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Influences of Early Motor Proficiency and Socioeconomic Status on the Academic Achievement of Primary School Learners: The NW-CHILD Study

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Abstract

Motor proficiency and socioeconomic status are considered critical role players in setting children on an early trajectory of academic failure or success. To determine longitudinal influences of motor proficiency (MP) and socioeconomic status (SES) on academic achievement of primary school learners, a mediating model was constructed and tested with structural equation modelling (SEM). Primary school learners ($N = 381$) took part in this 7 school year NW-CHILD longitudinal study, with baseline measurements in grade 1 and follow-up measurements in grades 4 and 7. Academic achievement was based on school, national, and provincial assessments, and the *Bruininks Oseretsky Test of Motor Proficiency-2* (*BOT-2*) assessed MP. SES was operationalized as poverty classification which was based on school SES. Significant small to moderate correlations ($r = .19$ to $r = .36$) were confirmed between early MP and later academic achievement, with impaired academic achievement and MP ($p < .05$) in low SES participants. MP, SES and academic performance in grade 1 were all significantly related. A direct association between academic achievement in grade 1 and grade 7 were confirmed. Academic achievement in grade 4 did however act as mediator and indirectly associated SES (− .413; − .417), MP (.083; .093) and academic achievement in grade 1 (.401; .398) with academic achievement in grade 7. Grade 4 academic achievement portrayed the largest standardized regression coefficients with grade 7 (.693; .731). Low SES, and poor MP in first graders can contribute to compounded academic risk that are detrimental to academic achievement throughout the primary school years and should be addressed by timely interventions.

Keywords Academic achievement · Motor development · Socioeconomic backgrounds · Structural equation modelling

Introduction

Children's potential for academic success can be reduced at a young age by various factors. Among these are inadequate early motor proficiency (MP) and adverse environmental influences such as poverty (Cadoret et al. 2018; Hair et al. 2015; Lawson and Farah 2017; MacDonald et al. 2018; Piek et al. 2008). Various studies support relations between gross motor skills and academic achievement (Da Silva Pacheca 2016; Graf et al. 2004; Lopes et al. 2013; Piek et al. 2008). Various underlying internal processes are responsible for moving the body or parts of the body in space to produce gross and fine motor skills (Cameron et al. 2016). The critical role of body actions in cognitive control is also emphasized by theories where learning is facilitated or constrained by a changing motor repertoire. Shared higher order cognitive processes between motor and cognitive functions (Diamond 2000; Hartman et al. 2010; Roebers and Kauer 2009; Westendorp et al. 2011) are provided as a possible explanation for this relation.

A recent review paper by MacDonald et al. (2018) found significant positive small to moderate relationships between overall MP and math and reading performances. However, this relationship is considered to be complex and

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evidence is scant according to MacDonald et al. (2018). In this regard, researchers (Geertsen et al. 2016; Cadoret et al. 2018) report that the positive correlation between MP and academic achievement does not seem to be direct, but rather to be impacted indirectly by cognitive abilities such as positive influences of working memory and perceptual processes. The specificity of motor effects is also still unclear, i.e., whether some skills will have stronger influences on academic achievement, remains a complex question to be answered (Cadoret et al. 2018; MacDonald et al. 2018). MacDonald et al. (2018) recommended that further examination of the relationships among MP, cognition, and academic performance is still warranted, as reviews on this relationship is are limited and evidence of these relationships are in most cases inconclusive. The relationship of gross motor proficiency and academic performance is especially less studied in this regard (MacDonald et al. 2018). The use of more robust study designs is also recommended to investigate these relationships. The question also remains if MP only has early influences, as some evidence indicates only earlier influences (Cameron et al. 2016; Morales et al. 2011).

Childhood SES is considered to be a powerful predictor of academic achievement throughout childhood and adolescence (Cheng and Kaplowitz 2016). The bio-ecological model of Bronfenbrenner implies that development in low socioeconomic environments is largely affected by the interaction (or lack thereof) between the individual and environment (Bronfenbrenner and Morris 2006). A number of factors are reported to vary along SES gradients and are likely to influence child development, including: parenting practices and investment in children's cognitive development, school quality, neighborhood characteristics, cultural exposure, and children's chronic stress exposure (Bradley and Corwyn 2002). In addition, executive function (EF) is considered to be among the most pronounced cognitive correlates of SES (Lawson and Farah 2017), as it supports school achievement by encompassing cognitive processes that enable top-down control of attention and behavior (Best and Miller 2010). In this regard, the findings of Hair et al. (2015) suggest that specific brain structures tied to processes critical for learning and educational functioning, such as sustained attention, planning, and cognitive flexibility, are vulnerable to the environmental circumstances of poverty such as limited stimulation, life stresses, and nutrition. These researchers found developmental differences between 15 and 20% in brain structures that are known to influence critical processes and skills, including reading comprehension, language usage, and associative learning and thinking, which can explain achievement deficits in low income children.

It is also reported that the longer children live in poverty the greater their academic deficits will be (Harwell et al. 2017). As such, childhood SES can be conceptualized as a proxy for many experiences that tend to differ along SES lines. A recent review of relations between measures of SES and academic achievement (Harwell et al. 2017) however, found that this relationship is surprisingly modest, reporting an average SES-achievement correlation of 0.22. The association does however appear to have strengthened in the past three decades. Longitudinal research findings of Marks (2016) also showed that early cognitive skills rather than SES play a role in the later academic achievement of fourteen to sixteen year-olds, which adds to contradictory findings regarding the role of SES in academic achievement. These results also contradict the findings of Hair et al. (2015) by stating that SES does not have a significant influence on early cognitive skills (Marks 2016). Ferreira et al. (2018) report that the effect of SES was lower in older children than for younger children.

MP of children growing up in poverty is also linked to negative academic outcomes and cognitive skills (Ferguson et al. 2007; Krombholz 2012; Pienaar et al. 2013; Bellibas 2016; Corso et al. 2016). Several other researchers also claim socioeconomic influences on children's perceptual and motor skills (Krombholz 2012; Pienaar and Kemp 2014; Morley et al. 2015). The dynamic systems theory that is generally used when studying the motor development of children, postulates that motor development is influenced by the complex interaction between environmental demands, the characteristics of the task, and the child itself (Newell 1986). Thus, the development of children, whether positive or negative, is influenced on both motor and academic achievement levels by their interactive surroundings (Newell 1986). Negative influences can include a lack of stimulation and environmental opportunities to develop these skills.

