ASSESSING NEUROMOTOR READINESS FOR LEARNING

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Abstract

During the last 20 years, the incidence of underachievement amongst children in elementary schools has increased dramatically. However new research and evaluated remedial programmes are emerging to support these children. The aim of this study was the investigation of the level of neuro-psychological development of children in the first year of school in Russia. 87 pupils from two private schools in Moscow were tested using the INPP developmental screening test. Results of the assessment showed that about 40% of children according to the 25+% criterion show signs of neuromotor immaturity(NMI); there are significant differences between boys (21 out of 35, 60%) and girls (14 out of 51, 27.5%) who have a level of neuromotor immaturity >25%. This suggests that the number of children with neuromotor immaturity who started school is approximately the same in Russia as in other European countries. To increase the success of learning, it is advisable to introduce routine screening of children's neuromotor skills and developmental motor programmes in schools, such as the INPP school intervention programme.

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. Education tends to focus primarily on outcomes using measures of educational and cognitive performance but an increasing body of research indicates that physical development,

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reflected in children's neuromotor skills, can have a significant influence on academic achievement.

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 specific stages in development a child is expected to have attained a certain level of neuromotor performance. Motor milestones and motor performance provide outward signs or *reflections* of functional neuromotor maturity (Goddard Blythe 2012) and indicators of neuromotor readiness for learning.

Neuromotor *im*maturity describes the retention of immature patterns of movement control. These may occur as a result of classical signs (pathology) or be reflective of functional or developmental delay in the pathways involved. The INPP screening tests (Goddard Blythe 1996, 2012) were developed for use as an initial screening instrument with which to:

a) Identify children whose neuromotor skills were not commensurate with age expectations at the time of school entry;

b) Provide a baseline for comparing children's neuromotor status with measures of educational performance;

c) If indicated, introduce a developmental movement programme into schools;

d) Investigate a relationship between improved neuromotor skills and educational achievement.

The screening device comprises simple tests to identify "soft signs" of neurological dysfunction together with evidence of three primitive reflexes, which should not be active beyond the first 6 – 12 months of life.

Rationale

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The presence or absence of primitive reflexes at key stages in development provide recognised signposts of maturity in the functioning of the central nervous system and as such can provide indications of *neuromotor immaturity (NMI).*

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. Postural reactions develop from birth, 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.

Additional features of NMI can include immaturity in control of balance, postural stability, eye movements and visual-perception (González et al. 2008, Goddard Blythe 2017, Andrich et al. 2018). These aptitudes are needed to sit still, develop the eye tracking movements involved in reading, eye-hand 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 an initial screening tool with which to identify signs of neuromotor immaturity, which might have an impact on the motor aspects of learning and subsequently on learning performance (North Eastern Education and Library Board 2014) and behaviour (Marlee R 2008, Taylor B et al. 2019).

Although the cognitive processing of experience takes place in the brain, learning is also a physical activity. Just as children have to learn how to move, movement is also involved in almost every aspect of classroom learning. An increasing body of evidence obtained from the use of the screening test (Goddard Blythe 2012) has indicated a relationship between maturity in children's physical skills, (partly measured through competency in control of movement) and educational achievement (NEELB 2004, Goddard Blythe 2005, Gieysztor et al. 2016 & 2017, Ivanović et al. 2018) with children with immature neuromotor skills performing less well

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on educational measures than children whose neuromotor skills were commensurate with expectations for chronological age (Griffin P 2013, Harte 2014).

Despite this historical evidence, assessment of children's neuromotor skills as indicators of neuromotor readiness for learning is not carried out in many educational systems as a matter of routine. Children with immature neuromotor skills can compensate to some degree, but often at the expense of under-achieving at motor dependent tasks. Viewed in this context, 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 to prevent the development of under-achievement, some subsequent specific learning difficulties and related behavioural problems.

The research presented here examined the extent to which signs of neuromotor immaturity were present in a sample of 87 children in the year that they started formal schooling in Russia.

