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The immediate and longer-term effectiveness of a speech-rhythm-based reading intervention for beginning readers

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Despite empirical evidence of a relationship between sensitivity to speech rhythm and reading, there have been few studies that have examined the impact of rhythmic training on reading attainment, and no intervention study has focused on speech rhythm sensitivity specifically to enhance reading skills. Seventy-three typically developing 4- to 5-year-old children were randomly allocated to one of three treatment groups and received a speech-rhythm-based intervention, a phonological-awareness-based intervention, or a control intervention over 10 weeks. All children completed pre-test, post-test and delayed post-test measures of speech rhythm sensitivity, single-word reading, phonological awareness and vocabulary. The results show that it is possible to train speech rhythm sensitivity in this age group and that children who undertook the speech rhythm intervention showed a significant improvement in their word reading performance compared to children in the control group. Group differences were maintained 3 months later.

A robust relationship between segmental phonological awareness (PA) (awareness of, and the ability to manipulate, the individual units of sound in speech) and reading performance has been demonstrated, with phonemic awareness being particularly important (e.g., Melby-Lervåg, Lyster, & Hulme, 2012; Snowling & Hulme, 2005). This has been demonstrated across diverse languages and orthographies (e.g., Constantinidou & Stainthorp, 2009; Pan et al., 2011; Russak & Saiegh-Haddad, 2011; Taibah & Haynes, 2011). Such evidence led Fowler (1991) to suggest that well-specified phonological representations are important for the development of reading ability (e.g., Snowling, 2000). Children with reading difficulties have consistently been shown to display deficits in segmental PA, theorised as the *phonological deficit hypothesis* (Stanovich, 1986), which proposes that word-level reading impairments can be traced back to deficits in speech-based processes.

Such literature has contributed to the development of phonologically based reading interventions, such as phonics tuition, where letter–sound correspondences are systematically taught. Ehri, Nunes, Stahl, and Willows (2001) conducted a meta-analysis of 43 studies and found that phonics instruction was effective for children up to the first grade. Torgesen, Wagner, Rashotte, and Herron (2003) also found that phonic-based methods were able to reduce the number of children with poor reading skills from 6% to 1%, but there was still a small proportion of children who did not respond. Similarly, Savage, Carless, and Erten (2009) examined the impact of phonics interventions administered by teaching assistants and found that, although effective, they only helped around two thirds of children at risk of reading problems. Given that a subset of children appear to require alternative approaches, we argue that another type of phonology, known as suprasegmental phonology, has been neglected in accounts of reading development and could support the acquisition of early word recognition for some children.

Suprasegmental phonology, speech rhythm and reading

Suprasegmental phonology refers to rhythmic elements of speech such as stress, tone and duration, which extend over multiple speech segments. Speech rhythm is not represented by diacritics in English orthography and has to be inferred. The correct application of speech rhythm when reading is an essential aspect of decoding, both at the phrase level (knowing where and how to place emphasis to portray the intended meaning) and at the word level (pronouncing multisyllabic words). Cutler and Mehler (1993) suggested that children are born with a *periodicity bias*, an innate tendency to attend to the rhythmic features of language, which is used by children to 'bootstrap' their way into segmenting speech into words. We suggest that this bias could also underpin the development of segmental PA at the sub-word level. For example, sensitivity to the 'beat' in syllables (where a peak in amplitude occurs) corresponds with the production of the vowel sound in that syllable. Therefore, sensitivity to the location of beats in spoken language cues onset–rime boundaries and therefore may contribute to rhyme awareness, and awareness of individual phonemes in the case of single-phoneme onsets. Wood and Terrell (1998) also highlighted that phonemes are more fully articulated in stressed (compared to unstressed) syllables. The ability to assign stress to syllables therefore requires well-specified phonemic representations of those syllables. Given the aforementioned associations between segmental PA and reading, we suggest that there should be an association between decoding ability (word reading) and speech rhythm sensitivity in early readers, which is mediated by segmental PA.

Recent research has explored the associations between speech rhythm sensitivity and reading. These studies have found that sensitivity to aspects of speech rhythm can account for variance in decoding and comprehension in typically developing children (e.g., Holliman, Wood, & Sheehy, 2008; Whalley & Hansen, 2006), children at risk of reading failure (e.g., de Bree, Wijnen, & Zonneveld, 2006) and children and adults with reading difficulties (e.g., Goswami, 2002; Pasquini, Corriveau, & Goswami, 2007; Thomson, Fryer, Maltby, & Goswami, 2006; Wood & Terrell, 1998). Similarly, Schwanenflugel, Hamilton, Kuhn, Wisenbaker, and Stahl (2004) assessed reading comprehension and decoding in 123 third graders and 24 adult readers and found a significant relationship between decoding speed and expressive reading in both groups.

Longitudinal studies show similar patterns of association. For example, Miller and Schwanenflugel (2008) assessed the oral language abilities of children through first, second and third grades. They found that reading with fewer pauses in the first grade was positively related to good use of intonation (pattern of pitch) in the second grade and that this measure of intonation was a significant predictor of later reading fluency. Holliman, Wood, and Sheehy (2010a) explored whether sensitivity to stress, intonation and timing could significantly predict the reading performance of 5- to 7-year-olds 1 year later. They found that speech rhythm sensitivity was able to predict unique variance in reading ability and fluency after controlling for age, vocabulary and PA. So, for children at least, speech rhythm sensitivity appears to play a role in reading development, which is independent of, and additional to, segmental PA.

These findings suggest that speech rhythm may contribute to word reading independently of PA. An indirect contribution may occur where speech rhythm sensitivity influences word reading via vocabulary knowledge (Wood, Wade-Woolley, & Holliman, 2009). That is, literacy development is ‘parasitic’ on language skills (Carroll, Snowling, Stevenson, & Hulme, 2003; Nation & Snowling, 2004), and speech rhythm is a mechanism by which children bootstrap their way into speech segmentation and therefore vocabulary acquisition. Therefore, individual differences in speech rhythm sensitivity could impact vocabulary development in ways that ultimately impact word reading ability.