The demographics of South Africa includes a large variety of ethnic groups, languages, cultures and socioeconomic circumstances that contribute to extremes and inequalities in the development of children (Edginton et al. 2012). Approximately 63% of young South African children live in poverty, which could negatively influence their cognitive, emotional and physical development (Hall et al. 2016). When South African children enter their grade 4 school year after completing the foundation phase, they are confronted with various changes in the school curriculum to which they need to adapt. From grade 4, all learners receive learning content and instructions in English, while their official home language is one of the various African languages spoken in South Africa. This results in the majority of learners receiving instruction in their second or third language during their intermediate and senior phase years (Hugo and Nieman 2010). These researchers argue that when learners can speak and write in a second language, it does not automatically mean they have the ability to understand concepts, reason, or study successfully in the second language. Instruction in a second language not only leads to 20% of learners not understanding the instructions, having limited vocabulary, being unfamiliar with phonics and struggling with correct spelling, but also leads to errors that are transferred to learners by teachers who also are not proficient in the second language used (Nel and Müller 2010). New learning areas are also introduced in this grade, which require moving to different classes and different teachers during the school day. As children progress through formal schooling they are also constantly presented with changing tasks that increase in complexity and applications of cognitive load in early childhood (Cameron et al. 2016). Associations and trajectories between required tasks and motor demands may therefore change over time and become less relevant for achievement. Longitudinal studies are however needed for an improved understanding of these associations. Cameron et al. (2016) confirmed a relationship between MP and academic achievement, but encourages a theoretical and methodological approach to clarify the mechanisms that implicate motor skills in school performance and achievement, while theoretical models are also encouraged when the relationship between SES and academic achievement is assessed (Harwell et al. 2017).

Taking into account the unique demographics of the South African population and the challenges that it poses to academic achievement, in combination with the complex array of other possible influences on academic achievement as indicated in the literature background, a deeper understanding of these interrelations will be of value. Understanding of changes in the importance of SES and MP on academic achievement of primary school children over the short and long term are also warranted. No evidence of longitudinal analysis of these relations is currently available on South African children, which necessitates research to fill this knowledge gap in the literature. The main interest of this study is therefore the prolonged influences of MP and SES on academic achievement over the primary school years. The above literature review portrays correlations between motor proficiency and academic achievement, as well as between motor movement and brain development, while reporting on the influences of SES on various developmental domains of young children. Low SES seems to influence both academic achievement and MP, perhaps not only in the short term, but also in the long term. Limited evidence is also reported to conclusively confirm relationships between MP and academic performance, while the reasons behind SES and MP influences on academic achievement are also still not clear and, in some cases, conflicting. The role of academic achievement in the relation is also still unclear.

Thus, to examine these interrelations and to verify if these relationships influence later academic achievement, a mediating model was constructed (see Fig. 1). To construct this model, we first hypothesized that MP (a composite measure that includes fine motor control, manual coordination, strength and agility, and balance), SES (a composite measure of school quality and location of the school), and academic achievement would be interrelated over the primary school grades. Our second hypothesis was that academic achievement in grade 4 would mediate the relationship between MP, SES and academic performance. We used a SEM analysis to analyze mediation influences (when a predictor affects an outcome through the mechanism of a third variable), that may help explain the possible harmful effects of differences in SES and MP on academic achievement.

Methods

Study Design

Grade 1- to 7-learners in the North-West Province of South Africa were the target population for this study. The *North-West Child Health, Integrated with Learning and Development* (NW-CHILD) longitudinal study which extended over the entire primary school period of seven school years (2010–2016) was used and included a baseline and two follow-up measurements within this period. Participants were identified in 2010 in their grade 1 year by means of a random sample, with the baseline measurements done in the same year, where after the first follow-up measurements were completed in 2013 (grade 4) and the final measurements in 2016 (grade 7). This study design enabled three time point measures within a six-year follow-up period. The population was selected by means of a stratified random sample in conjunction with the Statistical Consultation Service of the North-West University.

To determine the sample, a list of schools in the North-West Province was obtained from the Department of Basic Education, where after stratification was done

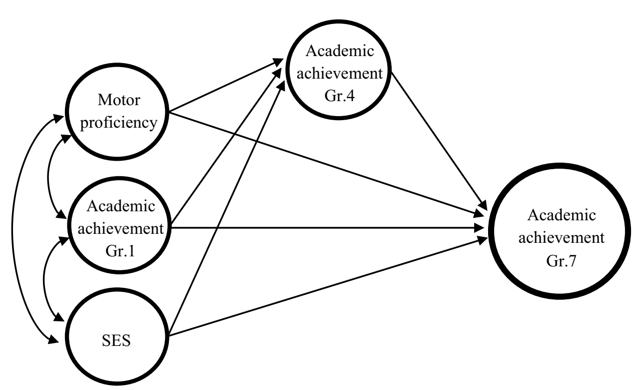

Fig. 1 Visual representation of the proposed theoretical mediating model

according to school districts, school types (quintile 1 to 5), and gender. From this list, which is grouped into eight education districts, each with 12 to 22 regions that represent approximately 20 schools (minimum 12, maximum 47) per region, four school districts and 20 schools were randomly selected with regard to population density and school status (quintile 1—schools from poor economic areas to quintile 5—schools from good economic areas).

South Africa uses a poverty classification system to categorize schools in different quintile groups based on SES factors. The classification system of the National Census information was used, which included income, ratio of dependents, and literacy levels (Pauw 2005). Schools with a quintile 4 and 5 classification represented high socioeconomic areas, while quintiles 1, 2 and 3 schools represent children from low socioeconomic areas. These schools are also poorly equipped with teaching aids and provide free education and school feeding schemes to children.

Participants

The research group formed part of the 2010, 2013 and 2016 measurements of the NW-CHILD longitudinal study (N = 381). In 2010, 880 participants were invited to participate of which 816 took part in the base line testing. Almost half (46.69%) of the participants were involved in all three measurements, with a random loss of participants. The group of 381 participants represented different quintile schools (quintile 1 to 5), as well as various racial groups (black and white) (Table 1).

The mean age of the group was 6.86 years (± 0.39) in 2010, 9.90 years (± 0.38) in 2013 and 12.9 years (± 0.38) in 2016. The total group included an equal distribution of boys and girls, with the majority of the participants being black (72.70%). A large number of participants were from low socioeconomic circumstances (57.22%). These statistics correspond with the population demographics within South Africa and indicate a good representation of the country's population composition.

Data was collected by senior researchers in Kinderkinetics and Kinderkinetics Honours students. Trained interpreters explained the test instructions to the participants whenever the mother tongue of the participant was neither English nor Afrikaans. Training enabled the interpreters to act with insight.