Literature Review

A *relationship* between aberrant reflexes and specific learning disabilities is not a new area of investigation. In the 1970's a number of studies were carried out which compared the primitive reflex status of learning-disabled children to those without learning disabilities. In one such study all children in a learning-disabled group were found to have a cluster of residual primitive reflexes whilst no primitive reflexes were present in children without learning disabilities (Gustafsson D, 1971). A similar study, which used tests for the presence of primitive reflexes and the Wide Range Achievement Tests (WRAT) - a group of tests which focus on providing norm-referenced measures of reading, spelling, and mathematics computation - in a diagnosed learning disabled and non-learning disabled group, found a higher incidence of abnormal reflexes in the learning disabled group, but also revealed some reflex abnormalities amongst the undiagnosed group. When tests for aberrant reflexes were compared to performance on the WRATs, those children in the non-learning disabled group who were found to have traces of aberrant reflexes were also found to be under-achieving in reading and writing (Rider B, 1976). 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.

Wilkinson (1994) replicated Rider's study and discovered not only a link between atypical primitive reflexes and learning difficulty, but that it was possible to identify which children were under-achieving in the classroom simply by analysing the reflex profile of each child. Other researchers have examined the incidence of aberrant reflexes in specific populations, including retention of the Asymmetrical Tonic Neck Reflex (ATNR) in children diagnosed with reading difficulties (McPhillips et al. 2000, McPhillips & Sheehy 2004) ATNR, STNR and TLR in children diagnosed with dyslexia (Goddard Blythe 2001) and the Moro reflex in children diagnosed with ADHD (Taylor et al. 2004).

Significance of 3 Primitive Reflexes

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.

Tonic Labyrinthine Reflex (TLR)

The TLR is elicited in two positions in the full-term neonate: a) Extension of the head below the midplane in the supine position will result in an increase in extensor tone throughout the body. b) Flexion of the head above the midplane 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 affect 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 the infant is learning to push up into the quadruped position in preparation for creeping on hands on knees. If the head is flexed in the quadruped position, it will elicit increase in flexor tone in the arms and extensor tone in the lower half of the body. If the head is extended, the opposite reaction will occur.

If the STNR persists in its crude form, the infant may have difficulty coordinating use of the top and bottom halves of the body to creep on hands and knees. A 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 integrates use of balance, proprioception and vision in a new relationship with gravity for the first time, helping to develop coordination of the two sides and the upper and lower sections of the body in synchronised action. It may also help to train eye-hand coordination at the same visual distance a child will use to read and write a few years later (Hansen et al. 2010, Visser &Franzen 2010, Kari et al. 2014). If the STNR remains when a child enters school it can affect sitting posture including the ability to sit still (O'Dell and Cook 2004), aspects of eye-hand coordination and the vertical eye tracking movements (Bein-Wiezibinski 2001), needed for aligning columns correctly in maths.

Results from various projects using the screening test *Assessing Neuromotor Readiness for Learning* (Goddard Blythe 2012), have revealed a consistent relationship between the persistence of primitive reflexes in children of school age (Gieyzstor et al. 2016, 2017) and lower academic performance (NEELB 2004, Goddard Blythe 2005, Griffin 2013, Harte 2015, Ivanović et al. 2018). In view of these findings, routine assessment of 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, to help identify children who are at risk of under-achieving as a result of immature neuromotor skills; secondly, to introduce 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 the environments in which children are developing *before* entering school to support the development of neuromotor skills.

Aims

As part of wider scale research carried out in several countries the aim of this research was to investigate the incidence of NMI (>25% on screening test) in a sample of 87 children in Russia in their first year of formal schooling. This project should be viewed as the first phase of a longer project in which researchers in Russia are also working with teachers from two schools to develop a system for monitoring the relationship between neuromotor development indicators and learning success in the context of the Russian education system.

Participants

The sample comprised 87 children of whom 35 were male and 52 were female. The average age of the sample was 7 years and 1 month. The research was conducted in the daytime. Assessment of visual perception and visual-motor integration was performed in groups. Assessment of gross muscle coordination, balance and reflexes, visual tracking and integration, also auditory-speech recognition was performed individually.

Ethics

In order to maintain confidentiality, the names of children are hidden under ciphers indicating their age and gender. School names are also hidden.

Method

Assessment using the screening test *Assessing Neuromotor Readiness for Learning* was carried out between the 23th September and the 18th October in a single year.

Using a five-point assessment scale, the assessments comprised a series of tests for:1. Gross muscle coordination and balance and evidence of three primitive reflexes.

2. Sub-tests for:
    a. Visual tracking and integration.
    b. Visual-speech recognition.
    c. Visual-perception and visual-motor integration (VMI)

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Assessment Scale

0 = No abnormality detected (NAD)
1 = 25% dysfunction
2 = 50% dysfunction
3 = 75% dysfunction
4 = 100% dysfunction

In each section, scores for individual tests were recorded over the total possible score that could be obtained in each section (100% dysfunction). The results were also recorded for all tests.