Existing rhythmic-based reading intervention studies

The question of whether speech rhythm awareness can be trained is raised by such research, along with whether such training can also impact reading outcomes. Previous rhythm-based training studies have targeted older children with reading difficulties. For example, Thomson, Leong, and Goswami (2013) compared a rhythmic-based intervention to a phonetic training programme in 33 dyslexic children, training children in the rhythm group on both speech and nonspeech rhythm tasks. Children receiving this intervention made significant gains in their spelling, single-word and nonword reading, PA and rise time discrimination (i.e., the ability to discriminate between the amplitude envelopes of two different auditory stimuli). Similarly, Bhide, Power, and Goswami (2013) compared the effects of a rhythm intervention to that of a letter-based phonological intervention in nineteen 6- to 7-year-old struggling readers. The children completed tapping exercises, same–different judgments of tempo and rhythm, rise time discrimination, clapping to a beat, answering questions on the rhythm of poetry and a speech rhythm task. It was suggested that this intervention could benefit both single-word reading and PA, but no significant group differences were observed. However, as both the study by Bhide et al. and the study by Thomson et al. incorporated nonspeech rhythm training into their programmes, the question of whether training children to be more aware of *speech* rhythm specifically might impact reading skills remains. Goswami’s own theoretical account focuses on sensitivity to acoustic ‘beats’ and does not differentiate between speech and nonspeech rhythmic sensitivity, as both are seen as the products of the same auditory processing system. We argue, consistent with the results of Holliman, Wood, and Sheehy

(2010b), that although there is an association between sensitivity to speech rhythm and nonspeech rhythm, it is speech rhythm sensitivity that best accounts for the relationship between rhythmic processing and reading. An intervention study that focuses exclusively on speech-rhythm-based training would enable a direct test of this claim.

Rationale

Research has demonstrated that sensitivity to speech rhythm is linked to segmental PA, reading acquisition, reading comprehension and decoding. There are fewer studies investigating the effects of rhythm-based training on reading, and those published have studied children with reading difficulties and trained rhythmic awareness in general rather than speech rhythm specifically. This paper reports the first study to consider the impact of speech-rhythm-based training on the reading skills of typically developing 4- to 5-years-olds. We asked whether speech rhythm sensitivity can be trained, and if so, whether it can impact reading. We expected the intervention to benefit children's reading more than that of a control (maths-based) intervention. However, for the intervention to be considered effective, it also needed to demonstrate effects equivalent to those achievable with segmental PA-based training. We therefore also included a group of children who received PA training.

Method

Participants

Seventy children (41 girls and 29 boys, M_{age} = 4 years 6 months, age range: 4 years 1 month–5 years) were recruited from two primary schools in Derbyshire, England, which were comparable in terms of locality, socioeconomic status, number of pupils and academic achievement. Both schools implemented Jolly Phonics. All participants had English as a first language, and five were exposed to a second language at home. No children had attentional, hearing or speech issues. The mean standardised vocabulary score for the sample at Time 1 (using the *British Picture Vocabulary Scales III*, Dunn & Dunn 2011) was 100.07 (SD = 16.34). The mean word reading raw score (using the *British Ability Scales II* word reading subtest, Elliot, Smith, & McUlloch, 1996) was 0.23 words (SD = 0.68). It was not possible to calculate standardised scores because of the children's age. The children were randomly allocated to treatment groups to receive the newly developed speech-rhythm-based intervention (N = 27), a more traditional PA-based intervention (N = 24) or a maths-based intervention (N = 19). Forty children were recruited from School A (15 in the speech rhythm group, 15 in the PA group and 10 in the control group), and 30 from School B (12 in the speech rhythm group, 9 in the PA group and 9 in the control group).

Test battery

Speech rhythm sensitivity (α = .790). Three subtests were used, focusing on either stress, intonation or timing, as Holliman et al. (2014) showed that these elements of speech rhythm may relate to different literacy skills. These three scores were summed to give an overall score out of 15. We used five items per subscale to maximise the children's attention on task. All audio stimuli were played free field: the training was in small groups, in a quiet area away from the classroom.

Stress sensitivity subtest (after Wood, 2006). The children were presented with a picture of an item in the print vocabulary of a 4- to 5-year-old child (identified via the Children's Printed Word Database, http://www.essex.ac.uk/psychology/cpwd/), together with a corresponding pre-recorded audio file that named the object in the picture. For each item, the stress was either correct (e.g., 'SOfa') or reversed (e.g., 'soFA'; Appendix A).

Intonation contour sensitivity subtest (after Holliman et al., 2014). The children were presented with a picture and corresponding pre-recorded audio stimuli, this time either representing a statement (no rise or fall in intonation) or a question (rising in intonation), for example, 'raining outside' or 'raining outside?' (Appendix B).

Timing sensitivity subtest (after Kitzen, 2001). The children were presented with a picture card containing two options – on the left were two pictures depicting, for example, a tin of paint and a brush, and on the right hand side of the card was a single picture depicting a paintbrush. Children were presented with pre-recorded audio stimuli that stated either 'paint, brush' or 'paintbrush'. The children had to determine whether the speaker was saying one (compound) word or two words (Appendix C).

Phonological awareness, reading and vocabulary. Phonological awareness was assessed using the rhyme and alliteration subtests of the Phonological Assessment Battery (Frederickson, Frith, & Reason, 1997). There were 21 test items in the rhyme test (α = .836) and 10 test items in the alliteration test (α = .800). Single-word reading was assessed using the British Ability Scales II word reading subtest (Elliot et al., 1996) (α = .957). Vocabulary was assessed using the *British Picture Vocabulary Scales III* (Dunn & Dunn, 2011) (α = .857).

Speech-rhythm-based intervention

The speech rhythm intervention lasted 10 weeks. Each week, participants completed three activities in small groups of three, together with the first author. The activities trained participants on the three key elements of speech rhythm: stress, intonation and timing. The activities were completed in a 15-minute session (overall training time = 150 minutes).

All tasks used pictures and pre-recorded audio stimuli, and children used response cards to give their answers. For the stress task, children were given two response cards, one with a happy face and one with a sad face. If the stress placement was correct in the audio stimuli, then they would show the happy face, and if the stress was incorrect, they would show the sad face. For the intonation task, children were given a response card depicting a large question mark and were required to determine whether the audio stimuli were 'telling them something' or 'asking them a question' about the picture. Each time they thought they heard a question, they were required to hold up the question mark, turning it over on the table if they thought it was not a question. For the timing task, children were given two response cards, one with a number '1' on and one with a number '2' on. If they thought what they heard represented one word, they were to hold up the card with '1' on it, and if they thought they heard two separate words, they were to hold up the card with '2' on it. The responses given by each child during training were noted, and the children received feedback and were encouraged to interact and repeat what they had heard. There were five items in each activity, giving a total of 15 items that were trained each week, and the items differed each week (N.B.: the training items used in the intervention were different from items used in the pre-test and post-test assessment of speech rhythm).

