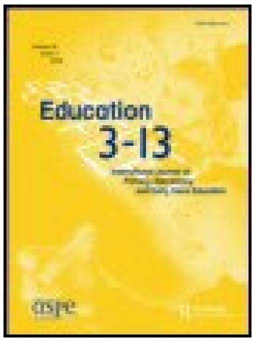

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Neuromotor readiness for school: the primitive reflex status of young children at the start and end of their first year at school in the United Kingdom

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ABSTRACT

The presence of primitive (infant) reflexes in school-aged children as indicators of immaturity in neuromotor functioning has been associated with under-achievement in terms of reading, writing and mathematics, and been linked to conditions such as dyslexia, developmental coordination disorder (DCD) and attention deficit and hyperactivity disorder (ADHD). The research presented here explores the extent to which three such reflexes, previously linked to learning and behavioural difficulties in the classroom, were present in a sample of 120 children in the September that they started formal schooling (aged 4–5) in the United Kingdom (UK). Approximately half of these children then participated in a movement programme and 108 were then tested again towards the end of their first year at school. The data demonstrate that a high percentage of young children are, indeed, starting school with one or more of these reflexes present to some extent. Those children who received no additional input throughout the school year showed no improvements in their reflex status when compared to children who had participated in a developmental movement programme. Thus, recommendations are made for further research; particularly in relation to neuromotor screening, appropriate physical development provision prior to and during school; and developmental movement interventions for older children.

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Primitive reflexes; neuromotor maturity; early years; foundation stage; physical development; educational achievement

Introduction

There are many factors involved in school readiness; a term commonly used to describe the extent to which a child is prepared cognitively, socially, emotionally and physically to start school. Whilst these areas of development are all important and interconnected, the focus of this paper is on children's physical readiness to start school and, more specifically, their neuromotor readiness to start formal schooling.

Neuromotor performance describes a complex functional behaviour which results from activation of the central and peripheral nervous systems and involves motor structures, which operate through the musculo-skeletal system involving multiple inputs from the individual's internal and external environment. The systems and structures responsible for movement within an individual are constantly evolving throughout the developmental process, but at particular stages in development, a child is expected to have attained a certain level of neuromotor performance. Motor milestones

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and motor performance provide outward signs or reflections of functional neuromotor maturity (Goddard Blythe 2012), which provide an indication of neuromotor readiness for learning and point to relevant and effective remedial interventions.

Although it is impossible to consider motor development in isolation, as it must be considered within a broader context, readiness for school involves much more than a child simply reaching the chronological age for school entry. For example, Goddard Blythe (2012) identifies a number of physical abilities that a child must be able to do well in order to succeed in an educational environment. These include an ability to: sit still; focus attention; hold a pencil correctly; control eye movements in order to follow a line of print and adjust vision from near to far; skills that illustrate the relationship between educational performance and neuromotor maturity. However, with an increasing focus on academic subjects and, despite physical development being a prime area of the early years' curriculum in the UK (Early Years Foundation Stage Framework: EYFS, DfE 2017), this key area is often neglected. Indeed, growth and development have largely been ignored by the educational system since routine developmental testing of all children was phased out in the United Kingdom in the 1980s (Goddard Blythe 2012).

Primitive reflexes

One marker of neuromotor immaturity/maturity is the presence or absence of primitive reflexes at key stages in development (Goddard Blythe 2005; Gieysztor, Sadowska, and Choińska 2017; Gieysztor, Choińska, and Paprocka-Borowitz 2018). Primitive reflexes are a group of reflexes (automatic stereotyped reactions to specific stimuli), which develop during life in the womb, are fully present in the full-term neonate, active during the first months of post-natal life and inhibited by six months of age (when awake) as connections to higher centres in the brain mature (Capute and Accardo 1992). Examples of primitive reflexes in infancy with which readers should be familiar, include the grasping and sucking reflexes. Postural (more mature) reactions emerge after birth and continue to develop during the first three and a half years of life, gradually replacing primitive reflexes and reflecting increased control by higher centres in the brain. Collectively, postural reactions provide a stable platform for sub-conscious control of balance, posture and coordination. It is a medically accepted fact that, if primitive reflexes persist, they are markers of immaturity in the functioning of the central nervous system. They may be voluntarily released to enhance specific skills later in life but this is very different from retention when they limit the range of movement possibilities in response to specific stimuli. Primitive reflexes in infancy are normal but even partial retention beyond this period can be problematic.

