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Influence of Different Visual Perceptual Constructs on Academic Achievement Among Learners in the NW-CHILD Study

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Abstract

Visual perception plays an important and integrating role in the development of cognitive abilities and perceptual-motor skills. Visual perception comprises different independent constructs that may function in an integrative manner. This study aimed to determine whether (and the extent to which) various visual-perceptual constructs influence the academic achievement of 12-year-old school children. In a cross-sectional analysis, we extracted only 2016 data from 581 learners (mean age $=$ 12.92 years, $SD = 0.42$) who were participants in the North-West Child Health, Integrated with Learning and Development longitudinal study (2010–2016). We used the Test of Visual Perceptual Skills, Third Edition, the North-West Provincial Assessment and mid-year school examination reports to determine visual perceptual abilities and academic achievement of this participant group. We calculated correlations between visual perceptual constructs and academic performance using Spearman rank order correlations and separately analyzed the influence of gender and socioeconomic status with independent *T* tests. Different visual perceptual constructs did have significant influences on specific areas of academic learning and on academic achievement generally ($r = .26$ to $r = .41$). Spatial relationships showed slightly greater correlations with academic achievement ($r = .15$ to $r = .33$) than did other basic visual perceptual

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constructs, possibly because spatial relationships are not completely developed at age 12. Complex and basic visual perceptual skills had medium significant retrospective correlations with grade point average ($r = .40$ and $r = .41$) and first additional language ($r = .30$ and $r = .33$). We concluded that basic and complex visual perceptual constructs remain important for academic achievement in this age-group, while gender and socio-economic status influence both visual perceptual abilities and academic achievement.

Keywords
visual perception, academic achievement, visual-perceptual motor skills, visual-motor integration, child

Introduction

Deficient or underdeveloped visual perception, or aspects thereof, negatively influence academic tasks such as reading and writing (Ayhan, Aki, Mutlu, & Aral, 2015; Bezrukikh & Terebova, 2009; Kramer & Hinojosa, 2010). Visual perception is a complex and systematic neurophysiological process that is dependent on relevant brain development. Perception, coding, analysis, recognition, identification, and evaluation of information significance are all processes of visual perception (Farber & Beteleva, 2005). Visual perception thus describes the ability to correctly identify and effectively assimilate visual stimuli (Martin, 2006). Visual perception, according to Gestalt theory, is more than object identification; it includes the interpretation and organization of that which was visually seen (Martin, 2006). Visual perception is connected with visual-motor integration (Ayhan et al., 2015; Brown, 2012), motor skills, and broad cognitive development and academic ability (Brown, 2012; Thelen, Schöner, Scheier, & Smith, 2011). Bezrukikh and Terebova (2009) examined visual-spatial perception, visual-motor integration, and figure-background discrimination during the execution of coordinated fine motor tasks, leading them to state that visual-motor integration is a main component of visual perception that significantly influences cognitive development and children's successful learning.

Visual perception forms the basis of a child's cognitive activity in the sense that it orientates and controls a child's behavior, and as a systematic process, it includes a variety of brain structures, each of which makes an important contribution to active perception (Bezrukikh & Terebova, 2009). Morozova, Zvyagina, and Terebova, (2008) indicate that visual perception is linked to the functional ability of the cerebral cortex and the regulatory structures of the brain. The prefrontal cortex, more specifically the dorsolateral section, is activated during tasks requiring conscious attention, planning, and decision-making (Doya, 2000), thus indirectly affecting tasks where interpretation and organization occur. Certain motor task executions and cognitive skills activate the prefrontal cortex, the cerebellum (primary motor activity), and the basal ganglia (primary cognitive skills) (Diamond, 2000). Furthermore, the cerebellum is associated with the integration of visual information, while the premotor cortex and the posterior parietal cortex are especially involved in formulating perceptions about nearby objects and executing appropriate motor responses (Willingham, 1999).

Structurally, visual perception consists of different types of perceptual constructs which, functionally, can be described as visual discrimination, visual memory, spatial relationships, form constancy (basic processes), sequential memory (sequential processes), figure-ground discrimination, and visual closure (complex processes) (Martin, 2006). The latter processes include more complex sensory mechanisms such as coordination, accuracy, and integration of visual and motor functions (Bezrukikh & Terebova, 2009; Martin, 2006). The improvement of these interdependent visual-perceptual constructs occurs through experience, stimulation, and exercise (Bezrukikh & Terebova, 2009; Kramer & Hinojosa, 2010) and reflects age-related development. The functioning of the visual-perceptual system is thus reflected within its individual components of visio-spatial perception, figure-background differentiation, visual constancy, and visual-motor integration, each of which must ensure sufficient reflection of external objects and their characteristics (Bezrukikh & Terebova, 2009). Although these structural components can be differentiated, they are functionally interrelated (Martin, 2006). Brown (2012) adds that both figure-background discrimination and sequential memory are required during the execution of everyday activities employing visual-motor integration abilities. Visual-motor integration refers to the ability to integrate visual-spatial information to ensure coordinated motor actions (Bezrukikh & Terebova, 2009; Cheatum & Hammond, 2000). Aspects such as body awareness and body scheme, spatial orientation, direction awareness, temporal awareness, balance, bilateral integration, and depth perception depend on these various visual-perceptual and kinesthetic skills (Gallahue, Ozmun, & Goodway, 2012) and visual-perceptual constructs (Martin, 2006).