Table 1 Descriptive statistics of the participant group (N = 381)

Variables	Number (*N*)	%
Boys	181	47.51
Girls	200	52.49
White	104	27.30
Black	277	72.70
Low SES	218	57.22
Boys	92	24.15
Girls	126	33.07
White	0	0.00
Black	218	57.22
High SES	163	42.78
Boys	89	23.36
Girls	74	19.42
White	104	27.30
Black	59	15.48

N number of participants, *SES* socioeconomic status

Data Collection

Bruininks Oseretsky Test of Motor Proficiency, Second Edition

The *Bruininks Oseretsky Test of Motor Proficiency, second edition (BOT-2)* uses purposeful activities to determine motor skills proficiency between the ages of four and 21 years of age. The *BOT-2* consists of four main components, namely; fine motor control, manual coordination, body coordination, strength and agility, and the following eight sub-components form part of the aforementioned main components: (1) fine motor precision, (2) fine motor integration, (3) manual dexterity, (4) bilateral coordination, (5) balance, (6) running speed and agility, (7) upper limb coordination and (8) strength. Four options are available to use (complete form, short form, selected composites and subcomponents). Internal consistency values of between r = 0.70 and r = 0.89 are reported, indicating reliability between subtest scores, composite scores, Short Form scores and *BOT-2* complete form scores (Bruininks and Bruininks 2005). The *BOT-2* Short Form is also found to be reliable (r = 0.88–0.92) in children living in remote Australian Aboriginal communities (Lucas et al. 2013).

For the purposes of this study the short form (referred to as *BOT-2 Short Form Total* in the results), as well as three complete subcomponents (strength, running speed and agility, and balance) were used. The short form takes approximately 20 to 30 min to complete, with an additional 10 min to prepare the testing area. Raw scores were converted to point scores and converted to gender specific standard scores which were then used to determine age equivalent descriptive categories and percentile values (Bruininks and

Bruininks 2005, pp. 1–6). Percentile values less than 18.0% were classified as below average MP (Bruininks and Bruininks 2005). The *BOT-2* is considered a reliable test battery with values varying between r = 0.7 and r = 0.8 for different age groups with sufficient validity, which provides effective measurements of gross and fine motor control skills (Bruininks and Bruininks 2005). Excellent psychometric properties (α = 0.92) and strong test-rest reliability are reported for the *BOT-2* (Wuang and Su 2009; Yoon et al. 2006).

Academic Achievement

In 2010 when the participants entered the Foundation phase of primary school (grade 1), the mid-year June progress reports of each participant were used as a proxy of their academic achievement. Basic academic literacy skills (numeracy, literacy and writing skills) were assessed by the class teachers by means of *The Mastery of Basic Learning Areas* assessment method. Numeric skills (mathematics) as well as reading (language literacy) and writing skills (standard of handwriting and pencil grip) were evaluated on a scale of one (1) to four (4). A score of (1) indicated no mastery; (2) partial mastery; (3) if the skill has been mastered; and (4) for exceptional mastery (CAPS Foundation 2011). These scale scores were then converted to percentages.

In 2013 and 2016 (the intermediate and senior phase years of primary school), the academic mid-year June school progress reports of the participants were used. Achievement percentages in six learning areas including Mathematics; Home Language; Second Language; Natural Sciences; Social Sciences and Technology and Life Orientation, as well as a grade point average (GPA) (CAPS Intermediate 2011), were included in this report. Academic percentages were interpreted as follows: 80–100% reflect excellent achievement; 70–79% meritorious achievement; 60–69% described significant achievement; 50–59% adequate achievement; 40–49% average achievement; 30–39% basic achievement; and 0–29% indicated that the learning outcome "was not reached".

In 2013 the results of the Annual National Assessment (ANA) of academic achievement were additionally used. This assessment took place in the third semester (September) of each year. During this assessment, the language (Home and Second language) and mathematical abilities of all South African learners were assessed nationally and were made available in percentages to our research team (Department of Education 2014).

In 2016, the Annual National Assessment (ANA) was not written because of unforeseen reasons and was nationally replaced by provincial assessments which were similar and comparable. The results obtained in the North-West Provincial Assessment (NWPA) were therefore used which included assessments in percentages of all learners in the North-West Province in Afrikaans, English, Setswana (languages), and Mathematics. To be able to compare academic achievement results in grades 1, 4 and 7, academic achievement percentages in only languages (reading in grade 1, and Home and second language in grade 4 and grade 7) and Mathematics were used in this study.

Procedure

Ethical Considerations

Ethical approval based on the Helsinki Declaration and "Ethics in Health Research: Principles, processes and structures" (Department of Health, South Africa 2015) was obtained for the NW-CHILD study, from the Ethics Committee of the North-West University (No. NW-00070-09-A1). Permission was also obtained from the Department of Basic Education of the North-West Province, South Africa, while the school principals had to grant permission for the gathering of the data during school hours. The parents and legal guardians of all participants had to grant parental permission, while participants had to provide written assent after all testing procedures were explained to them. Participants had time to ask questions and were informed of the option to decline participation. Exclusion criteria were applied when the participant did not meet the abovementioned criteria, was not present on the day and time of testing or was feeling sick.

Statistical Methods

The TIBCO *Statistica for Windows*, Version 13.3 and the *Analysis of Moment Structures* (*AMOS,* version 25) computer programs were used to analyze the data (AMOS 2017; StatSoft 2016). For descriptive purposes, means (M), standard deviations (SD) and minimum and maximum values were calculated (StatSoft 2016). Spearman Rank Order correlations were used to analyze correlations between early MP and academic achievement where the following cut offs were used as guidelines for practical significance: $r \approx 0.1$ indicate a small practical effect, $r \approx 0.3$ a moderate practical effect and $r \geq 0.5$ a large practical effect (Cohen 1988).

Repeated measures ANOVA was performed on all MP and academic achievement variables for the different SES groups over time. A p value smaller than or equal to 0.05 indicated statistical significance, while practical significant effects were indicated by Cohen's d values of d = 0.2 (small); d = 0.5 (medium) and d = 0.8 (large) cut-offs (Cohen 1988).

The *Analysis of Moment Structures* computer program (*AMOS, v.25*) was used to execute a latent growth curve analysis within a structural Equation Model (*Structural Equation Modeling/SEM*) framework to determine the relation between MP, SES and academic achievement over the period of seven primary school years. The effect of SES was determined by using a dummy variable. Children from low SES backgrounds received a “1” coding, and children from a high SES coded as “0”.

Results

Correlations between early MP and later academic achievement are presented in Table 2 as well as between academic achievements in the different grades. These results confirm small to moderate correlations between early MP (grade 1) and academic achievement in language, math and the grade point averages in grades 4 and 7.

Early academic achievement also correlated significantly with academic achievement in grades 4 and 7. All correlations ranged between small to moderate, with slightly higher correlations found between academic achievements during the earlier grades.

