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Effects of replicating primary-reflex movements on specific reading difficulties in children: a randomised, double-blind, controlled trial

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Summary

Background Children with specific reading difficulties have problems that extend beyond the range of underlying language-related deficits (eg, they have difficulties with balance and motor control). We investigated the role of persistent primary reflexes (which are closely linked in the earliest months of life to the balance system) in disrupting the development of reading skills.

Methods We assessed the efficacy of an intervention programme based on replicating the movements generated by the primary-reflex system during fetal and neonatal life. A randomised, individually matched, double-blind, placebo-controlled design was used and children (aged 8–11 years) with persistent primary reflexes and a poor standard of reading were enrolled into one of three treatment groups: experimental (children were given a specific movement sequence); placebo-control (children were given non-specific movements); and control (no movements).

Findings From an initial sample of 98 children, 60 children, 20 in each group were matched on age, sex, verbal intelligence quotient (IQ), reading ability, and persistent asymmetrical tonic neck reflex. For asymmetrical tonic neck-reflex levels there was a significant (group by time) interaction ($p<0\cdot001$). The experimental group showed a significant decrease in the level of persistent reflex over the course of the study (mean change $-1\cdot8$ [95% CI $-2\cdot4$ to $-1\cdot2$], $p<0\cdot001$), whereas the changes in the placebo-control and control groups were not significant ($-0\cdot2$ [$-0\cdot9$ to $0\cdot6$] and $-0\cdot4$ [$-0\cdot9$ to $0\cdot2$]).

Interpretation This study provides further evidence of a link between reading difficulties and control of movement in children. In particular, our study highlights how the educational functioning of children may be linked to interference from an early neurodevelopmental system (the primary-reflex system). A new approach to the treatment of children with reading difficulties is proposed involving assessment of underlying neurological functioning, and appropriate remediation.

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Introduction

There is substantial controversy about the development and teaching of reading skills, which has often led to a polarisation in teaching methods between meaning-emphasis approaches (in which the focus is on whole words in meaningful contexts—eg, the use of 'real books') and code-emphasis or phonics approaches (in which the focus is on links between sounds and letters). The relative merits of these approaches are debated,[1,2] but both advance a cognitive model for reading development. Furthermore, the phonological-deficit hypothesis, which emphasises the importance of phonological skills (eg, the ability to detect rhyme, to segment and blend sounds) in reading acquisition, has assumed a dominant position in describing reading failure.[3–7]

Research with dyslexic children, however, suggests that there may be other deficits as well. Children can have deficits in several areas of the visual system,[8–11] and auditory temporal processing can be impaired.[12,13] Children who have specific learning difficulties actually show diverse problems, some of which seem far removed from the reading process (eg, difficulty with catching a ball[14]).

Nicolson and Fawcett[15] proposed that phonological deficits were part of a deeper underlying learning deficit for any skill and showed how dyslexic performance was characterised by poor motor skills and, in particular, poor balance (as well as the expected poor phonological skills).[16] These deficits in balance led to the suggestion that a dysfunction in the cerebellum might underlie the major deficits seen in dyslexic children.[17] The role of the cerebellum extends beyond motor control into higher cognitive functioning.[18] These studies suggest that an exclusively cognitive model of the processes underlying reading development may have major limitations.

A neurological basis for a range of learning difficulties, including reading delay, is further suggested by evidence linking the persistence of primary reflexes and learning difficulties.[19] Primary (or primitive) reflexes are movement patterns that emerge during fetal life and are critical for the survival of the newborn infant (eg, infant suck reflex). These reflexes are readily elicited during the first 6 months of life.[20] As the nervous system develops, however, primary reflexes are inhibited or transformed. The persistence of primary reflexes beyond their normal timespan (12 months) interferes with subsequent development and indicates neurological impairment.[21]

More than 70 primary reflexes have been identified.[22] A particular focus of this study is the asymmetrical tonic neck reflex (ATNR). This reflex is elicited by a sideways turning of the head when the baby is supine. The response consists of extension of the arm and leg on the side to which the head turns, and flexion of the opposing limbs.[22] The ATNR is involved in the orientation of the neonate and, because the reflex is present when near-point fixation is developing, it has an important role in visuomotor development.[21] This reflex should be inhibited at around 6 months of age, and persistence is a clinical indicator of abnormal development. The ATNR is the most commonly observed persistent reflex in infants with neurological lesions.[23]

Severe persistence of primary reflexes indicates predominantly intractable organic problems as seen in children with cerebral palsy.[24] These children have great difficulty with movement and reading but may have normal intelligence.[25] Milder persistence, however, is associated with less severe disorders (including specific reading difficulties).[19] The process of inhibition of reflexes in the earliest months of life is not known but is generally assumed not to occur after early childhood. The question remains of whether inhibition is a maturational process controlled entirely by internal mechanisms or whether there are external behavioural factors that may affect or interact with this process.

