orientation and direction on clock face and compass tasks; and also, with the visualisation of three-dimensional space (Dorman, Laatsch, & Hurley, 1985; Dorman et al., 1984; Dorman, 1987). Visual impairments such as these may affect the ability to scan letters in written words and sentences (Schuett, Heywood, Kentridge, & Zihl, 2008). Thus, there may be important relationships between visual processes and reading, however, there are uncertainties about the presence of these relationships, (Dorman et al., 1984, 1985; Dorman, 1987; Sandberg & Hjelmquist, 1997). The present investigation builds on these previous research findings by assessing a range of visual and spatial perception abilities.

1.3. Summary

Research into the literacy abilities of children with CP, who can speak, are very limited in number and have conflicting findings. The present study was conducted to provide additional and up-to-date research in an investigation of whether pre-adolescent children with CP have impairments in reading (decoding) and spelling, despite having typical levels of communication and language. A further aim of this study was to examine whether verbal and non-verbal abilities, phonological processes and visual-spatial perception abilities were related to the children's reading and spelling.

2. Methodology

2.1. Participants

Fifteen children with CP aged between 6:9 years and 11:6 years, from two special schools, were chosen by their head teachers in consultation with the researchers (see Table 1). The children had to meet specific criteria in order to be able to access all the assessments without the need for any specialised equipment, e.g. communication devices. They had to have the ability to speak verbally and understandably; have typical hearing and eyesight (with glasses if necessary); and work at typical, or just below typical levels in most school subjects. Out of approximately sixty children with CP across the two schools, fifteen children were selected by their teachers to take part in the study. The other children were either unable to clearly verbalise or the nature of the CP was too severe for them to manually access tests by pointing.

In the UK, children are formally assessed at the age of 7 years at the end of Key Stage 1 which covers the 5–7 years age group and at the end of Key Stage 2 which covers the 7–11 years age group. Assessments from the results of Key Stage 1 Science tests were obtained for children below 11 years, and, results of the statutory tests at Key Stage 2 were obtained for the three children over the age of 11 years. Table 1 shows that the younger children generally were working between Levels 1 and 2 or at Level 2 at the age of six to seven years, which is just at or below the standard expected for their age, but still within the typical range. The older children achieved Level 4, the expected standard in mainstream schools, apart from Rob who achieved Level 3. However, his score would still be considered within typical ranges in a mainstream school.

Table 1
Information about the fifteen children in the study (ordered by age).

Names (changed for confidentiality)	Age at start of testing	Type of CP or description	**Science KS1 assessment	***Science KS2 SAT results	Comments
Ian	6y 9m	Athetoid: all limbs	Level 2		Occasional stammer
Will	6y 11m	Spastic hemiplegia	Level 1		
Jon	7y 1m	Hypotonic and poor coordination	No information		
Harry	7y 3m	Spastic quadriplegia	Level 1-2		Slow speech
Linda	7y 10m	Spastic quadriplegia	Level 1-2		
Cleo	8y 8m	*Wheelchair user	No information		
Joe	8y 11m	Spastic quadriplegia	Level 2		Slow speech
Garth	9y 3m	*Athetoid-like CP	No information		
Beth	9y 7m	Spastic quadriplegia	Level 2		
Lee	9y 8m	Spastic quadriplegia	Level 2		Slow speech
Lewis	9y 9m	*Wheelchair user	No information		
Chris	10y 0m	*Extreme stiffness	No information		
Amy	11y 4m	Spastic hemiplegia		Level 4	Slow speech
Emma	11y 5m	Spastic hemiplegia		Level 4	Selective mutism
Rob	11y 6m	Spastic quadriplegia		Level 3	

* No medical information available.

** Typical Level at Key stage 1 (KS1) is Level 2 (teacher assessment).

*** Typical level at Key stage 2 (KS2) is Level 4 (marked externally).

2.2. Ethical considerations

As the study consisted of children with predominantly spastic or dyskinetic CP (many of whom were affected in all four limbs), special attention was paid to the ethical guidelines of the British Educational Research Association ([British Educational Research Association \(BERA\), 2008](#)). To ensure that the children did not become too tired or were in discomfort, so testing sessions were kept short (usually lasting 20–30 minutes) and were held in a quiet room close to the children's classrooms. The tests were held at a suitable-height table to ensure the children were comfortable particularly when reading or writing or they used a table attached to their wheelchairs. They were reminded at the beginning of each testing session that they could stop at any time. Letters giving informed consent were signed by the children and their parents, and approval was given by the head teacher and the school governors.