The results of a repeated measures ANOVA of MP and academic achievement of the participants divided into low and high SES groups over the three time-points, are presented in Table 3. Statistically significant ($p > 0.01$) SES and SES over time differences are found in the strength and overall MP and also between math, language, and the GPA

Table 2 Spearman rank order correlations between MP and academic achievement in grade 1 (2010), and grade 4 and grade 7

Year	Grade 1				Grade 1		
	Motor proficiency (2010)				School assessment (2010)		
	BOT-2 total (ss)	R and A (sc)	Strength (sc)	Balance (sc)	Language	Math	GPA
Motor proficiency							
2013							
R and A (sc)	.23*	.43*	.28*	.27*	− .01	.00	− .01
Strength (sc)	.30*	.20*	.32*	.21*	.05	.08	.06
Balance (sc)	.21*	.21*	.20*	.38*	− .09	− .04	− .08
BOT-2 total (ss)	.53*	.30*	.31*	.27*	.21*	.24*	.23*
2016							
R and A (sc)	.25*	.30*	.15*	.10	− .05	− .05	− .06
Strength (sc)	.29*	.21*	.26*	.16*	.05	.09	.06
Balance (sc)	.08	.11*	.14*	.26*	− .08	− .10	− .09
BOT-2 total (ss)	.42*	.20*	.19*	.22*	.11*	.24*	.11*
Academic achievement							
School assessments							
2013							
Language	.33*	.00	.09	− .05	.40*	.43*	.44*
Mathematics	.22*	.04	.06	− .02	.34*	.42*	.39*
GPA	.29*	− .00	.09	− .04	.44*	.46*	.47*
2016							
Language	.23*	.08	− .00	− .06	.43*	.41*	.45*
Mathematics	.23*	.02	.13*	− .00	.28*	.28*	.31*
GPA	.33*	.01	.09	− .07	.39*	.42*	.43*
Provincial assessments							
2013							
Language	.32*	.01	.17*	− .00	.38*	.41*	.43*
Mathematics	.31*	− .00	.08	− .04	.36*	.36*	.38*
GPA	.36*	.01	.13*	− .03	.42*	.42*	.45*
2016							
Language	.19*	.01	.03	− .08	.38*	.37*	.40*
Mathematics	.26*	.03	.01	.01	.33*	.31*	.35*
GPA	.35*	.01	.08	− .05	.40*	.40*	.43*

Ss scale score, *sc* standard score, *R and A* running speed and agility, *BOT-2 total BOT-2 S*hort Form Total, *Maths* mathematics, *GPA* grade point average, *MS Error* mean square error

$r > .1$, $r > .3$, $r > .5$; $^*p \leq .05$

Table 3 Repeated measures ANOVA results on MP and academic achievement time point differences between low and high SES participants

	Low socioeconomic status			High socioeconomic status			MS error	SES *p* value	Time *p* value	SES–time *p* value	Effect sizes (E) Between group differences *d* value		
	2010	2013	2016	2010	2013	2016					2010	2013	2016
Motor proficiency													
R and A (sc)	18.33	18.08	17.49	17.52	17.53	17.68	14.9	.213	.481	.189	$0.43^{\#}$	$0.32^{\#}$	0.08
Strength (sc)	15.82	16.61	13.43	16.46	17.83	14.60	6.4	.<01*	.<01*	.233	$0.34^{\#}$	$0.68^{\#\#}$	$0.74^{\#\#}$
Balance (sc)	12.88	13.75	15.62	12.37	12.91	15.13	12.4	.082	.<01*	.805	0.26	$0.38^{\#}$	0.26
BOT-2 total (ss)	39.63	48.06	44.03	44.36	52.60	47.11	25.0	.<01*	.<01*	.046*	$1.91^{\#\#\#}$	$1.67^{\#\#\#}$	$1.29^{\#\#\#}$
School assessments													
Language	68.19	49.97	58.26	77.71	67.93	64.92	142.0	.<01*	.<01*	.<01*	$2.22^{\#\#\#}$	$4.60^{\#\#\#}$	$1.87^{\#\#\#}$
Mathematics	71.95	57.90	45.39	83.92	66.13	58.54	184.0	.<01*	.000*	.<01*	$2.83^{\#\#\#}$	$2.07^{\#\#\#}$	$3.30^{\#\#\#}$
GPA	69.42	54.58	52.78	79.78	68.79	64.29	108.0	.<01*	.000*	.039*	$2.50^{\#\#\#}$	$3.98^{\#\#\#}$	$3.47^{\#\#\#}$
Provincial assessments													
Language	69.63	46.18	54.50	77.72	69.60	62.24	175.0	.<01*	.000*	.<01*	$1.89^{\#\#\#}$	$5.68^{\#\#\#}$	$2.15^{\#\#\#}$
Mathematics	72.10	41.48	41.80	84.03	60.12	58.79	236.0	.<01*	.000*	.014*	$2.82^{\#\#\#}$	$4.48^{\#\#\#}$	$3.91^{\#\#\#}$
GPA	69.61	42.95	45.66	79.78	64.76	60.31	134.0	.<01*	.000*	.<01*	$2.46^{\#\#\#}$	$5.54^{\#\#\#}$	$4.50^{\#\#\#}$

Ss scale score, *sc* standard score, *R and A* Running speed and Agility, *BOT-2 total BOT-2 S*hort form total, *GPA* Grade Point Average, *MS Error* mean square error

$^{\#}$d = .2; $^{\#\#}$d = .5; $^{\#\#\#}$d = .8; *p ≤ .05

during both the school and provincial assessments. The established effect sizes (ES) showing poorer performance in the low SES group, were all of moderate to large practical significance (ES > 0.5). This confirms a negative impact from low SES on MP and academic achievement.

Statistically significant (0.046 < p < 0.000) SES over time interaction effects were also established for overall MP (*BOT-2 total*) and math, language, and GPA during the school and provincial academic assessments, indicating higher performance in the high SES group over all three time points. Up to 10 percent variations were evident between the groups in language achievement with slightly higher differences in math and the GPA during each time point assessment. Differences in math between the groups also widened to almost 13% in grade 7 in the school assessment (45.39% vs. 58.54%) and to 16% in the provincial assessment (41.8% vs. 58.79%).