Perception and cognition are interrelated, and, although perceptual components function separately, these functions overlap during the execution of everyday activities (Martin, 2006). Mathematical skills require, among others, the ability to solve problems and make visual-spatial interpretations (Department of Basic Education, South Africa, 2011), including spatial and numerical perception. Both the cerebellum and the parietal cortex are involved in spatial and numerical perception and are thus important during the execution of mathematical tasks (Bueti & Walsh, 2009; Van Lill, 2011) and the formulation of visual perceptions (Willingham, 1999). Within the South African educational context, 12-year-old learners are expected to master mathematical skills such as fractions, organization, and summarizing of data, functions and relationships, geometric patterns, lines and shapes, surface areas, perimeters, volumes, and algebraic expressions (Department of Basic Education, South Africa, 2011). These skills require the ability to make comparisons, think abstractly, discriminate between concepts and interpret three-dimensional figures (Department of Basic Education, South Africa, 2011). Skills in which discrimination, intuition, comparison, and estimation abilities are used depend on the ability to organize and interpret mathematical concepts spatially (Van Lill, 2011), thus emphasizing the importance of visual-spatial integration for mathematical calculations (Carlson, Rowe, & Curby, 2013). Supportive results in this regard were reported among a group of 16–18-year-old mathematical achievers, for which better discriminatory ability (identifying and grouping) was found that are part of the visual processing ability when compared to less talented peers (Paz-Baruch, Leikin, & Leikin, 2016).

Cameron et al. (2012) are of the opinion that fine motor skills and, specifically, spatial integration involving external visual stimuli, correlate with academic achievement in young, 3-year-old, children. Visual perception and visual-motor integration were strongly linked to achievements in reading, writing, and mathematics of Grade 1 learners in South Africa from high and low socioeconomic backgrounds (Pienaar, Barhorst, & Twisk, 2013). According to Lotz, Loxton, and Naidoo (2005), primary school learners (Grade 1–4 learners) from low socioeconomic areas in South Africa reflected poor visual-motor integration skills which had a negative effect on their academic achievement due to the important role that visual-motor integration skills play during early academic tasks (Chen, Bleything, & Lim, 2011; Kulp, 1999; Pienaar et al., 2013). Visual-motor integration has thus been linked to cognitive achievement and influences through intelligence coefficients (Duijff et al., 2012), mathematical and writing skills (Kulp, 1999; Pienaar et al., 2013), and general academic achievement of primary school learners (Chen et al., 2011). According to Son and Meisels (2006), visual-motor integration influences visual-motor skills, gross motor skills of Grade-R learners, and their reading and mathematical achievements in Grade 1.

Belgium research on 7-year-old learners with learning deficits showed a correlation between poor cognitive abilities and moderate deficits in visual-motor integration, visual perception, and motor coordination, as well as serious deficits in motor skills (Pieters, Desoete, Roeyers, Vanderswalmen, & Van Waelvelde, 2012). The influence of visual-motor coordination on academic success appears to decrease with increasing age, probably due to children reaching a basal development skill level in visual-motor coordination, while visual-spatial integration continues to develop and influence further learning (Carlson et al., 2013). Bezrukikh and Terebova (2009) report that visual-motor integration improves with age and should be well developed at seven years of age. In South Africa, there has been a documented link between visual-motor coordination and children's academic achievement and, more specifically, their mathematical abilities (Department of Education, South Africa, 2015), directly linked to their perceptual skills (Carlson et al., 2013). The very few studies addressing visual perception and academic achievement have used the *Beery Visual-Motor Integration Test* to confirm a relationship between these variables among young children (Lotz et al., 2005; Pienaar et al., 2013; Van Wyk, Pienaar, & Coetzee, 2012). However, a hiatus in this relationship was identified among 12- to 13-year-olds in the last grade of their primary school years.

From the aforementioned literature, it appears that young children's visual perception has been clearly related to their academic achievement during the early school years (Ayhan et al., 2015; Bezrukikh & Terebova, 2009; Kramer & Hinojosa, 2010; Pieters et al., 2012; Willingham, 1999). Yet, few studies have established the relationship of visual perception through further development or whether different functional perceptual skills among older children continue to influence their application of higher cognitive skills after their exposure to formal education. This paucity of research among older children may stem from research indications that the influence of visual perception declines with increasing age, such that other factors may then play a greater role and have therefore enjoyed greater research attention. However, against a theoretical background, visual perception may be linked not only to visual-motor integration skills but also to cognitive achievement over a longer developmental period, particularly since optimal functioning depends on developing underlying brain structures regulating these functions. The combined use of different brain structures during visual-perceptual and cognitive tasks suggests that deficits in one of these visual-perceptual skills can negatively influence academic achievements. Although very few studies have utilized the *Test of Visual Perceptual Skills, Third Edition* (*TVPS-3*) on older children to test visual-perceptual functioning during nonmotor tasks in order to determine its influence on later academic achievement (Martin, 2006), we used the *TVPS-3* in this study to examine to what extent different functional visual-perceptual abilities influenced academic achievement among 12-year-old learners, in the North West province of South Africa.

Method

Study Design

Grade 6 and 7 learners in the North West province of South Africa served as the target population for this study. We employed a cross-sectional research design within an ongoing longitudinal study over seven school years (2010–2016) called the *North-West Child Health, Integrated with Learning and Development* study *[NW-CHILD]*). We relied only on data collected during 2016. In 2010, the NW-CHILD received ethical approval as a longitudinal study (No. NW-00070-09-A1). This study involved a stratified random sample of Grade 1 learners identified from within a list of schools in the North West province obtained from the Department of Basic Education and stratified according to school regions and school types. More specifically, from the list of schools in the North West province which are grouped in eight education districts, each representing 12 to 22 regions and approximately 20 schools (minimum 12 and maximum 47), four regions and 20 schools were selected randomly with regard to population density and school status (Quintile 1—schools from poor economic areas to Quintile 5—schools from good economic areas). Baseline measurements were taken in 2010, and there were two-point follow-up testing events (2013, 2016). Boys and girls who formed part of the 2010 study were again tested in 2013 during the first follow-up measurements during their Grade 4 year (for some participants, their Grade 3 year) and in 2016 during their Grade 7 year (for some participants, their Grade 6 year). New participants were also randomly selected in 2013 from the participating schools, due to some participants having left the study during the prior 3-year period.