All children in this group also received a weekly group activity. Children were read a story from the *Hairy MacLary* series by Lynley Dodd. These stories follow a strong and predictable rhythm. Words at the end of each sentence were altered so that the sentences did not rhyme but the rhythmic pattern remained. The sentences were read aloud, but instead of the final words in each sentence, the children were given three options that required the group to discuss and choose the one that fitted the rhythm. For example,

'Slinky Malinki
was blacker than black
a stalking and lurking
...'

(a) adventurous cat, (b) scary cat, (c) misbehaving cat.

Control conditions

Phonological awareness intervention. The PA-based training used tasks were selected from *Sound Linkage* (Hatcher, 2000). Children were trained in groups of three as in the rhythm condition. Each week, participants completed one activity from the Sound Linkage intervention lasting approximately 15 minutes. Activities included rhyming games and letter and sound identification (Appendix D).

Maths intervention. The maths intervention was a combination of number games based on Numicon activities. Children completed one activity per week in groups of three, with each session lasting approximately 15 minutes. Activities comprised number recognition, matching colours, matching shapes, simple addition and subtraction and domino games (Appendix E).

Procedure

Information sheets and consent forms were sent to the parents of all reception children. Participating children completed assessments of single-word reading, PA, speech rhythm sensitivity and vocabulary in September 2012 and were then randomly allocated to one of the three treatment groups. Interventions were administered weekly between September and December 2012. Following the final week of intervention, the children all completed a postintervention assessment of their single-word reading, PA, speech rhythm sensitivity and vocabulary knowledge. Delayed follow-up data were collected in March 2013 (Time 3).

Results

Table 1 shows the mean raw scores, mean change scores and standard deviations on outcome measures for all groups between Time 1 and Time 2. There were no significant group

Table 1. Mean changes between pre-test and post-test for children in each group.

Variable	Group	Mean T1 score	*SD*	Mean T2 score	*SD*	Mean change T1: T2	*SD*
BAS word reading	Speech rhythm	0.22	0.80	9.59	5.19	9.37	5.09
	PA	0.13	0.34	7.38	4.06	7.25	3.93
	Maths	0.37	0.83	6.11	4.05	5.74	3.74
Rhyme detection	Speech rhythm	6.00	4.60	7.19	4.01	1.19	3.74
	PA	4.42	4.06	4.79	2.77	0.38	3.28
	Maths	3.89	3.31	6.95	5.21	3.05	4.16
Alliteration detection	Speech rhythm	1.89	1.48	2.78	2.31	0.89	2.56
	PA	0.96	1.81	2.58	2.19	1.63	2.10
	Maths	1.32	1.97	2.05	2.25	0.74	1.33
Vocabulary	Speech rhythm	62.41	11.62	70.93	12.31	8.52	6.12
	PA	60.75	17.75	68.17	12.37	7.42	10.01
	Maths	60.68	16.29	65.68	14.73	5.00	7.12
Speech rhythm – stress sensitivity	Speech rhythm	3.59	1.05	4.59	0.64	1.00	1.27
	PA	3.88	0.95	4.42	0.83	0.54	1.06
	Maths	3.79	0.98	3.95	0.91	0.16	1.21
Speech rhythm – intonation sensitivity	Speech rhythm	2.30	1.20	4.04	0.85	1.74	1.68
	PA	2.50	1.10	2.58	0.93	0.08	1.61
	Maths	2.37	0.83	2.53	1.07	0.16	1.30
Speech rhythm – timing sensitivity	Speech rhythm	4.11	0.93	4.70	0.87	0.59	1.08
	PA	4.00	0.98	4.67	0.76	0.67	1.05
	Maths	3.68	0.82	4.21	0.92	0.53	1.02
Speech rhythm total	Speech rhythm	10.00	2.15	13.33	1.73	3.33	2.65
	PA	10.29	1.97	11.67	1.71	1.38	2.18
	Maths	9.84	1.26	10.68	1.89	0.84	2.06

Note. BAS = British Ability Scales; PA = phonological awareness; T1 = Time 1; T2 = Time 2.

differences on any of the literacy measures at pre-test: single-word reading, $F(2, 67) = 0.666$, $p = .517$; rhyme awareness, $F(2, 67) = 1.707$, $p = .189$; alliteration awareness, $F(2, 67) = 1.869$, $p = .162$; vocabulary, $F(2, 67) = 0.102$, $p = .903$; stress sensitivity, $F(2, 67) = 0.541$, $p = .585$; intonation sensitivity, $F(2, 67) = 0.230$, $p = .795$; timing sensitivity, $F(2, 67) = 1.239$, $p = .296$; total speech rhythm sensitivity, $F(2, 67) = 0.323$, $p = .725$.

Table 1 shows that the speech rhythm group could read, on average, 9.19 words more at Time 2 than they could at Time 1, compared to 7.35 words in the PA group and 5.17 words in the maths group. Participants in the speech rhythm group additionally showed the greatest improvement in their vocabulary, stress sensitivity, intonation sensitivity, timing sensitivity and overall speech rhythm sensitivity.

We conducted analysis of covariance (ANCOVA) on the children's total speech rhythm scores at Time 2, after controlling for Time 1 performance and age, to address the question of whether speech rhythm sensitivity can be trained. We found a significant main effect of group on Time 2 total speech rhythm scores, $F(2, 65) = 14.003$, $p < .001$, partial $\eta^2 = .301$. Tukey honest significant difference tests were used for all post hoc analyses. These showed a significant difference between the speech rhythm and PA groups ($p = .001$, Cohen's $d = 0.968$), between the speech rhythm and control groups ($p < .001$, Cohen's $d = 1.464$), but not between the PA and control groups ($p = .071$). When we look at the subscales of this measure, we found no significant differences between groups on sensitivity to timing, but there was a significant difference between groups on their improvement in sensitivity to stress, $F(2, 65) = 4.007$, $p = .023$, partial $\eta^2 = .110$. Specifically, there was a significant difference between the speech rhythm and the control group ($p = .007$, Cohen's $d = 0.834$), but no difference between the speech rhythm and PA groups ($p = .379$) or between the PA and control groups ($p = .059$). There was also a significant difference between groups on their improvement in intonation sensitivity, $F(2, 65) = 20.986$, $p < .001$, partial $\eta^2 = .392$. That is, the speech rhythm group outperformed both the PA group ($p < .001$, Cohen's $d = 1.631$) and the control (maths) group ($p < .001$, Cohen's $d = 1.568$); there was no significant difference between the PA group and the maths group ($p = .702$). There was no significant difference between groups on their improvement in timing sensitivity, $F(2, 65) = 1.533$, $p = .224$, partial $\eta^2 = .045$.