Final scores

Gross muscle coordination, balance and reflexes	/48
Visual tracking and integration	/8
Auditory-speech recognition	/16
Visual perception and visual motor integration	/24
Total (raw score)	/96
Percentage score	

Results

Findings were submitted for independent statistical analysis[1]

Analyses were performed on SPSS version 26 using listwise to deal with missing data.

Issue 1: Incidence of NMI in the sample

The possible range on the combined raw scores of the four NMI sub-scales was 0-96, with higher scores being indicative of greater NMI. In line with previous studies, raw scores were converted into percentages to aid interpretation (called the 'Percentage Dysfunction Score'). For example, a child with a raw score of 48, exactly half of the possible range, would be given a Percentage Dysfunction Score of 50%. Children scoring 25% or higher on the Percentage Dysfunction Score of NMI were classified as showing evidence of NMI.

The mean Percentage Dysfunction Score within the sample was 22.6, a value approaching the cut-off for showing evidence of NMI. The standard deviation was 8.3, indicating that approximately two thirds of the sample scored between about 15 and 31 (i.e., between about one standard deviation above, and one standard deviation below, the mean).

Out of the sample of 87 children:

18 (about 20%) approached the 25+% criterion for showing evidence of NMI (scored between 20% and 24%)

35 children (**about 40%)** met the 25+% criterion for showing evidence of NMI

17 children (about 20%) scored well in excess of the 25+% criterion for showing evidence of NMI (scored 30% or above). [NB These 17 children are included in the 35 children identified in the previous line.]

Issue 2: Are there sex differences in NMI?

2a Sex differences in raw scores on the four NMI sub-scales

Descriptive statistics (primarily means and standard deviations) are shown in Table 1 in the Appendix. The presence or absence of statistically significant sex differences were identified with Independent Samples t-Tests (see Table 2 in the Appendix).

Boys (mean = 13.0, standard deviation = 5.6) scored significantly higher than girls (mean = 8.7, standard deviation = 5.6) on Gross Motor, Balance and Reflexes, t (82) = 3.42, p <.001.

Boys (mean = 1.9, standard deviation = 1.3) scored significantly higher than girls (mean = 1.3, standard deviation = 0.9) on Visual Tracking and Integration, t (57.9, degrees of freedom adjusted due to a significant Levene's test for equality of variances) = 2.34, p = .023.

Girls and boys did not differ significantly on either Visual/Auditory/Speech Recognition or Visual Perception and Visual Motor Integration (VMI).

2b Sex differences in categories of NMI

Children scoring 25% or higher on the Percentage Dysfunction Score of NMI were classified as showing evidence of NMI. To test if one sex was statistically significantly more likely to be classified as meeting this criterion for NMI than the other, a Chi-square Test of Association was employed (see Table 3 in Appendix).

A significantly higher proportion of boys (21 out of 35, 60%) than girls (14 out of 51, 27.5%) met the criterion for NMI, $\chi2$ (1) = 9.11, p = .003.

Issue 3: Correlations between the four NMI sub-scales

Pearson correlation tests were used to determine if there were statistically significant correlations between children's scores on the four NMI sub-scales (see Table 4 in the Appendix). A significant correlation between any pair of sub-scales indicates that children tended to score relatively similarly on both of them.

Scores on Gross Motor, Balance and Reflexes and on Visual Tracking and Integration were significantly correlated, r(n=85) = .46, $p < .001$.

Scores on Gross Motor, Balance and Reflexes and on Visual/Auditory/Speech Recognition were significantly correlated, r(n=85) = .30, $p = .005$.

Scores on Visual/Auditory/Speech Recognition and on Visual Tracking and Integration were significantly correlated, r(n=87) = .31, $p = .003$.

Issue 4: Does age correlate with (i) the four NMI sub-scales, (ii) Percentage Dysfunction Score, and/or (iii) classification of having versus not having NMI (25+% criterion)?

Using Pearson correlation tests, and a point-biserial correlation for the analysis involving the 25+% dichotomous variable, there was no evidence that age correlated with any of the measures of NMI employed in this study (see Table 5 in the Appendix). This indicates that the older children were as likely to show (or not show) indications of NMI as the younger children.

[NB eight children were excluded from this analysis due to missing data concerning age.]