If primitive reflexes persist after the first six months of life, and/or postural reactions are underdeveloped after three and a half years of age, they provide evidence of a structural weakness in the functioning of the Central Nervous System (CNS); these are sometimes described as aberrant reflexes, minor neurological dysfunction (ND) or neuromotor immaturity (NMI). Additional features of NMI can include immaturity in control of balance, postural stability, eye movements and visual-perception (Bein-Wierzibinski 2001; González et al. 2008; Goddard Blythe 2009; Andrich et al. 2018). These abilities are needed to sit still, develop the eye tracking movements involved in reading, hand-eye coordination (writing), adjustment of visual focus between different visual distances (copying and catching a ball) and freedom from distractibility (attention). In this context, the presence or absence of primitive reflexes after four years of age can be used as a screening tool to identify signs of neuromotor immaturity, which might have an impact on the motor aspects of learning and subsequently on academic performance. Immature reflexes are not the primary cause of the presenting problems, but rather provide a reflection of immaturity in the functioning of pathways involved, thereby providing indications as to what type and developmental level of intervention may be effective.

Research has indicated a relationship between maturity in children's physical skills, partly measured through competency in control of movement, and educational achievement (North

Eastern Education and Library Board 2004; Goddard Blythe 2005; Ivanović, et al. 2018), with children with immature neuromotor skills performing less well on educational measures than children whose neuromotor skills were commensurate with expectations for chronological age (Griffin 2013; Harte 2015).

Despite this historical evidence, assessment of children's neuromotor skills as indicators of neuromotor readiness for learning is not carried out in the educational system as a matter of routine. Empirical evidence obtained from observation and use of the Draw a Person (DAP) test has indicated that children with immature neuromotor skills can compensate to some degree, but often at the expense of under-achieving at motor dependent tasks (Silvester 2006). Routine screening of children's neuromotor skills at key stages in the educational process, followed up by introduction of effective physical remedial programmes could, in theory, help children to reach their academic potential.

This lack of screening for retained primitive reflexes alongside a general lack of awareness and acceptance in schools may be due, in part, to a traditional medical view of primitive reflexes that assumed testing for primitive reflexes beyond six months was not necessary unless underlying pathology had been identified. This has led to the development of a 'grey area' between Medicine and Education, which has allowed some children to be overlooked. Such children might present with coordination difficulties which are not 'bad enough' to be examined and diagnosed with a medical condition but who have also not developed the full range of neuromotor skills needed to support specific skills and aspects of educational performance in the classroom. It is these children who could be better supported in order to reach their academic and physical potential. Research to date has identified that neuromotor immaturity is a factor in children in mainstream schools both in the United Kingdom and other countries (North Eastern Education and Library Board (NEELB) 2004; Goddard Blythe 2005; Gieysztor, Sadowska, and Choińska 2017; 2018) and pointed to a correlation between high levels of neuromotor immaturity and lower academic performance (NEELB 2004; Griffin 2013; Harte 2015). Despite this, research investigating the impact of specific movement programmes has either tended to comprise small sample numbers or has only been published in the form of reports prepared for the education authorities involved. The North Eastern Education Library Board project (2004) did show that there were significant improvements in measures of neuromotor maturity in the group who followed the Institute of Neuro Physiological Psychology's (INPP) developmental movement programme compared to the control group and a small but significant improvement in one measure of non-verbal cognitive performance, but the number of children in the sample who met the criteria for which the intervention programme had been designed was too small to reach statistical significance. For the above reasons, the subject of primitive reflexes as markers of neuromotor immaturity, their relationship to academic performance and receptiveness to change through application of specific developmental movement programmes has remained controversial. This controversy could be resolved through large-scale independent studies. This project was the first step in indicating that there is a need for such studies.

The research presented here examined the extent to which three primitive reflexes were present in young children as they started formal schooling in the UK (in September after their fourth birthday) and again towards the end of the academic year. The aim of the research was to establish the extent to which primitive reflexes were aberrant in a sample of 120 children as they started school. Three key primitive reflexes were examined: The Tonic Labyrinthine Reflex (TLR); the Symmetrical Tonic Neck Reflex (STNR) and the Asymmetrical Tonic Neck Reflex (ATNR). Research has shown these reflexes to be closely associated with later difficulties in the classroom and, as such, they were chosen for further investigation. Further details regarding these three reflexes are provided later. Additionally, the research aimed to identify whether and to what extent a daily developmental movement programme, delivered throughout one academic year, could reduce the presence of these three reflexes in children of this age.