Research Group

As noted earlier, the research population used for this study were part of the last follow-up measurements of the 2016 NW-CHILD study. This subset of 581 Grade 6 and Grade 7 learners were from all four selected regions in the North West province of South Africa, different quintile schools (Quintiles 1–5), and varied racial groups (White, Black, Indian, non-White). Among these 581 participants, 383 were from the original 2010 research group, while 198 were added on a random basis in 2013 and were incorporated into the 2016 research group. All data were collected by senior researchers qualified as Kinderkineticists and Kinderkinetic Honors students who all completed in-depth training of the applicable standard test before data collection started. In cases where English or Afrikaans were not a participant's mother tongue, pretrained interpreters explained each test to the participant.

Ethical considerations. Ethical approval (based on the Helsinki guidelines) for the execution of the NW-CHILD study was obtained 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. Furthermore, school principals of the various identified schools granted permission for the collection of data during school hours. The parents or legal guardians of all the learners who participated in the study at each of the selected schools had received informed parental permission forms to complete. Learners whose parents or legal guardians provided written parental permission for participation in the study also had to provide written consent themselves on the day of testing. Testing only took place after all the procedures had been explained to them, an opportunity for questions had been given and the option to decline participation was granted. Research was done according to the declaration of Helsinki and ''Ethics in Health Research: Principles, processes and structure'' (Department of Health, South Africa, 2015). Learners were excluded from this study if permission had not been granted, if they were not in the selected grades, or if their medical history forms indicated serious developmental deficiencies.

Measuring Instruments

Scholastic achievement. We requested from each involved school, Grade 6 and Grade 7 participants' academic progress reports from June 2016, reflecting percentages obtained in each learning area, a grade point average and grading codes in the learning areas set out by the Department of Basic Education Curriculum and Assessment Policy Declarations (CAPS): (a) mathematics, (b) native language, and (c) first additional language (Department of Basic Education, South Africa, 2011). The grading codes were as follows: (a) ''7'' was awarded for exceptional achievement (80–100%), (b) ''6'' for meritorious achievement (70–79%), (c) ''5'' described significant achievement (60–69%), (d) ''4'' sufficient achievement (50–59%), (e) ''3'' average achievement (40–49%), (f) ''2'' basic achievement (30–39%), and (g) ''1'' was allocated when the learning outcome ''was not reached'' (0–29%). In addition, we obtained scores (also in percentages) on the North West Province Assessment (NWPA), conducted on a provincial level to assess learners' achievement, including the following learning areas: Afrikaans, English, Setswana, and Mathematics.

Test of Visual Perceptual Skills, Third Edition. The *TVPS-3* (Martin, 2006) is a test battery for determining individual visual-perceptual abilities of children from 4-18 years of age. The format for learner responses is suitable for both typically developing learners and those with deficits or disabilities. The *TVPS-3* can be used for practical, diagnostic, and research purposes. Test administration time is approximately 30 minutes. Respondents are expected to execute a variety of visual-perceptual tasks across seven subtests, including visual discrimination, visual memory, spatial relationships, form constancy, sequential memory, figure-ground discrimination, and visual closure, and are tested in this particular order. Each subtest is further divided into basic processes (visual discrimination, visual memory, spatial relationships, and form constancy), sequence processes (sequential memory), and complex processes (figure-ground discrimination and visual closure). During the visual discrimination subtest, a figure is shown to the respondent, and the respondent must then choose a corresponding figure from within a series of response choices. Similarly, the visual memory subtest requires the respondent to study a figure for five seconds and then identify a correct corresponding figure from among response choices. For the spatial relationship subtest, the respondent must identify the figure that does not belong to the response set, and, for the form constancy subtest, the respondent must identify a figure, from among similar choices that vary by form, size, and orientation. For the sequential memory subtest, the respondent must recall and identify progressively more difficult shapes after having examined the applicable series for five seconds. For the figure-ground discrimination subtest, the respondent is expected to notice and identify one figure against a complex background. During the visual closure subtest, the respondent must identify the correct complex figure from within a series of incomplete patterns. The seven subtests are successive; each start with the easiest skill and become progressively more difficult. Each subtest consists of two ungraded practice activities followed by 16 scored activities. One point is allocated for each correct answer, and the subtest is discontinued after the respondent makes three successive errors. The test battery is not timed, but during the time limits on the visual memory and sequential memory subtests require a response within five seconds. Respondents may answer verbally or point to their response choice. The test manual guides the conversion of raw scores to norm-based scaled scores and percentiles, and age equivalents are also calculated. The respondent's performance may be represented by the total raw score and by combined scores (basic processing, sequential processing, and complex processing) that supply significant information about related skills. Respondent percentile values are classified as follows: above 97% = *excellent*, 91% to 97% = *very good*, 75% to 90% = *above average*, 25% to 73% = *average*, and 9% to 23% = *below average*. A value is classified as borderline when values fall between 2% and 8%, while values lower than 2% are regarded as low achievement. The *TVPS-3* has been found to have good construct validity for measuring visual perceptual skills, with reliability coefficients between $r = .75$ to $r = .88$ for the subtests and $r = .96$ for the test battery in its entirety (Brown et al., 2012; Martin, 2006). In the standardization of the test, every attempt was made to ensure that the tests were performed in a quiet area with adequate lighting and ventilation (Martin, 2006).

Data Analysis

We used *Statistica for Windows* software (StatSoft, 2016) to analyze data. For purposes of description, we presented data in terms of means, standard deviations (*SD*), and minimum–maximum ranges. We used Spearman correlation coefficients to analyze relationships between variables of interest, and, as guidelines for practical significance, $r \approx .1$ indicated a small effect, $r \approx .3$ a moderate effect, and $r \geq .5$ a large effect size (Cohen, 1988). We conducted independent t tests to identify differences between participant groups of gender, and socioeconomic status, using $p < .05$ for statistical significance. Practically, $d > .2$ reflected a small effect, $d > .5$ a medium effect, and $d > .8$ a large effect (Cohen, 1988).

Results

Descriptive and demographic characteristics of the research sample are shown in Table 1. The total research group consisted of 581 learners with a mean age of 12.92 years ($SD = 0.42$). They were distributed comparably with regard to gender, race, school region and school types (quintiles), and socioeconomic status. This research group acceptably represented 12-year-old learners in the

Table 1. Descriptive Statistics of the Participants.

