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Longitudinal influences of socio-economic status on visual-motor integration: The North-West Child Health, Integrated with Learning and Development study

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Background: Visual motor integration plays an important role in academic skills of learners in the early school years and can have an impact on their overall academic performance.

Aim: This study aimed to determine the influence of socio-economic status (SES) on changes in visual-motor integration, visual perception and motor coordination over a period of three years.

Setting: Four school districts in the North West province of South Africa were used.

Methods: Five hundred and seventy-three learners (282 boys, 291 girls) were randomly selected (representing different SES schools) and evaluated at baseline during 2010 when they were in Grade 1 (6.9 years ± 0.38), and again 2013 (9.9 years ± 0.42), as part of a longitudinal research study. The Beery Visual-Motor Integration Test 4th edition was used to evaluate the visual-motor integration, visual perception and motor coordination skills at baseline and three years later.

Results: Baseline measurements were higher among high SES learners in all three skills. Although learners from high SES still outperformed the learners from low SES three years later, low SES learners showed statistically significant improvements over the three years in visual-motor integration (88.24 to 89.85, $p = 0.041$) and visual perception (89.69 to 90.04, $p \leq 0.001$).

Conclusion: Age-related development and improvement of the visual-motor integration skills were reported over the three-year period. However, more learners from the low SES still showed delays in these skills. Delays in the development of these skills could contribute to poorer academic and learning-related achievements.

Keywords: VMI-4; Visual-Motor Integration; Visual Perception; Motor Coordination; Longitudinal Development Changes; Socio-Economic Status.

Introduction

Visual-motor Integration (VMI) plays an important role in academic skills of learners in the early school years and can have an impact on their reading, writing, mathematical skills or overall academic performance (Chen, Bleything & Lim 2011; Kramer & Hinojosa 2009; Marr & Cermak 2002; Pienaar Barhorst & Twisk 2013; Sortor & Kulp 2003).

The development of VMI occurs from birth until about 15 years and is described as the transference of Visual Perception (VP) in motor functions that play an important role in the harmonious interaction of hand–eye coordination (Sanghavi & Kelkar 2005; Weil & Cunningham-Amundson 1994). Case-Smith and O'Brien (2010) report that children are not born with adequate VMI skills, but that these skills develop from reflexes and become more controlled and coordinated with increasing age. According to Beery and Beery (2010), VP can be defined as the process responsible for receiving stimuli and the cognition of visual stimuli. The sensory function, or otherwise called visual-receiving component, is the process of refusal, organising of information from the environment as well as the specific cognitive functions that produce the visual cognitive component to be able to organise, give structure and interpret visual stimuli, in other words, to give meaning to what is seen (Cheatum & Hammond 2000). Together these components enable a person to understand what he or she sees and both these components are needed for functional vision. Furthermore, Lane (2005) describes VP as the ability to copy geometrical forms, letters and pictures in a given space correctly and this skill is considered important for effective Motor Coordination (MC).

Farber and Beteleva (2005) reported that VP involves various structures of the brain, each of which makes a specific contribution to active perception. These structures include concentration or attention, recognition, memory, comparison of stimuli by way of referential images, as well as an evaluation of the significance of these with regard to the context and decision-making based on the purpose of the intended activity. The cerebral structures involved in VP do not reach maturity during the developmental period simultaneously. A rapid development of the cortical areas and intra-cortical connections of the brain are reported between 5 and 7 years, which is considered an important developmental age for VP skills (Farber & Beteleva 2005). The human cortex has three different visual functional areas, firstly the primary visual projection areas situated in the occipital lobes that play a role in reading, spelling and writing; secondly, the secondary cortical area; and thirdly, the tertiary cortical area. The primary visual projection areas are responsible for the relaying and decoding of incoming sensory information; the secondary cortical areas are responsible for meaningful observational content formation; and the tertiary cortical area is responsible for visual association (Jordaan & Jordaan 1989). Bezrukikh and Terebova (2009) are of the opinion that VP is foundational to a child's cognitive activity because it orientates and controls a child's behaviour. The development of VP is one of the most important tasks of preschool education, as it forms the foundation for writing and reading skills as well as visual learning in later school years. Lane (2005) and Winnick (2005) describe MC as the ability to effectively coordinate bodily movement (tactile and kinaesthetic perception) with vision, which also plays an important role in a child's ability to learn, read and write (Wilson & Falkel 2004). Learners may have well-developed visual and motor skills, but do not necessarily have the ability to apply these skills in a coordinated manner (Beery & Buktenica 1997; Lane 2005).

Early life experiences and interactions, including stimulation of the senses, have a strong influence on the development of the brain, as well as visual and visual–perceptual skills (O'Brien Caughy et al. 2004). Various researchers have studied the influence of maturing on the development of VMI, VP and MC skills and found that maturity (as measured in terms of age) plays a primary role in the development of these skills (Bezrukikh & Terebova 2009; Decker et al. 2011; Lane 2005; Tekok-Kiliç, Elmastas-Dikec & Can 2010). Tekok-Kiliç et al. (2010) found age-related improvements in VMI skills between the ages of 6 and 15 years, in middle and high Socio-economic Status (SES) groups. Bezrukikh and Kreshchenko (2004) report in this regard an increase in the percentage of children with well-developed visual-motor skills from 6 to 10 years and also a decrease in the correlation between VP and effective learning during this period. Decker et al. (2011) are of the opinion that the developmental trend that links cognitive abilities to quantitative and non-verbal reasoning abilities shows a correlation with visual-motor skills among 4–7-year-old learners.