2.3. Materials: the assessments

The materials were especially chosen to enable the children to access the tests. Although two of the reading tests and the spelling test were timed, in all cases the children completed these tasks and did not appear to need additional time; this was despite a number of the children having slower speech. However, their slower speech may have affected the scoring on the timed rapid naming task (see below).

2.3.1. Reading and spelling tests

The following tests were employed to assess the children's literacy abilities. Each test was especially chosen for ease of access for the children. In all the assessments the children's performance can be calculated as percentile scores which takes account of differences in age and enables comparisons to be made of performance on different assessments.

2.3.1.1. Decoding. This test of decoding is the One Minute Reading Test from the Dyslexia Screening Test, Junior [DST-J], ([Fawcett & Nicolson, 2004](#)) and is commonly used in schools. The child has a practice of reading six words in a list and then is asked to read from a card made up of four columns each containing thirty words. The scoring is one mark for each word correctly read within the time limit.

2.3.1.2. Sentence reading. This assessment from the Salford Reading Test ([Vincent & Crumpler, 2002](#)) is an untimed assessment made up of sentences, which are graded and marked in reading ages. Children are asked to read the sentences and any words that are incorrectly read are marked as errors. After six mistakes the child is asked to stop, and the reading age is scored from the final mistake.

2.3.1.3. Nonsense passage reading. This assessment was from the DST-J. The test has non-words, which are phonologically plausible, placed within a passage or sentence which otherwise makes sense. The reading is timed to be completed within three minutes and discontinued at the end of that time, or if the child is unable to read five consecutive words. The scoring is one mark for each correct real word and two marks for each non-word with a plausible pronunciation, or one mark for a close approximation.

2.3.1.4. Non-word decoding. This untimed assessment of non-word decoding is from the Thames Valley Test Company (TVTC) Graded Non-word reading test ([Snowling, Stothard, & McLean, 1996](#)). The children are asked to read out loud a list of phonologically plausible non-words. The total number of correctly read words is calculated.

2.3.1.5. Spelling. This assessment was from the Two Minute Spelling Test from the DST-J. The test consists of eight single syllable words for younger children (6:5-9:4 years) while the second test for older children consists of twenty-four words of increasing complexity with up to five syllables. The younger children can continue with the test if successful in their spellings. As some of the children would be disadvantaged in this test due to their handwriting difficulties, the children were able to choose whether they wanted to handwrite, type or verbalise their spellings.

2.3.2. Non-verbal reasoning and assessments of communication/language

2.3.2.1. Non-verbal reasoning. Non-verbal reasoning was assessed using Raven's Standard Progressive Matrices (RPM) ([Raven, Raven, & Court, 2008](#)). This test has five sections, each involving twelve problems relating to images and shapes in which the problems become progressively harder.

2.3.2.2. Communication abilities. The children's general communication abilities were assessed using the Children's Communication Checklist (CCC2) ([Bishop, 2003](#)). The test is made up of two sections: one containing fifty statements relating to difficulties with communication; and another section of twenty statements relating to strengths with communication. Each statement has to be marked with a number which best describes the child's the child's communication ability. The questionnaire was completed by the first author with the help of school staff where necessary.

2.3.2.3. Receptive vocabulary. This assessment from the DST-J was used to measure receptive vocabulary in a multi-choice format. The child has to pick out one picture from four that most clearly matches a given word. The scoring is a mark for each correct picture

with a maximum of 16 marks.

2.3.2.4. Semantic abilities. The Mill Hill Vocabulary Scale (Raven et al., 2008) assesses semantic abilities and consists of two sections. In the first section the children were asked to explain the meanings of words and, in the second section, to select the correct synonym from the provided words. In all cases, the test was given orally so that children who were unable to read or write were not disadvantaged, therefore caution must be exercised when interpreting the percentile scores.

