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Primary reflex persistence in children with reading difficulties (dyslexia): A cross-sectional study

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Abstract

The primary reflex system emerges during fetal life and is inhibited during the first year after birth. Our aim was to examine the effects of persistence of this early neurological system on the attainment of core literacy skills in dyslexic and non-dyslexic poor readers. We assessed the prevalence of a persistent primary reflex in a cross-sectional, representative sample of children ($n = 739$) aged 7–9 years old attending mainstream primary school in Northern Ireland using standardised educational tests, and a clinical diagnostic test for a primary reflex (the asymmetrical tonic neck reflex (ATNR)). Multiple regression analyses, involving all of the sample children, revealed that persistence of the ATNR was significantly predictive of attainments in reading ($t = -8.34$, $p < .001$), spelling ($t = -8.00$, $p < .001$), non-word reading ($t = -16.15$, $p < .001$), and verbal IQ ($t = -4.71$, $p < .001$). ANOVA tests revealed that there were no differences between the performance of dyslexic and non-dyslexic poor readers on any of the outcome measures (reading ($F(1, 289) = 0.51$, $p = .48$), spelling ($F(1, 289) = 0.02$, $p = .90$), non-word reading ($F(1, 289) = 0.76$, $p = .38$), ATNR level ($F(1, 289) = 2.54$, $p = .11$)). Further ANOVA tests revealed that males had significantly higher levels of persistent reflex than females ($F(1, 737) = 15.21$, $p < .001$), and that children from socially disadvantaged backgrounds had significantly higher levels of reflex than children who were not socially disadvantaged ($F(1, 737) = 20.84$, $p < .001$). The findings suggest that for many children in mainstream schooling, the attainment of core educational skills may be affected by the persistence of a brainstem mediated reflex system that should have been inhibited in the first year after birth. Furthermore, these findings suggest that dyslexia is not a distinct category of poor reading, and that it may be more valid to term all poor readers as dyslexic irrespective of IQ.

Keywords: Motor skills; Neurodevelopment; Fetus; Brainstem

1. Introduction

Conventional definitions of dyslexia that distinguish dyslexics from other poor readers on the basis of a reading–IQ discrepancy have been extensively criticised (Siegel & Himel, 1998; Stanovich & Siegel, 1994). Furthermore, a large body of research suggests that children with reading difficulties, irrespective of IQ, have the same phonological problems, and respond equally well to phonological training methods (e.g. Vellutino, Fletcher, Snowling, & Scanlon, 2004).

Deficits in phonological coding in reading acquisition (difficulty in mapping alphabetic symbols to sound) have assumed a dominant position in describing dyslexia (Snowling, 2000), and brain-imaging studies have shown the direct impact of phonological training on brain metabolic functioning (Eden et al., 2004). The conception of dyslexia, however, as a discrete phonological phenomenon does not convey the full nature of this disorder as the development of literacy is dependent on a complex interaction of cognitive, environmental, and biological factors over time. This is highlighted in family risk studies where many young children at high risk of dyslexia (poor phonological reading and spelling strategies at the outset of schooling) manage to overcome these disadvantages (e.g. Snowling, Gallagher, & Frith, 2003). These studies suggest that there may be a gradation of risk of becoming dyslexic which is dependent on the developmental mix of strengths and weaknesses in reading related cognitive abilities, and the degree of exposure to compensatory environmental experience.

The continuous nature of dyslexia is further emphasised in studies which suggest that children with reading difficulties have problems that extend beyond the range of underlying language-related deficits. A number of studies have shown that some

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children with dyslexia have impairments in several areas of the visual system (Stein & Walsh, 1997) and that auditory temporal processing may be impaired (Witton et al., 1998). Furthermore, dyslexic performance is often characterised by poor motor skills and poor balance, and it has been suggested that a dysfunction in the cerebellum might underlie the major deficits seen in dyslexic children (Fawcett, Nicolson, & Dean, 1996). Neuro-imaging studies have shown abnormal activation and morphology of a number of brain regions in adults with dyslexia including the cerebellum (Rae et al., 2002). Finally, there is considerable evidence of comorbidities involving reading difficulties, attention deficits and motor coordination deficits (e.g. Iversen, Berg, Ellertsen, & Tønnessen, 2005; Visser, 2003).