Neonatal movement is largely stereotypical[26,27] and follows the patterns of the primary-reflex system. The early movements of the fetus and neonate, which were previously viewed as passive byproducts of rapid neural wiring, are now viewed as interactive, that is, having a reciprocal effect on the underlying structure and function of the central nervous system.[28] Thus, the rehearsal and repetition of primary-reflex movements may have a part in the inhibition process itself. We examined the effects of a specific-movement programme, which replicates the reflex movements of the primary-reflex system, on the inhibition of persistent primary reflexes, specifically the ATNR, and the educational performance of a clearly defined group of children with reading difficulties. We aimed to find out whether the ATNR could be inhibited by the sterotypical movements of the primary-reflex system (including ATNR movement) and whether reading skills would improve as ATNR persistence decreased.

Methods

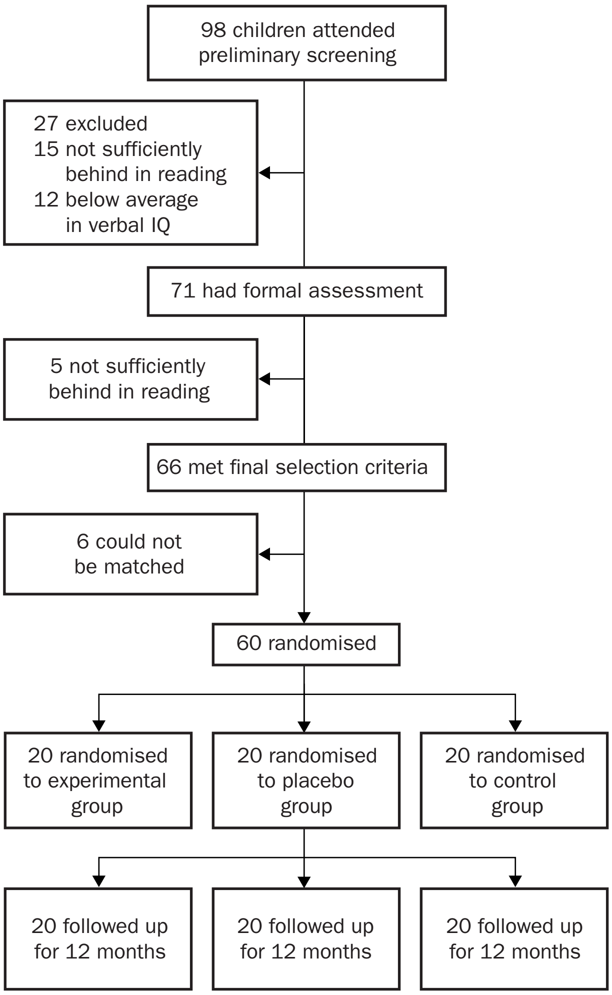
Participants and design

We did a randomised, matched subjects, double-blind placebo-controlled trial and targeted children who attended ordinary primary schools. Written consent was obtained from the parents after formal assessment. Approval for this study and earlier preliminary work was given by the research ethics committee, School of Psychology, Queen's University, Belfast.

After we had issued a local release and notified parents of children with dyslexia through local dyslexia groups, children in the sample population who were aged 8–11 years underwent a preliminary screening procedure. We identified and included children with: reading difficulties (at least 12 months behind the standard for age on the Salford sentence reading test[29]); average verbal IQ (between 85 and 115 on the non-reading intelligence test[30]); and a persistent ATNR (a positive score on the Schilder test). For this test the child stands upright with feet together and arms held straight out in front at shoulder level, with wrists relaxed. The tester stands behind and gives the instruction: "In a moment, you will close your eyes and I will turn your head slowly first to one side and then the other, all you have to do is to keep your arms in exactly the same position as they are now; only your head moves". The tester then slowly turns the child's head to one side (70–80° or until the chin is over the shoulder), pauses for 5 s, and then slowly turns the head to the other side. After another pause for 5 s the whole sequence is repeated once more. Positive indicators of this reflex include movement of the extended arms in the same direction as the head turn, dropping the arms, or swaying and loss of balance. (0=no response [arms remain straight out in front]; 1=slight movement of the arms [up to 20°] to the same side as the head is turned, or slight dropping of the arms; 2=movement of the arms [up to 45°] as the head is turned, or marked dropping of the arms; 3=arm movement greater than 45° either to the side or down, swaying and loss of balance. Each side of the body is scored separately and then a total obtained for both sides).