As there were different results for the different measures of speech rhythm, we considered whether performance on one speech rhythm measure was correlated with performance on the others. There were no significant correlations between stress and intonation ($r = .150$, $p = .214$), stress and timing ($r = .020$, $p = .873$) or intonation and timing ($r = .046$, $p = .703$).

Analysis of covariance was conducted to compare the groups on word reading after controlling for age and Time 1 reading performance. We found a significant difference between groups on the change in reading performance from Time 1 to Time 2, $F(2, 65) = 4.403$, $p = .016$, partial $\eta^2 = .119$. The speech rhythm group had a higher Time 2 score than the control group ($p = .005$, Cohen's $d = 0.754$). There was no significant difference between the speech rhythm group and the PA group ($p = .101$), nor between the PA group and the maths group ($p = .186$). There was no significant difference between groups on the other literacy measures including rhyme awareness, $F(2, 65) = 2.926$, $p = .061$, partial $\eta^2 = .083$; alliteration awareness, $F(2, 65) = 0.694$, $p = .503$, partial $\eta^2 = .021$; or vocabulary, $F(2, 65) = 2.421$, $p = .097$, partial $\eta^2 = .069$.

As a result of the theoretical potential for vocabulary to account for the aforementioned effect, we conducted a further ANCOVA, which included age, Time 1 word reading and vocabulary scores as covariates. This analysis still revealed a significant main effect of group on the word reading scores, $F(2, 64) = 4.149$, $p = .020$, partial $\eta^2 = .115$. There was a significant difference between the speech rhythm group and the maths control group ($p = .006$, Cohen's $d = 0.754$). There was no significant difference between the speech rhythm group and the PA group ($p = .100$), nor between the PA and control groups

Table 2. Mean changes between pre-test (Time 1) and delayed post-test (Time 3) for all three groups.

Variable	Group	Mean T1 score	*SD*	Mean T2 score	*SD*	Mean change T1: T2	*SD*
BAS word reading	Speech rhythm	0.22	0.80	16.35	7.62	16.12	7.51
	PA	0.13	0.34	12.13	7.49	12.00	7.39
	Maths	0.37	0.83	10.89	6.02	10.50	5.57
Rhyme detection	Speech rhythm	6.00	4.60	8.15	4.36	2.65	4.03
	PA	4.42	4.06	4.61	2.15	0.17	3.49
	Maths	3.89	3.31	7.44	5.70	3.67	4.79
Alliteration detection	Speech rhythm	1.89	1.48	2.88	2.36	0.96	2.05
	PA	0.96	1.81	2.48	2.92	1.52	2.39
	Maths	1.32	1.97	2.61	2.95	1.33	2.38
Vocabulary	Speech rhythm	62.41	11.62	74.31	10.99	12.00	6.42
	PA	60.75	17.75	71.13	15.50	9.48	7.34
	Maths	60.68	16.29	70.22	12.25	9.67	7.87
Speech rhythm – stress sensitivity	Speech rhythm	3.59	1.05	4.65	0.63	1.12	1.18
	PA	3.88	0.95	3.96	0.82	0.09	1.12
	Maths	3.79	0.98	4.33	0.97	0.56	1.25
Speech rhythm – intonation sensitivity	Speech rhythm	2.30	1.20	3.35	0.98	1.08	1.52
	PA	2.50	1.10	2.13	1.06	−0.35	1.56
	Maths	2.37	0.83	2.33	1.28	−0.06	1.63
Speech rhythm – timing sensitivity	Speech rhythm	4.11	0.93	4.08	0.98	0.00	1.30
	PA	4.00	0.98	3.83	1.23	−0.22	1.20
	Maths	3.68	0.82	3.83	1.38	0.17	1.38
Speech rhythm total	Speech rhythm	10.00	2.15	12.08	1.74	2.19	2.30
	PA	10.29	1.97	9.91	2.25	−0.39	2.50
	Maths	9.84	1.26	10.50	2.12	0.67	2.28

Note. BAS = British Ability Scales; PA = phonological awareness; T2 = Time 2; T3 = Time 3. Vocabulary scores are British Picture Vocabulary Scale raw scores.

(p = .217). There were no significant main effects found in subsequent ANCOVA looking at Time 2 rhyme awareness, alliteration awareness or vocabulary knowledge.

Further analysis was conducted to investigate group differences between Time 1 and Time 3, to determine the overall long-term impact of the intervention (Table 2). When we look at speech rhythm sensitivity, there was a significant difference between groups on their improvement in stress sensitivity after controlling for Time 1 scores and age,

$F(2, 63) = 4.876$, $p = .011$, partial $\eta^2 = .134$. The speech rhythm group outperformed the PA group ($p = .003$, Cohen's $d = 0.886$), but there was no significant difference between the speech rhythm group and the control group ($p = .133$) or between the PA and control groups ($p = .158$). As before, there was a significant difference between groups on intonation scores, $F(2, 63) = 8.148$, $p = .001$, partial $\eta^2 = .206$. The speech rhythm group outperformed the PA group ($p < .001$, Cohen's $d = 1.195$) and the control group ($p = .004$, Cohen's $d = 0.875$). There was no significant main effect of group on scores on the delayed timing sensitivity assessment, $F(2, 63) = 0.257$, $p = .774$, partial $\eta^2 = .008$. There was, however, a significant main effect of group on the Time 3 total speech rhythm sensitivity scores after controlling for Time 1 performance and age, $F(2, 63) = 8.165$, $p = .001$, partial $\eta^2 = .206$. Children in the speech rhythm group showed better Time 3 speech rhythm sensitivity than did children in the PA group ($p < .001$, Cohen's $d = 1.083$) and children in the control group ($p = .014$, Cohen's $d = 0.782$). There was no difference between the PA and control groups on this measure ($p = .231$).