Primary reflexes are brainstem mediated responses (e.g. Capute et al., 1982) that emerge *in utero*, and play an important role in generating movement during fetal and neonatal life. They are critical for the survival of the baby in the first weeks after birth, and many of these reflexes are familiar (e.g. rooting, suck, grasp and startle reflexes). They are readily elicited in the first 6 months after birth (Holt, 1991; Illingworth, 1987), and primary reflex tests are used in routine paediatric tests to assess the neurological integrity of the neonate.

Primary reflexes are, however, inhibited or transformed during the first year of postnatal life. Abnormalities of the primary reflex system either in the degree or rate of disappearance (persistence) may lead to significant problems in the development of motor functioning (Holt, 1991), and there are very close links between the inhibition of primary reflexes and the attainment of gross-motor milestones (Capute, Accardo, Vining, Rubenstein, & Harryman, 1978).

Severe persistence of primary reflexes indicates predominantly intractable organic problems as seen in children with cerebral palsy (Bobath & Bobath, 1975) while milder persistence has been associated with less severe disorders including reading difficulties and motor problems (McPhillips, Hepper, & Mulhern, 2000). However, there is little research on the effects of reflex persistence with children who have not been diagnosed with specific neurological difficulties, and it is not known if reflex persistence affects the attainment of core educational skills such as reading and spelling in mainstream education.

A particular focus of the present study is the asymmetrical tonic neck reflex (ATNR) which is most obvious in the 3 months after birth, and 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 (Illingworth, 1987). The ATNR should be inhibited around 6 months after birth, and persistence is a clinical indicator of abnormal development. The ATNR is the most commonly observed persistent reflex in infants with neurological lesions (Paine, 1964).

The major aim of the present study is to investigate the prevalence of ATNR persistence in children attending mainstream primary school using a large, representative, naturalistic sample. The primary question, therefore, concerns the degree of association between reflex persistence and the development of early literacy skills, within the context of other well-known predictors of reading/spelling attainment such as verbal IQ and social advantage. The study also examines the validity of distinguishing dyslexics from other poor readers, on the basis of an IQ–reading level discrepancy, using a sample that is not based on clinical or self-referral procedures. In particular, we address the issue of possible differential levels of reflex persistence in dyslexics and poor readers.

Finally, there have been concerns about the relative underachievement of boys in public examinations for many years, and in their development of early literacy skills (e.g. Epstein, Elwood, Hey, & Maw, 1998). Social disadvantage has also been highlighted as a major factor in poor academic attainments (e.g. Riddell, 1998). The present study asks; is reflex persistence greater in males than females, and are children from a socially disadvantaged background at greater risk of reflex persistence than other children?

2. Methods

2.1. Participants

Thirteen primary schools from the South Eastern Education and Library Board (SEELB) area in Northern Ireland were selected as representative of the total district. All of the children attending Years 3 and 5 classes at all of the schools were included in the sample. Parental consent was obtained for all the children who participated in the study. Two children were withdrawn by parental request before the assessments were carried out. A total of 739 children were assessed: 363 Year 3 (7 year olds) and 376 Year 5 (9 year olds). Approval for the study was given by the research ethics committee, School of Psychology, Queen's University, Belfast.

2.2. Procedure

At the end of the school year, all of the children in Years 3 and 5 attending the 13 selected schools were tested individually on a range of measures that included standardised tests of reading, spelling and non-word reading, and a clinical diagnostic test for the asymmetrical tonic neck reflex (ATNR). The ATNR tests were videotaped for external validation and inter-rater reliability purposes ($r_s = .91$, $n = 739$, $p < .01$). The children were also tested in their class groups for verbal IQ. All of the individual assessments were carried out by a small group of testers from a 'bank' of experienced testers used by the School of Psychology in applied educational projects.

2.3. Measures

Verbal IQ was measured using the Non-Reading Intelligence Tests (Young, 1989), and reading and spelling were assessed using theWechsler Objective Reading Dimensions (WORD) (Rust, Golombok, & Trickey, 1993). The two WORD subtests used in this study were Basic Reading and Spelling. The Graded Non-Word Reading Test (Snowling, Stothard, & McLean, 1996) was used to identify children whose reading difficulties were associated with impaired phonological skills, and raw scores were used as individual standardised scores were not available for this test.