SEM analyses were performed separately for both the school and provincial assessments and nearly similar results were obtained. We therefore only displayed the SEM results of the school assessment. Figures 2 (saturated model) and 3 (mediation model) portray the interrelations between MP and SES with academic achievement in grade 1, grade 4, and grade 7. The models showed acceptable Comparative fit index (CFI) values of both 0.924, while the Degrees of Freedom (CMIN/DF) values of respectively 3.054 and 2.997 were also acceptable (Mueller 1996). The Root Mean Square Error of Approximation (RMSEA) values of respectively 0.074 and 0.072 with a 90% interval of [0.063; 0.084] and

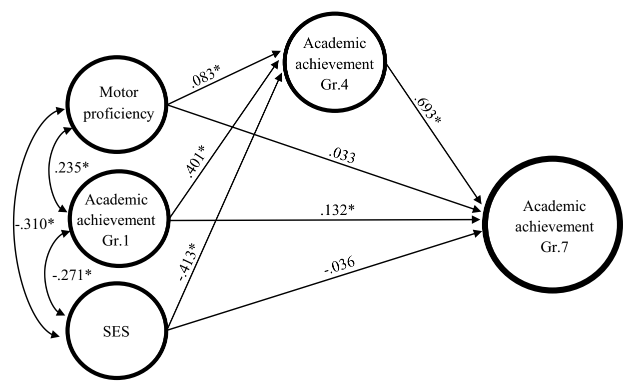

Fig. 2 Growth curve (saturated model) of academic achievement for MP, SES with standardized regression coefficients (*p < .05)

[0.062; 0.083] were found, which indicated good fit criteria for these models according to Blunch (2008).

The SEM analysis (Fig. 2) showed significant interrelations between MP, SES and academic achievement in grade 1. MP and academic achievement correlated positively (0.235), SES and academic achievement negatively (− 0.271), while SES and MP also showed a significant negative correlation (− 0.310). Grade 1 academic achievement (0.401) and SES (− 0.413) showed direct significant regression coefficients with academic achievement in grade 4.

Grade 4 academic achievement acted as a full mediator of these relationships (0.693), therefore only an indirect relationship with grade 7 academic achievement was evident.

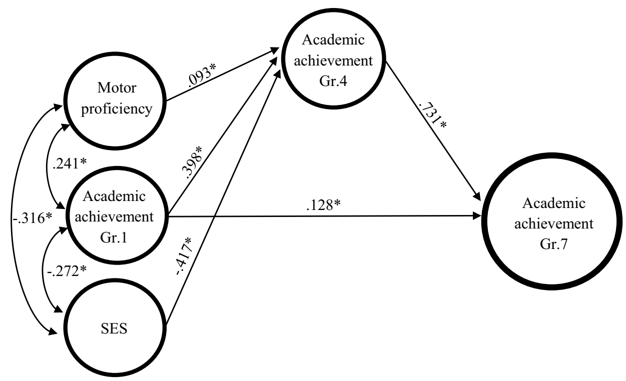

Fig. 3 Growth curve (mediation model) of academic achievement for MP, SES with standardized regression coefficients (*p < .05)

No direct effect for MP or SES was found with grade 7 academic achievement. Academic achievement in grade 1, however showed a direct regression coefficient with academic achievement in grade 7 (0.132). A partial mediation percentage of 67.8% was established for academic achievement in grade 4, while academic achievement in grade 1 was not fully mediated but still displayed a 33.0% direct effect (0.132) on grade 7 academic achievement. The influence of SES (− 0.413) was however very similar to academic performance in grade 1 (0.401) on grade 4 academic achievement in the saturated model, although slightly higher in the mediated model (− 0.413 vs. − 0.417, Fig. 3). Academic achievement in grade 4 acts as a partial mediator variable between academic achievement in grade 1 and grade 7, therefore completely mediating the unique relationship of early MP and SES on academic achievement in grade 7.

Discussion

This study first aimed to determine the interrelations between MP, SES and academic achievement in grade 1 and over the span of 7 school years, in South African primary school children. The second aim was to determine whether these influences might be mediated by other influences such as academic achievement in grade 4.

Spearman rank order correlations confirmed small-to-moderate significant correlations between MP in grade 1 and academic achievement in grade 4 ($r = 0.22$ to $r = 0.36$), and in grade 7 ($r = 0.19$ to $r = 0.35$). The SEM analyses furthermore confirmed significant inter correlations in grade 1 between MP and academic performance (0.241), SES and academic performance (-0.272), while SES and MP were also moderately correlated (-0.316) in both the saturated and mediated models. Such interrelations are also confirmed by other studies (Cadoret et al. 2018; Corso et al. 2016; Cheng and Kaplowitz 2016; Da Silva Pacheca 2016; Hair et al. 2015; Krombholz 2012; Lawson and Farah 2017; MacDonald et al. 2018; Piek et al. 2008; Pienaar et al. 2013; Son and Meisels 2006).

The mechanisms behind the association between movement and SES in academic achievement are considered to be complex (MacDonald et al. 2018). Shared higher order cognitive processes are reported for motor and cognitive functions (Diamond 2000) where the use of corresponding brain structures, such as the cerebellum and the prefrontal cortex, in the execution of both cognitive and motor tasks is considered by some researchers as a possible explanation for this association (Diamond 2000; Westendorp et al. 2011). Cameron et al. (2016) furthermore reasoned that influences of movement should be analyzed outside the movement itself as motor skills include cognitive processes that give rise to movements, including perceptual-motor, sensorimotor, and psychomotor skills which implicate sensory perception and the interaction of the movement systems (i.e., body parts) with the cognitive system (Adolph and Berger 2006).

Influences of Academic Achievement

Academic achievement in grade 1 influenced academic achievement in grade 7, revealing a 33% direct influence. In both the saturated and mediated models, academic performance in grade 1 (which is influenced by SES and MP and thereby presenting a carry-over effect of these influences to academic achievement in grade 7), also correlated with later academic achievement in grade 4 (0.401; 0.398), and consequently with grade 7 achievement. In agreement, Marks (2016), reported that prior academic achievement and cognition during early childhood influenced later academic achievement in Australian children.

Influences of SES

Repeated measures of ANOVA confirmed significant differences between participants from low and high socioeconomic backgrounds. Participants from low SES portrayed statistical ($p \leq 0.05$) and practically poorer academic achievement (math, languages and GPA), strength and overall MP (*BOT-2* total). Supporting findings are reported indicating that the longer children are exposed to the influences of adverse environments, the worse their academic outcomes will become (Coro et al. 2009; Harwell et al. 2017). Our findings specifically showed increasing differences in math performance between SES groups from grade 1 to grade 7, which is consistent with the longitudinal findings of Corso et al. (2009) who also reported widening SES achievement differences in Canadian children.

SES appears to play a moderate significant role in academic achievement, with a direct influence on grade 4 achievement (− 0.413; − 0.417) and thereby indirectly affecting academic achievement in grade 7. In the study of Marks (2016), SES explained between 6 and 15% of the variation in academic achievement. The researchers confirmed a long-term influence of SES on academic achievement, albeit small, after the early cognitive skills and academic achievement of 3537 Australian children were considered in the analysis. Pokropek et al. (2015) used structural equation modelling and also confirmed a long-term negative influence of low SES on academic achievement.