According to Bronfenbrenner's (1979) Ecological Systems Theory (EST), the learning environment in which a child's development takes place is divided into four systems of social development, namely, micro-, meso- exo- and macro-systems. The development of the child occurs within these specific systems, in which each system contains its own role, norms and rules, which can exert an influence on the development of the child. The *micro-system* refers to influences of the child itself (e.g. gender, age and health); the *meso-system* involves influences from the child's immediate environment (e.g. home, family and friends, church, school and socio-economic situation); the *exo-system* involves the influences from organisational or institutional factors (e.g. healthcare services, social services, extended family, family friends and neighbours); and the *macro-system* involves the cultural context within which the child grows up (Bronfenbrenner 1979). Various factors influence development in the early childhood years, including sleep, nutrition, parenting strategies, health problems, limited access to learning materials and learning opportunities, educational resources, defective school education and non-stimulating home environments (Goodway & Branta 2003; Pienaar & Lennox 2006; Swain 2014; Venetsanou & Kambas 2010; Walker et al. 2007). Socio-economic status is regarded by many researchers as one of the most influential factors that can have a direct negative effect on the development of young children (Gallahue & Ozmun 2006; Pienaar & Lennox 2006; Venetsanou & Kambas 2010).

In the South African context, various studies have been conducted to determine whether SES has an influence on learners' VMI, VP and MC (Lotz, Loxton & Naidoo 2005; Makhele, Walker & Esterhuyse 2006; Pienaar et al. 2013), although none of these studies had analysed this influence over time. The study of Lotz et al. (2005) indicated that learners in Grade 1 to Grade 4 in the Western Cape province of South Africa, who grew up in disadvantaged and less privileged communities, experienced significantly more deficits in VMI, VP and MC skills. Pienaar et al. (2013) confirmed these findings in Grade 1 learners with a low SES in the North West province of South Africa, who experienced significantly more VMI, VP and MC delays compared to learners from high SES, independent of race. This relationship has also been reported and confirmed by other researchers (Dunn 2001; Goodway & Branta 2003; Robinson & Goodway 2009). In contrast, Makhele et al. (2006) reported cross-sectional results, indicating that SES (sub-categories within a previously disadvantaged community) had no effect on the VMI skills of 7–9-year-old Sotho-speaking learners in the Free State province of South Africa, with no visible age-related improvements.

From the literature it can be seen that studies in general mostly focused on VMI as a whole, and not on the sub-components, VP and MC separately. In addition, few studies in the South African context could be found that investigated the influence of age and SES separately in VMI, VP and MC development. The South African society is characterised by significant socio-economic inequalities (Stats SA 2014); therefore, it is important to determine the extent of this influence in primary school children. Visual-motor integration, VP and MC delays can contribute significantly to poor academic achievement; therefore, longitudinal analyses of these influences are of importance. Possible relationships that can be established through this study could contribute to establishing early interventions for learners with academic delays that are the result of this and, in so doing, may offer support in the prevention of academic delays at an early age, especially among learners from low SES. The purpose of this study was therefore to determine the possible effect of SES on changes in learners' VMI, VP and MC over a 3-year period from 6 to 9 years.

Research methodology and design

Research design

The study formed part of a cross-sectional design that is based on data that were collected as part of a longitudinal research project, the North-West Child Health, Integrated with Learning and Development (NW-CHILD) study that ran over a 6-year period (2010–2016). The NW-CHILD study consisted of baseline and two follow-up measurements. The baseline measurements were done in 2010 on a selected group of learners living in different regions of the North West province, with the first follow-up measurements being done in 2013. The second set of follow-up measurements was done in 2016. For the purposes of this article, only the measurements of learners who were present in both 2010 and 2013 were included.

Participants and research setting

The sample was selected by means of a stratified random sampling technique and in conjunction with the Statistical Consultation Services of the university. A list of names of schools was provided by the North West Provincial Department of Basic Education, which was used to determine the sample. From the list of schools in the North West province, grouped into eight education districts, and each with 12–22 regions with about 20 schools (minimum 12 and maximum 47) being represented, regions and schools were randomly chosen with regard to population density and school status (Quintile 1 – schools from poor or low economic areas, to Quintile 5 – schools from good or high economic areas). For the purposes of this study, the five Quintile schools were grouped together in only a low SES group (quintiles 1–3) and a high quintile group (quintiles 4 and 5). Boys and girls in Grade 1 were randomly selected from each school. Twenty schools, with a minimum of 40 learners per school and an equal gender representation, were involved in the study (see Table 1 for the complete discussion of the study group).