Children who met the preliminary criteria went on to complete a detailed individual assessment. All children excluded at this stage were not sufficiently behind in reading ability or were below average in verbal IQ. Hearing difficulties were excluded by means of a standard audiogram. Reading ability was assessed by the Neale analysis of reading ability[31] and the Wechsler objective reading dimensions (WORD)[32] and spelling by the WORD spelling test. The Schilder test for the ATNR, which was used in the initial screening, was repeated and quantified. Preliminary work indicated that this reflex provided a good index of total reflex persistence. To assess motor impairment a timed writing test (copying of a set passage; three levels of difficulty according to initial reading ability) was done. Because of the suggested involvement of the ATNR in visual development, we devised an eye-tracking test with the Ober2 infrared digital eye registration system. This procedure involved horizontal tracking of a small cross (5 by 5 pixels) from the centre of a monitor (10 ms delay after start) to the extreme left, to the extreme right, and back again to the centre, with the object moving in 10 pixel steps (120 steps per s). Eye movements for ten continuous cycles (30 s) were recorded (sampling frequency 100 Hz). The number of saccades that the child used to follow the cross was used as an index of visual smooth-pursuit functioning. Finally, two subtests (naming speed [pictures] and spoonerisms) from the phonological assessment battery were completed.

All children met the final selection criteria of substantial reading difficulties—ie, at least 24 months behind on the Neale analyses of reading ability test, at least 18 months behind on WORD, and a persistent ATNR. Sets of three children were then matched on age,



Trial profile

sex, verbal IQ, reading ability, and persistent ATNR level. One investigator who was not involved directly in assessment or administration of the movement programmes, randomly assigned children in blocks to the three treatment groups by means of random-number tables.[33] Originally we planned to have a fourth group of children with reading difficulties and average verbal IQ, but without a persistent ATNR. This inclusion proved impractical because of the high prevalence of persistent ATNR in the sample.

Children in the control group carried on with their normal daily life for the duration of the study. Children assigned to the experimental group were given a specific movement sequence to repeat each evening at home (this took about 10 min). Each child was seen once every 2 months so that the movement sequence could be changed or adapted; children did the movement programme for 12 months. The movements used were based on the Moro reflex, the tonic labyrinthine reflex, the ATNR, and the symmetrical tonic neck reflex. For example, for the ATNR movement the child sat on a chair with eyes closed and turned the head slowly to one side followed by a slow extension of the arm on the same side. The arm was then flexed with the hand returning towards the shoulder while the head was turned back towards the mid-line. This procedure was then repeated for the opposite side, and the sequence repeated twice.

Children in the placebo-control group were also given a set of movements that were similar in style but were non-specific (ie, not based on the replication of primary reflexes). For example, for the placebo movement corresponding to the ATNR specific movement the child sat on a chair and slowly raised the right arm (extended) up to shoulder height, counted to ten, and slowly lowered the arm; the sequence was repeated with the left arm. This entire sequence was then repeated. These children were assigned a new movement at the same time as their matched participants in the experimental group. We thought that the similarity of movements would help to disguise the nature of the study from both the administrator of the movements and the parents and children involved.

All movements were coordinated by an assessor who was unaware of the group identity of the children and the exact nature of the study. The movements were changed for two reasons. First, this change allowed the experimental group to follow a sequence of movements that replicated four early reflexes of the newborn, namely, the tonic labyrinthine reflex, the Moro reflex, the ATNR, and the symmetrical tonic neck reflex. Second, regular changing of the movements might encourage compliance by retaining the child's interest.

A final questionnaire was used to assess compliance in completing the movements for both experimental and placebo-control groups and to monitor extraneous factors such as school attendance, illness, the use of specialised help outside of school provision, and changes in circumstance. This questionnaire was in addition to a log book of how well movements were completed, which was updated at the administration of new movements. Although some children had difficulty in completing all the movements, compliance was very high for both groups and all children returned for reassessment after 12 months. At this assessment all the baseline tests were repeated by a different assessor.