2.3.2.5. Semantic fluency. This is a test from the DST-J which assesses children's ability to write as many names of things within a semantic category such as food in the practice trial, or animals in the main test. The time is limited to one minute and the scoring is one mark for each valid animal's name. Due to the difficulties that most of the children had with writing, all of the children dictated their answers, so that caution must be exercised when interpreting the children's percentile scores.

2.3.3. Phonological assessments

There were two assessments of phonological awareness involving phonemic segmentation and phonemic fluency as well as a rapid automatic naming test which is sometimes considered an assessment of phonological abilities (Hulme & Snowling, 2009). All of the tests require oral answers.

2.3.3.1. Phonemic segmentation. The phonemic segmentation test from DST-J was utilised to identify whether children were able to manipulate phonemes or syllables in common words. The test consists of a list of twelve words which are manipulated in different ways, starting with easy manipulations, e.g. what is left of the word football if ball is taken away?

2.3.3.2. Phonemic fluency. The phonemic fluency test was taken from DST-J and involves asking the child to name as many words as possible beginning with a single letter 's', within a minute, after doing a practice test. The scoring is one mark for every correct word which is not repeated.

2.3.3.3. Rapid naming. This test from DST-J consists of a card with 40 images of common objects, for example, book, boat, tree; in which the first twenty images are repeated on the second half of the card. The scoring takes into account the length of time taken in seconds, any mistakes made, for which five seconds is added for each one, and an additional ten seconds is added if the child needs a card to help keep their place along the rows.

2.3.4. Visual and spatial perception assessments

The Test of Visual-Perceptual Skills-3, TVPS-3 (Martin, 2006) is an assessment commonly used by occupational therapists in the UK. It has been used in many research studies about people with cerebral or ocular impairment (e.g. Kibby et al., 2015). It consists of seven subtests which are individually scored and also provides an overall percentile score from all of the seven subtests. Each subtest is described below.

2.3.4.1. Visual memory. This is the ability to remember an image within a short space of time. The test consists of an image shown on one page for five seconds. The page is turned, and the child has to choose the image they have seen from four shapes.

2.3.4.2. Visual sequential memory. The test requires the child to remember a set of common geometric forms. The child is shown a set of images, e.g. circle, triangle, square, the page is turned, and then the child has to select the same grouping of shapes from a series of four.

2.3.4.3. Visual spatial relationships. The test requires a child to look at a series of five shapes on a page. One of the shapes is slightly different, e.g. it may be facing the opposite way. The child has to identify the odd one out.

2.3.4.4. Visual discrimination. Visual discrimination is the ability to distinguish between similar and dissimilar shapes, colours, patterns, forms, and their positioning. The test requires a child to match one shape at the top of a page with one of the five shapes at the bottom of a page.

2.3.4.5. Visual form constancy. This is the ability to recognise and remember shapes, objects and forms by their particular characteristics. One shape is presented in the top half of the page. The child has to select the same shape from five images in the bottom half of the page which involve the first shape being rotated or disguised in some way.

2.3.4.6. Visual figure ground. This is the ability to perceive an image which is hidden against a background. The test requires a child to look at a shape at the top of a page. Underneath are four images; the child has to select the one which has the same shape embedded within other patterns.

2.3.4.7. Visual figure closure. Visual closure is the ability to identify or fill in, mentally, an incomplete image. The test requires a child to look at an incomplete image and identify the completed form from four images on the same page.

Table 2
Percentile scores of reading and spelling (percentile scores within the typical range are shown in bold).

Reading Group and Name	Decoding	Sentence Reading	Non-word Decoding	Nonsense Passage Reading	Spelling
Readers					
Ian	70	58	60	75	43
Lewis	43	40	75	73	26
Beth	27	26	25	65	25
Garth	16	32	1	40	8
Joe	9	30	50	21	9
Non-Readers					
Harry	7	7	1	13	25
Emma	3	1	4	30	6
Cleo	2	6	1	4	5
Linda	2	1	1	1	5
Amy	2	4	1	5	5
Chris	1	5	9	5	7
Rob	1	4	15	4	7
Lee	1	1	3	2	5
Jon	1	5	0	1	8
Will	1	1	1	1	5
Mean	12.4	14.7	16.87	22.7	12.6
SD	19.98	17.89	24.58	27.6	11.5
scores > 24	3	5	4	5	4

2.3.4.8. *Visual perception total score.* An overall percentile score was calculated from the seven subtests.