Measuring instruments

The Developmental Tests of Visual-Motor Integration, Fourth Edition

The Developmental Tests of Visual-Motor Integration, Fourth Edition (VMI-4) (Beery & Buktenica 1997) is a measuring instrument that consists of three parts, namely, a VMI section and two supplementary tests – VP and MC. The VMI-4 was developed to measure the extent to which an individual can integrate his or her visual and motor capabilities and to identify possible problems that children may have in specific areas of VMI as well as the degree to which VP and finger–hand movements are well coordinated. The VMI test can be done in a group context or individually within a period of about 10–15 min. The 27-item test can be used to test 3–18-year-old children and requires the geometrical shapes (in developmental succession) to be copied with pencil and paper. The VP sub-test requires a learner to identify the exact match for as many as possible of the 27 geometric forms during a 3-min period. The last sub-test, MC, involves simply tracing the stimulus forms (completing dots in a shape) with a pencil without going outside double-lined paths and takes 5 min to complete.

The tests are stopped after three consecutive mistakes are made or when time is up, except for the MC section which is only stopped when the time limit elapses. The marks allocation for the raw score is done according to the number of test items that the learner had completed correctly. A point value of '1' is awarded for the correct figures and a '0' for figures that are incorrect. The raw scores from each of the sub-tests are converted to standard scores. Using the standard score of each sub-test, learners can be grouped into five different mastery categories, ranging from well above average in Category 1 (133–160), above average (118–132), average (83–117), below average (68–82) to well below average (40–67) in Category 5. The VMI test as well as supplementary VP and MC tests each had a total reliability of r = 0.92, r = 0.91 and r = 0.89, , respectively (Beery & Buktenica 1997). The VMI-4 test has been reported to be a culture-free and a valid test. Poor results in the VMI-4 could be ascribed to the inability to integrate visual–perceptual and motor abilities and not necessarily to inadequate abilities.

TABLE 1: Number of participants, gender, racial feature and socio-economic status.

Gender	Race		SES		Total		Mean age			
	White learners (*n*)	Black learners (*n*)	Low (*n*)	High (*n*)	*N*	%	2010		2013	
							M	SD	M	SD
Boys	82	200	160	122	282	49.21	6.9	0.38	9.9	0.37
Girls	61	230	187	104	291	50.79	6.8	0.38	9.8	0.39
Total	143	430	347	226	573	100.00	6.9	0.38	9.9	0.38
Totals %	**24.96**	**75.04**	**60.56**	**39.44**	**100**	-	-		-	

SES, socio-economic status; M, means; *N*, number of subjects; SD, standard deviation.

Classification of schools according to quintiles

In South Africa, the determination of poverty classification of schools is made in accordance with the national poverty table as compiled by the treasury (Hall & Giese 2009). The poverty table includes income levels, dependency ratios and literacy of the residents in the area. The Department of Basic Education divides the schools on the basis of their poverty classification into five quintiles (Hall & Giese 2009), where Quintile 5 represents the most affluent schools and Quintile 1 is classified as the least affluent schools.

Research procedure

Ethical approval for conducting the project was obtained from the ethics committee of the university. Furthermore, permission was also obtained from the Department of Basic Education before the project started. Permission was requested from the principals of the identified schools so that data collection could be done during school hours. Each learner's parent or legal guardian had to fill in an informed consent form before the learner could participate in the project. All learners, whose parents or legal guardians had responded favourably to the consent forms, also had to provide consent before taking part in any measurements. The same procedure was followed again in 2013 where permission was once again obtained from all the principals, parents, legal guardians and learners.

Data analysis and statistical procedures

StatsSoft-computer package (StatSoft 2015) was used for the data processing. Data were, firstly, analysed for descriptive purposes through Arithmetical Means (M), minimum and maximum values and Standard Deviations (SD). Dependent *t*-test was used to determine the meaningful in-group differences for the total group as well as for the SES groups. Two-way frequency tables determined meaningful shifts over the period of 3 years between the different categories for the group as a whole and per SES. Statistical corrections were done for differences during the 2010 measurements by using adjusted means as determined by Analysis of Variance (ANOVA) method. The Pearson's chi-square test was used to indicate statistical significance of differences where values of $p \leq 0.05$ (medium) and $p \leq 0.01$ (large) were used (Steyn 2002). The Phi-coefficient indicated a small practical significance at $w \geq 0.1$, a medium significance at $w \geq 0.3$ and a large practical significant effect at $w \geq 0.5$ (Steyn 2002). Independent *t*-test and effect sizes were further used to determine group differences with regard to the VMI, VP and MC results. The following guidelines were used to determine practical significance: $d \geq 0.2$ (small effect), $d \geq 0.5$ (medium effect) and $d \geq 0.8$ (large effect) (Cohen 1988).

Results

Table 1 describes the group with regard to age, gender, race and SES. In 2010, the group of 573 learners had a mean age of 6.9 years (SD = 0.38) (boys: 6.9 years, girls: 6.8 years), while in 2013 they had a mean age of 9.9 years (SD = 0.42) (boys: 9.9 years, girls: 9.8 years). Both the high and the low SES groups displayed a more or less equal gender representation.