Literature review

A relationship between aberrant reflexes, as markers of neuromotor immaturity, and specific learning disabilities is not a new area of investigation. In the 1970s, a number of studies were carried out which compared the primitive reflex status of learning-disabled children to those without learning disabilities. All children in the learning-disabled group were found to have a cluster of residual primitive reflexes whilst no primitive reflexes were present in the children without learning disabilities (Gustafsson 1971). A similar study, which used tests for the presence of primitive reflexes and the Wide Range Achievement Tests (WRATs) − a group of tests which focus on providing norm-referenced measures of reading, spelling, and mathematics computation − in diagnosed learning disabled and non-learning disabled groups, found a higher incidence of abnormal reflexes in the learning disabled group, but also discovered some reflex abnormalities amongst the undiagnosed group. When tests for aberrant reflexes were compared to performance on the WRATs, those children in the comparison group who had aberrant reflexes were found to be under-achieving in reading and writing. In other words, the combination of reflex tests and measures of educational performance was able to identify children who were under-achieving and who might otherwise have been overlooked in the classroom as already performing to potential (Rider 1976). A replica study, carried out 18 years later, revealed a link not only between atypical primitive reflexes and learning difficulty but also enabled the researcher to identify which children were under-achieving in the classroom simply by analysing the reflex profile of each child. These results also suggested that one reflex − the Tonic Labyrinthine reflex (TLR) − underpinned all problems detected (Wilkinson 1994). Likewise, Bender (1976) investigated the incidence of the STNR and its connection to educational outcomes and found it to be present in 75% of a group of children with learning disabilities but not present in any of the comparison group.

Despite a paucity of literature investigating the relationship between residual primitive reflexes and educational under-achievement from the early 1980s until the late 1990s, more recently, researchers have examined the incidence of aberrant reflexes in specific populations. Amongst the 'cluster' of aberrant primitive reflexes assessed, the incidence of individual reflexes has also been investigated and linked to specific difficulties, including presence of the Asymmetrical Tonic Neck Reflex (ATNR) in children diagnosed with reading difficulties (McPhillips, Hepper, and Mulhern 2000; McPhillips and Sheehy 2004), dyslexia (Goddard Blythe 2001) and the Moro reflex in children diagnosed with ADHD (Taylor, Houghton and Chapman 2004). Additional research published after this study was completed has identified a link between behavioural problems in children and significant levels of motor difficulties, persistence of primitive reflexes and family upset, as well as, significant literacy problems, attention deficits, and raised levels of hyperactivity/impulsivity relative to the comparison groups. Researchers concluded that these factors were all'significant predictors of psycho-social functioning' and that 'specific movement interventions should be adopted to complement existing provision for children at risk of psycho-social problems' (Taylor, Hanna, and McPhillips 2019).

The impact of specific developmental movement programmes on neuromotor status has also been investigated (Goddard Blythe 2005). When compared to baseline data, children who had participated in 10 minutes of daily physical activities made twice the improvement on measures of neuromotor maturity compared to those who did no additional activity but only half the improvements compared to those who participated in a developmental movement programme (INPP school programme). This would suggest that daily physical activity of any kind is beneficial, but activities targeted at children's developmental needs may be more effective.

Significance of three primitive reflexes

Tonic Labyrinthine Reflex (TLR)

The TLR is elicited in two positions in the full-term neonate: (a) Lowering the head below the mid-plane (below the level of the spine) in the supine (on the back) position will result in an increase in extensor tone throughout the body; (b) elevating the head above the midplane (head flexion) will result in an increase in flexor tone throughout the body.

If the TLR is still active when a child goes to school, it can undermine control of upright balance, postural stability, and the operation of centres involved in the control of the eye movements needed to support reading and writing.

Symmetrical Tonic Neck Reflex (STNR)

The STNR emerges between 5 and 8 months of age as an infant is learning to push his/her body weight off the ground on to all fours (quadruped position) in preparation for creeping on hands on knees. If the head is flexed (looking down) in the quadruped position, it will elicit an increase in flexor tone in the arms and extensor tone in the lower half of the body. If the head is extended (looking upwards) in the quadruped position, the opposite reaction will occur: head extension will elicit an increase in extensor tone in the upper portion of the body and increase in flexor tone in the lower half of the body.