The prolonged development of EF that includes cognitive processes, which enable top-down control of attention and behavior, may make school achievement particularly susceptible to differences in experiences associated with childhood SES (Best and Miller 2010). These might be important reasons for the direct influence of SES on academic achievement that remains up to grade 4 (Hackman et al. 2009). In support to this possible explanation, Hair et al. (2015) found that specific brain structures tied to processes critical for learning and educational functioning, such as sustained attention, planning and cognitive flexibility, are vulnerable to the environmental circumstances of poverty. These environmental circumstances include limited stimulation, life stresses, and nutrition. Reading comprehension, language usage, and associative learning and thinking, of between 15 and 20 percent could explain achievement deficits in low income children (Hair et al. 2015). A recent review of relations between measures of SES and academic achievement, Harwell et al. (2017) report a correlation of 0.22, with the association strengthening in the past 3 decades.

On a conceptual level, home language education during the early childhood development years is considered to be vital, as concepts that are imperative for attaining academic literacy since school entry are formed through language (Wright 2012). Alivernini and Manganelli (2015) report that SES impeded a significant and direct effect ($p < 0.001$) on reading skills (55%) of grade 4 Italian learners. The effect of SES was considered in their study along with pre-school education, and the influence of SES rather than pre-school education remained significant ($p < 0.001$), on both reading (31%) and early education (16%) (Alivernini and Manganelli 2015). As of 2012, English as First Additional Language (FAL) was introduced from grade 1 in some schools in SA, instead of only from grade 3, while children whose education was in their mother tongue up to grade 3, received further education from grade 4 in their second language, namely English. Hugo and Nieman (2010) argue that the ability to speak and to write in a second language, which is required from most intermediate phase children in South African schools who are also often from poor SES backgrounds, does not infer the ability of concept understanding, reasoning, thinking and studying. As learners have to adapt to many changes in grade 4, this barrier could have influenced academic performance negatively.

On a practical level, Wright (2012) emphasizes that language education requires three essential aspects to be successful, independent of when and which of the 11 official South African languages are taught (Wright 2012). Low SES schools often struggle with one or more of these aspects, which can contribute to poor language education, which again can have a ripple effect on academic achievement. These include a lack of well-educated and well-trained second language fluent teachers (Nel and Müller 2010; Wright 2012); state-of-the-art textbooks; and adequate school facilities (Wright 2012).

Influences of MP

Results of the present study indicated that MP of first graders play a practically significant role in their academic achievement in grade 1, and also influences academic achievement in grade 4, where after an indirect path of influence on academic achievement in grade 7 was established. This indicates that at later ages influences of MP is still recognized, although masked by other influences such as grade 4 academic achievements. Some researchers that studied the relationship between MP and academic achievement also report higher relationships at a younger age (Cameron et al. 2016; Coetzee et al. 2019; Morales et al. 2011). The involvement of perceptual processes such as perceiving spatial relations in academic outcomes such as math, however, are still verified at older ages (De Waal et al. 2018).

Successful behavior in the classroom is complex and requires perceptual, EF, spatial, and motor processes that interrelate and build on each other (Cameron et al. 2016). In the study of Van der Fels et al. (2015), complex motor skills, demanding higher order thinking such as fine motor skills, bilateral body coordination, and timed movements showed the strongest relations with cognitive skills, while less complex motor skills such as balance and strength/agility were less related to cognitive skills. Movement should therefore be considered to be important for brain integration (Krog 2015) and prepares the brain for academic tasks.

Our study included a composite score (*BOT-2 SF* total score) of gross and fine motor skills, which made it difficult to isolate specific motor effects as possible contributors to academic achievement. The *BOT-2 SF* total did however, correlate with academic achievement. Composite scores of strength, balance, and speed and agility skills were also available. Our findings ruled out balance and, speed and agility as contributors to academic differences, which agrees with other findings (Van der Fels et al. 2015; Ferreira et al. 2018; MacDonald et al. 2018). Three sets of interrelated cognitive processes that contribute to self-regulation in children are furthermore reported to be required by tasks that traditionally measure motor skills which are motor coordination, EF, and visuospatial skills and implicate the role of motor skills in emergent academic numeracy and language literacy (Cameron et al. 2017).

Mediating Effects and Longitudinal Influences

As from grade 4, SES and MP were not directly associated with academic achievement in grade 7, as academic achievement in grade 4 mediated these influences. This partial mediating influence of grade 4 academic achievement was 67.8%, indicating the highest direct effect on academic achievement in grade 7 (0.693; 0.731). In accordance with reported results prior academic achievement influenced later academic achievement more profoundly than other variables, such as SES (Marks 2016).

According to our results a good academic foundation, as well as academic concepts that are endorsed by MP and SES, have a higher claim on early academic success up to 9 years. Although these influences lose their unique contribution after grade 4 to previous academic achievement, it remains important to academic achievement over the primary school period. The mediation effect of grade 4 academic achievement might for instance be attributed to intelligence coefficients that may become more important at older ages, which was unfortunately not measured in this study. It might also be that associations may change over development and that cognitive load or demands of characteristics related to MP and SES, which are important for early academic success, might become less important in more complex tasks. When such automaticity occurs, the cognitive resources that were originally needed to perform the novel task become available for other challenges, such as effective problem solving and higher order learning (Ackerman et al. 1995). Understanding of such possible changes in associations, however, needs more longitudinal research.

The findings do not only confirm the importance of a proper basic academic literary foundation for later academic achievement in grade 7. The carry-over/residue effect of grade 1 academic performance to later academic achievement is also significantly influenced by the relationships that academic performance in grade 1 have with negative influences of SES and inadequate MP. As poor SES is related to impaired MP, a combination of these negative influences on cognitive abilities which are needed in academic processes, can therefore be detrimental to early academic success. This can again contribute to later academic difficulties. Without consideration of the interrelations between MP and early academic achievement (Morales et al. 2011; Westendorp et al. 2011) the influences of SES (Bellibas 2016; Cheng and Kaplowitz 2016; Corso et al. 2016) on academic achievement throughout the primary school period cannot be completely interpreted or addressed. It can therefore be concluded that no single variable is entirely responsible for the academic achievement of children, but various factors play a role in children' academic achievements.

The strengths of this study were the randomized and longitudinal nature of the study design which portray a good representation of the South African demographics and which made robust analyses of the set hypotheses possible. A limitation was, however, the large percentage of participants (53.31%) that were lost-to-follow up, which might have influenced the generalization of the results. The results should therefore be interpreted with this shortcoming in mind. Another limitation includes the fact that SES was only based on the SES of the child's school which is a SES proxy that portrays influences of the location and quality of the environment, while other indicators of SES, such as the environment at home or the income of parents, weren't taken into consideration.