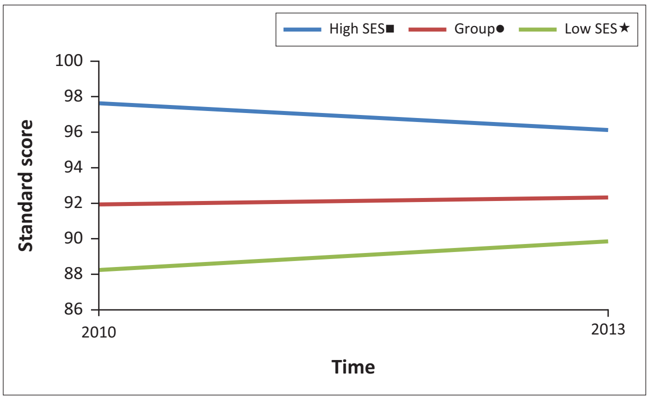
Dependent *t*-test was used to determine developmental changes not only in the group but also for the SES groups (high and low) separately over the 3-year period of this study (see Table 2 and Figure 1 – Figure 3). Figure 1 displays VMI changes over time in the group and per SES group, Figure 2 displays VP and Figure 3 displays MC skills.

Table 2 and Figure 1 indicate that only the low SES group experienced statistically significant changes in their VMI, where standard scores of 88.24 (±13.01) improved from baseline in 2010 to 89.85 (±13.6) ($p = 0.041$) in 2013, although these changes were not of particular significance ($d = 0.12$). Statistically and moderately practically significant improvements were found for VP skills in the group ($p \leq 0.001$, $d = 0.22$) and in the low SES group ($p \leq 0.001$, $d = 0.41$),

TABLE 2: Significant differences from 2010 to 2013 in visual-motor integration, visual perception and motor coordination in the group and per socio-economic status.

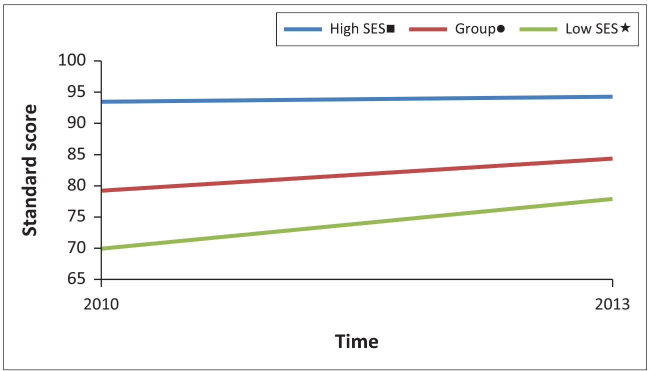
Variables	2010		2013		Significance of differences		
	M	SD	M	SD	*t*	*p*	*d*
VMI							
Low SES	88.24	13.01	89.85	13.60	-2.052	0.041*	0.12
High SES	97.63	11.80	96.12	14.60	1.553	0.122	0.11
Group total	91.94	13.35	92.32	14.33	-0.618	0.540	0.03
VP							
Low SES	69.91	20.30	77.91	18.25	-6.267	≤0.001**	0.41†
High SES	93.47	20.62	94.29	16.06	-0.606	0.545	0.04
Group total	79.20	23.44	84.37	19.16	-5.166	≤0.001**	0.22†
MC							
Low SES	89.69	13.74	90.04	12.06	-0.436	0.663	0.03
High SES	98.31	13.20	98.14	14.58	0.160	0.873	0.01
Group total	93.09	14.16	93.23	13.68	-0.220	0.830	0.01

SES, socio-economic status; M, means; SD, standard deviation; VMI, visual-motor integration; VP, visual perception; MC, motor coordination.
*$p \leq 0.05$; **$p \leq 0.01$; †$d \geq 0.2$; $d \geq 0.5$.



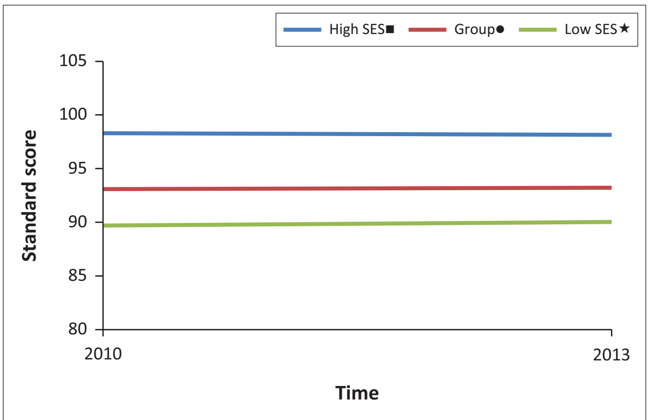
■p = 0.122; d = 0.11; ●p = 0.54; d = 0.03; ★p = 0.041; d = 0.12

FIGURE 1: Developmental changes in visual-motor integration in the group and per socio-economic status



■p = 0.545; d = 0.04 ●$p \leq 0.001$; d = 0.22 ★p = 0.001; d = 0.41

FIGURE 2: Developmental changes in visual perception in the group and per socio-economic status.



■p = 0.873; d = 0.01 ●p = 0.83; d = 0.01 ★p = 0.663; d = 0.03

FIGURE 3: Developmental changes in motor coordination in the group and per socio-economic status.

while no significant changes (p = 0.545, d = 0.04) occurred in the high SES group. This improvement of VP skills in the low SES group was the biggest improvement observed during the present study (from 69.91 to 77.91). Table 2 and Figure 3 indicate no significant changes in MC skills of the group (p = 0.83, d = 0.01) or per high (p = 0.873, d = 0.01) or low (p = 0.663, d = 0.03) SES groups.