Category	Number ($N = 581$)	Percentage
Age (years)		
Mean age (*M*)	12.92	–
Minimum (min)	11.28	–
Maximum (max)	13.92	–
Standard deviation	0.42	–
Gender		
Boys	302	51.98
Girls	279	48.02
School type stratification		
Quintile 1	121	20.83
Quintile 2	114	19.62
Quintile 3	111	19.10
Quintile 4	109	18.76
Quintile 5	126	21.69
Socioeconomic status		
Low	346	59.55
Black learners	346	
White learners	0	
High	235	40.45
Black learners	88	
White learners	147	
TVPS-3 category		
1 (*Very low*)	128	22.03
2 (*Borderline case*)	157	27.02
3 (*Below average*)	168	28.92
4 (*Average*)	112	19.28
5 (*Above average*)	16	2.75

Note. N = number of participants; TVPS-3 = Test of Visual Perceptual Skills, Third Edition.

North West province of South Africa. Table 1 also shows that 19% were classified with average visual-perceptual skills, while most were found to have weaker visual-motor skills that were below average (29%), borderline (27%) or low average (22%). Only 16 learners (2.75%) were above average in their visual-motor skills.

Correlations between different functional visual-perceptual constructs (subskills) and the overarching visual-perceptual processes they represent were analyzed by means of Spearman rank-order correlations (Table 2). Statistical correlations with medium to large practical significance ($r = .28$ to $r = .51$) were found between the various visual-perceptual functional constructs (subtest scores), while large practical significant correlations ($r = .50$ to $r = .99$) were evident between interdependent functional visual-perceptual constructs and the overarching visual-perceptual processes of basic, sequential, and complex visual perception processes. The total score on the *TVPS-3* correlated strongly with basic processes ($r = .65$) and complex processes ($r = .82$) but showed only an average-level relationship with sequential memory ($r = .33$). The total score correlations with the various visual-perceptual constructs (subtests) ranged from $r = .54$ to $r = .73$.

Table 3 depicts correlations between the participants' different visual-perceptual constructs on the *TVPS-3*, their academic learning areas reflected by June 2016 examination grades, and their provincial NWPA assessment. The visual-perceptual constructs (with the exception of sequential memory) were generally strongly and positively correlated ($p \leq .05$) with the attained grade point average. Both the *TVPS-3* total score and the basic processing skills (especially spatial relationships) correlated statistically significant with the participants' first additional language ($r = .38$; $r = .33$), mathematics ($r = .34$; $r = .32$), and attained grade point average ($r = .47$; $r = .41$) during June 2016 examinations. Statistical correlations with medium practical effect were also found for first additional language ($r = .36$; $r = .30$) and the grade point average ($r = .45$; $r = .40$) during the NWPA examinations. Sequential processes showed correlations with only small practical effect ($r = .14$ to $r = .28$) during both academic assessments for all areas of academic learning. Complex visual-perceptual processes, including figure-ground discrimination and visual closure, also showed average-level correlations with first additional language ($r = .33$) and academic achievement ($r = .39$) as measured by the NWPA. There were average-level correlations between figure-ground discrimination ($r = .34$) and visual closure ($r = .36$) and academic achievement marks during the June examination, while both of the subtests within complex processes correlated significantly at an average level ($r = .40$) with average academic achievement. The *TVPS-3* total score showed the largest correlation (moderate level) ($r = .47$) with academic achievement during the June examination.

Table 4 shows percentage differences between learner groups of gender and socioeconomic status on performance categories within the *TVPS-3*

Table 2. Spearman Rank Order Correlations Between Different Functional Visual-Perceptual Constructs and Overarching Visual-Perceptual Processes' Percentages ($N = 581$).

Visual-perceptual constructs	VD	VM	SR	FC	SM	FD	VC	General	Basics	Sequential	Complex	Category
Basic processes												
Visual discrimination	1.00	0.37*	0.47*	0.42*	0.28*	0.36*	0.38*	0.65*	0.74*	0.28*	0.42*	0.55*
Visual memory		1.00	0.35*	0.30*	0.28*	0.36*	0.36*	0.60*	0.66*	0.28*	0.40*	0.53*
Spatial relationships			1.00	0.48*	0.38*	0.46*	0.45*	0.73*	0.76*	0.37*	0.50*	0.64*
Form constancy				1.00	0.31*	0.51*	0.48*	0.72*	0.73*	0.30*	0.56*	0.58*
Sequential processes												
Sequential memory					1.00	0.31*	0.33*	0.54*	0.41*	0.99*	0.35*	0.44*
Complex processes												
Figure-ground discrimination						1.00	0.51*	0.73*	0.56*	0.30*	0.88*	0.59*
Visual closure							1.00	0.71*	0.56*	0.33*	0.82*	0.61*
Total score								1.00	0.92*	0.54*	0.82*	0.84*
Basic processes									1.00	0.40*	0.63*	0.78*
Sequential processes										1.00	0.35*	0.43*
Complex processes											1.00	0.67*
Category												1.00

Note. Basic processes: VD = visual discrimination, VM = visual memory, SR = spatial relationships; FC = form constancy; sequential processes: SM = sequential memory; complex processes: FD = figure-ground discrimination, VC = visual closure.
$r > .1$. $r > .3$. $r > 0.5$. $^*p < .05$.

Table 3. Spearman Rank Order Correlations Between Visual-Perceptual Constructs and Academic Learning Areas ($N = 581$).