3. Results

The percentile scores of each child were calculated and used to investigate the relationship between cognitive abilities and reading. A percentile score of below 25 is usually considered as indicating that a child's ability is appreciably below those of typically developing children, and this is the reason why this particular score is referred to when reporting the data. A descriptive approach was utilised in this investigation wherein individual scores are displayed in tables which allows the consideration of individual differences, an approach used by Snowling (2008). In cases where inspection of the data suggested a possible relationship between an assessment with reading and spelling, non-parametric correlations were calculated (Spearman).

3.1. Reading and language abilities

Table 2 shows the children's percentile scores for reading and spelling, approximately ordered according to these abilities, with the most able readers and spellers at the top of the table. The three most able children all had percentile scores on all four assessments above 25, the next two children had percentile scores on two of the tests above 25. These five children appeared to have age appropriate reading and will be referred to as *readers*. Of the remaining children, two had only one percentile score above 25 on the assessments (Harry and Emma), the other eight children had no percentile scores above 25. These ten children are referred to as *non-readers*. The reading and spelling abilities of the ten non-readers were extremely low; most of these children had percentile scores below 10 and many of the scores were just 1. Two of the five readers had low spelling scores and in general their spelling was worse than their reading.

Table 3 concerns assessments of non-verbal reasoning, communication and language abilities. As in the previous table, the children are ordered according to their reading and spelling abilities, and this order is the same in all subsequent tables. The table shows that all the readers and the non-readers had percentile scores of non-verbal reasoning below 26. This suggests that all the children had low non-verbal reasoning abilities, even those who had age appropriate reading (Joe had the highest percentile of non-verbal reasoning and this was 25). There were no significant correlations between the RPM and the five assessments of language and communication.

The very low percentile non-verbal reasoning scores of all the children on the RPM contrasts with the language assessments. All the readers had percentile scores above 25 on the language assessments, except for one child on one of the assessments. All the non-readers had at least one percentile score on a language assessment that was above 25 with at least one other score that was above 20, and 5 of the 10 non-readers had three percentile scores on these 5 tests above 25. Thus, language abilities did not appear to be related to reading and spelling. This was confirmed by the absence of significant correlations between the language assessments with reading and spelling. The only correlation to approach significance was between the semantic fluency test and the Salford Reading Test ($r = 0.46, p < .083$), suggesting that the children's categorical understanding may have helped their ability to decode sentences.

These findings reveal a notable discrepancy between the scores from RPM and the language assessments. The percentiles for non-verbal reasoning indicated that all the children had very poor non-verbal reasoning, while the language assessments suggested that the same children had adequate or above average communication and language abilities. The findings also indicated that neither non-

Table 3

Percentile scores from the assessments of verbal and non-verbal ability (scores above 24 are in bold).

Reading Group and Name	Non-verbal Reasoning	Communication abilities	Receptive vocabulary	Semantic abilities	Semantic Fluency
Readers					
Ian	0.1	95	8	25	30
Lewis	5	70	65	84	95
Beth	0.4	84	50	37	25
Garth	9	45	25	37	35
Joe	25	52	50	63	95
Non-readers					
Harry	0.1	74	50	50	20
Emma	1	21	55	9	8
Cleo	5	60	22	16	75
Linda	5	70	25	37	25
Amy	0.1	18	40	37	91
Chris	0.1	10	15	25	15
Rob	1	74	20	16	10
Lee	1	79	65	37	50
Jon	0.1	9	22	25	22
Will	0.1	82	30	50	20
Mean	3.53	56.21	36.13	36.53	41.07
SD	6.52	28.9	18.5	19.5	31.86
scores > 24	1	11	10	12	9

verbal reasoning nor the language assessments clearly discriminated between readers and non-readers.

3.2. Phonological abilities, reading and spelling

If phonological abilities affected the children's literacy abilities, one might expect the readers to have better phonological abilities than the non-readers, and phonological abilities would be correlated with reading and spelling abilities. Table 4 provides information about the children's percentile scores on the three assessments relating to phonological abilities. In the case of the assessments of phonemic segmentation and phonemic fluency, four of the five readers had percentile scores on both assessments above 25, whereas only two of the ten non-readers had a percentile score on one of these assessments that was above 24. Consequently, as might be expected, the readers had better phonological abilities on these two assessments than the non-readers. For rapid naming, which is likely to assess other abilities in addition to phonology (Messer, Henry, & Nash, 2016), the difference between the percentile scores of the readers and non-readers was less marked. Two of the five readers had percentiles above 25 on rapid naming, and two of the 10 non-readers had percentile scores above 25, with most of the non-readers having percentile scores below 8.