Subsequently, the results of the VMI (Box 1a – Box 1c), VP (Box 2a – Box 3c) and MC (Box 3a – Box 3c) skills were divided into nine figures that report the developmental

BOX 1a*:* Developmental changes in visual-motor integration in the group and per socio-economic status.

VMI	**Group**					
	$p \leq 0.001$ w = 0.41▼**					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	2	0	0	**2**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	4	11	0	0	**15**
	0.00%	26.67%	73.33%	0.00%	0.00%	
3	3	25	324	77	2	**431**
	0.70%	5.80%	75.17%	17.87%	0.46%	
4	1	0	56	48	3	**108**
	0.93%	0.00%	51.85%	44.44%	2.78%	
5	0	0	8	6	3	**17**
	0.00%	0.00%	47.06%	35.29%	17.65%	
2013 Total	**4**	**29**	**401**	**131**	**8**	**573**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average; % = the percentage of learners in this category.

BOX 1b*:* Developmental changes in visual-motor integration in the group and per socio-economic status.

VMI	**High SES**					
	p = 0.015* w = 0.37▼					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	2	0	0	**2**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	3	6	0	0	**9**
	0.00%	33.33%	66.67%	0.00%	0.00%	
3	2	13	148	31	0	**194**
	1.03%	6.70%	76.29%	15.98%	0.00%	
4	1	0	11	6	1	**19**
	5.26%	0.00%	57.89%	31.58%	5.26%	
5	0	0	1	1	0	**2**
	0.00%	0.00%	50.00%	50.00%	0.00%	
2013 Total	**3**	**16**	**168**	**38**	**1**	**226**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average; % = the percentage of learners in this category.

BOX 1c*:* Developmental changes in visual-motor integration in the group and per socio-economic status.

VMI	**Low SES**					
	$p \leq 0.001$ w = 0.42▼**					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	0	0	0	**0**
	0.00%		0.00%	0.00%	0.00%	
2	0	1	5	0	0	**6**
	0.00%	16.67%	83.33%	0.00%	0.00%	
3	1	12	176	46	2	**237**
	0.42%	5.06%	74.26%	19.41%	0.84%	
4	0	0	45	42	2	**89**
	0.00%	0.00%	50.56%	47.19%	2.25%	
5	0	0	7	5	3	**15**
	0.00%	0.00%	46.67%	33.33%	20.00%	
2013 Total	**1**	**13**	**233**	**93**	**7**	**347**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average; % = the percentage of learners in this category.

BOX 2a: Developmental changes in visual perception in the group and per socio-economic status.

VP	Group					
	$p \leq 0.001$** $w = 0.45$▼					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	2	0	0	**2**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	3	19	2	0	**24**
	0.00%	12.50%	79.17%	8.33%	0.00%	
3	0	12	143	47	11	**213**
	0.00%	5.63%	67.14%	22.07%	5.16%	
4	0	1	80	69	33	**183**
	0.00%	0.55%	43.72%	37.70%	18.03%	
5	1	1	40	64	45	**151**
	0.66%	0.66%	26.49%	42.38%	29.80%	
2013 Total	**1**	**17**	**284**	**182**	**89**	**573**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$; ✟$w \geq 0.5$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

BOX 2b: Developmental changes in visual perception in the group and per socio-economic status.

VP	High SES					
	$p = 0.001$** $w = 0.53$✟					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	2	0	0	**2**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	2	18	2	0	**22**
	0.00%	9.09%	81.82%	9.09%	0.00%	
3	0	11	103	20	3	**137**
	0.00%	8.03%	75.18%	14.60%	2.19%	
4	0	1	33	12	4	**50**
	0.00%	2.00%	66.00%	24.00%	8.00%	
5	1	0	2	7	5	**15**
	6.67%	0.00%	13.33%	46.67%	33.33%	
2013 Total	**1**	**14**	**158**	**41**	**12**	**226**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$; ✟$w \geq 0.5$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

BOX 2c: Developmental changes in visual perception in the group and per socio-economic status.

VP	Low SES					
	$p \leq 0.001$** $w = 0.47$▼					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	0	0	0	**0**
	0.00%	100.00%	0.00%	0.00%	0.00%	
2	0	1	1	0	0	**2**
	0.00%	50.00%	50.00%	0.00%	0.00%	
3	0	1	40	27	8	**76**
	0.00%	1.32%	52.63%	35.53%	10.53%	
4	0	0	47	57	29	**133**
	0.00%	0.00%	35.34%	42.86%	21.80%	
5	0	1	38	57	40	**136**
	0.00%	0.74%	27.94%	41.91%	29.41%	
2013 Total	**0**	**3**	**126**	**141**	**77**	**347**

*$p \leq 0.05$; **$p \leq 0.01$; ▼$w \geq 0.3$; ✟$w \geq 0.5$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

BOX 3a: Developmental changes in motor coordination in the group and per socio-economic status.