Conclusion

Children's potential for academic success can be influenced at a young age by various factors. Our findings based on hierarchical linear modelling and a robust SEM analysis of longitudinal data confirmed the influences of SES and MP on early academic success, while also improving our understanding of these associations with early and later academic achievement over the primary school period. Our results confirmed a direct association between academic achievement in grades 1, 4, and 7, and interrelations between academic achievement, MP, and SES. Therefore, MP and SES influences can be considered to be critical role players and building blocks, especially in early academic achievement, that can set children on a trajectory of academic failure or success. Our findings thereby add to the scarce evidence that are provided by limited other studies in this area.

Recommendations

A deeper understanding of the mechanisms behind these associations are, however, still needed and recommended. Further examination of the relationships between MP, cognition and academic performance is still warranted as reviews on these relationships are scant, especially the relationship between gross motor proficiency and academic performance. The use of more robust study designs is recommended to investigate these relationships.

Proficient motor skills are foundational skills in the academic success of school-beginners, especially with obtaining literacy in reading, writing and mathematics depending on it to a large degree. The development of perceptual-motor skills should therefore receive proper attention at a young age, especially at the pre-school level, by movement development specialists, teachers and educators in early child development centers, and in the formal school setup. The development of perceptual-motor concepts is of particular importance before the age of nine to ten (grade 4), since academic achievement in grade 4, according to the model, makes the biggest direct contribution to academic achievement in grade 7. The negative influences of adverse SES on children's MP should also be addressed early, with specific focus on parental and school involvement to ensure the optimal stimulation of children. Focus should also be placed on children engaging in opportunities to improve perceptual-motor skills, as perceptual-motor skills are to a large extent improved by only age-appropriate learning and experiences. Academic achievements in grade 1 and grade 4 again provide important foundations for later academic achievement and attention should thus be paid to quality education in these early grades to ensure that basic concepts for further academic learning are mastered. Well qualified language teachers should be provided with the best textbooks and school facilities, to effectively teach language related skills. The findings are of theoretical importance and of practical relevance, especially with respect to designing optimized interventions for enhancing perceptual-motor and school readiness in young children, especially in low SES environments.

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Compliance with Ethical Standards

Conflict of interest The authors declare that there is no conflict of interest.

References

Ackerman, P. L., Kanfer, R., & Goff, M. (1995). Cognitive and noncognitive determinants and consequences of complex skill acquisition. *Journal of Experimental Psychology: Applied, 1*, 270–304.

Adolph, K. E., & Berger, S. E. (2006). Motor development. In W. Damon, R. M. Lerner, D. Kuhn, & R. S. Siegler (Eds.), *Handbook of child psychology: Cognition, perception, and language* (pp. 161–213). Hoboken, NY: Wiley.

Alivernini, F., & Manganelli, S. (2015). A multilevel structural equation model testing the influences of socioeconomic status and pre-primary education on reading literacy in Italy. *Social and Behavioural Sciences, 205*, 168–172.

Amos Development Company. (2017). *Amos 25.0.0*. Armonk: Build IBM Corporation.

Bellibas, M. S. (2016). Who are the most disadvantaged? Factors associated with the achievement of students with low socioeconomic backgrounds. *Educational Sciences: Theory & Practice, 16*(2), 691–710.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660.

Blunch, N. J. (2008). *Introduction to structural equation modelling using SPSS and AMOS*. London: Sage.

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Reviews of Psychology, 53*, 371–399.

Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology: Theoretical models of human development*. Hoboken, NJ: Wiley.

Bruininks, R. H., & Bruininks, B. D. (2005). *BOT-2 Bruininks-Oseretsky test of motor proficiency, second edition manual*. Minneapolis: Pearson Assessments.

Cadoret, G., Bigras, N., Duval, S., Lemay, L., Tremblay, T., & Lemire, J. (2018). The mediating role of cognitive ability on the relationship between motor proficiency and early academic achievement in children. *Human Movement Sciences, 57*, 149–157.

Cameron, C. E., Cottone, E. A., Murrah, W. M., & Grissmer, D. W. (2016). How are motor skills linked to children's school performance and academic achievement? *Child Development Perspectives, 10*(2), 93–98.

Caro, D. H., McDonald, J. T., & Willms, J. D. (2009). Socioeconomic status and academic achievement trajectories from childhood to adolescence. *Canadian Journal of Education, 32*(3), 558–590.

Cheng, S. T., & Kaplowitz, S. A. (2016). Family economic status, cultural capital, and academic achievement: The case of Taiwan. *International Journal of Education Development, 49*, 271–278.

Coetzee, D., Pienaar, A. E., & van Wyk, Y. (2019). Longitudinal influences of socio-economic status on visual-motor integration: The NW-CHILD Study. *South African Journal of Childhood Education*. https://doi.org/10.4102/sajce.v9i1.645.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillside, NJ: Erlbaum.

Corso, H. V., Cromley, J. G., Sperb, T., & Salles, J. F. (2016). Modeling the relationship among reading comprehension, intelligence, socioeconomic status, and neuropsychological functions: The mediating role of executive functions. *Psychology and Neuroscience, 9*(1), 32–45.

Curriculum and Assessment Policy Statements – Foundation Phase. (2011). Department of Basic Education. Retrieved from May 2, 2018, from https://www.education.gov.za/CurriculumAssessmentPolicyStatements(CAPS)/CAPSFoundation/.

Curriculum and Assessment Policy Statements – Intermediate Phase. (2011). Department of Basic Education. Retrieved from January 20, 2019https://www.education.gov.za/CurriculumAssessmentPolicyStatements(CAPS)/CAPSIntermediate.aspx/.

Da Silva Pacheco, S. C., Gabbard, C., Kittel Ries, L. G., & Godoy Bobbio, T. (2016). Interlimb coordination and academic performance in elementary school children. *Pediatrics International, 58*, 967–973.

De Waal, E., Pienaar, A. E., & Coetzee, D. (2018). The influence of different visual perceptual constructs on academic achievement among learners in the NW-CHILD Study. *Perceptual and Motor Skills, 125*(5), 966–988.

Department of Education. (2014). *Education statistics in South Africa 2013*. North-West: Department of Education.

Department of Health, South Africa. (2015). *Ethics in health research: Principles, processes and structures* (2nd ed.). Pretoria: Department of Health.

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development, 71*, 44–56.

Edginton, C. R., Chin, M., Amusa, L. O., & Toriola, A. L. (2012). Health and physical education: A new global statement of consensus—Perspectives from South Africa. *African Journal of Physical, Health Education, Recreation and Dance, 18*(2), 434–441.