Statistical analysis

We calculated that a sample size of 22 children in each group would provide 80% power to detect a significant difference on the assumption of a strong effect using GPOWER (version 2.0). Groups of 20 children were used, however, and power was calculated at 78%. Data were analysed by means of 3 by 2 repeated-measures ANOVA with group (experimental, placebo-control, and control) and time (before test and after test) as within participant factors.

Results

From an initial sample of 98 children (27 girls, 71 boys) 66 children (16 girls, 50 boys) met the final selection criteria of substantial reading difficulties. Six of these children were not able to be matched. 20 sets of three children were matched on age, sex, verbal IQ, reading ability, and persistent ATNR level (figure, table 1). These 60 children were randomised into the three trial groups.

For ATNR levels there was a highly significant (group by time) interaction ($p<0{\cdot}001$). The experimental group showed a significant decrease in the level of persistent reflex over the course of the study (mean change −1·8 [95% CI −2·4 to −1·2], $p<0{\cdot}001$), whereas the changes in the placebo-control and control groups were not significant, (−0·2 [−0·9 to 0·6] and −0·4 [−0·9 to 0·2]).

For the Neale analysis of reading ability and WORD there were significant (group by time) interactions ($p<0{\cdot}001$) for both tests. Although all groups showed a significant improvement over time for both tests (table 2), there was a substantially greater increase in reading scores for the children in the experimental group than in the other groups with a significant difference between the groups after the intervention ($p<0{\cdot}001$ for both tests), but not before.

	Experimental group	Placebo-control group	Control
Age (months)	113·1 (12·4)	110·9 (14·1)	114·6 (13·6)
Verbal IQ	99·8 (8·4)	97·9 (6·5)	98·7 (6·5)
Neale analysis of reading ability*	30·2 (6·4)	29·5 (5·2)	31·8 (8·0)
WORD*	24·4 (6·1)	24·2 (7·2)	25·1 (7·2)
Level of ATNR	3·1 (1·4)	3·1 (1·5)	2·9 (1·4)

All data are mean (SD). *Months behind chronological age.

Table 1: **Baseline characteristics of matched groups**

	Experimental group			Placebo-control group			Control group		
	Pretest	Post-test	Difference (95% CI)	Pretest	Post-test	Difference (95% CI)	Pretest	Post-test	Difference (95% CI)
ATNR level	3·1 (1·4)	1·3 (0·8)	−1·8 (−2·4 to −1·2)	3·1 (1·5)	2·9 (1·6)	−0·2 (−0·9 to 0·6)	2·9 (1·4)	2·5 (1·6)	−0·4 (−0·9 to 0·2)
Reading age (months)									
Neale analysis of reading ability	82·9 (13·1)	102·5 (16·3)	19·6 (16·5 to 22·6)	81·5 (13·1)	88·8 (14·6)	7·3 (4·9 to 9·7)	82·8 (13·3)	89·7 (14·8)	6·9 (5·1 to 8·6)
WORD	88·7 (10·3)	104·0 (15·5)	15·3 (11·8 to 18·8)	86·7 (11·2)	93·8 (13·7)	7·1 (3·6 to 10·5)	89·6 (12·6)	95·9 (15·3)	6·3 (2·8 to 9·8)
Saccadic frequency	67·4 (9·7)	55·9 (8·9)	−11·5 (−15·8 to −7·3)	69·5 (12·9)	66·4 (11·2)	−3·2 (−8·8 to 2·5)	66·1 (8·9)	65·5 (11·0)	−0·6 (−4·5 to 3·3)
Writing speed (words per min)	8·6 (2·66)	11·8 (3·36)	3·2 (2·0 to 4·4)	7·9 (2·93)	9·2 (3·66)	1·3 (0 to 2·6)	8·7 (3·34)	9·7 (3·71)	1·0 (−0·5 to 2·5)
WORD spelling age (months)	95·0 (13·1)	102·5 (13·9)	7·5 (1·8 to 13·2)	92·3 (14·2)	97·7 (16·0)	5·5 (−0·8 to 11·7)	91·7 (12·0)	97·7 (13·5)	6·0 (−0·7 to 11·3)
Phonological skills									
Naming speed	58·8 (7·7)	50·5 (8·8)	−8·3 (4·9 to 11·7)	57·6 (10·0)	56·3 (9·8)	−1·3 (−3·2 to 5·7)	60·8 (13·7)	59·5 (16·9)	−1·3 (−4·7 to 7·3)
Spoonerisms	15·6 (7·3)	19·3 (8·3)	3·7 (0·5 to 6·9)	15·2 (7·1)	17·3 (6·8)	2·1 (−1·0 to 5·2)	18·3 (8·4)	21·0 (9·0)	2·7 (−1·0 to 6·4)

Data are mean (SD) except differences, for which 95% CI are given.