MC	Group					
	$p = 0.001$** $w = 0.26^{o}$					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	1	0	0	**1**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	1	6	0	0	**7**
	0.00%	14.29%	85.71%	0.00%	0.00%	
3	2	25	350	77	7	**461**
	0.43%	5.42%	75.92%	16.70%	1.52%	
4	0	1	50	23	1	**75**
	0.00%	1.33%	66.67%	30.67%	1.33%	
5	0	0	13	13	3	**29**
	0.00%	0.00%	44.83%	44.83%	10.34%	
2013 Total	**2**	**27**	**420**	**113**	**11**	**573**

*$p \leq 0.05$; **$p \leq 0.01$; $^{o}w \geq 0.1$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

BOX 3b: Developmental changes in motor coordination in the group and per socio-economic status.

MK	High SES					
	$p = 0.201$ $w = 0.3$▼					
2010 Class	**2013 Class**					**2010 Total**
	1	2	3	4	5	
1	0	0	1	0	0	**1**
	0.00%	0.00%	100.00%	0.00%	0.00%	
2	0	1	6	0	0	**7**
	0.00%	14.29%	85.71%	0.00%	0.00%	
3	2	18	161	19	2	**202**
	0.99%	8.91%	79.70%	9.41%	0.99%	
4	0	1	10	0	1	**12**
	0.00%	8.33%	83.33%	0.00%	8.33%	
5	0	0	2	1	1	**4**
	0.00%	0.00%	50.00%	25.00%	25.00%	
2013 Total	**2**	**20**	**180**	**20**	**4**	**226**

*$p \leq 0.05$; **$p \leq 0.01$; $^{o}w \geq 0.1$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

BOX 3c: Developmental changes in motor coordination in the group and per socio-economic status.

MC	Low SES					
	$p = 243$** $w = 0.24^{o}$					
2010 Class	**2013 Class**					**2010 Total**
	1	**2**	**3**	**4**	**5**	
1	0	0	0	0	0	**0**
	0.00%	100.00%	0.00%	0.00%	0.00%	
2	0	0	0	0	0	**0**
	0.00%	100.00%	0.00%	0.00%	0.00%	
3	0	7	189	58	5	**259**
	0.00%	2.70%	72.97%	22.39%	1.93%	
4	0	0	40	23	0	**63**
	0.00%	0.00%	63.49%	36.51%	0.00%	
5	0	0	11	12	2	**25**
	0.00%	0.00%	44.00%	48.00%	8.00%	
2013 Total	**0**	**7**	**240**	**93**	**7**	**347**

*$p \leq 0.05$; **$p \leq 0.01$; $^{o}w \geq 0.1$; ▼$w \geq 0.3$.

n, number of subjects; VMI, visual-motor integration; VP, visual perception; MC, motor coordination; 1 = far above average; 2 = above average; 3 = average; 4 = below average; 5 = far below average.

changes from 2010 to 2013 for the group as well as per high and a low SES group. Box 1a to Box 1c show the results of VMI in terms of developmental changes over the 3-year period for the group and per SES group separately by representing the learners' shifts between the mastery categories. In Box 1a to Box 1c, the total group of learners, and also per high and low SES, showed statistically and practically significant ($p \leq 0.001$, $w \geq 0.3$) shifts between the different mastery categories. Of the 431 learners who had tested in the average mastery category during 2010, only 324 learners (176 low SES, 148 high SES) were still in this category in 2013. Of these learners, 25 had improved to the above average category (12 low SES and 13 high SES) and 77 (46 low SES and 31 high SES) moved to the below average category. Of the 108 learners (89 low and 19 high SES) who had been in the below average mastery category in 2010, 51.85% (45 low SES and 11 high SES) improved and moved to the average category, while 44.44% (42 low SES and six high SES) still showed below average mastery.

The results of the visual–perceptual skill developmental changes over the 3-year period are shown in Box 2a to Box 2c for the group and per SES group separately. The visual–perceptual skills of the group showed statistically and practically significant ($p \leq 0.001$, $w = 0.45$) shifts between mastery categories. Overall, 199 learners (144 low SES and 55 high SES) improved to a higher category, 260 remained in the same category (138 low SES and 122 high SES) and 114 regressed (65 low SES and 49 high SES). Of the 213 learners who had tested in the average mastery category during 2010, only 143 learners (40 low SES and 103 high SES) were still in this category in 2013. Of these learners, 12 had improved to the above average mastery category (1 low SES and 11 high SES) and 47 (27 low SES and 20 high SES) moved to the below average mastery category. Of the 183 learners (133 low and 50 high SES) who had been in the below average mastery category in 2010, 80 (47 low SES and 33 high SES) improved and moved to the average mastery category, while 69 (57 low SES and 12 high SES) still showed below average mastery. Of the 136 low SES learners that tested in the far below average mastery category in 2010, 95 improved to higher mastery categories in 2013.