	Academic learning areas							
	June school assessment, 2016				North West provincial assessment, 2016			
Functional and overarching visual-perceptual constructs	Home language	First additional language	Maths	Grade point average	Home language	First additional language	Maths	Grade point average
Basic processes								
Visual discrimination	0.17*	0.24*	0.25*	0.31*	0.18*	0.21*	0.19*	0.30*
Visual memory	0.15*	0.25*	0.24*	0.31*	0.11*	0.23*	0.18*	0.30*
Spatial relationships	0.16*	0.31*	0.24*	0.33*	0.15*	0.28*	0.20*	0.30*
Form constancy	0.14*	0.24*	0.23*	0.32*	0.15*	0.21*	0.16*	0.31*
Sequential processes								
Sequential memory	0.17*	0.24*	0.25*	0.28*	0.14*	0.23*	0.16*	0.26*
Complex processes								
Figure-ground discrimination	0.09*	0.24*	0.22*	0.34*	0.14*	0.28*	0.22*	0.35*
Visual closure	0.17*	0.28*	0.28*	0.36*	0.14*	0.28*	0.20*	0.33*
Total score	0.20*	0.38*	0.34*	0.47*	0.21*	0.36*	0.27*	0.45*
Basic processes	0.19*	0.33*	0.32*	0.41*	0.19*	0.30*	0.24*	0.40*
Sequential processes	0.17*	0.24*	0.26*	0.29*	0.14*	0.23*	0.16*	0.27*
Complex processes	0.13*	0.30*	0.28*	0.40*	0.16*	0.33*	0.24*	0.39*
Category	0.22*	0.44*	0.29*	0.45*	0.17*	0.39*	0.32*	0.46*

Note. Basic processes includes visual discrimination, visual memory, spatial relationships, and form constancy. Sequential processes include sequential memory. Complex processes include figure-ground discrimination and visual closure.
$r > .1$. $r > .3$. $r > .5$. $^{*}p < .05$.

Table 4. Gender, and Socioeconomic Differences in *TVPS-3* Categories.

	Gender				Socioeconomic status			
	Boys		Girls		High		Low	
TVPS-3 categories	*n*	%	*n*	%	*n*	%	*n*	%
1 (*Very low*)	55	18.21	73	26.16	14	5.96	114	33.14
2 (*Borderline*)	77	25.50	80	28.67	46	19.57	111	32.08
3 (*Below average*)	87	28.81	81	29.03	87	37.02	81	23.55
4 (*Average*)	69	22.85	43	15.41	74	31.49	38	10.98
5 (*Above average*)	14	4.64	2	0.72	14	5.96	2	0.58

Note. N = number; % = percentage. *TVPS-3* = Test of Visual Perceptual Skills, Third Edition.

performance. For example, 27.49% of boys showed average and above average visual perceptual ability, as compared to 16.13% of girls. Average visual-perceptual skills were found in 23% of boys and 15% of girls. With regard to socioeconomic status, most learners from low socioeconomic circumstances (65.22%) obtained low or borderline results. Average visual-perceptual skills were evident from 31% of learners from high socioeconomic backgrounds and 11% of learners of low socioeconomic status.

Table 5 shows the results of independent t testing of differences between boys and girls and between learners from high and low socioeconomic status. Boys statistically showed stronger visual-perceptual skills in all components than girls, especially with reference to complex visual perceptual skills; while learners from high socioeconomic status performed better on all the components of the *TVPS-3* than did learners from low socioeconomic areas. Practically, however, effect sizes of differences between socioeconomic groups were small. Medium effect sized differences did occur in basic visual-perceptual processes ($d = .65$) (visual discrimination, visual memory, spatial relationships), complex visual-perceptual processes ($d = .59$) (figure-ground discrimination, visual closure), and on the overall score obtained for visual-perceptual skills ($d = .66$). There were no significant group differences for sequential memory. There was a small effect size difference ($d = .35$) between boys and girls on visual closure ($d = .35$).

Discussion

This study investigated the relationship between different functional visual-perceptual skills and the academic achievements of a large group of 12-year-old learners in the North West province of South Africa. We found significant correlations between these variables (Table 2), with strong associations evident between interrelated visual-spatial skills and their corresponding broader

Table 5. Significant Percentile Differences in Visual-Perceptual Functions and Overarching Processes With Regard to Gender, and Socioeconomic Status.

	Gender				Socioeconomic status			
	Boys (*M*%)	Girls ($\overline{M}$ %)	*p*	Effect size	High (*M*%)	Low ($\overline{M}$ %)	*p*	Effect size
VD	20.49	16.27	.040*	0.17	26.54	12.98	<.01*	0.44#
VM	24.50	18.57	.004*	0.21	31.05	15.27	<.01*	0.58##
SR	38.55	32.76	.022*	0.19	46.13	28.73	<.01*	0.57##
FC	23.10	16.33	.003*	0.23	28.10	14.25	<.01*	0.42#
SM	31.94	27.70	.033*	0.17	36.38	25.51	<.01*	0.30
FD	37.66	27.34	<.01*	0.30	45.23	24.20	<.01*	0.55##
VC	38.60	28.56	<.01*	0.35#	43.90	26.90	<.01*	0.50##
Total score	26.41	19.03	<.01*	0.32	32.89	16.06	<.01*	0.66##
Basic	22.78	16.54	.01*	0.27	29.37	13.28	<.01*	0.65##
Sequential	31.51	27.41	.036*	0.17	36.12	25.07	<.01*	0.30
Complex	37.95	26.86	<.01*	0.36#	44.94	24.26	<.01*	0.59##

Note. (*M*%) = mean percentile value; VD = visual discrimination; VM = visual memory; SR = spatial relationships; FC = form constancy; SM = sequential memory; FD = figure-ground discrimination; VC = visual closure.
*$p \leq .05$. #$d > .2$. ##$d > .5$. ###$d > .8$.

visual-spatial processes. This finding is consistent with Martin's (2006) observation that although the different structural components can be differentiated, they remain functionally related. Furthermore, Chalfant and Scheffelin (1969) stated that tasks in which visual information must be analyzed, integrated, and combined require cognitive processing, and cognitive processing serves to relate them to one another (Colarusso & Hammil, 2003). In addition, Bezrukikh and Terebova (2009) state that complex visual-perceptual processes include more complex sensory mechanisms, such as coordination, accuracy, and integration of visual and motor function. Visual closure and figure-background discrimination are the two visual-perceptual constructs which were evaluated by Foreman (1991) using the *Gollin* and *Mooney* tests; they found that these complex skills are not only important for task execution but remain relevant at an older age. Although Bezrukikh and Terebova (2009) claimed that figure-background discrimination skills develop faster between five and six years of age, Martin (2006) asserted that the cognitive process providing background information to adolescents and adults varies with the figure's complexity. Thus, this complex skill can be acquired and developed at a young age, but its application at an older age depends on the cognitive complexity of the task. We might therefore assume that basic as well as complex processes are important for good overall visual-perceptual skills. Basic processes must be in place for early school years, and complex processes are needed at an older age, due to the integrated nature of these different visual-perceptual constructs in their involvement with cognition.