The correlations (Spearman) between phonemic segmentation with the five tests of reading and spelling were: decoding, $r = 0.59$,

Table 4

Percentile scores from three tests related to phonological abilities (scores above 24 are in bold).

Reading Group and Name	Phonemic segmentation	Phonemic Fluency	Rapid Naming
Readers			
Ian	80	30	1
Lewis	65	35	61
Beth	6	55	15
Garth	35	2	9
Joe	35	55	45
Non-Readers			
Harry	6	10	5
Emma	10	3	95
Cleo	10	50	8
Linda	1	2	1
Amy	15	10	4
Chris	35	10	2
Rob	4	8	1
Lee	5	13	1
Jon	8	3	30
Will	5	10	1
Mean	21.3	19.7	18.6
SD	24.1	19.8	27.9
Scores > 24	5	5	4

Table 5
Percentile scores of visual and spatial perception (scores above 24 are in bold).

Reader's Group and name	Visual memory	Visual sequen memory	Spatial relation	Visual disc	Form const	Figure ground	Figure close	Total VP
Readers								
Ian	0	37	50	2	0	2	0	3
Lewis	2	37	25	5	0	0	2	4
Beth	1	47	1	1	1	8	3	2
Garth	50	25	95	9	2	5	5	19
Joe	27	55	66	79	32	82	88	68
Non-Readers								
Harry	0	0	0	0	0	0	0	0
Emma	55	12	73	5	10	27	1	7
Cleo	1	9	9	2	5	9	1	18
Linda	1	8	1	1	4	53	1	1
Amy	0	0	0	0	0	1	16	0
Chris	9	25	2	1	0	0	0	1
Rob	1	1	1	1	1	1	1	0.1
Lee	1	1	1	1	14	8	1	6
Jon	2	9	5	5	0	25	0	3
Will	0	0	0	1	0	0	16	0
Mean	10	17.7	21.9	7.53	4.6	14.73	9	8.8
SD	18.61	18.86	32.4	19.92	8.66	23.71	22.5	17.47
Score > 24	3	6	5	1	1	4	1	1

$p < .05$; sentence reading, $r = 0.74$, $p < .01$; non-word decoding, $r = 0.42$, *n.s.*; nonsense passage reading, $r = 0.72$, $p < .01$; and spelling, $r = 0.54$, $p < .05$. Phonemic fluency had only one significant correlation with non-word decoding, $r = 0.54$, $p < .05$.

3.3. Visual and spatial perception

If visual and spatial perceptual abilities were an influence on these children's reading and spelling then it might be expected the readers would have higher percentile scores on these assessments than the non-readers, and that visual perception abilities would be significantly correlated with reading and spelling.

Table 5 shows that for two of the subtests, involving visual sequential memory and spatial relationships, the five readers all had percentile scores above 25 (except in one instance), and the non-readers generally had very poor scores on these two tests. In addition, both the assessments of visual sequential memory and spatial relationships were significantly correlated with reading and spelling abilities; visual sequential memory had significant correlations with all the tests of reading and spelling: decoding, $r = 0.63$, $p < .05$; sentence reading, $r = 0.67$, $p < .01$; non-word decoding, $r = 0.62$, $p < .05$; nonsense passage reading, $r = 0.67$, $p < .01$; spelling, $r = 0.63$, $p < .05$. The test of visual spatial relationships had one significant correlation with the nonsense passage reading test ($r = 0.52$, $p < .05$). These findings suggest that visual sequential memory and visual spatial abilities were related to reading and spelling abilities in this sample of children. A very different set of findings occurred for the remaining five tests, the percentile were very low and there did not appear to be any notable difference of the percentile scores for the readers and non-readers.

4. Discussion

4.1. Language, non-verbal reasoning, reading and spelling

The assessments confirmed that many of the children had difficulties with reading and spelling. Out of the fifteen children, only five scored above the twenty-fifth percentile on most of the reading and spelling tests, the other ten children had very low percentile scores.