Analysis of covariance controlling for age and Time 1 word reading revealed a significant difference between groups on their word reading scores at Time 3, $F(2, 63) = 3.756$, $p = .029$, partial $\eta^2 = .107$. The speech rhythm group outperformed the maths control group ($p = .012$, Cohen's $d = 0.720$), but there was no significant difference between children in the speech rhythm group and children in the PA group ($p = .058$) or between children in the PA group and children in the control group ($p = .465$). As before, we also ran an additional analysis, which also controlled for the potential contribution of vocabulary to this result. This showed that there was still a main effect of group on the Time 3 word reading scores, $F(2, 62) = 3.849$, $p = .027$, partial $\eta^2 = .110$. There were significant differences between the speech rhythm and PA groups ($p = .038$, Cohen's $d = 0.558$) and between the speech rhythm and control groups ($p = .014$, Cohen's $d = 0.720$), but no significant difference between the PA and control groups ($p = .611$).

There was also a significant difference between groups on the Time 3 rhyme awareness scores after controlling for age and Time 1 scores, $F(2, 63) = 4.788$, $p = .012$, partial $\eta^2 = .132$. The speech rhythm group outperformed the PA group ($p = .007$, Cohen's $d = 1.805$), and the maths control group also outperformed the PA group ($p = .014$, Cohen's $d = 0.702$), but there was no significant difference between the speech rhythm group and the control group on this measure ($p = .956$). These differences remained after also controlling for Time 1 vocabulary as a general measure of language ability, revealing that the speech rhythm group continued to outperform the PA group on rhyme awareness ($p = .002$, Cohen's $d = 1.805$), the maths group continued to outperform the PA group ($p = .005$, Cohen's $d = 0.956$) and there was no significant difference between the speech rhythm and maths groups ($p = .862$).

There were no significant main effects observed for alliteration or vocabulary knowledge.

Finally, as children received the interventions in small groups, analysis of variance was therefore run to monitor whether there were significant differences between training groups on outcomes. For the speech rhythm intervention group, there was no significant difference between training groups on their progress on stress, $F(8, 1) = 0.900$, $p = .537$; intonation, $F(8, 1) = 1.088$, $p = .415$; timing, $F(1, 8) = 0.611$, $p = .757$; total speech rhythm sensitivity, $F(8, 1) = 0.432$, $p = .886$; or word reading, $F(8, 1) = 0.772$, $p = .632$. There was also no significant difference between training groups within the PA intervention on progress in reading, $F(7, 1) = 0.730$, $p = .650$, nor was there a difference between training groups in the control intervention on progress in reading, $F(6, 1) = 2.521$, $p = .081$. Overall, across all participants, there was no significant main effect of training group on the participants' progress on the word reading measure between Time 1 and Time 2, $F(23, 1) = 1.300$, $p = .220$; between Time 2 and Time 3, $F(23, 1) = 1.074$, $p = .407$; or between Time 1 and Time 3, $F(23, 1) = 1.622$, $p = .083$.

Discussion

This study examined the immediate and longer-term impact of a speech-rhythm-based intervention in a group of beginning readers. We found that the speech-rhythm-based intervention resulted in significant immediate and longer-term gains in sensitivity to intonation above and beyond those experienced by children in either the PA or maths control groups. It would seem that sensitivity to intonation (in the simple way assessed and trained in this study) was the aspect of speech rhythm that was least well developed in this age group and therefore most amenable to training. However, all three elements showed development between Time 1 and Time 2, and mean improvement scores for all three components were observed to be highest in the speech rhythm group. It appears that children may enter school less sensitive to intonation than they are to stress and timing. In line with Holliman et al. (2014), this challenges the idea of speech rhythm being a unitary construct. That is, research has focused on stress sensitivity as a proxy for speech rhythm, based on an assumption that speech rhythm comprises a set of inter-correlated component skills. However, our data are not consistent with this assumption and we suggest that the interpretation of previous work needs to be considered only in relation to stress processing rather than speech rhythm more generally. Future work should assess multiple components of speech rhythm if arguments are to be made about the development of speech rhythm skills in general. However, it would be an overstatement to say that the improvements in intonation sensitivity entirely accounted for the effect of the speech rhythm training, as stress sensitivity improved, on average, twice as much as was observed in the PA group and five times as much as it did in the maths control group. Ceiling effects were observed for the timing component.

The improvement in speech rhythm observed in the speech rhythm intervention group is perhaps to be expected given the similarities between the assessments and training activities, although the items used in the assessments were different from those used during training. However, we recommend that further research should utilise measures of prosody less directly linked to training, such as subscales from the Profiling Elements of Prosody in Speech-Communication test, to assess training outcomes more robustly.

The speech-rhythm-based training resulted in gains in word reading performance that were significantly greater than those achieved by children in the control condition. Our data, however, do not appear to support the Wood et al. (2009) hypothesis that a speech-rhythm-based intervention could impact word reading through the mechanism of (a) improved vocabulary knowledge and (b) improved onset–rime awareness. This raises the question of how else might speech rhythm training impact word reading ability. It is still possible that there is an indirect effect that is mediated by improved vocabulary, given that the children in this condition were exposed to a large number of words over the sessions. Knowledge of these items is unlikely to have been captured by the vocabulary measure we used here, and so this explanation is possible. Another possibility is that as the speech rhythm training teaches explicit awareness of stress and intonation, this may stimulate the children's metalinguistic skills. Alternatively, the training may be more motivating or engaging for the children, relative to the other conditions, and this may have resulted in the children being more engaged with reading. There is therefore a need for replication and further examination of how such training may benefit children's experience of early reading.

The PA-based intervention did not impact literacy skills as strongly as we expected. It seems that 10 weeks of weekly 15-minute training sessions was not enough for the PA intervention to have had a significant impact. Alternatively, the wide variety of skills covered within Sound Linkage could have meant that children did not receive sufficient training on the specific aspects of PA that were assessed at the pre-test and post-test. If we consider the week-by-week training data for children in the PA group, performance on the training tasks did not improve consistently over the intervention period. It may also therefore be the case that some of the tasks were too difficult for the children. This seems possible as a study by Hatcher et al. (2005) found the Sound Linkage intervention to be successful in participants in Year 1 (aged 5–6 years), who were 1 year older than the children we recruited. It should also be noted that the children in the control group showed the greatest gains in rhyme detection ability. The reasons for this are not clear. Rhyme awareness in this group could be linked to the Jolly Phonics training that they were receiving whilst the other two groups were being trained. This will also have contributed to the lack of a significant difference between the control and PA groups.