A second finding from our study was that basic as well as complex visual-perceptual processes correlated with academic achievement as a whole (language, mathematics, and average marks) for our 12-year-old participants (Table 3). Basic visual-perceptual abilities, which include visual discrimination, visual memory, spatial relationships, and form constancy, seem to be especially important for achievement in first language learning, mathematics, and grade point averages, given high correlations between these skills. However, complex processes (figure ground discrimination and visual closure) showed medium correlations with first additional language learning and grade point average. Although these results indicate that there were not large significant correlations between different functional visual-perceptual constructs and different specific learning skills in Grade 7, there was a significant association between visual perceptual functioning as a whole and academic achievement. According to their performance on categories of the *TVPS-3* most learners showed less than average visual perceptual skills (Table 1), suggesting a possible negative influence on their academic achievements. In a study with the same population in their Grade 4 year, most of these learners also displayed poor visual perception, although their visual perception from Grade 1 to Grade 4 had developed more than their visual-motor integration and motor coordination (Van Wyk, Coetzee, & Pienaar, 2016). Our results suggest that spatial relationships have a slightly bigger influence than other basic processes on academic achievement, given differences in the correlations between these measures. Carlson et al. (2013) found that visual-spatial integration continues to develop with increased age, which could provide an explanation for our results. Carlson et al. (2013) used the *Developmental Test of Visual-Motor Integration—6* (Beery & Beery, 1997) to show that visual-spatial integration remains a significant predictor of math and writing throughout childhood and adolescence. The influence of visual perception on mathematical achievement at a young age was also reported by Bueti and Walsh (2009) and Pienaar et al. (2013), and links between mathematical skills and spatial integration were shown by others (Bueti & Walsh, 2009; Van Lill, 2011). Our results do not necessarily reflect specific relationships between spatial integration and mathematical achievement, but they support Carlson et al. (2013) generally in showing a continued relationship between visual-spatial integration and academic skill at an older age. Bezrukikh and Terebova (2009) found that visual-spatial perception is sufficiently developed at the age of 7 years, but that spatial orientation and the position of objects in space are interdependent and that the development of these visual-spatial perception mechanisms is heterogeneous by nature. Bezrukikh and Terebova's (2009) findings suggest that the development of visual-perceptual skills occurs early, between five and seven years of age, while Maslo, Frostig, Lefever, and Whittlesey (1964) highlight the significant progression of visual-perceptual skills between 3.5 and seven years of age. Furthermore, Chalfant and Scheffelin (1969) claim that a continued improvement of perceptual skills can occur through further exposure to learning experiences such that these skills are not only dependent on natural cognitive maturation. These findings accentuate the importance of visual-perceptual stimulation at a young age. Contrary to our findings, in a South African study with 173 Grade 1 to Grade 4 learners in a remedial school in KwaZulu-Natal, Richmond and Holland (2011) found no significant correlations between visual-perceptual constructs and academic achievement as stipulated by the *Developmental Test of Visual Perception*, *Second Edition* and the TVPS-Revised. These researchers, however, stated that academic evaluation methods in their study had to be adapted due to the children's learning deficits and therefore do not reflect the expected academic level of mainstream schools. Therefore, these researchers suggested that their results should not be generalized to all remedial situations and should also be applied cautiously to nonremedial children.

Our study's results with regard to relating group differences on gender and socioeconomic status to total scores on the *TVPS-3* (Tables 4 and 5) are important within the South African context. We found that learners from low socioeconomic backgrounds performed significantly poorer on the *TVPS-3* than learners from higher socioeconomic backgrounds. Research by various other researchers on young primary school learners in South Africa also confirmed that low socioeconomic status negatively impacted visual-motor integration skills (visual perception included) leading to poorer academic performance (Du Plessis, Coetzee, & Pienaar, 2015; Lotz et al., 2005; Pienaar et al., 2013). Findings also state that stunted children from low socioeconomic areas in Zanzibar, with nutritional deficiencies, growth delays or malaria, can miss out on important visual-perceptual and motor developmental experiences and consequently have poorer locomotion and motor abilities, as well as impaired cognitive development (Olney et al., 2007). Others have also shown that low socioeconomic status has a direct negative effect on academic achievement (Cheng & Kaplowitz, 2016; Ferguson, Bovaird, & Mueller, 2007; Krombholz, 2012). With regard to gender in our study, boys did better than girls, although these differences were mainly of a statistical nature with a very small effect size. Lotz et al. (2005) also found that boys reflected better visual-motor integration skills than girls, although their findings were based on younger children (Grade 1–4 learners). In contrast, Coetzee and Du Plessis (2013) detected no significant differences between Grade 1 boys' and girls' visual-motor integration, visual perception, and motor coordination skills. Similarly, Lachance and Mazzocco (2006) found no gender differences in visual-motor integration and visual spatial skills for 249 Grade 1 to Grade 3 learners in the United States. Age and cultural factors may interact to explain these varied results.