The asymmetrical tonic neck reflex was assessed using the Schilder Test (Morrison, 1985). The test position and procedure were demonstrated. The child, then, stood upright with feet together and arms held straight out in front at shoulder level, but with the wrists relaxed. The tester stood behind the child and gave 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 turned the child's head to one side (70–80° or until the chin was over the shoulder), paused for 5 s and then slowly turned the head to the other side. After another pause for 5 s the whole sequence was repeated once more. Positive indicators of this reflex included movement of the extended arms in the same direction as the head turn, dropping of the arms or swaying and loss of balance. (Scoring: 0, no response (the 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 or loss of balance.) The test was repeated twice and each side was scored separately. A total impairment score was obtained (maximum of 12).

2.4. Statistical analysis

We used multiple regression analyses to evaluate a predictive model of reading, spelling, and non-word reading for the Years 3 and 5 children using the four predictor variables available in this study: verbal IQ, ATNR persistence, gender, and free school meal entitlement.

We used ANOVA to evaluate differences in reading, spelling, non-word reading, and ATNR persistence between dyslexic and non-dyslexic poor readers. Dyslexia is conventionally defined in terms of a discrepancy between age appropriate reading attainment and measured IQ (e.g. American Psychiatric Association (2000)). A discrepancy of more than one S.D. (more than 15 standardised score points) between reading (Basic Reading, WORD) and IQ scores was used to identify the dyslexic poor readers in this study. ANOVA was also used to evaluate the effect of gender and social disadvantage on reading, spelling, non-word reading and ATNR persistence. Effect Sizes were calculated to assess the magnitude of significant differences.

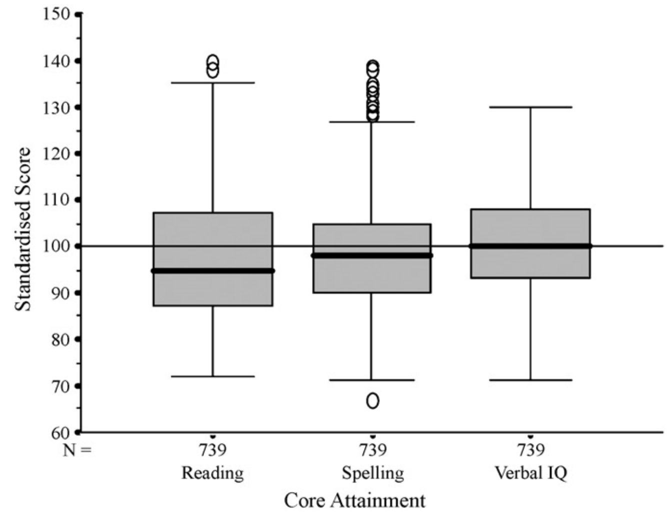

Fig. 1. The distributions of reading, spelling and verbal IQ scores for the total sample. Each ‘box’ delineates the distribution of scores for the middle 50% and the horizontal lines within each box denote the median values. The ‘whiskers’ (the top or bottom 25%) extend upwards to the highest score and downwards to the lowest score, and the circles indicate ‘outliers’.

3. Results

3.1. Sample characteristics

The verbal IQ scores (mean: 100.6, S.D.: 11.0) for all 739 children suggested that the sample schools were representative of the wider population of children attending mainstream primary school in Northern Ireland. Similarly, the reading and spelling standardised scores were normally distributed with means of 97.5 and 98.4 for reading and spelling and S.D.s of 12.9 and 12.5, respectively (Fig. 1). We used free school meal entitlement as an index of social disadvantage and the proportion of children receiving free school meals in the study sample was 24% which compares with 22% for the total primary school population in Northern Ireland (Department of Education, Northern Ireland, 2002/2003).

