Research Paper

RELATIONS OF GROSS AND FINE MOTOR SKILLS WITH GRAPHOMOTOR SKILLS IN PRESCHOOL YEARS

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Abstract

The study aims to explore the correlation between gross and fine motor skills and graphomotor skills of preschool children. It examines the relation of three factors of fine and gross motor skills, namely fine motor precision and integration, bilateral coordination and balance, and upper-limb coordination and agility respectively, with several factors of graphomotor skills, namely pencil and scissors manipulation, writing space orientation, handwriting control, figure reproduction and concepts about space. The sample consisted of 166 preschoolers (mean age in months 66.01, sd. 7.16), from public kindergartens in Crete, Greece. A path model that examines the relation between gross and fine motor skill factors along with graphomotor skills, with age and gender being considered, showed an acceptable fit. According to the model, upper-limb coordination and agility influence bilateral coordination, which, in turn, influences fine motor precision and integration. All five factors of graphomotor skills are influenced by fine motor precision and integration, with handwriting control having the largest influence, followed by figure reproduction. This model shows the importance of gross and especially fine motor skills on the handwriting readiness of preschool children and the significance of their reinforcement in kindergarten.

Keywords: Motor development, handwriting

Introduction

For Leisman et al. (2016) the connection between the areas of the brain where the child's motor and cognitive functions are based is clear. In fact, motor skills acquired at an early age are related to cognitive skills and can influence a child's cognitive development up to adulthood. According to Rigal (2009), a child's achievements come, in large part, from his or her motor activity and sensory experiences. Bushnell and Boudreau (1993) argue that motor development may act as a controlling factor for a child's future development and that some motor skills may be prerequisites for other developmental functions.

Therefore, as building blocks of human mobility, the development of gross and fine motor skills also follows a typical sequence. In time, that is, according to the principle of centrifugal development, young children are able to control the torso muscles that control the shoulders, arms, and forearms faster than the muscles of the limbs that control the wrists, palms, and fingers. This process explains the development of gross motor skills before fine motor skills (Douret & Auzias, 1993; Gallahue, 1996; Rigal, 2009). In fact, basic motor skills (such as running, jumping, kicking, throwing, catching, etc.) are the building blocks for the child's development and performance of more advanced forms of motor skills (Gallahue 2011). This view is shared by Yakimishyn & Magill-Evans (2002) who argue that the development of basic skills (running, bouncing, throwing, etc.) should be pursued in young

children, to form the basis for the development of their fine motor skills that will enable them to use school tools such as scissors, markers, pencils, etc.

For some children, however, their hands do not seem to work together effectively. This can lead to such frustration that they react adversely to activities that require them to coordinate their hands and fingers' muscles and joints. As a result, they cannot practice these skills properly or develop the right muscle groups (Woodward & Swinth, 2002). This, in turn, may affect the development of higher-level fine motor skills, such as handwriting. In fact, at the stage where typical instructions for writing begin, children are often described as having fine motor weaknesses (Amundson & Weil, 2005; Dennis & Swinth, 2001). Grissmer et al. (2010) argue that children with fine motor difficulties often have lower academic performance than their peers.

The relationship between gross motor skills and a child's academic performance is supported by several studies (Barnett, et al., 2008; Berniger 2009; Lopes, et al., 2013; Mampane, et al., 2018; Mavilidi, et al., 2015; 2017; Pieket, et al., 2008; Son & Meisels, 2006). Barnett et al. (2008) found significant changes in language and academic performance after eight months of motor intervention. According to Berniger (2009), the criteria for assessing motor skills related to writing have an indirect effect on the writing of children attending primary school. Mampane et al. (2018) found that incorporating structured movement activities into the teaching of mathematical and linguistic concepts positively influences the physical, social, and cognitive development of preschool children. Mavilidi et al. (2015, 2017) showed increased learning and working memory after a four-week motor intervention.