In addition to the effect of general visual perception ability on mathematics and language achievement, several additional findings from our study are important to highlight. Of all the visual-perceptual constructs, visual closure was the only construct with a boy-girl difference effect size that was practically significant. Visual sequencing reflected no practically significant difference when comparing gender or socioeconomic status groups. Although Lachance and Mazzocco (2006) found that Grade 3 girls reflected better figure-background skills than boys, they did not report any gender differences for visual closure, form constancy, and position in space. They stated that similar findings could be possible on the same population up to and including Grade 6, but that gender differences, keeping puberty in mind, might be quite different at higher ages. Due to hormone changes during puberty, gender differences in the development of certain mathematical and spatial skills might vary with age (Casey, Nuttall, & Pezaris, 2001). Very little research is available relating to gender differences, specifically with regard to visual closure among primary school children. Foreman (1991) did, however, find that adult men show better visual closure than women, while women more easily identify visual signs. The visual sequence ability of learners in this study was tested by having them look for five seconds at a series of shapes that were not divided spatially and then choose the correct series from a group of options. As the number of shapes in the series increased from two to eight, this task tested not only short-term memory but also the learners' ability to identify and distinguish the shapes (Martin, 2006). According to Magill (2011), cognitive processing acts as a mediator when perception is utilized during the execution of a skill and serves as cognitive memory between perception and action execution. Due to the nature of visual sequential tasks in the *TVPS-3*, working memory is probably utilized during this task, making it a measure of both cognitive and executing functioning as well. Bharadwaj and Mehta (2016) also add that the visual sequential division of the *TVPS-3* requires learners to process large volumes of sequential stimuli and that the complexity of these tasks could possibly influence the results. Thus, our failure to show group differences in the relation between visual sequencing and academic achievement may be complicated by the complex, challenging, and cognitive nature of this task on the *TVPS-3*.

The findings of this study must be considered in the light of its strong points and shortcomings which include the following: A strong point is the large number of participants who were selected randomly which increases the generalization of the findings. Limitations of this study include the cross-sectional nature of our study's design and our correlative approach to data analysis, limiting the extent to which we can make causal inferences about relationships between visual perceptual skills and academic achievement. This study could be improved by comparing two different cross-study relationship sets between these variables at different grade points within this longitudinal data sample. Thus, future research might determine whether relationships between variables at a younger grade are different from relationships between variables at an older grade for the same children. Charting those differences would better reveal how these correlations change with age and experience. Of course, even this approach would be limited by its reliance on a single data set, and future longitudinal research with children from other cultures will also be needed. Future research regarding the correlation between visual perception and academic achievement, across South Africa, is also recommended, especially taking the influence of puberty and adolescence among older primary boys and girls into account.

Conclusion

In sum, visual perception ability (basic and complex constructs) seems to remain relevant to academic achievement at age 12 years, and children's gender and socioeconomic status can still exercise significant influence on both visual-perceptual skills and associated academic achievement and cognitive processes. Subsets of different visual-perceptual constructs do not appear to correlate significantly to specific learning areas such as mathematics or language, except that visual spatial relationships correlate with particular significance to academic achievement, in comparison with other basic visual-perceptual constructs. This may be because this construct continues to develop in older learners. Thus, visual spatial relationship skills have particular importance for predicting and perhaps improving academic achievement among older learners. As academic content of older students' curricula become more difficult and demand more cognitive ability, it is important to ensure that students have underlying visual perceptual abilities to meet these challenges. Visual perception is also linked to learners' executive functioning, and the planning of task execution (Hanlon, Thatcher, & Cline, 1999) making further research of this kind important to understanding the relation between older children's executive function and visual perception. Learners from low socioeconomic circumstances may need special attention in the development of their visual perceptual skills.

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References

Ayhan, A. B., Aki, E., Mutlu, B., & Aral, N. (2015). A study of conceptual development and visual perception in six-year-old children. *Perceptual and Motor Skills: Perception*, *121*(3), 832–839.

Beery, K. E., & Beery, N. A. (2006). *The developmental test of visual motor integration* (6th ed.). Minneapolis, MN: NCS Pearson.

Bezrukikh, M. M., & Terebova, N. N. (2009). Characteristics of the development of visual perception in five-to-seven-year-old children. *Human Physiology*, *35*(6), 684–689.

Bharadwaj, S. V., & Mehta, J. A. (2016). An exploratory study of visual sequential processing in children with cochlear implants. *International Journal of Otorhinolaryngology*, *85*, 158–156.

Brown, T. (2012). Are motor-free visual perceptual skill constructs predictive of visual-motor integration skill constructs? *Hong Kong Journal of Occupational Therapy*, *22*, 48–59.

Brown, T., Elliot, S., Bourne, R., Stutton, E., Wigg, S., Morgan, D., . . . Lalor, A. (2012). The convergent validity of the developmental test of visual perception-adolescent and adult, motor-free visual perception test-third edition and test of visual perceptual skills (non-motor)-third edition when used with adults. *The British Journal of Occupational Therapy*, *75*(3), 65–78.

Bueti, D., & Walsh, V. (2009). The parietal cortex and the representation of time, space, number and other magnitudes. *Philosophical Transactions of the Royal Society*, *364*, 1831–1840.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, *83*(4), 1229–1244.

Carlson, A. G., Rowe, E., & Curby, T. W. (2013). Disentangling fine motor skills' relations to academic achievement: The relative contributions of visual-spatial integration and visual-motor coordination. *The Journal of Genetic Psychology*, *174*(5), 514–533.

Casey, M. B., Nuttall, R. L., & Pezaris, E. (2001). Spatial-mechanical reasoning skills versus mathematics self-confidence as mediators of gender differences on mathematics subtests using cross-national gender-based items. *Journal for Research in Mathematics Education*, *32*(1), 28–57.

Chalfant, J. C., & Scheffelin, M. A. (1969). *Central processing dysfunctions in children: A review of research*. Bethesda, MD: U.S. Department of Health, Education and Welfare (DHEW).

Cheatum, B. A., & Hammond, A. A. (2000). *Physical activities for improving children's learning and behavior: A guide to sensory motor development*. Champaign, IL: Human Kinetics.

Chen, A. H., Bleything, W., & Lim, Y.-Y. (2011). Relating vision statement to academic achievement among year-2 schoolchildren in Malaysia. *American Optometric Association*, *82*, 267–273.

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., & Du Plessis, W. (2013). The visual-motor status of grade 1 learners in the North West Province of South Africa: The NW-CHILD study. *South African Journal for Research in Sport, Physical Education and Recreation*, *35*(2), 37–50.