3.2. Predictors of reading, spelling and non-word reading

The multiple regression analyses showed that the linear combination of the four predictors available in this study were significantly related to reading level ($R = 0.65$, $R^2 = 0.42$, $R^2_{adj} = 0.42$, $F(4, 734) = 134.5$, $p < .001$), spelling ($R = 0.61$, $R^2 = 0.37$, $R^2_{adj} = 0.37$, $F(4, 734) = 107.9$, $p < .001$) and non-word reading ($R = 0.75$, $R^2 = 0.56$, $R^2_{adj} = 0.56$, $F(5, 733) = 188.7$, $p < .001$). These equations suggest that 42%, 37%, and 56% of the variance in reading, spelling, and non-word reading, respectively, can be predicted on the basis of the four predictors used in this model. The bivariate and semipartial correlations of the individual predictors for each outcome measure are summarised in Table 1.

The bivariate correlations and semipartial correlations suggest that verbal IQ is a relatively strong predictor of attainments in reading and spelling which is in line with previous research using large, representative samples (Rust et al., 1993). In this study we were particularly interested in the predictive power of ATNR persistence. The results suggest that persistence of the ATNR is predictive of attainments in reading and spelling, and that ATNR persistence is a relatively strong predictor of non-word reading attainment.

This is further illustrated in Fig. 2 which shows the association between ATNR persistence and reading level. Sixty two percent of the bottom 10% of readers showed clinically high levels of reflex persistence. (A similar pattern of persistence was

Table 1
Bivariate correlations (and semipartial correlations) for each predictor and attainments in reading, spelling, and non-word reading

	Predictors			
	Verbal IQ	ATNR	Free meals	Gender
Reading	.60*** (.39***)	−.46*** (−.23***)	−.33*** (−.08**)	.06*** (.04)
Spelling	.55*** (.35***)	−.44*** (−.23***)	−.29*** (−.06*)	.12*** (.05)
Non-word reading[a]	.46*** (.23***)	−.60*** (−.35***)	−.25*** (−.06*)	.09** (.02)

[a] As the Non-Word Reading Test was not standardised, age was also included as a predictor in this analysis.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

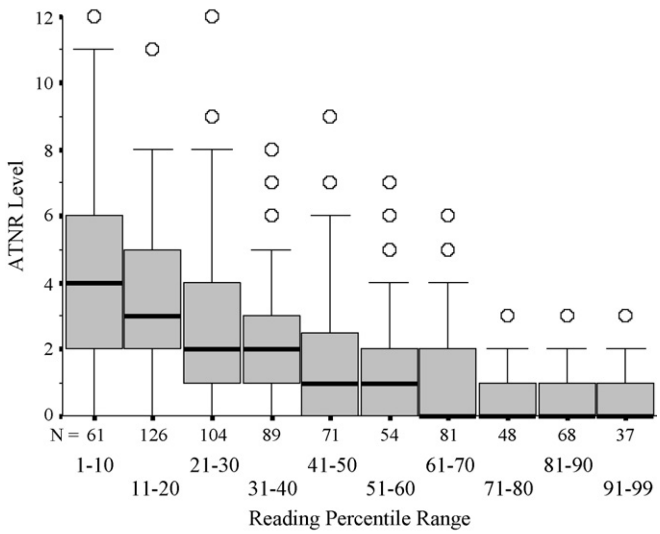

Fig. 2. The relationship between ATNR persistence and reading attainment (WORD). The boxplots show that children in the lower reading percentile groups have higher ATNR persistence than children in the higher reading percentile groups. For the weakest readers (the bottom 10%) 50% are showing levels of ATNR above a score of 4 (62% of the bottom 10% of readers score at 4 or above) with 25% (the upper 'whisker') showing extremely high levels of persistent reflex. For the top readers, more than 50% (62%) show no evidence of reflex (the median is at 0) and 25% (the upper line of the 'box') show a minimal score of 1. There are, however, 'outliers' across the range of reading attainments illustrating that, for example, there are some children who have average reading attainment but a relatively high level of ATNR.