The overall gains in performance between the pre-test and delayed post-test showed that the speech rhythm group still made the largest overall gain in speech rhythm sensitivity and word reading. Our results suggest that speech rhythm training may be suitable for early years classrooms, but that should be maintained until speech rhythm awareness has been established, as there was a slight decrease in speech rhythm scores between Time 2 and Time 3. We also suggest that it would be optimal to combine speech rhythm activities with PA training and/or phonic activities, although the impact of this approach would need to be assessed empirically.

The results support the findings of both Bhide et al. (2013) and Thomson et al. (2013) that rhythmic-based training can be effective in improving reading ability. The results are not entirely consistent, however, with the proposal that speech rhythm training can impact PA; although there were gains in rhyme awareness, greater gains were observed in the control group, and until we understand this, we need to be cautious about this aspect of our theorising. Similarly, we are cautious with respect to our interpretation of the comparison with the PA intervention. The lack of independent fidelity data on the intervention deliveries may also be noted as problematic in this study. Arrangements were not put in place for an independent observation of the trainer by another member of the project team, although the trainer kept detailed session-by-session notes of activities, absences and individual pupil progress, and these records were checked by co-authors throughout the project.

Overall, this study is the first to have found that an intervention based entirely on speech rhythm activities can be successful at improving both speech rhythm sensitivity and reading beyond that of a non-reading control intervention. However, continued classroom support to emphasise speech rhythm is recommended.

References

Bhide, A., Power, A. & Goswami, U. (2013). A rhythmic musical intervention for poor readers: A comparison of efficacy with a letter-based intervention. *Mind, Brain and Education*, 7(2), 113–123. https://doi.org/10.1111/mbe.12016.

Carroll, J.M., Snowling, M.J., Stevenson, J. & Hulme, C. (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, 39(5), 913. https://doi.org/10.1037/0012-1649.39.5.913.

Constantinidou, M. & Stainthorp, R. (2009). Phonological awareness and reading speed deficits in reading disabled Greek-speaking children. *Educational Psychology*, 29(2), 171–186. https://doi.org/10.1080/01443410802613483.

Cutler, A. & Mehler, J. (1993). The periodicity bias. *Journal of Phonetics*, 21, 103–108.

de Bree, E., Wijnen, F. & Zonneveld, W. (2006). Word stress production in three-year-old children at risk of dyslexia. *Journal of Research in Reading*, 29(3), 304–317. https://doi.org/10.1111/j.1467-9817.2006.00310.x.

Dunn, L. & Dunn, L.M. (2011). *British picture vocabulary scales III*. Windsor: NFER-Nelson.

Ehri, L., Nunes, S., Stahl, S. & Willows, D. (2001). Systematic phonics instruction helps students learn to read: Evidence from the national reading panel's meta-analysis. *Review of Educational Research*, 71(3), 393–447. https://doi.org/10.1598/RRQ.36.3.2.

Elliot, C., Smith, P. & McUlloch, K. (1996). *British ability scales II*. Windsor: NFER Nelson.

Fowler, A. (1991). How early phonological development might set the stage for phoneme awareness. In S.A. Brady & Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman*, (pp. 97–117). Hillsdale: Laurence Erlbaum Associates.

Frederickson, N., Frith, U. & Reason, R. (1997). *Phonological assessment battery*. Windsor: NFER.

Goswami, U. (2002). Phonology, reading development and dyslexia: A cross-linguistic perspective. *Annals of Dyslexia*, 52, 141–163. https://doi.org/10.1007/s11881-002-0010-0.

Hatcher, P. (2000). *Sound linkage*. (Second edn). London: Whurr.

Hatcher, P. J., Hulme, C., Miles, J. N. V., Carroll, J. M., Hatcher, J., Gibbs, S. et al. (2005). Efficacy of small group reading intervention for beginning readers with reading-delay: a randomised controlled trial. *Journal of Child Psychology and Psychiatry*, 47(8), 820–827. https://doi.org/10.1111/j.1469-7610.2005.01559.x

Holliman, A., Wood, C. & Sheehy, K. (2008). Sensitivity to speech rhythm explains individual differences in reading ability independently of phonological awareness. *British Journal of Developmental Psychology*, 26(3), 357–367. https://doi.org/10.1348/026151007X241623.

Holliman, A., Wood, C. & Sheehy, K. (2010a). Does speech rhythm sensitivity predict children's reading ability one year later? *Journal of Educational Psychology*, 102(2), 356–366. https://doi.org/10.1037/a0018049.

Holliman, A., Wood, C. & Sheehy, K. (2010b). The contribution of sensitivity of speech rhythm and non-speech rhythm to early reading development. *Educational Psychology*, 30(3), 247–267. https://doi.org/10.1080/01443410903560922.

Holliman, A.J., Williams, G.J., Mundy, I.R., Wood, C., Hart, L. & Waldron, S. (2014). Beginning to disentangle the prosody–literacy relationship: A multi-component measure of prosodic sensitivity. *Reading and Writing*, 27(2), 255–266. https://doi.org/10.1007/s11145-013-9443-6.

Kitzen, K. R. (2001). Prosodic sensitivity, morphological ability, and reading ability in young adults with and without childhood histories of reading difficulties. Dissertation Abstracts International Section A: Humanities and Social Sciences 62 (2-A), 460

Melby-Lervåg, M., Lyster, S.H. & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, 138(2), 322–352. https://doi.org/10.1037/a0026744.

Miller, J. & Schwanenflugel, P.J. (2008). A longitudinal study of the development of reading prosody as a dimension of oral reading fluency in early elementary school children. *Reading Research Quarterly*, 43, 336–354. https://doi.org/10.1598/RRQ.43.4.2.

Nation, K. & Snowling, M.J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. *Journal of Research in Reading*, 27(4), 342–356. https://doi.org/10.1111/j.1467-9817.2004.00238.x.