Table 2: **Results of tests before and after study period**

There was a significant (group by time) interaction for saccadic frequency (p=0·0019) with only the experimental group showing a significant decrease in saccadic frequency (p<0·001, table 2).

There was a significant (group by time) interaction for writing speed (p=0·0043). All groups showed a significant improvement over time. The experimental group showed a substantially greater improvement although the difference between the groups post-test was not significant (p=0·052). There was no (group by time) interaction (p=0·5782) for spelling. All groups showed a significant improvement in spelling age over time (p<0·001 for experimental group, p=0·002 for placebo-control, and p=0·004 for control). A significant (group by time) interaction (p<0·001) was seen in the experimental group only for increase in naming speed (p<0·001). There was no (group by time) interaction (p=0·1104) for spoonerisms. All groups showed a significant improvement over time (p<0·001 for the experimental and control group and p=0·013 for the placebo-control group).

Discussion

The results suggest that the repetition of primary-reflex movements plays a major part in the inhibition of primary reflexes and that inhibition can be brought about at a much later stage in development than is generally accepted. The results confirm previous work[19] that the effects of persistent primary reflexes (in particular the ATNR) extend beyond the obvious disruption of motor development into cognitive areas. The reading gains achieved by the experimental group in this study are clinically significant.

The teaching of reading begins late in the developmental process (usually around age 4–5 years) after a substantial period of interaction between, for example, cognitive, social, and neurodevelopmental factors. To provide a detailed model of how the primary-reflex system impinges on the early precursors to reading acquisition is beyond the scope of this study. Extensive work will be needed on how, for example, persistent reflexes affect sensorimotor play or early language development. However, the results of this study suggest that these movements may have a critical role in early neurological maturation which, in turn, has repercussions for later reading development.

There is little evidence of substantial phonological differences (including spelling, generally viewed as a phonological skill[35]) between the groups at this stage. Whether the gains made by the experimental group transfer at a later stage into better phonological skills requires further research. The children participating in this study had received a substantial amount of teaching and reading instruction. We could not assess the role of previous phonological knowledge, over the limited period of this study.

Our results contrast with those of previous, controlled, efficacy studies[36] of movement intervention programmes. The significant differences between the experimental and placebo-control groups emphasise the specific effects of replicating primary-reflex movements. Although there is no evidence of a placebo effect for the placebo-control group in relation to the other control group, the 7-month reading gains for both control groups are good and indicate a possible placebo effect for both groups. Children of this age range and with this degree of reading difficulty (the bottom 10% of the population) would be expected to achieve reading gains of 4–6months over a 12-month period.[31] An average child without reading difficulties would be expected to achieve a reading gain of 12 months over the same period. The follow-up questionnaire showed that the control group, who did not receive a movement intervention, had received more private educational provision. Participation in a study of this kind heightend awareness of suspected difficulties and parents find it difficult to do nothing.

The difficulty in finding a fourth group of children with similar reading difficulties to the three groups in this study, but who did not have persistent ATNR, was not predicted. There may be a selection bias in the sample towards children who were not responding to traditional interventions and whose parents were motivated and proactive in seeking help. This factor may also have contributed to the size of the treatment effect. Further studies should assess the value of this intervention in situations where provision of individual support is not possible.

The prevalence of persistent reflexes in children attending ordinary school, and how this feature relates to academic and other problems, is one of several questions currently under investigation. Another important consideration is the long-term efficacy of intervention. Many improvements gained by specialised, intensive teaching methods are not retained long term without continued support. The progress of all the children who participated in this study, including the placebo-control group and control group who now receive the movement intervention, will be followed closely.

This study demonstrates the importance of assessing underlying neurodevelopmental functioning and, in particular, the persistence of primary reflexes when considering the basis of learning difficulties. A practical technique for promoting the development of reading skills is suggested. This approach could complement cognitive methods that cannot address some of the fundamental neurological prerequisites for educational progress.

Contributors

M McPhillips was responsible for the conception of the study and for devising the movement programmes. The design was developed and planned by all the investigators. P G Hepper arranged ethical permission. M McPhillips and G Mulhern analyed the data. All investigators contributed to the writing and critical revision of the paper.

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