If the STNR remains active, the infant may have difficulty coordinating use of the top and bottom halves of the body to creep on hands and knees. Most infants go through a brief phase of 'rocking' on hands and knees, which helps to integrate the reflex so that the upper and lower halves of the body can be coordinated for locomotion, irrespective of the position of the head.

If the STNR persists, the child may omit the creeping stage of development, bottom shuffle or creep with the hands or feet in unusual positions. Creeping is thought to be an important stage in development because it helps to integrate use of the balance mechanism, proprioceptive and visual systems in a new relationship with gravity for the first time, helping to develop coordination of the two sides and upper and lower sections of the body in synchronised action. It may also help to entrain eye-hand coordination at the same visual distance a child will use to read and write a few years later (Hansen, Josh, and Dex 2010; Visser and Franzen 2010). If the STNR is active when a child enters school it can affect control of sitting posture including the ability to sit still (O'Dell and Cook 2004), aspects of eye-hand coordination and vertical eye tracking movements needed for aligning columns correctly in maths (Bein-Wierzibinski 2001).

Asymmetrical Tonic Neck Reflex (ATNR)

The ATNR is present in the full-term neonate and describes a reflex reaction to lateral rotation of the head. When the head is rotated to one side, it elicits an increase in extensor tone in the limbs on the side to which the head is turned and an increase in flexor tone in the occipital (opposite) limbs. This reaction should be inhibited by higher centres in the developing brain by circa 6 months of age (when awake).

If the ATNR persists beyond the first 6 months of age, it can interfere with the development of subsequent motor abilities, such as crawling on the stomach (commando crawling) and the ability to cross the midline of the body when the head is turned to the affected side. If it is still active in the school-aged child, it can impede the hand-eye coordination needed for writing and, if present in combination with under-developed postural reflexes (head-righting reflexes), can affect the development of the eye movements needed for reading (Goddard Blythe 2009). Head-righting reflexes respond to a change in body position and should ensure that there is an equal and opposite adjustment of head position in response to displacement of the body thus ensuring that the head 'rights' to the midline. This head-righting reaction provides a stable reference point for centres involved in the control of eye movements.

Results from various projects using the screening test *Assessing Neuromotor Readiness for Learning* have revealed a consistent relationship between the persistence of primitive reflexes in children of school age and lower academic performance (Goddard Blythe 2005; Griffin 2013; Harte 2015). Additional research, which has investigated the impact of the INPP daily movement (school intervention) programme (Goddard Blythe 1996) on measures of neuromotor performance, has shown:

(a) A significant reduction in evidence of primitive reflexes in the experimental groups compared to control groups.
(b) Improvement in one measure of non-verbal cognitive performance (Draw a Person [DAP] test).
(c) Improvement in educational measures in children who showed signs of both NMI and under-achievement at the outset (North Eastern Education and Library Board 2004).

In view of these findings, assessing children's neuromotor skills at the time of school entry and at key stages in the educational process may be useful for three reasons: Firstly, in helping to identify children who are at risk of under-achieving as a result of immature neuromotor skills; secondly, to introduce effective physical intervention programmes into schools to improve neuromotor skills with the aim of preventing children with immature motor skills from under-achieving in the future, and thirdly to explore what may need to change in order for these reflexes to have been inhibited through more natural means before children start school.

Aims

As part of a wider research project that investigated the impact of a daily movement programme on young children's physical development, the data reported below examined the presence of three primitive reflexes (the TLR, ATNR and STNR) in 120 children, aged 4−5 years old as they started school and then again towards the end of the school year. The intervention was a daily physical development programme (Movement for Learning) run in school time and by the class teacher. While it was designed with developmental movements in mind and some more advance skills such as throwing and catching, it had not specifically been designed to address primitive reflexes. Rather, its purpose was to enable children to consolidate their physical skills in order that some may not require further intervention and others would, hopefully, have developed sufficient motor control and coordination to benefit from further intervention. That said, the developmental nature of many of the activities should, in theory, have a positive effect on primitive reflexes. Further details about the programme and related research can be found in (Duncombe and Preedy 2020; Preedy, Duncombe and Gorely 2020). The aims of this aspect of the wider research project and, therefore, of this paper are to explore the primitive reflex status of young children in their first year of formal schooling as a sign of neuromotor maturity, and to examine whether participation in a daily developmental movement programme may help to reduce the presence of these three reflexes.