Pan, J., McBride-Chang, C., Shu, H., Liu, H., Zhang, Y. & Li, H. (2011). What is in the naming? A 5-year longitudinal study of early rapid naming and phonological sensitivity in relation to subsequent reading skills in both native Chinese and English as a second language. *Journal of Educational Psychology*, 103(4), 897–908. https://doi.org/10.1037/a0024344.

Pasquini, E.S., Corriveau, K.H. & Goswami, U. (2007). Auditory processing of amplitude envelope rise time in adults diagnosed with developmental dyslexia. *Scientific Studies of Reading*, 11(3), 259–286. https://doi.org/10.1080/10888430701344280.

Russak, S. & Saiegh-Haddad, E. (2011). Phonological awareness in Hebrew (l1) and English (l2) in normal and disabled readers. *Reading and Writing*, 24(4), 427–442. https://doi.org/10.1007/s11145-010-9235-1.

Savage, R., Carless, S. & Erten, O. (2009). The longer-term effects of reading interventions delivered by experienced teaching assistants. *Support for Learning*, 24(2), 95–100. https://doi.org/10.1111/j.1467-9604.2009.01405.x.

Schwanenflugel, P.J., Hamilton, A.M., Kuhn, M.R., Wisenbaker, J.M. & Stahl, S.A. (2004). Becoming a fluent reader: Reading skill and prosodic features in oral reading of young readers. *Journal of Educational Psychology*, 96(1), 119–129. https://doi.org/10.1037/0022-0663.96.1.119.

Snowling, M.J. (2000). Language and literacy skills: Who is at risk and why? In D.V.M. Bishop & L.B. Leonard (Eds.), *Speech and language impairments in children*, (pp. 245–259). New York, US: Psychology Press.
Snowling, M.J. & Hulme, C. (Eds.) (2005). *The science of reading*. Oxford: Blackwell Publishing Ltd.
Stanovich, K.E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, 21, 360–364.
Taibah, N.J. & Haynes, C.W. (2011). Contributions of phonological processing skills to reading skills in Arabic speaking children. *Reading and Writing*, 24(9), 1019–1042. https://doi.org/10.1007/s11145-010-9273-8.
Thomson, J.M., Fryer, B., Maltby, J. & Goswami, U. (2006). Auditory and motor rhythm awareness in adults with dyslexia. *Journal of Research in Reading*, 29(3), 334–348. https://doi.org/10.1111/j.1467-9817.2006.00312.x.
Thomson, J.M., Leong, V. & Goswami, U. (2013). Auditory processing interventions and developmental dyslexia: A comparison of phonemic and rhythmic approaches. *Reading and Writing*, 26(2), 139–161. https://doi.org/10.1007/s11145-012-9359-6.
Torgesen, J. K., Wagner, R. K., Rashotte, C. A., & Herron, J. (2003). Summary of outcomes from first grade study with read, write, and type and auditory discrimination in depth instruction and software with at-risk children. Florida Center for Reading Research [online]. Retrieved on 24 January 2014, from http://www.fcrr.org/TechnicalReports/RWTfullrept.pdf
Whalley, K. & Hansen, J. (2006). The role of prosodic sensitivity in children's reading development. *Journal of Research in Reading*, 29(3), 288–303. https://doi.org/10.1111/j.1467-9817.2006.00309.x.
Wood, C. (2006). Metrical stress sensitivity in young children and its relationship to phonological awareness and reading. *Journal of Research in Reading*, 29(3), 270–287. https://doi.org/10.1111/j.1467-9817.2006.00308.x.
Wood, C. & Terrell, C. (1998). Pre-school phonological awareness and subsequent literacy development. *Educational Psychology*, 18(3), 253–274. https://doi.org/10.1177/00222194060390040401.
Wood, C., Wade-Woolley, L. & Holliman, A.J. (2009). Phonological awareness: Beyond phonemes. In C. Wood & V. Connelly (Eds.), *Contemporary perspectives on reading and spelling*. London: Routledge.

Appendix A. Stress Task Item List

Word
balloon
blanket
butterfly
camera
candle
carrot
chicken
chocolate
coffee
computer
cupcake
crayons
dinner
dinosaur
finger
flower
football

kettle
money
monkey
paper
parrot
pencil
potato
rabbit
shower
sofa
table
teddy
television
tomato
trumpet
vegetables
window
yoghurt

Appendix B. Intonation Task Item List

Stimuli	Target word
school bag	bag
Bedtime	bedtime
read book	book
Breakfast	breakfast
mummy’s coat	coat
Coffee	coffee
play on the computer	computer
dinner time	dinner
play football	football
eat your fruit	fruit
having fun	fun
play game	game
bake gingerbread	gingerbread
Laughing	laughing
Listen	listen
monday today	monday
your name	name

Painting	painting
draw a picture	picture
Playtime	playtime
listen to the radio	radio
raining outside	raining
build a rocket	rocket
daddy's shoes	shoes
go shopping	shopping
Shower	shower
sit on the sofa	sofa
go to the station	station
sunny outside	sun
go swimming	swimming
cup of tea	tea
watch television	television
push the trolley	trolley
washing up	washing
look out the window	window

Appendix C. Timing Task Item List

Compound noun	First noun	Second noun
apple pie	apple	pie
armchair	arm	chair
basketball	basket	ball
batman	bat	man
blackbird	black	bird
breadstick	bread	stick
butterfly	butter	fly
chocolate cake	chocolate	cake
cowboy	cow	boy
cupcake	cup	cake
doorbell	door	bell
earring	ear	ring
fish fingers	fish	fingers
football	foot	ball
greenhouse	green	house
hairbrush	hair	brush

horse shoe	horse	shoe
icecream	ice	cream
ice lolly	ice	lolly
jacket potato	jacket	potato
jelly baby	jelly	baby
jellyfish	jelly	fish
keyring	key	ring
lipstick	lip	stick
paintbrush	paint	brush
pancake	pan	cake
rainbow	rain	bow
sandcastle	sand	castle
spiderman	spider	man
starfish	star	fish
sunflower	sun	flower
sunglasses	sun	glasses
toothbrush	tooth	brush
twenty one	twenty	one
wheelchair	wheel	chair

Appendix D. The Phonological Awareness Intervention

Activities taken from the 'Sound Linkage' intervention (Hatcher, 2000*)*

Week 1: 'Beginning', 'Middle' and 'End'
Section 1: Activities 1, 2, 3
Week 2: 'Syllabic Rhythm'
Section 2: Activities 2, 3, 4
Week 3: 'Syllables'
Section 2: Activities 5, 6, 7
Week 4: 'Phoneme Blending'
Section 3: Activities 1, 2, 3
Week 5: 'Phoneme Blending'
Section 3: Activities 6, 7
Week 6: 'Rhyming Words'
Section 4: Activities 1, 2, 3
Week 7: 'Rhyming Words'
Section 4: Activities 6, 7
Week 8: 'Identifying and Discriminating Phonemes'
Section 5: Activities 2, 4, 5
Week 9: 'Discriminating Phonemes'
Section 5: Activities 6, 10
Week 10: 'Segmenting Phonemes'
Section 6: Activities 1, 2, 3

Appendix E. Details of the Maths Control Intervention

Activities adapted from the Numicon intervention and maths activities from the CBeebies© website.