Both gross and fine motor skills appear to play an important role in the child's cognitive performance (Lopes, et al., 2013; Luo, et al., 2007), indeed Piek et al. (2008) after a longitudinal study of children ranging from 4 months to 12 years of age, found that assessment of their gross motor skills could predict their future cognitive performance.

For fine motor skills in particular, it is reported that 30-60% of children's time in school is spent performing tasks that require fine motor skills (McHale, & Cermak, 1992), making them the most important skills for academic performance (Marr, et al., 2003). Research in kindergarten shows that fine motor skills explain later academic development in primary school (Suggate, et al., 2019). Cameron (2012), found higher academic performance in children with increased fine motor skills. Gaul and Issartel (2016) report that poor fine motor skills may contribute to children's increased anxiety, negative self-esteem, and decreased academic performance. The results of Michel and Molitor (2022) showed that preschool children with possible fine motor disorders are at risk of academic problems due to lower performance on graphomotor tasks and working memory.

Graphomotor skills, as a particular type of fine manipulation skill with high demands (Bonoti, Vlachos, & Metallidou, 2005), refer to the manual use of a writing tool mainly to write or draw and are often used interchangeably with "writing ability" (Ratzon, et al., 2007). Skills such as visuomotor hand-eye coordination, concentration, mnemonic retention of a letter's image during copying, and control of the fine motor skills and the pressure exerted by the fingers and hand on the writing tool (Stevenson & Just, 2014), can only affect the writing outcome.

According to Margalit (1998), and Pavri & Monda-Amaya (2000), due to the negative impact of graphomotor difficulties on a child's academic performance and self-esteem, the early assessment of fine and gross skills as well as specific graphomotor skills in preschool children is of particular importance. Levine (1987) found that children's writing errors are due to lack of fine motor coordination, incomplete visuomotor development, and perceptual and attentional impairments. Fine motor skills are also essential to form letters accurately, as synchronization of the movements of the palm, arm, and fingers and control of one's strength are required (Alston & Taylor, 1987; Thomassen & Teulings, 1983).

Complete and balanced development of the child appears to occur during the critical period of preschool, as between the ages of two to seven years, control of basic stabilization, locomotion, and manipulation skills is acquired (Gallahue & Ozmun, 1998; Gallahue, 1996). Gross and fine motor skills form the basis of a child's development, and for Cahill (2009), the acquisition of writing skills at the beginning of the children's education forms the basis of their future academic success.
So far, research examining the relationship between different subsets of gross and fine motor skills and the different graphomotor factors in preschool-age children is limited.

Aim of the study

The current study aims to explore the correlation between young children's gross motor skills and fine motor skills, as well as the correlation with preschool children's graphomotor skills. It examines the relations of three particular factors of fine and gross motor skills, namely fine motor precision and integration, bilateral coordination and balance, and upper-limb coordination and agility respectively, with several factors of graphomotor skills, namely pencil and scissors manipulation, writing space orientation, handwriting control, figure reproduction and concepts about space.

Methodology

Participants

The study participants were 166 randomly selected typical children/preschoolers (mean age 66.01 months, sd. 7.16), 50.6% girls, from 12 public kindergarten classrooms in Crete, Greece. Cluster sampling was applied to the kindergarten classes, where classes were randomly selected from the reference population, whereas all students of the selected classes were included in the sample. Classes had to meet the criterion of having a space outside the classroom so that tests and assessments could be delivered individually without the children being distracted. Students with known/diagnosed difficulties (learning etc.) and/or severe hearing/vision problems were excluded from the analysis sample.

Instruments

Fine and gross motor skills were assessed by the Bruininks-Oseretsky Test of Motor Proficiency-Short Form (BOT-2-SF, Bruininks, & Bruininks, 2005). In addition, the graphomotor skills were assessed by the Scale of Preschool Graphomotor Skills (SPGS4-6, Trouli, et al., 2012).