Methods

Three primitive reflexes (the TLR, ATNR and STNR) were assessed in 120 children from four schools between 2015 and 2017 using reflex tests from The INPP Developmental Screening Test and School Intervention Programme (Goddard Blythe 2012). These tests were administered at the start of the school year (N = 120) and again towards the end of the school year (N = 108) − this discrepancy from baseline arose because it was not possible to test all children again at the end of the academic year. During the school year, approximately half of the children participated in Movement for Learning and half acted as a comparison group.

Additional tests were carried out to assess balance, aiming and catching, manual dexterity and overall physical development, using the Movement ABC-2 (MABC-2) (Henderson, Sugden, and Barnett 2007); the findings of the second group of tests are reported elsewhere (Duncombe and Preedy 2020; Preedy, Duncombe and Gorely 2020).

Participants

Four schools were recruited over two years to participate in the research project. Two schools were state (government) funded and two were independent (fee paying) schools. In total, baseline data were obtained for 120 children (N = 120) aged 4–5 years. Of these, 63 were male (52.5%) and 58 were female (47.5%). Full data sets from three schools were then available for 108 children at the end of the school year (post-intervention) – one independent school was discounted from the end of intervention analysis because there was no comparison group, due to a very low class size (eight children).

Ethics

A full ethics application was submitted to and cleared by the ethics committee at Loughborough University prior to the research commencing. This addressed the issues of informed consent, data protection, gaining permission from parents and head teachers as well as assent from the young children themselves. In addition, procedures were put in place to ensure that the children were safe physically and emotionally during the assessments. For example, members of staff from the school with whom the children were familiar were present in the room during testing and a box of toys was provided for the children to play with whilst they were not participating in the testing process. The children were told about the research by their class teachers before meeting the researchers and given opportunities at this stage to withdraw. Upon entering the room provided by each school for the research, the children were asked to sit down with one of the researchers who worked through the approved (child-friendly) information sheet. At this point, the children were asked to place a smiley sticker into a circle on a sheet of paper if they wished to take part, but it was made very clear, that they did not have to participate and that they would not be in any trouble if they chose not to.

The researchers were all experienced with working with young children of this age and had attended a minimum of one day's training in the assessments being used. In addition, the researcher who assessed the children's reflexes reported in this paper had also been trained at the Institute of Neuro-Physiological Psychology and had been practicing in these techniques for over 20 years. This ensured that there was consistency in the way the tests were conducted and scored.

Reflex assessments

Reflex assessments were carried out in the September that children started school and towards the end of the school year (June/July). In the United Kingdom, where the research was conducted, children start school in the September after their fourth birthday. Tests for primitive reflexes are used in mainstream medicine to assess the reflex status of the neonate; some have been adapted for use beyond the period of infancy. These assessments comprised reflex tests from the screening test *Assessing Neuromotor Readiness for Learning* (Goddard Blythe 2012) to assess the ATNR, the STNR and the TLR as follows:

(1) The Asymmetrical Tonic Neck Reflex (ATNR) was assessed using the quadruped test for the ATNR (Ayres 1976).
(2) The Symmetrical Tonic Neck Reflex (STNR) was assessed using the quadruped test for the STNR.
(3) The Tonic Labyrinthine Reflex (TLR) was assessed using the erect test for the TLR (Goddard Blythe 1996).

Space does not allow for a full description of each test but further details can be found in *Assessing Neuromotor Readiness for Learning* (Goddard Blythe 2012). In summary, however, in each test the child is instructed to rotate, flex or extend the head in a specific test position and reflex reactions are observed in other areas of the body. For example, when assessing the TLR in an erect position, the child is asked to move their head slowly down so that they are looking at their toes, and changes in muscle tone or a loss of balance are noted. The degree to which these changes are evident is recorded using a 5-point scoring system. A score of 0 indicates that no abnormality is detected (NAD) and a score of 4 indicates that the reflex is fully retained at 100%:

Scoring

0 = No abnormality detected (NAD) – No evidence of reflex
1 = Reflex present to 25% (evident)
2 = Reflex present to 50% (residual)
3 = Reflex present to 75% (virtually retained)
4 = Reflex present to 100% (retained)

A score of 1 or more on all three tests is indicative of immaturity in the functioning of pathways involved and is likely to interfere with specific aspects of motor control. The higher the score, the more likely that associated functions will be affected.

The majority of the assessments conducted as part of the wider research project required a quantitative measure but the reflex assessments reported here all required a qualitative judgement (using the 0–4 scoring system). To facilitate a more reliable result, the same researcher tested all children both at baseline and end of intervention.