The MC results regarding the developmental changes over the 3-year period are shown in Box 3a to Box 3c for the group and per SES group separately. The total group showed statistically and practically significant ($p \leq 0.001$, $w \geq 0.3$) shifts between mastery categories, but not per low ($p = 0.234$, $w = 0.24$) or high ($p = 0.201$, $w = 0.3$) SES, respectively. During 2010, 461 of the learners tested in the average mastery category, of whom 350 (189 low SES and 161 high SES) were still in this category in 2013. Twenty-five learners (7 low SES and 18 high SES) improved to the above average mastery category and 77 (58 low SES and 19 high SES) moved to the below average mastery category. Of the 75 learners (63 low and 12 high SES) who had been in the below average mastery category in 2010, 50 (40 low SES and 10 high SES) improved to the average mastery category, while 23 (23 low SES and 0 high SES) still remained in the below average mastery category. Of the 25 low SES learners who tested in the far below average mastery category in 2010, 23 had improved to higher mastery categories in 2013.

Ethical considerations

Ethical approval to conduct the project was obtained from the Ethics Committee of the North-West University, Potchefstroom Campus (No. NW-00070-09-A1).

Discussion

The purpose of this study was to determine if SES plays a role in changes in learners' VMI, VP and MC status over a period of 3 years. The results indicated age-related improvements in VMI, VP and MC skills in the group from 7 to 10 years. Visual perception skills demonstrated the largest improvement over time, while MC skills demonstrated the least age-related improvement.

No statistically or practically significant developmental changes occurred in the group's VMI ($p = 0.54$, $d = 0.03$) or MC skills ($p = 0.83$, $d = 0.01$), although slight increases were observed in the standard scores. Beery and Beery (2010) report average VMI, VP and MC standard scores of 100 (SD = 15) for learners of all age groups. The 2010 baseline scores of the group were already within the acceptable mastery skills category (standard score from 83 to 117) for both VMI (91.94 ± 13.35 to 92.32 ± 14.33) and MC skills (93.09 ± 14.16 to 93.23 ± 13.68). From this it can be argued that these skills had only undergone the normal age-related development.

The only statistically and practically significant ($p \leq 0.001$, $d = 0.22$) developmental changes that were found in the group were in VP, where improvements in the standard scores occurred from 79.2 (±23.44) to 84.37 (±19.16). These improvements allowed the group to move from the below average mastery category (standard scores from 68 to 82) in 2010 to the average mastery category (standard scores from 83 to 117) in 2013. According to Farber and Beteleva (2005), the cortical brain areas and the intra-cortical connections develop rapidly from the ages of 5–7, and thus this age is an important developmental age for VP skills.

The normal improvement that is associated with maturity that was found is also in accordance with the results of other researchers' findings (Bezrukikh & Kreshchenko 2004; Decker et al. 2011). Bezrukikh and Kreshchenko (2004) evaluated 60 learners (in Moscow, Russia) in Grade 1 (6–7 years old) and 60 learners in grades 3 and 4 (9–10 years old) and found that the number of learners with well-developed visual-motor coordination skills increased significantly from 19.6% to 46.3% with an increase in age (Bezrukikh & Kreshchenko 2004). Although the study was executed on a younger age group than the present study, Decker et al. (2011) did a pre-test and post-test study (*n* = 846) in Columbia, South Carolina, USA, on 4–7-year-olds to determine whether any developmental changes had occurred over time. These researchers found that maturation (measured in age) played a primary role during visual and perceptual motor integration skills.

Regarding the SES status of the participants and its influence on the developmental changes in VMI, VP and MC status, the results of this study confirmed that no statistically or practically significant changes occurred over the 3-year period with regard to the VMI (p = 0.122, d = 0.11), VP (p = 0.545, d = 0.04) or MC skills (p = 0.873, d = 0.01) in the high SES group. Although not significant, slight decreases were seen in the standard scores of the high SES group's VMI (97.63 ± 11.8 to 96.12 ± 14.6) and MC skills (98.31 ± 13.2 to 98.14 ± 14.58). These non-significant changes (which can be described as a stabilising trend) that occurred in the high SES group's VMI, VP and MC skills are in contradiction with the above-quoted literature, which reported age-related improvements. A possible reason for this could be that the high SES group already demonstrated good VMI skills during the baseline measurements (as seen in Beery & Buktenica's [1997] age-expected norms), and thus reaching a ceiling effect with not much room for further improvement. In contrast to this finding, Tekok-Kiliç et al. (2010) reported age-related improvements in VMI skills of children from middle and high SES groups. This study was done in Bursa (Turkey) on 1887 learners (896 girls and 991 boys) between the ages of 6 and 15.11 years, and they also used the VMI-4. However, these findings are based on cross-sectional data, and only used raw scores and percentiles, compared to the present study that used the standard scores.