Ferguson, H. B., Bovaird, S., & Mueller, M. P. (2007). The impact of poverty on education outcomes in children. *Peadiatric Child Health, 12*(8), 701–706.

Ferreira, L., Godinez, I., Gabbard, C., Vieira, J. L. L., & Caçola, P. (2018). Motor development in school-age children is associated with the home environment including socioeconomic status. *Child: Care, Health and Development, 44*(6), 801–806.

Geertsen, S. S., Thomas, R., Larsen, M. N., Dahn, I. M., Andersen, J. N., Krause-Jensen, M., et al. (2016). Motor skills and exercise capacity are associated with objective measures of cognitive functions and academic performance in preadolescent children. *PLoS ONE, 11*(8), e0161960.

Graf, G., Kock, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., … Dordel, S. (2004). Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-project). *International Journal of Obesity*, *28*, 22–26.

Hackman, D. A., Farah, M. J., & Meaney, M. J. (2009). Socioeconomic status and the brain: Mechanistic insights from human and animal research. *Nature Reviews Neuroscience, 11*, 651–659.

Hair, N. L., Hanson, J. L., Wolfe, B. L., & Pollak, S. D. (2015). Association of child poverty, brain development, and academic achievement. *Journal of American Medical Association Pediatrics, 169*(9), 822–829.

Hall, K., Sambu, W., Berry, L., Giese, S., Almeleh, C., & Rosa, S. (2016). *South African early childhood review 2016*. Cape Town: Children's Institute, University of Cape Town and Ilifa Labantwana.

Hartman, E., Houwen, S., Scherder, E. J. A., & Visscher, C. (2010). On the relationship between motor performance and executive functioning in children with intellectual abilities. *Journal of Intellectual Disability Research, 54*, 468–477.

Harwell, M., Maedab, Y., Bishopc, K., & Xied, A. (2017). The surprisingly modest relationship between SES and educational achievement. *The Journal of Experimental Education, 85*(2), 197–214.

Hugo, A. J., & Nieman, M. (2010). Using English as a second language as the language of instruction: Concerns and needs of primary school teachers in South Africa. *Journal of Language Teaching, 44*(1), 59–69.

Krog, S. (2015). Movement activities: A critical link in developing motor skills and learning in early childhood. *African Journal for Physical, Health Education, Recreation and Dance, 21*(1:2), 426–443.

Krombholz, H. (2012). The motor and cognitive development of overweight preschool children. *Early Years, 32*(1), 61–70.

Lawson, G. M., & Farah, M. J. (2017). Executive function as a mediator between SES and academic achievement throughout childhood. *International Journal of Behavioral Development, 41*(1), 94–104.

Lopes, L., Santos, R., Pereira, B., & Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. *Human Movement Science, 32*, 9–20.

Lucas, B. R., Latimer, J., Doney, R., Ferreira, M. L., Adams, R., Hawkes, G., et al. (2013). The Bruininks-Oseretsky Test of Motor Proficiency-Short Form is reliable in children living in remote Australian Aboriginal communities. *BMC Pediatrics, 13*(135), 1–12.

MacDonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: A systematic review. *International Journal of Environmental Research in Public Health, 15*(1603), 1–28.

Marks, G. N. (2016). The relative effects of socioeconomic, demographic, non-cognitive and cognitive influences on student achievement in Australia. *Learning and Individual Differences, 49*, 1–10.

Morales, J., González, L. M., Guerra, M., Virgili, C., & Unnithan, V. (2011). Physical activity, perceptual-motor performance, and academic learning in 9- to 16-years-old school children. *International Journal of Sport and Psychology, 42*, 401–415.

Morley, D., Till, K., Ogilvie, P., & Turner, G. (2015). Influences of gender and socioeconomic status on the motor proficiency of children in the UK. *Human Movement Sciences, 44*, 150–156.

Mueller, R. O. (1996). *Basic principles of structural equation modeling: An introduction to LISREL and EQS*. New York: Springer.

Nel, N., & Müller, H. (2010). The impact of teachers' limited English proficiency on English second language learners in South African schools. *South African Journal of Education, 30*, 635–650.

Newell, K. M. (1986). Constraints on the development of coordination. In M. G. Wade & H. T. Whiting (Eds.), *Motor development in children: Aspects of coordination and control*. Boston, MA: Martinus.

Pauw, K. (2005). Profile of the North West Province: Demographics, poverty, inequality and unemployment. *Project Background Paper, 1*(3), 1–19.

Piek, J. P., Dawson, L., Smith, L. M., & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. *Human Movement Science, 27*, 668–681.

Pienaar, A. E., Barhorst, R., & Twisk, J. W. R. (2013). Relationships between academic performance, SES school type and perceptual-motor skills in first grade South African learners: NW-CHILD study. *Child: Care, Health and Development, 40*(3), 370–378.

Pienaar, A. E., & Kemp, C. (2014). Motor proficiency profile of Grade 1 learners in the North-West province of South Africa: NW-CHILD study. *South African Journal of Research in Sport, Physical Education and Recreation, 36*(1), 167–182.

Pokropek, A., Borgonovi, F., & Jakubowski, M. (2015). Socioeconomic disparities in academic achievement: A comparative analysis of mechanisms and pathways. *Learning and Individual Differences, 42*, 10–18.

Roebers, C. M., & Kauer, M. (2009). Motor and cognitive control in a normative sample of 7-year-olds. *Developmental Science, 12*, 175–181.

Son, S. H., & Meisels, S. J. (2006). The relationship of young children's motor skills to later reading and math achievement. *Merill-Parmer Quarterly, 52*(4), 755–778.

StatSoft. (2016). *Statistica for Windows: General conventions & statistics.* Tilsa, OK: Statsoft.

Van der Fels, I. M. J., Te Wierikea, S. C. M., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science in Medicine and Sport, 18*, 697–703.

Westendorp, M., Hartman, E., Houwen, S., Smith, J., & Visscher, C. (2011). The relationship between gross motor skills and academic achievement in children with learning disabilities. *Research in Developmental Disabilities, 32*, 2773–2779.

Wright, L. (2012). Implications of the National Language Policy in the South African classroom. *The English Academy of Southern Africa*, *2*(1), 111–123.

Wuang, Y. P., & Su, C. Y. (2009). Reliability and responsiveness of the Bruininks-Oserestky test of motor proficiency-second edition in children with intellectual disability. *Research in Developmental Disabilities, 30*, 847–855.

Yoon, D. Y., Scott, K., Hill, M. N., Levitt, N. S., & Lambert, E. V. (2006). Review of three tests of motor proficiency in children. *Perceptual and Motor Skills, 102*(2), 543–551.