A detailed description of findings can be found in Appendix 1.

Discussion

The above results indicate that a significant percentage (40%) of children in this sample entered the school system with indications of immature motor skills (total scores of >25%). When these results are compared to findings based on use of the *same* screening test used in samples of children in schools in Northern Ireland in 2004 (NEELB), Poland (Gieysztor et al.,2016, 2017) Serbia (Ivanović et al. 2019) and a project in preparation conducted in the United Kingdom (Goddard Blythe et al. 2020), the findings from the current study suggest that neuromotor immaturity was a consistent factor in more than one third of the children assessed across at least four different educational systems.

Although the continued presence of primitive reflexes is only a *sign* of immaturity in the functioning of the central nervous system and *not* the primary cause of presenting difficulties, the findings show a correlation between high scores on signs of immaturity in gross motor skills, balance and residual reflexes and skills assessed on other sub-tests for signs of difficulties with visual tracking and integration, auditory-speech recognition, visual perception and visual-motor integration, suggesting that immaturity in mechanisms involved in postural control and balance do affect higher related skills. The latter are likely to influence performance in reading and writing and undermine aspects of educational achievement.

Conclusions

The findings from this study build on *historical* findings in relation to the coexistence of primitive reflexes, specific learning difficulties and under-achievement. Primary data obtained from teachers about the difficulties of children who participated in the study with a significant level of neuromotor immaturity contain those described earlier. These are motor and tonic difficulties in writing, spatial orientation of letters and numbers, difficulties in keeping the eye on the line, reading with repetition of the read syllables, slow work when writing off the board, and the admission of numerous impulsive errors.

Thus, the study conducted in Russia confirms many years of research conducted in other countries of the world. Today's children need programmes to assess their neurophysiological readiness for school. The introduction of special movement programmes in schools and kindergartens for the development of functional maturity of the nervous system can be a significant incentive to increase the success of learning.

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Declaration of interest

As author of the screening test used in this study, Sally Goddard Blythe receives royalties on sales of the publication.

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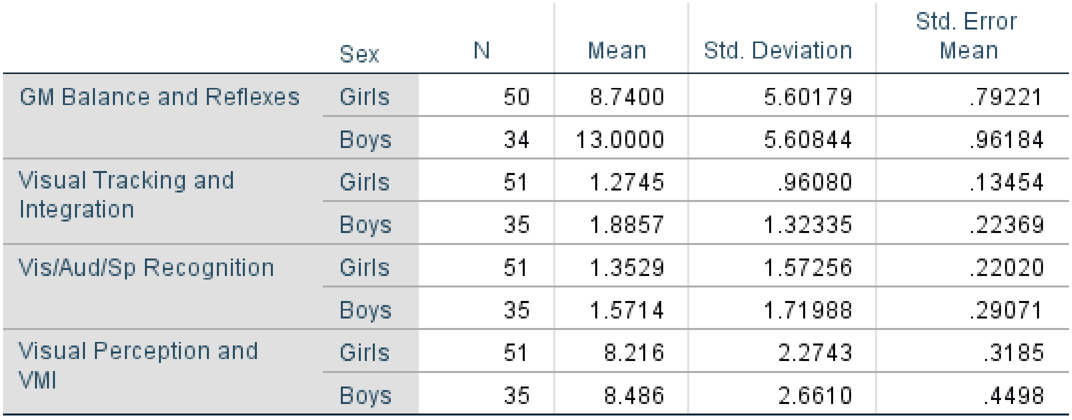
Appendix

Table 1: Descriptive statistics for tests of sex differences in raw scores on the four NMI sub-scales



	Sex	N	Mean	Std. Deviation	Std. Error Mean
GM Balance and Reflexes	Girls	50	8.7400	5.60179	.79221
	Boys	34	13.0000	5.60844	.96184
Visual Tracking and Integration	Girls	51	1.2745	.96080	.13454
	Boys	35	1.8857	1.32335	.22369
Vis/Aud/Sp Recognition	Girls	51	1.3529	1.57256	.22020
	Boys	35	1.5714	1.71988	.29071
Visual Perception and VMI	Girls	51	8.216	2.2743	.3185
	Boys	35	8.486	2.6610	.4498

Table 2: Independent Samples t-Tests of sex differences in raw scores on the four NMI sub-scales