Data analysis

For the baseline data, the raw score (from 0 to 4) was noted manually for each child and later entered into Excel for analysis. It was then possible to generate the percentage of children having each reflex retained at 0, 25%, 50%, 75% and 100%. The combined total reflex score (across all three tests) was then calculated and, thus, the findings below present the reflex scores individually first and combined second. The data were then analysed to establish the proportion of children who scored 2 or more on each of the three tests (i.e. had each reflex retained at 50% or more). The score for this final level of analysis was calculated by returning to the raw data and identifying each child individually.

Statistical analysis was then performed to explore differences between the two groups. The reflex data are ordinal, therefore, the non-parametric Mann–Whitney test was employed. Following Field (2013), we first explored whether there were differences between the groups at baseline, we then explored differences at post-intervention. Significance was set at $p < .05$.

Results

Baseline findings

Table 1 presents the percentage of children in the sample who had elevated scores on tests for the continued presence of primitive reflexes. The table shows that almost 85% of the participants had a retained ATNR at 50% or more (a score of 2–4 on the rating scale) and that just over 25% had retained this reflex at 100% (a score of 4 on the rating scale). A similar result was found for the STNR. Almost a third of the children tested had retained their TLR at 100% (a score of 4 on the rating scale). The potential impact of this on both learning and behaviour has been described above and will be further discussed in the next section.

Table 1 . Individual reflex scores – percentage of children who obtained a score of 2 or more on each individual reflex test.

Reflex	Percentage of sample with a score of 2 or more (i.e. reflex evident at 50% or more)	Percentage of sample with a score of 4 (i.e. reflex retained at 100%)
Asymmetrical Tonic Neck Reflex (ATNR)	84.9%	25.2%
Symmetrical Tonic Neck Reflex (STNR)	83.2%	27.7%
Tonic Labyrinthine Reflex (TLR)	69.7%	33.6%

In addition to the scores for each of the three individual reflexes (TLR, ATNR and STNR), children's combined scores across all three reflexes were also calculated. A child with each reflex fully retained at 100% (i.e. those scoring 4 on all three tests) would score a total of 12. Table 2 shows that this was the case for 13 (of the 120 children), which represented 10.8% of the sample. Interestingly, just 3 children (2.5%) displayed no signs of retained reflexes (i.e. no abnormality was detected on any of the three tests).

Also notable is the number of children who scored 2 or more on each reflex test (i.e. those who had all three reflexes retained at 50% or more; a score of 2, 3 or 4). This equated to 73 of the 120 children and represented 60.8% of the sample.

Intervention findings

Table 3 shows the results of the Mann–Whitney tests at baseline. There were no differences between the groups at baseline for any of the variables (p > .05). Table 4 shows the results of the Mann–Whitney tests at post-intervention. There were significant differences between the groups in favour of the intervention group for all variables. The mean rank scores show that, at post-intervention, the intervention group had significantly lower mean rank scores, which reflects lower (better) reflex scores. Effect sizes (r) ranged from small to medium.

Discussion

Overview

The above results indicate that a significant percentage of children in this sample entered the school system with indications of immature motor skills (as reflected by their primitive reflex status). Secondly, the end of intervention data illustrates that participation in a daily developmental movement programme can improve functional neuromotor maturity in young children. Interestingly, however, engagement solely in activities outlined by the early years' curriculum in the UK (the EYFS) does not appear to impact reflex status. As such, and despite physical development being given equal status to other areas of the curriculum for the Early Years in the UK, it arguably does little to improve neuromotor maturity.

When the baseline findings are compared to findings based on use of the same screening test used in a sample of 672 children in schools in Northern Ireland in 2004, in which 48% of a sample of children aged 5–6 years and 35% of children age 8–9 years had scores of >25% on tests for NMI, the findings from the current study suggest that the problem may be increasing. However, age differences between participants in the samples should also be taken into account, particularly in view of the findings of Gieysztor, Sadowska, and Choińska (2017) that primitive reflex status

Table 2. Combined reflex scores.

Total score across 3 reflex tests (out of 12)	Number of children	% of children
0	3	2.5
1	1	0.8
2	2	1.7
3	5	4.2
4	7	5.8
5	10	8.3
6	13	10.8
7	12	10
8	11	9.2
9	10	8.3
10	21	17.5
11	12	10
12	13	10.8

Table 3. Mann–Whitney results comparing intervention to comparison group at baseline.