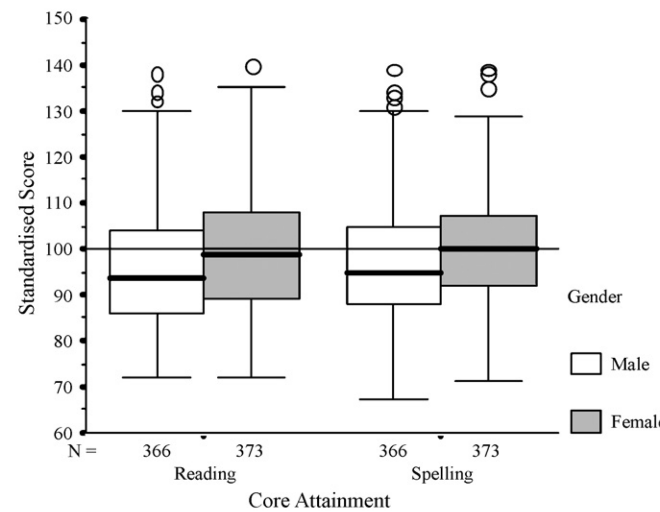

Fig. 3. A boxplot of male and female attainment levels for reading and spelling. Both plots for the females distribute evenly around a standardised score of 100 while both plots for the males show that most of their scores are below 100. A standardised score of 100 would be the expected mean.

found for spelling and non-word reading levels.) Entitlement to free school meals was also predictive for all of the outcome measures. It should be noted, however, that the size of the semi-partial correlations can only provide a rough measure of the relative importance of the predictors as the multiple regression model works on a principle of parsimony, and some of the predictive power of individual predictors may be subsumed by other predictors.

3.3. *Comparison of dyslexic and non-dyslexic poor readers*

The means (and S.D.s) for the dyslexic and non-dyslexic poor readers on all of the dependent measures are shown in Table 2. Ninety-four dyslexics were identified in the total sample (12.7%) using a reading–IQ discrepancy criterion of more than 15 standardised score points. Some of the dyslexics were reading at or above their chronological age and, for the purpose of comparison with the non-dyslexic poor readers, a reading level cut-off point (below the 30th percentile, (Basic Reading, WORD)) was used. This subsample of the bottom 30% of readers ($n = 291$) included 64 dyslexics and 227 non-dyslexic poor readers. The ANOVA tests revealed that there was no difference between the performance of dyslexic and non-dyslexic poor readers on any of the outcome measures used in this study (reading ($F(1, 289) = 0.51$, $p = .48$), spelling ($F(1, 289) = 0.02$, $p = .90$), non-word reading ($F(1, 289) = 0.76$, $p = .38$), ATNR level ($F(1, 289) = 2.54$, $p = .11$)).

3.4. *ATNR persistence and gender*

We compared the relative attainments in reading, spelling, non-word reading and verbal IQ of the male and female children participating in the study (Fig. 3). The females in this study had significantly higher mean attainments in reading ($F(1, 737) = 11.51$, $p < .001$), spelling ($F(1, 737) = 11.60$, $p < .001$), non-word reading ($F(1, 737) = 5.45$, $p = .02$) and verbal IQ ($F(1, 737) = 5.36$, $p = .02$). We calculated Effect Sizes of 0.25 (moderately small) for the impact of gender on both reading and spelling and Effect Sizes of 0.17 (small) for the impact of gender on both non-word reading and verbal IQ. The Effect Sizes reflect the considerable overlap between male and female attainments across all measures.

Table 2
Means (and S.D.s) for dyslexic and non-dyslexic poor readers on all measures by year group

Poor reader		Measures					
		Age (months)	Verbal IQ	Reading	Spelling	Non-word reading	ATNR
Dyslexic $n = 64$ (36 male; 28 female), 12.5% entitled to free school meals	Year 3 ($n = 33$)	87.1 (3.6)	107.7 (5.4)	87.0 (3.5)	89.2 (6.9)	3.6 (3.3)	3.1 (2.0)
	Year 5 ($n = 31$)	109.9 (4.3)	101.6 (5.9)	81.9 (5.6)	86.8 (8.1)	7.5 (5.6)	2.8 (2.5)
Non-dyslexic $n = 227$ (132 male; 95 female), 45.4% entitled to free school meals	Year 3 ($n = 125$)	86.5 (3.6)	90.7 (7.9)	85.9 (3.9)	87.5 (6.7)	2.5 (2.8)	3.7 (2.5)
	Year 5 ($n = 102$)	108.5 (4.1)	90.8 (7.3)	84.2 (5.2)	88.3 (7.7)	8.3 (4.9)	3.2 (2.5)