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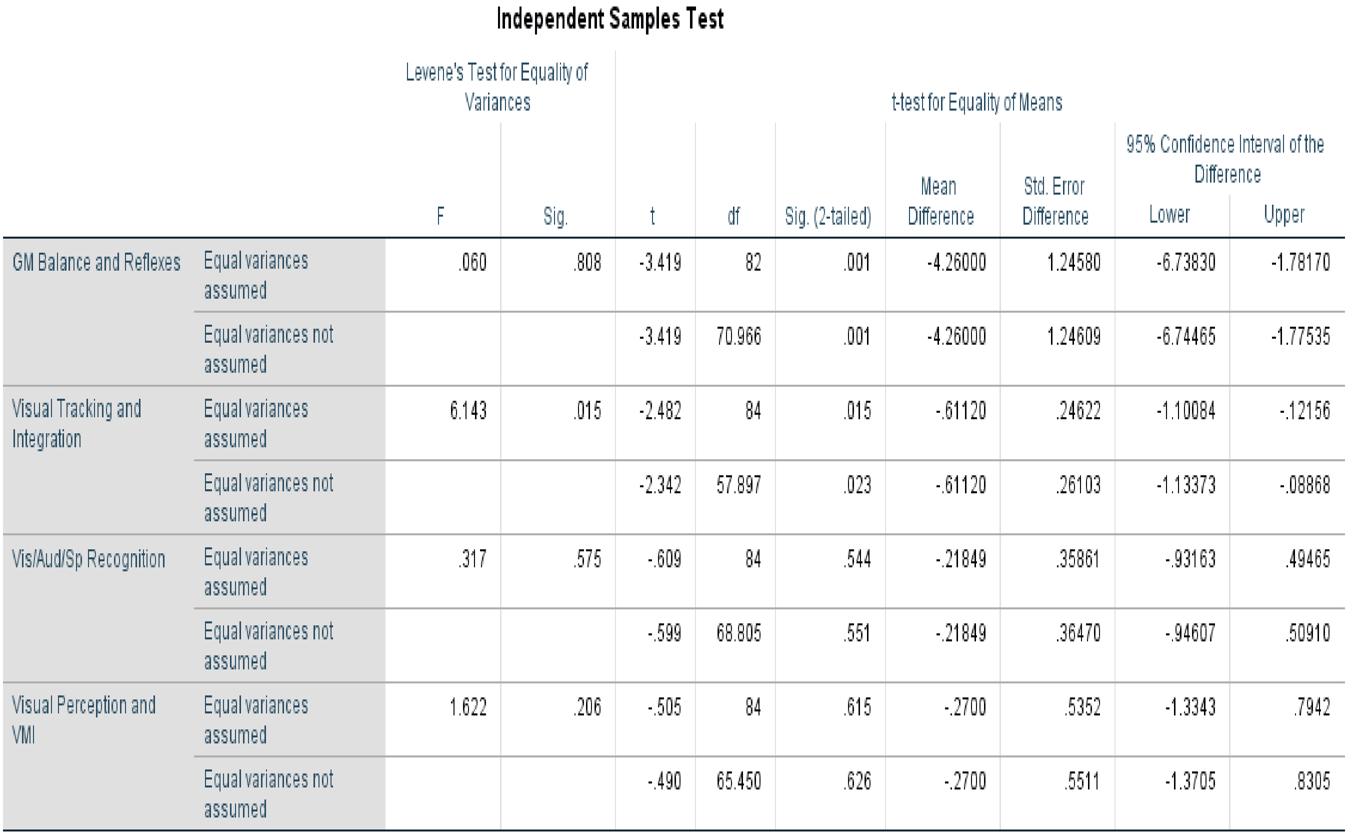
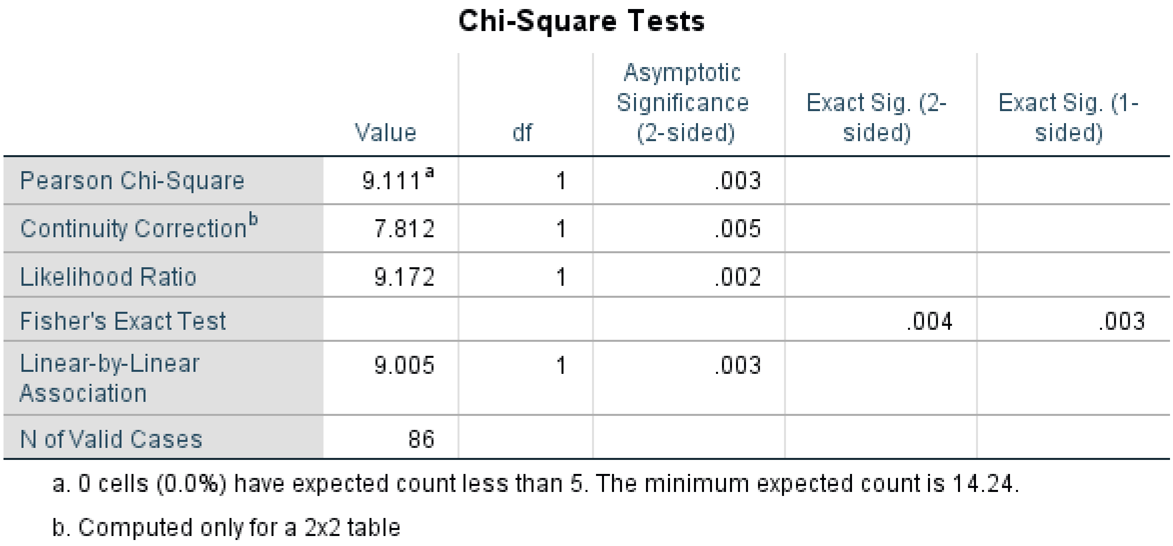


Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
GM Balance and Reflexes	Equal variances assumed	.060	.808	-3.419	82	.001	-4.26000	1.24580	-6.73830	-1.78170
	Equal variances not assumed			-3.419	70.966	.001	-4.26000	1.24609	-6.74465	-1.77535
Visual Tracking and Integration	Equal variances assumed	6.143	.015	-2.482	84	.015	-.61120	.24622	-1.10084	-.12156
	Equal variances not assumed			-2.342	57.897	.023	-.61120	.26103	-1.13373	-.08868
Vis/Aud/Sp Recognition	Equal variances assumed	.317	.575	-.609	84	.544	-.21849	.35861	-.93163	.49465
	Equal variances not assumed			-.599	68.805	.551	-.21849	.36470	-.94607	.50910
Visual Perception and VMI	Equal variances assumed	1.622	.206	-.505	84	.615	-.2700	.5352	-1.3343	.7942
	Equal variances not assumed			-.490	65.450	.626	-.2700	.5511	-1.3705	.8305

Table 3: Chi-square Test of Association to test if one sex was statistically significantly more likely to be classified as meeting the 25% criterion for NMI than the other



Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.111[a]	1	.003		
Continuity Correction[b]	7.812	1	.005		
Likelihood Ratio	9.172	1	.002		
Fisher's Exact Test				.004	.003
Linear-by-Linear Association	9.005	1	.003		
N of Valid Cases	86				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.24.

b. Computed only for a 2x2 table

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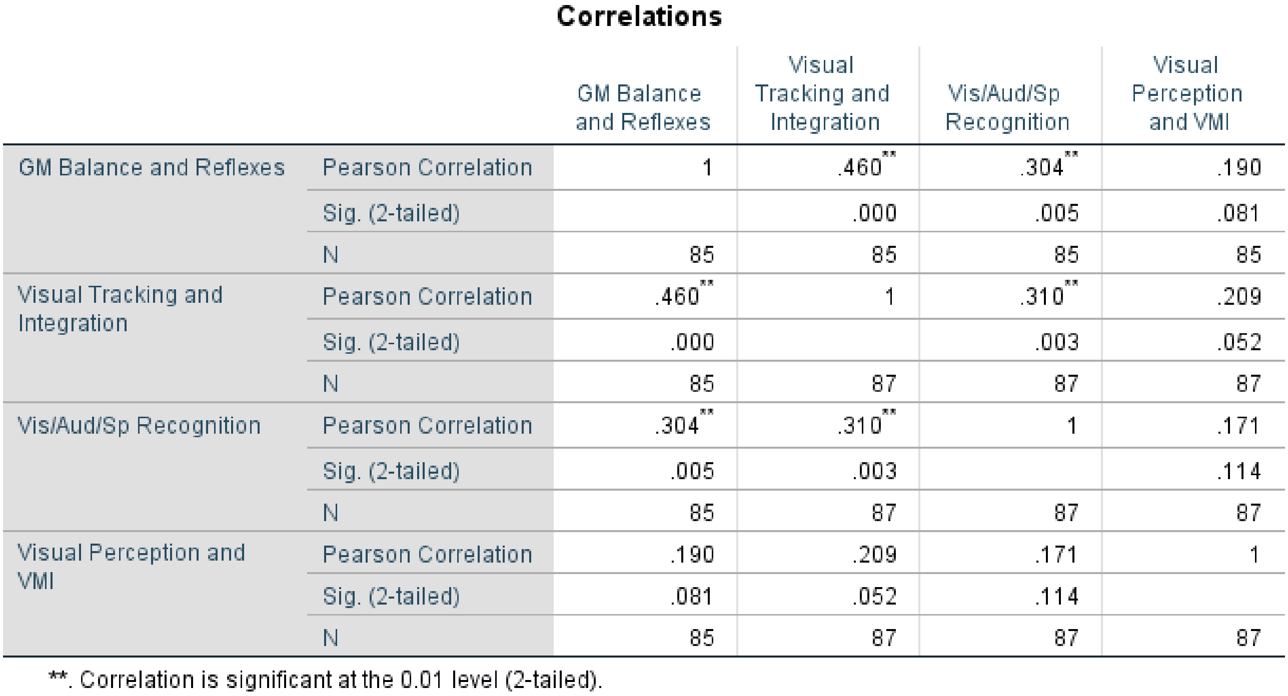
Table 4: Pearson Correlation tests to determine if there were statistically significant correlations between children's scores on the four NMI sub-scales