	Baseline scores					
	Mean rank intervention	Mean rank comparison	U	z	p	r
TLR	58.5	50.3	1237.0	−1.40	.163	−0.13
ATNR	56.2	52.7	1363	−0.61	.545	−0.005
STNR	54.2	53.8	1420.0	−0.065	.948	−0.001
TLR, ATNR and STNR combined	57.4	51.5	1296.0	−0.998	.318	−0.096

improves in some children between the ages of 4 and 9 years. The findings of this study where 60.8% of children aged 4–5 were found to have scores of >25% for the TLR, ATNR and STNR combined could in part be due to the age difference between the two samples. In view of the 12-month difference in age in this sample and developmental differences that might influence neuromotor skills in this younger age groups, scores of >50% (>2) or 100% (4) were recorded as being indicative of immaturity in neuromotor skills. That said, the post-intervention data do show that natural development over the course of an academic year (i.e. without intervention) did little to improve neuro motor function.

Analysis of the results from this study alongside results from additional measures of motor competency (Movement ABC-2) used in this project, but reported independently (Duncombe and Preedy 2020; Preedy, Duncombe, and Gorely 2020) support the observations obtained from tests for primitive reflexes indicating a declining trend over the last two decades in children's neuromotor readiness at the time of school entry. Earlier pilot studies (Griffin 2013; Harte 2015) had found that the higher the incidence of NMI, the lower the performance on national curriculum levels of achievement. In other words, children with immature neuromotor skills enter the school system at a potential disadvantage compared to those whose neuromotor skills are commensurate with age expectations.

Explanation of findings

Individual causes for this apparent increase in the incidence of children entering the school system with immature neuromotor skills are likely to be multi-factorial and, as such, are beyond the scope of this report based on a relatively small sample. More detailed analysis of children's developmental histories, circumstances and environmental opportunities combined with socio-economic factors would need to be investigated either to speculate or deduce causal relationships in this apparent trend. However, what the results, viewed in the context of earlier research, do suggest, is a need for greater attention to be paid to children's developing neuromotor skills in the early years and throughout the education process. Moreover, the effectiveness of the daily developmental movement programme with young children in terms of improving neuromotor maturity would suggest that attention needs to turn to the potential of this and other programmes in relation to their ability to improve neuromotor readiness for learning especially for those children who are demonstrating neuromotor delay at the start of their school lives.

The development of neuromotor skills begins before birth and is influenced by genes and experience. While the process of maturation is 'hard-wired' into the developing brain from birth, it is experience which provides the environmental 'software', through which the process of development is

Table 4. Mann Whitney results comparing intervention to comparison group at post-intervention.

	Post-intervention scores					
	Mean rank intervention	Mean rank comparison	U	z	p	r
TLR	44.6	64.8	2005.0	3.49	<.001	0.34
ATNR	46.3	63.0	1906.5	2.91	<.01	0.28
STNR	45.01	64.35	1979.5	3.33	<.001	0.32
TLR, ATNR and STNR combined	43.0	66.4	2090.5	3.916	<.001	0.38

entrained. Maturation and experience act as twin sculptors in fashioning the developing nervous system of the child. Nature may provide the framework, but it is nurture in the form of opportunity, experience and engagement that help to build the structure. The apparent increase in the number of children starting school with immature motor skills may be, in part, a secondary effect of environmental and socio-economic factors influencing early child development, rather than of primary neurological dysfunction.

Environmental factors in societies that are increasingly driven by economics and technological advances, as sedentary lifestyles provide less opportunity for movement, and technology becomes a substitute for real social engagement, might be contributing. Lack of open spaces, safe and imaginative spaces to play, homes with small rooms, parental time, restrictions on physical play imposed by over-zealous interpretation of health and safety regulations, 'too much too soon' in terms of focus on formal education in the early years may also be having an impact on the development of children's gross motor skills. These are all areas for future research in relation to neuromotor maturity.

Although it is not possible to point to individual causes in the apparent rise in the number of children starting school with immature motor skills, these findings viewed in the context of earlier research, suggest:

(a) A primary emphasis in the early years should be the opportunity to develop and practise motor skills.
(b) Consideration should be given to the re-introduction of screening of children's neuromotor skills at the time of school entry to be repeated at key stages in the educational process, to help identify and prevent the onset of under-achievement and possible associated secondary behavioural problems.
(c) The introduction of specific movement programmes, which have been shown to be effective in reducing signs of neuromotor immaturity, into early years and primary education.