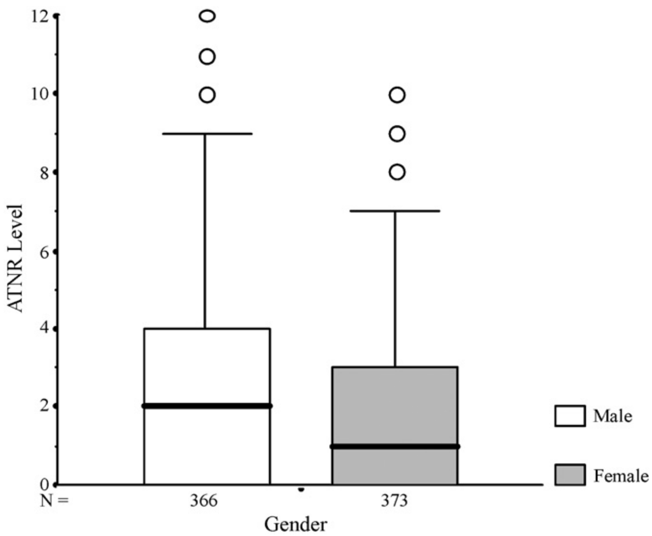

Fig. 4. The relationship between ATNR persistence and the gender of the child. While there is considerable overlap, the plots show that males are more at risk of higher levels of ATNR than females. Further, there are more females than males with very low levels of reflex persistence.

Furthermore, we found that ATNR persistence was significantly higher for males than females ($F(1, 737) = 15.21$, $p < .001$), and an Effect Size of 0.28 suggests that gender has a moderately small effect on ATNR persistence (Fig. 4). Although the Effect Sizes may be small or moderately small with regard to the impact of gender on educational attainments, and ATNR persistence, they may be relatively powerful in the context of large populations of male and female children attending school.

3.5. ATNR persistence and social disadvantage

We compared the relative attainments in reading, spelling, non-word reading and verbal IQ of the children participating in the study according to relative social advantage (as indexed by entitlement to free school meals). The socially advantaged children in this study had significantly higher mean attainments in reading ($F(1, 737) = 87.27$, $p < .001$), spelling ($F(1, 737) = 67.57$, $p < .001$), non-word reading ($F(1, 737) = 47.15$, $p < .001$) and verbal IQ ($F(1, 737) = 164.61$, $p = < .001$) than the socially disadvantaged children. We calculated Effect Sizes of 0.83, 0.71, 0.59 and 1.15 for the impact of social advantage on reading, spelling, non-word reading and verbal IQ, respectively. The Effect Sizes indicate that social advantage has a large effect on the core measures of educational attainment used in this study.

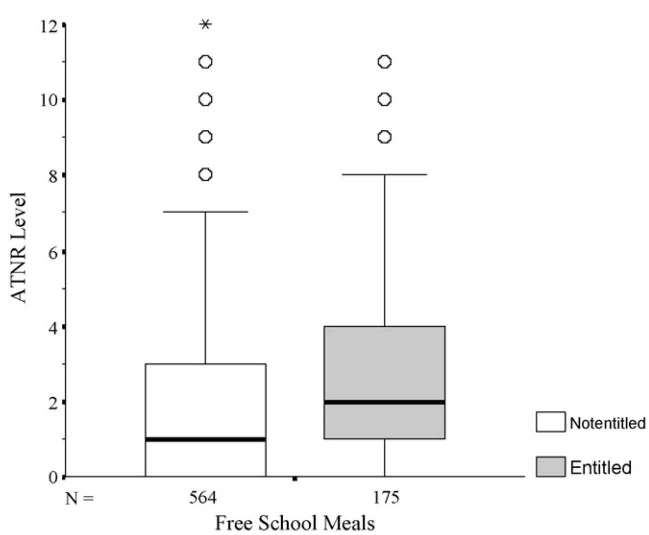

Fig. 5. The relationship between ATNR persistence and social disadvantage. The plots show that children from disadvantaged backgrounds have an increased risk of ATNR persistence.