The scores from a range of tests of general language and communication abilities confirmed that most readers and non-readers had age-appropriate communication and language, with all the children having a percentile score of 25 or above on at least one of the four tests. These results replicate previous findings which suggest that children with CP can have language abilities appropriate to their chronological age (Bishop, Brown, & Robson, 1990). Differences between the children's language abilities may be because of the heterogenic nature of CP (Rosenbaum et al., 2007) and reflect the divergence of the site of the original brain trauma, together with differences in the focus of the four assessments. It is worth mentioning that eight of the children had hesitations or slowness of speech (see Table 1), including four out of the five best readers.

The fact that the children had age appropriate language and communication, but only a minority had age appropriate reading suggests that general language and communication was not influential in the determination of reading or spelling abilities. This interpretation was supported by the lack of significant correlations between the language ability tests and reading and spelling.

The children were also given the RPM test to assess their non-verbal reasoning. Fourteen of the fifteen children had percentile scores of 5 or below on this test, the exception was Joe who scored at the 25th centile. In previous research in children with CP who

have age appropriate communication it has been reported that scores of non-verbal reasoning on the RPM can be age appropriate (e.g. Asbell, Donders, Van Tubbergen, & Warschausky, 2010), but in other research similar discrepancies in children with severe speech impairment have been reported (Berninger & Gans, 1986). Our findings suggest that the fifteen children in our sample had very poor non-verbal reasoning abilities which were comparable to children with moderate/severe learning difficulties. Scores at these levels might be expected to result in poor reading and spelling abilities (and poor language and communication). However, even the five readers had low percentile scores on this assessment, suggesting that poor scores were not necessarily associated with poor reading or spelling (or in poor language and communication). Furthermore, we failed to find significant correlations between non-verbal reasoning with reading and spelling, although it should be acknowledged that there was restricted variance in the non-verbal reasoning measure. In previous research involving children with CP who have age appropriate receptive vocabularies and age appropriate scores on Raven's Coloured Progressive Matrices, the latter was found to be a significant predictor of reading comprehension abilities (Asbell et al., 2010).

Thus, the children in this sample had age appropriate communication and language, a minority had age appropriate reading and spelling, and all had very low scores on non-verbal reasoning. These findings suggest that age appropriate communication and language were not sufficient to enable children to have age-appropriate reading and spelling. This is surprising as research with other groups has found that general language abilities are related to reading (Byrne, 2005; Hulme & Snowling, 2009). In addition, the low scores of non-verbal reasoning were a surprise given that most children had age appropriate communication and some children with very low scores of non-verbal reasoning had age appropriate reading and spelling. However, although the RPM is considered an assessment of non-verbal abilities, it contains images and patterns that may require typical visual perception abilities. The test was utilised in studies involving children with CP as a visual perception assessment (Critten, Campbell, Farran & Messer, 2018; Ego et al., 2015). In our study, Joe was the only pupil who scored at the 25th centile on the RPM and he was the only pupil who scored at typical levels across all the visual perception tests. We return to this issue later in the discussion.

4.2. Relationships between phonological processes and visual perception with reading and spelling

We were interested in examining whether phonological processes and visual perception were related to reading and spelling. An examination of phonologically related abilities (phonemic segmentation, phonemic fluency and rapid naming) revealed relationships between the assessments of segmentation and phonemic fluency with reading and spelling. Most readers had percentile scores on these two assessments above 25, and most non-readers had percentile scores below 25. Furthermore, there were significant correlations between phonemic segmentation in relation to four of the five assessments of reading and spelling, and a significant correlation between phonemic fluency and non-word decoding.

Research involving children with typical development indicates that phonological abilities predict reading success, (Hulme & Snowling, 2009; Nunes, Bryant, & Bindman, 1997). In children with reading difficulties such as dyslexia, one of the main causes is considered to be an impairment in phonological processing (Ehri, 2005; Snowling, 2008; Vellutino & Fletcher, 2005), and investigations into children with CP have provided similar results (Bishop et al., 1990; Sandberg & Hjelmquist, 1997). Consequently, the impaired phonological abilities of the non-readers could be a reason for their poor reading and spelling, although even the better readers had low scores in some of the tests, e.g. Ian, Beth and Garth who had low rapid naming scores. Ian and Garth both have slow speech which may have been a factor in their verbal production of names of images and may have affected the scores of some of the non-readers too.