Conclusion

The findings from this study build on historical findings in relation to the coexistence of primitive reflexes, specific learning difficulties and under-achievement. The data demonstrate a worryingly high proportion of children starting school with signs of immature neuromotor status and comparisons with earlier research (NEELB 2004; Goddard Blythe 2005) would suggest that this is a problem that has increased in recent years.

Tests for primitive reflexes, combined with other assessments of baseline educational performance, may be useful to identify and prevent children from falling under the radar of standard 'academic' assessments and under-achieving in the future. While it is possible to compensate for deficits in motor control, compensation exacts a price elsewhere, and this may be seen in performance on cognitive tasks that rely on the motor system to support them such as hand-eye coordination (handwriting), control of eye movements (reading) and freedom from distractibility. Children with high intelligence may be better at compensating, but ultimately pay a higher price in terms of under-achievement because they are assumed to be performing 'as well as can be expected'. In other words, children with signs of neuromotor immaturity enter the school system with a hidden disadvantage, which may undermine performance and learning outcomes in the future.

Whilst our sample size is arguably small, similar patterns of neuromotor immaturity were observed across four different schools from varying contexts, thusfurther research into the area of neuromotor and physical development in young children is recommended, especially in light of what appears to be a declining trend. In particular, we would suggest that: screening for early signs of neuromotor immaturity be considered; more appropriate physical and neuromotor development opportunities be provided for our youngest children; and existing developmental movement programmes be utilised and introduced where needed into early years and primary education (e.g. Movement for Learning) for children under the age of 7 years and the INPP programmes for schools (Goddard Blythe 2012) and pre-schools (Goddard Blythe 2018).

As with any small-scale exploratory study, caution is advised in generalising these findings to the wider population. In addition, although a baseline score of zero was used as a historical norm in children above the age of three and a half years on the three tests for primitive reflexes used in this study, results derived from the quadruped test for the ATNR with this age group should be treated with caution. Parmentier (1975) found that the ATNR can be elicited in normal primary school children up to eight years of age when tested in the quadruped position, with younger children (six years of age) showing more evidence of the reflex than children at eight years of age. Parmentier concluded that flexion of the elbow to 30̊ on the occipital side could be considered normal in children up to eight years of age while Silver (1952) had found the presence of the ATNR to be stronger in children over five years of age with maturational lag, emotional and reading disorders. Bearing this and the age range of children in the current sample in mind, results of the quadruped test for the ATNR should be viewed qualitatively in children under eight years of age with only medium to high scores (>50%) indicating increasing degrees of immaturity. Viewed in this context, the high incidence of children in this sample with scores of >50% on the quadruped test for the ATNR (84.9%) still points to a declining trend in children's neuromotor skills at this age.

Whilst identifying causes for the identified increase in the incidence of children entering the school system with retained reflexes requires further research, we can draw on what is already known in order to identify areas that might be appropriate for further investigation. Likewise, other areas for future study include: investigating neuromotor readiness for school in different populations by exploring the reflex status of children of a similar age from different socio-economic groups and ethnicities, as well as further examining the data to identify any gender differences. It may also have been useful to follow individual children from baseline to end of intervention to explore individual patterns of change. A case study approach, perhaps utilising interviews with parents and teachers, with some children may have helped highlight and explain individual variations.

A paper based on the assessment of 87 children aged 7 years in Russia using the same screening tests suggests that the incidence of neuromotor immaturity is higher in boys than in girls at this age (Goddard Blythe and Lunina 2020). This may be related to gender differences in trajectories of when boys and girls show accelerated development in specific skills and have implications for learning environments and educational expectations of boys and girls at different stages in an educational system which is currently designed for 'one size to fit all'. Repeat studies with larger sample sizes would also, clearly, be of value as would further study into the longer-term implications of this.

Given that the developmental movement programme used in this study, designed to be used with children aged 4–7 years, has demonstrated that 20 minutes of daily movement activities undertaken in class time and led by class teachers has the potential to improve neuromotor function, we would also suggest that future research could turn to examine optimal ways that this and similar age appropriate programmes could be introduced into all schools to improve children's neuromotor readiness for learning. It is also suggested that more detailed attention could be paid to the relevance of physical foundations for learning in teacher training, educational policy and practice throughout the education process.

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