Furthermore, we found that ATNR persistence was significantly higher for socially disadvantaged children ($F(1, 737) = 20.84$, $p < .001$), and an Effect Size of 0.39 suggests that social advantage has a moderately small effect on ATNR persistence (Fig. 5).

4. Discussion

The findings in this study indicate that persistence of a brainstem mediated primary reflex (the asymmetrical tonic neck reflex (ATNR)) is associated with attainments in core literacy skills in young children. A continuum of reflex persistence is suggested where children with difficulties in reading, spelling and non-word reading show higher levels of reflex persistence than children without such difficulties. Furthermore, we found that males were more at risk of reflex persistence than females, and that children from socially disadvantaged backgrounds displayed higher levels of persistence than socially advantaged children.

The results also suggest that a definition of dyslexia based on a reading–IQ discrepancy may be invalid. It was not possible to distinguish between dyslexics and other poor readers on any of the measures used, and it may be more appropriate to term all poor readers as dyslexic, irrespective of IQ. This supports previous research that has failed to distinguish 'garden-variety poor readers' from 'dyslexic poor readers' (e.g. Stanovich, 1996). The present findings suggest that while IQ may be a strong predictor of reading attainment, it should be viewed within the context of other predictors. The level of social advantage, for example, within the dyslexic poor reader group is much higher than the non-dyslexic poor reader group (see Table 2), and social advantage is known to have an indirect effect on IQ scores (Siegel & Himel, 1998).

Furthermore, the regression model used in this study is limited and does not include other factors that may be predictive of literacy attainments. It was not possible, for example, to include a genetic heritability factor which is known to be a predictive component in dyslexia (e.g. Grigorenko, 2001). In spite of such limitations, the present study provides support for an emerging view that dyslexia represents a continuous rather than a discrete developmental phenomenon where severity may depend on the interaction of a range of cognitive, biological and environmental factors across the timespan of development.

It has been suggested that the high prevalence of reading difficulties (dyslexia) in males may be due to a reporting bias (e.g. Shaywitz, 1996), but there is considerable evidence from large-scale international studies that females consistently achieve higher literacy levels than males (Elley, 1992; OECD, 2002), and that gender differences are particularly pronounced at the lowest levels of performance (OECD, 2002). Furthermore, baseline assessment of children in their first year at school has shown that girls are particularly strong relative to boys in areas such as social skill, letter identification, writing and drawing (Arnot, David, & Weiner, 1996). We found that females out-performed males in reading, spelling and non-word reading, and that boys were more at risk of underachievement in these areas, but it should be stressed that there was considerable overlap between male and female attainments. With regard to reflex persistence, we found that males were significantly disadvantaged relative to females. This suggests that an early biological or neurodevelopmental factor may be associated with differential male–female attainment.

Similar to previous research (e.g. OECD, 2002), we found that social disadvantage had a powerful, negative effect on literacy attainments. The present study suggests that social disadvantage may impact to some extent on the development of an early neurological system, and provides some evidence of the complex interaction between environmental factors and a possible biological substrate in the emergence of literacy. It was beyond the scope of the present study, however, to examine the impact of specific socio-economic factors (such as family income, level of education of the parents) on core literacy skills and reflex persistence.

The first years of schooling provide the foundations for long-term educational success, and differences that emerge in the early years tend to remain or increase throughout the child's school life (Sammons, 1994). Early identification and remediation are considered critical but children with reading or spelling difficulties are often identified after they have failed to make the expected progress. Although it should be stressed that not all children with reading or spelling difficulties have persistent reflexes, testing for persistent reflexes at the earliest opportunity could complement other methods that seek to identify children at risk for later literacy difficulties, (such as phonological delays and possible visual and auditory processing problems).

In conclusion, this study suggests that for some children difficulties in acquiring core literacy skills are associated with the persistence of reflex activity that originates in the brainstem during fetal life. It is likely that reflex persistence is not directly causal of reading difficulty as there are some children with clinically high levels of persistent reflex who are good readers. Reflex persistence, therefore, may be viewed as an early developmental risk factor for some children where subsequent effects are dependent on the interplay of a range of cognitive, environmental, and biological factors. A prospective study of the predictiveness of early reflex persistence on later cognitive performance and why some children who do not demonstrate obvious neurological conditions should retain primary reflexes are concerns for future research.

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