Correlations

		GM Balance and Reflexes	Visual Tracking and Integration	Vis/Aud/Sp Recognition	Visual Perception and VMI
GM Balance and Reflexes	Pearson Correlation	1	.460**	.304**	.190
	Sig. (2-tailed)		.000	.005	.081
	N	85	85	85	85
Visual Tracking and Integration	Pearson Correlation	.460**	1	.310**	.209
	Sig. (2-tailed)	.000		.003	.052
	N	85	87	87	87
Vis/Aud/Sp Recognition	Pearson Correlation	.304**	.310**	1	.171
	Sig. (2-tailed)	.005	.003		.114
	N	85	87	87	87
Visual Perception and VMI	Pearson Correlation	.190	.209	.171	1
	Sig. (2-tailed)	.081	.052	.114	
	N	85	87	87	87

**. Correlation is significant at the 0.01 level (2-tailed).

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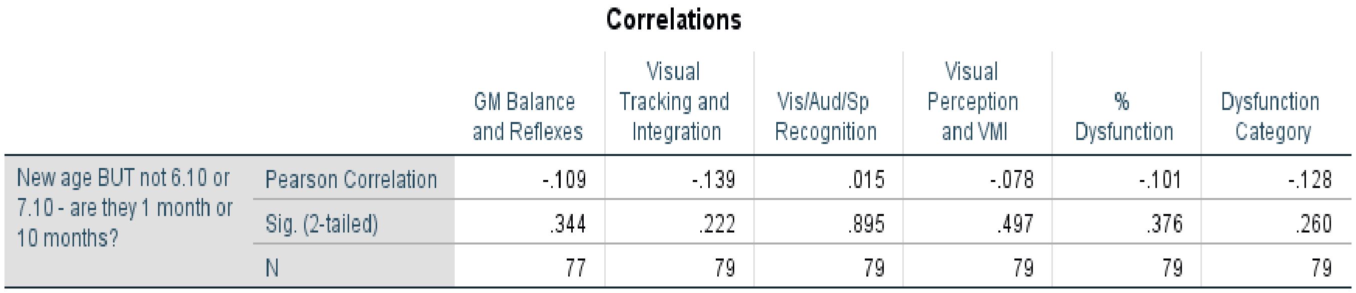
Table 5: Pearson Correlation tests to determine if there were statistically significant correlations between age and (i) the four NMI sub-scales, (ii) Percentage Dysfunction Score, and (iii) classification of having versus not having NMI (25+% criterion)



Correlations

		GM Balance and Reflexes	Visual Tracking and Integration	Vis/Aud/Sp Recognition	Visual Perception and VMI	% Dysfunction	Dysfunction Category
New age BUT not 6.10 or 7.10 - are they 1 month or 10 months?	Pearson Correlation	-.109	-.139	.015	-.078	-.101	-.128
	Sig. (2-tailed)	.344	.222	.895	.497	.376	.260
	N	77	79	79	79	79	79

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[1] Boulton M, 2020

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