Week 1: Counting and Number Recognition

Materials needed: Counters, Number Cards

Small group activity

Find me:

(a) 3 counters	[]
(b) 5 counters	[]
(c) 7 counters	[]
(d) 8 counters	[]
(e) 10 counters	[]
(f) 11 counters	[]
(g) 13 counters	[]
(h) 14 counters	[]
(i) 16 counters	[]
(j) 17 counters	[]
(k) 19 counters	[]
(l) 20 counters	[]
(m) 23 counters	[]
(n) 24 counters	[]
(o) 25 counters	[]

Carpet time activities

Counting: Group counting from 1 (as far as they can go, with a max of 50)

Number recognition: Show the number cards and ask children to say what number is being shown.

Week 2: Colours and Shapes

Materials needed: Coloured shape cards

Small group activity

Find me:

(a) A yellow square	[]	
(b) A red triangle		[]
(c) A blue circle		[]
(d) A green rectangle	[]	
(e) A yellow star		[]

(f) A red diamond	[]	
(g) 2 blue shapes		[]
(h) 2 triangles	[]	
(i) 2 green shapes		[]
(j) 2 stars		[]
(k) 2 red shapes		[]
(l) 2 diamonds		[]
(m) 2 yellow shapes	[]	
(n) 2 circles	[]	
(o) 2 squares	[]	

Carpet time activity

Colour and shape recognition: Show the shape and colour cards and ask children to say what is being shown.

Week 3: Spinners (Addition)

Materials needed: Two spinners

Small group activity

Children spin both spinners and add together the numbers they fall on, for example, if one spinner lands on a 1 and the second spinner lands on a 4, the sum is $1 + 4 = 5$.

Carpet time activity

Use the number cards to make a simple addition sum. Ask some children to come up to hold each of the cards, and the other children to work out the answer.

Week 4: Domino Maths

Materials needed: Numicon dominoes

Small group activity

Children use the dominoes to add together two numbers.

Carpet time activity

Dominoes game from the CBeebies website.

Week 5: Number Lines

Materials needed: Number cards

Small group activity

Which number is missing?

a 1, 2, 3, 5,
b 2, 3, 4, 5
c 3, 4, 5, 7
d 2, 3, 4, 6
e 1, 2, 4, 5
f 2, 4, 5, 8
g 2, 5, 6
h 1, 3, 4, 5, 7
i 1, 2, 3, 6
j 3, 4, 5, 7

Put these numbers in order:

a 1, 2, 3, 4
b 2, 3, 4, 5
c 2, 4, 6, 8
d 2, 3, 7, 10
e 1, 3, 4, 7

Carpet time activity

Give out the number cards to the children and ask them to stand in a line in order. Then make it harder by taking one number away and asking which is missing.

Week 6: Colour and Shape Matching

Materials needed:

Small group activity

Find me:

(a) All of the yellow shapes	[]
(b) All of the circles	[]
(c) All of the blue shapes	[]
(d) All of the red shapes	[]
(e) All of the rectangles	[]
(f) Two triangles	[]
(g) Two green shapes	[]
(h) Two stars	[]
(i) Two diamonds	[]
(j) Two blue shapes	[]
(l) A triangle and a square	[]
(m) A red shape and a green shape	[]
(n) A yellow shape and a blue shape	[]
(o) A red star and a blue rectangle	[]

Carpet time activity

Shape dominoes activity from the CBeebies website.

Week 7: Frogs and Lily Pads

Materials needed: Frogs and lily pads

Small group activity

Only one frog can fit on each lilt pad. Give the child the following and ask if all the frogs have somewhere to sit.

a 3 frogs, 4 lily pads
b 2 frogs, 6 lily pads
c 6 frogs, 5 lily pads
d 7 frogs, 8 lily pads
e 9 frogs, 7 lily pads

f 6 frogs, 7 lily pads
g 4 frogs, 3 lily pads
h 4 frogs, 5 lily pads
i 5 frogs, 4 lily pads
j 7 frogs, 6 lily pads
k 3 frogs, 3 lily pads
l 3 frogs, 4 lily pads
m 5 frogs, 6 lily pads
n 6 frogs, 6 lily pads
o 4 frogs, 8 lily pads

Carpet time activity
Shape game from the CBeebies website.
Week 8: More or Less? (Counters and Dominos)

Materials needed: Counters and dominoes
Small group activity
Children receive a domino and a number of counters. Ask the children to place one counter over each dot on the dominoes to see if there are more or less counters than the number of dots on the dominoes.

	Domino	Counters
(a)	3	4
(b)	5	6
(c)	1	2
(d)	2	5
(e)	4	5
(f)	5	2
(g)	6	8
(h)	9	5
(i)	7	6
(j)	6	4
(k)	8	3
(l)	4	2
(m)	2	3
(n)	8	7
(o)	9	6

Carpet time activity
More or less activity from the CBeebies website.
Week 9: Spinners (Subtraction)

Materials needed: Two spinners
Small group activity

Children spin the spinners and take the smaller number away from the bigger number, for example, if one spinner lands on 2 and the other spinner lands on 4, the sum is $4 - 2 = 2$.

Carpet time activity

Use the number cards to make a simple subtraction sum. Ask children to hold the cards up and the other children to work out the answer.

Week 10: Number Lines

Materials needed: Number cards, response sheets

Small group activity

As in Week 5, but children are asked to write the numbers down as well as say the answers.

Carpet time activity

Connect 4 from the CBeebies website.

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