Without the ability to effectively discriminate between phonemes as demonstrated in the literacy tests and the phonemic segmentation test, it is likely that the poor readers had difficulties linking the letters with specific sounds, or the ability to hold these representations in memory (McBride-Chang, 1995) and this impaired their progress (see Dorman, 1987; Dorman et al., 1985). It also is possible that the lack of progress with reading may have contributed to the low levels of phonological abilities as it is suggested that experience of reading helps to develop phonological awareness (Caravolas et al., 2001; Hulme & Snowling, 2009).

All of the non-readers could spell some of the initial eight single-syllable words in the spelling test. Although there was a two-minute limit on the spelling test, this did not affect the scoring as the non-readers were not able to successfully spell beyond those eight words. The eight single-syllable words were made up of three or four letters with a mixed order of vowels and consonants (V and C), e.g. some words were spelt CVCC or CCVC. The children needed to be able to sound out the letters of the words to spell them, which they were able to achieve by using a sounding-out strategy letter by letter (see Treiman, 2018). However, some of the words, e.g. day were not phonologically regular and the children made errors with the vowel sound or missed out a consonant, e.g. the 'y' in 'day' (see Kessler & Treiman, 2001). The children's difficulties with the spelling test may be linked to their inability to identify the segmented sounds in the phonemic segmentation task, in that they were unable to process the individual sounds verbally or by sight when spelling; or were insufficiently aware of morphemes or common orthographic units at this point in their spelling development (Caravolas et al., 2001; Treiman, 2018).

There has been discussion of the possibility that problems with the processing of visual information could be responsible for the reading difficulties of some individuals with dyslexia (Vidyasagar & Pammer, 2010). This has been a controversial topic with disputes about whether or not a visual processing deficit results in literacy difficulties in these children (Stein & Walsh, 1997; Vellutino & Fletcher, 2005). However, there is evidence that visual perception is related to academic achievement involving decoding and maths in a mainstream school sample (Sortor & Kulp, 2003). This latter study indicates that, in young kindergarten-age children, there are significant correlations between visual perception and early reading skills such as: the accurate visual perception of letters, phonemes, sight words, numbers, and the visual memory of letters.

The overall scores from the majority of the visual perception sub-tests show that, in common with other researchers' findings (Arp

& Fagard, 2005; Dorman, 1987; Kozeis & Jain, 2018), the children with CP had severe difficulties with visual and spatial perception. For the majority of the visual tests the children had percentile scores below 25, and often below 5. Joe was the only child to have scores in the typical range across all the sub-tests. This indicates severe visual perception difficulties in this group of children; an important consideration for practitioners and teaching professionals.

Even the children with typical or near typical literacy abilities had low percentile scores on the following tests: visual discrimination, form constancy, figure ground, and figure closure. This suggests the visual abilities assessed by these tests were not contributing to the children's literacy abilities. However, there were important exceptions to the very low visual perception abilities in the five children who were readers. The more able readers had percentile scores on two tests that were at or above 25: visual sequential memory and visual spatial relationships (except for one test with one child), whereas for the non-readers there were only two instances when the percentile scores on these two tests were at 25 or above. In addition, the percentile scores for visual sequential memory were significantly correlated with the scores for all five of the assessments of reading and spelling, and the percentile scores for visual spatial relationships were significantly correlated with nonsense passage reading. It seems likely that a very poor memory for the sequence of shapes affects the ability to remember a series of letters, or grapheme/phoneme correspondences, that makes up a word (see Snowling, 1987); as a result the development of reading could be delayed. The potential importance of the memory for sequences, rather than single shapes (i.e. visual memory), is apparent from the finding that the latter form of memory was not related to the children's reading and spelling.