The low SES learners showed statistically significant (p = 0.041, d = 0.12) improvements in their VMI standard score (88.24 ± 13.01 to 89.85 ± 13.6), with no significant (p = 0.663, d = 0.03) changes in their MC standard scores (89.69 ± 13.74 to 90.04 ± 12.06). The largest statistically and practically significant ($p \leq 0.001$, d = 0.41) developmental changes that were observed in our study were in the VP skills of the low SES learners, where an improvement occurred from 69.91 (±20.3) in 2010 to 77.91 (±18.25) in 2013. Lotz et al. (2005) conducted a cross-sectional study in the Western Cape province (Stellenbosch, South Africa) and assessed the VMI status of 339 learners (171 boys and 168 girls) in grades 1, 2, 3 and 4 separately. For the group (grades 1–4), Lotz et al. (2005) reported a mean standard score of 94.09 (SD = 23.24), compared to 88.84 (SD = 23.79) for those who were categorised in the low SES group (sub-category under already low SES school). These researchers reported a VMI-4 mean standard score of 76.21 (SD = 16.44) at 7 years of age, 83.58 (SD = 19.07) at 8 years, 93.23 (SD = 24.44) at 9 years and 100.60 (SD = 24.10) for the 10-year-olds. According to this, these results correlate with those of the present study, which reported age-related (from Grade 1 to Grade 4) improvement of low SES learners' VMI status, where the standard scores increased with age. Various researchers report, in accordance with this, that there is a significant link between the SES of learners and their VMI, VP and MC achievement (Dunn 2001; Du Plessis, Coetzee & Pienaar 2015; Lotz et al. 2005; Pienaar et al. 2013). Pienaar et al. (2013) assessed 812 Grade 1 learners (418 girls and 394 boys) in the North West province of South Africa with the VMI-4, and accordingly also found that the low SES learners demonstrated significantly poorer VMI, VP and MC skills than high SES learners. Du Plessis et al. (2015) reported in this regard that low SES Grade 1 learners experienced more delays in MC than high SES learners, which could also have a negative effect on the academic achievement of the learners.

In contrast, the study of Makhele et al. (2006) did not yield any age-related improvements of VMI skills, while SES had no effect on the performance of the group. It must, however, be taken into account that the SES groups that were compared in the study were all sub-categories within a low SES community.

The results of the present study indicate that the VMI, VP and MC skills of learners representing the low SES group improved over time in comparison to that of learners from the high SES group, who showed no improvement. One possible explanation for the increases of the low SES group's performance might be that these learners had existing delays which improved when they entered formal schooling as a result of the stimulation associated with them going to school. Visual perception is an ability that needs to be developed and many South African children from low SES areas are not exposed to conditions where such learning can take place, as they had probably not been in nursery schools before 2010 (baseline measurement when the study started), or been exposed to Grade R teaching. Statistics in this regard indicate that during 2009, 69% of children in the North West province had not been in a nursery school (Stats SA 2010). National statistics showed that the percentage of learners who entered Grade 1 in 2010, who had also been in Grade R, was only 62%.

A literature search for similar longitudinal studies in South Africa and the rest of the world yielded almost no results. Beckman (2011) reported that gaps between the performance levels of racial groups (and thus by implication gaps between high and low SES learners) have not narrowed, although access to education has increased dramatically. This improvement in the quality of the school educational system for low SES learners might perhaps explain the larger improvement in VMI, VP and MC skills that emerged among low SES learners over the 3-year period, although their end results were still lower compared to those of the high SES learners. Educational inequality comes about, according to Taylor and Yu (2009), as a result of the SES of the school attended by a learner, where learners in high SES schools receive better-quality education together with better facilities and more opportunity for optimal development. These researchers further report that in some countries, like in South Africa, the gap in educational inequality between high and low SES learners has a cumulative effect, and this in time leads to even larger gaps in academic achievement. The improvement of low SES learners in the present study is therefore, to some extent, in opposition to the findings of the researchers because although the low SES group showed a greater improvement, they still performed worse than the high SES group (Taylor & Yu 2009).

Visual-motor integration, VP and MC are all skills that can be improved with exercise and repetition. The improvement of the skills could possibly play a significant role in the solution of the very complex problem of academic underachievement of South African children, especially those from low SES environments. The associations that were established in this study highlight the need for the establishment of more focussed strategies for future interventions for learners with academic delays in the areas that were investigated, especially in VP. The longitudinal research design of the present study and the random sampling of groups are strong points of the study that make the results more generalisable and reliable. The influence of SES, which was underlined in the present study in the developmental changes that occur in VMI, VP and MC skills, also contributes to the uniqueness of the study. Because South Africa has a vast disparity when it comes to SES, it is important to determine the effect SES could have on these children's visual-motor skills. Visual-motor integration, VP and MC delays can contribute to poor academic achievement of learners, and for that reason longitudinal analyses are important because development of these skills can still take place between 7 and 10 years of age. This study, however, also has certain shortcomings that should be considered when it comes to the generalisation of the results. It is recommended that similar future studies should involve more of the provinces of South Africa as this study only involved learners from one of the nine provinces of South Africa.

Conclusion

From the results of this three-year longitudinal follow-up study, it can be reported that VMI, VP and MC skills improve with increasing age between the ages of 6 and 9 years, with VP skills demonstrating the biggest improvement over time.

The improvement over time was much higher among the low SES learners, although the high SES learners still performed significantly better in both the 2010 and 2013 measurements. Many learners from the low SES group improved from far below average and below average categories, putting more of them in the average mastery group, whereas the high SES learners largely still remained in the average mastery category. Developmental delays in any of the skills can probably contribute to academic and learning-related delays and must therefore receive attention for purposes of preventative and therapeutic interventions.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

Both D.C. and A.E.P. contributed to the conceptualisation of this study. D.C. and Y.v.W. performed all the data collection, while all the authors were involved in the statistical analyses. All three authors wrote the article together.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Disclaimer

Any opinions, findings, conclusions or recommendations emanating from this study are those of the authors and therefore the MRC, SASA and the NRF do not accept any responsibility or liability.

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