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

Colarusso, R. P., & Hammill, D. D. (2003). *Motor-free visual perception test* (3rd ed.). Novata, CA: Academic Therapy.

Department of Basic Education, South Africa. (2011). *Curriculum and assessment policy statements 2011—Senior phase*. Retrieved from https://www.education.gov.za/Curriculum/CurriculumAssessmentPolicyStatements(CAPS)/CAPSSenior.aspx

Department of Education, South Africa. (2015). *Action plan to 2019: Towards the realization of schooling 2030*. Retrieved from http://www.education.gov.za/LinkClick.aspx?fileticket=HHmKnb78Z7Q%3d&tabid=36&mid=1167

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

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development*, *71*(1), 44–56.

Doya, K. (2000). Complementary roles of basal ganglia and cerebellum in learning and motor control. *Current Opinion in Neurobiology*, *10*, 732–739.

Duijff, S., Klaassen, P., Beemer, F., Swanenburg de Veye, H., Vorstman, J., & Sinnema, G. (2012). Intelligence and visual motor integration in 5-year-old children with 22q11-deletion syndrome. *Research in Developmental Disabilities*, *33*, 334–340.

Du Plessis, W., Coetzee, D., & Pienaar, A. E. (2015). Interrelationships between visual-motor integration, visual perception, motor coordination and object control skills of grade 1-learners: NW-CHILD study. *South African Journal for Research in Sport, Physical Education and Recreation*, *37*(3), 69–81.

Farber, D. A., & Beteleva, T. G. (2005). Formation of the system of visual perception in ontogeny. *Human Physiology*, *31*(5), 26–36.

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

Foreman, N. (1991). Correlates performance on the Gollin and Mooney tests of visual closure. *The Journal of General Psycology*, *118*(1), 13–20.

Gallahue, D. L., Ozmun, J. C., & Goodway, J. D. (2012). *Understanding motor development* (7th ed.). New York, NY: McGraw-Hill.

Hanlon, H. W., Thatcher, R. W., & Cline, M. J. (1999). Gender differences in the development of EEG coherence in normal children. *Developmental Neuropsychology*, *16*(3), 479–506.

Kramer, P., & Hinojosa, J. (2010). *Frames of reference for pediatric occupational therapy* (3rd ed.). Philadelphia, PA: Wolters Kluwer health, Lippincott Williams and Wilkins.
Krombholz, H. (2012). The motor and cognitive development of overweight preschool children. *Early Years*, *32*(1), 61–70.
Kulp, M. T. (1999). Relationship between visual motor integration skill and academic performance in kindergarten through third grade. *Optometry and Vision Science*, *76*(3), 159–163.
Lachance, J. A., & Mazzocco, M. M. M. (2006). A longitudinal analysis of sex differences in math and spatial skills in primary school age children. *Learning and Individual Differences*, *16*, 195–216.
Lotz, L., Loxton, H., & Naidoo, A. V. (2005). Visual-motor integration functioning in a South African middle childhood sample. *Journal of Child and Adolescent Mental Health*, *17*(2), 63–67.
Magill, R. A. (2011). *Motor learning and control: Concepts and applications* (9th ed.). New York NY: McGraw-Hill International Edition.
Martin, N. A. (2006). *Test of visual perception skills: Manual* (3rd ed.). Novata, CA: Academic Therapy.
Maslo, P., Frostig, M., Lefever, D. W., & Whittlesey, J. R. B. (1964). The Marianne Frostig developmental test of visual perception, 1963 standardization. *Perceptual and Motor Skills*, *19*, 463–499.
Morozova, L. V., Zvyagina, N. V., & Terebova, N. N. (2008). Charactersitics of visual perception in seven-year-old children differing in functional maturity of brain structures. *Human Physiology*, *34*(1), 14–21.
Olney, D. K., Pollitt, E., Kariger, P. K., Khalfan, S. S., Ali, N. S., Tielsch, J. M., . . . Allen, L.H. (2007). Young Zanzibar children with iron deficiency, iron deficiency anemia, stunting, or malaria have lower motor activity scores and spend less time in locomotion. *The Journal of Nutrition*, *137*(12), 2756–2762.
Paz-Baruch, N., Leikin, R., & Leikin, M. (2016). Visual processing in generally gifted and mathematically excelling adolescents. *Journal of Education of the Gifted*, *39*(3), 237–258.
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.
Pieters, S., Desoete, A., Roeyers, H., Vanderswalmen, R., & Van Waelvelde, H. (2012). Behind mathematical learning disabilities: What about visual perception and motor skills? *Learning and Individual Differences*, *22*, 498–504.
Richmond, J., & Holland, K. (2011). Correlating the developmental test of visual perception-2 (DTVP-2) and the test of visual perceptual skills revised (TVPS-R) as assessment tools for learners with learning difficulties. *South African Journal of Occupational Therapy*, *41*(1), 33–37.
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.
Thelen, E., Schöner, G., Scheier, C., & Smith, L. B. (2001). The dynamics of embodiment: A field theory of infant perseverative reaching. *Behavioural and Brain Sciences*, *24*, 1–86.

Van Lill, J. (2011). *Jou kind kan wiskunde doen* [Your child can do mathematics]. Cape Town, South Africa: Metz Press.

Van Wyk, Y., Coetzee, D., & Pienaar. (2016). Risikoprofiele gebaseer op visueel-motoriese agterstande by 9- tot 1-jarige leerder in die Noordwes Provinsie: Die NW-CHILD studie [Risk profiles based on visual-motor delays in 9- to 10-year old learners in the North West Province: the NW-CHILD study] (Thesis – PhD). Potchefstroom, South Africa: North West University.

Van Wyk, Y., Pienaar, A. E., & Coetzee, D. (2012). Ocular motor control functions and visual-motor integration status of a selected group of 6- to 8-year old learners with ADHD. *South African Journal for Research in Sport, Physical Education and Recreation*, *34*(2), 215–226.

Willingham, D. B. (1999). The neural basis of motor-skill learning. *Current Directions in Psychological Science*, *8*(6), 178–182.

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