In relation to the findings about visual spatial relationships it seems likely that very poor memory of the orientation of shapes affects the ability to store precise information about the letters contained in a word and thereby impairs progress with the development of reading. Furthermore, as many words in English are not phonologically regular, readers need to rely on the visual recognition of these words to help them to decode and, indeed, to spell; and impairments to visual sequential memory and visual relationships could affect this process. Therefore, it would appear that visual sequential memory and the perception of spatial relationships might be essential for the typical development of literacy abilities in children with CP. These findings also raise the question of whether, in other groups of children, very poor visual sequential memory and poor visual spatial relationships could be contributing factors to literacy impairments; it is unlikely that such visual difficulties are detected in the classroom by teachers.

It is useful to consider our findings about phonological processes and visual perception in relation to the dual model of reading (Coltheart, 2006) in which a direct route involves matching the text of a word to an item in the visual lexicon which is connected to phonological representations of the word; in this way visual representations in long term memory allow the text of these words to be spoken. The indirect route involves translating letters into phonological representations so that the letters in words can be 'sounded out'; in this way a student can read non-words. The latter process is thought to depend on phonological awareness so that a precise match can be made between letters and phonemes when learning to read (Hulme & Snowling, 2009). The non-readers in the present study had very poor visual sequential memory and very poor phonological awareness, which suggests that both of the dual routes could have been impaired in these children. As a result, they would be expected to have limited abilities to process and remember letters when learning to read and this would make it more difficult to develop a visual lexicon, and the children's limited phonological segmentation abilities would make it more difficult to form phoneme/grapheme associations when learning to spell or acquire the phonological form of new words (see Sandberg, 2001; Dorman et al., 1985). In contrast, the children with CP who had age appropriate reading also had age appropriate phonology and visual sequential memory. Consequently, our findings suggest that the very poor progress in reading and spelling by many children with CP who have age appropriate language and communication abilities could be due to difficulties with both of the dual routes into reading.

When interpreting the findings from the present study, it is important to note that it was small in scale and as a consequence caution should be exercised in generalising the findings to other groups of children with CP. However, the relatively small size of the group enabled a detailed analysis of individual profiles. There was no control group employed in this research partly because of the difficulty of matching children with an uneven profile of abilities to a group of children with typical development, and because it was possible to use percentile scores to assess whether or not the children were performing at an age appropriate level.

5. Implications for teachers and clinicians

The results from the assessments suggest that the poorer readers in the study are impaired in two main areas which affect their reading and spelling abilities: phonological awareness and visual and spatial perception, particularly visual sequential memory. Many teachers use a phonological approach to teaching literacy in schools in the UK and, although these approaches were utilised in the teaching of these children, many of the children were delayed in their literacy development. It is possible that impairments to visual and spatial perception may have impeded the children's learning of letter-sound correspondences; knowledge of shapes of letters and sequencing of letters. There appears to be few evidence-based educational techniques to improve visual and spatial perception abilities but there are approaches which are recommended by occupational therapists for classroom use (see Poole Hospital: Children's Therapy Service, 2018), and it would be useful to evaluate the effectiveness of this approach with children with CP. Additionally, it has been found that verbalising visual stimuli may help with the perception and identification of patterns and sequences (Brown & Wesley, 2013), for example, saying the colours of a pattern may enable the children to perceive the order more readily creating a sensori-motor link that facilitates memory retention. At present, because of the emphasis on the teaching of phonics to develop literacy skills (see, e.g. Johnston, McGeown, & Watson, 2012) many teachers are unaware of any link between visual and spatial perception difficulties and possible detrimental effects on the learning of literacy skills in children with CP, and it is possible that other children with reading disorders may be similarly affected.

5.1. Conclusion

This study examined the literacy abilities of a group of 15 children with CP who had age-appropriate communication and language of whom two-thirds had impaired reading and spelling and a third had age appropriate reading and spelling. Utilising a number of phonological and visual and perceptual assessments enabled a comparison of the strengths and weaknesses of the better readers and those who were very poor at reading and spelling. The better readers were more able at phonetic segmentation, involving the chunking or deletion of syllables from words, which suggests that phonological awareness abilities are an influence on reading and spelling in children with CP, a finding similar to those in children with dyslexia and with typical development. The majority of the children had very poor visual and spatial perception, with an important exception that the children who could read had age-appropriate percentile scores of visual sequential memory and spatial relationships. These findings provide a new perspective on the education of children with CP, particularly in relationship to the development of literacy skills, and suggest new methods, including the teaching of visual sequential memory and visual spatial relationships, are needed to help support their reading and spelling.

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