BOT-2-SF (2005) includes 14 items that assess the performance of motor skills of individuals aged: 04:00 to 21:11 years old. It consists of eight sections (fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper-limb coordination, and strength), 5 of them assessing gross motor skills (bilateral coordination, balance, running speed and agility, upper-limb coordination, and strength) and the remaining three assessing fine motor skills (fine motor precision, fine motor integration, manual dexterity). Regarding the Greek population of typical preschool and primary school children, Kambas & Aggeloussis (2006), tested construct validity of BOT-2-SF and concluded it is a valid test of motor proficiency.

SPGS4-6 (Trouli et al. 2012) consists of 25 items that assess the graphomotor skills of kindergarteners aged 04:03 to 06:03 years old. These items form five factors, namely pencil and scissors manipulation, writing space orientation, handwriting control, figure reproduction, and concepts about space. The test has been standardized on the Greek population and was financially sponsored by the Research Committee of the University of Crete (Elke, UoC). Moreover, the research methodology, data collection, procedure, and analyses have been approved by the Pedagogical Institution of Ministry of Education, Greece, F15/266/29425/G1, 16/3/2011.

Procedure

The parents of the participants provided a written signed consent of agreement that their child can participate in the assessment and the data collection.

All participants were individually assessed on both tests (BOT-2 Short form and SPGS 4-6) on two different days, with each assessment lasting 15-20 mins.

Statistical analysis

Mplus 6.11 statistical software (Muthén & Muthén, 1998-2011) was used for the statistical analyses. We used a confirmatory factor analysis model with all the items of the short form of BOT2, which did not fit our data well. Therefore, a confirmatory factor analysis on selected items of the BOT2 scale was used. Through modification indices, we concluded on a three-factor model. All the fit indices showed a good fit of the final model on the data. In addition, a path model that examines the relation between gross and fine motor skills factors and graphomotor skills, considering age and gender, is used

Results

The Chi-Square test of model fit was 40.75 (df 36) with p-value>0.05. In addition, the fit indices were CFI=0.987, TLI=0.980, RMSEA=0.028, SRMR=0.01, all of them indicating a good fit of the model.

The factors of the estimated model are (a) fine motor precision and integration, (b) bilateral coordination and balance, and (c) upper limb coordination and agility respectively. The loadings of the items on the factors along with the standard errors (S.E.) and p values are shown in Table 1.

Table 1: Items and factor loadings of the 3-factor model on gross and fine motor skills

Item	Loading	S.E.	P-value
Factor 1: fine motor precision			
Drawing lines through paths – crooked (1a)	0,603	0,064	<0,01
Folding paper (1b)	0,945	0,141	<0,01
Copying a square (1c)	0,484	0,071	<0,01
Copying a star (1d)	0,517	0,068	<0,01
Factor 2: bilateral coordination and balance			
Jumping in place – same sides synchronized (2a)	0,597	0,065	<0,01
Tapping feet and fingers – same sides synchronized (2b)	0,700	0,062	<0,01
Walking forward on a line (2c)	0,436	0,075	<0,01
Standing on one leg on a balance beam – eyes open (2d)	0,457	0,075	<0,01
Factor 3: upper-limb coordination and agility.			
One-legged stationary hop (3a)	0,597	0,059	<0,01
Dropping and catching a ball – both hands (3b)	0,775	0,047	<0,01
Dribbling ball alternating hands (3c)	0,736	0,049	<0,01

Moreover, a path model that examines the correlation between gross and fine motor skills factors and graphomotor skills considering the age and gender, showed an acceptable fit (CFI=0.947, TLI=0.911, RMSEA=0.047, SRMR=0.059). On the right-hand side of the graph, the five factors of graphomotor skills are shown, which are pencil and scissors manipulation, writing space orientation, handwriting

control, figure reproduction, and concepts about space. According to the model in Figure 1, which shows only highly statistically significant paths, both age and gender influence fine motor precision and integration, upper limb coordination, and agility. Upper limb coordination and agility influence bilateral coordination, which, in turn, influences fine motor precision and integration. All five factors of graphomotor skills are influenced by fine motor precision and integration, with handwriting control having the largest influence, followed by figure reproduction.

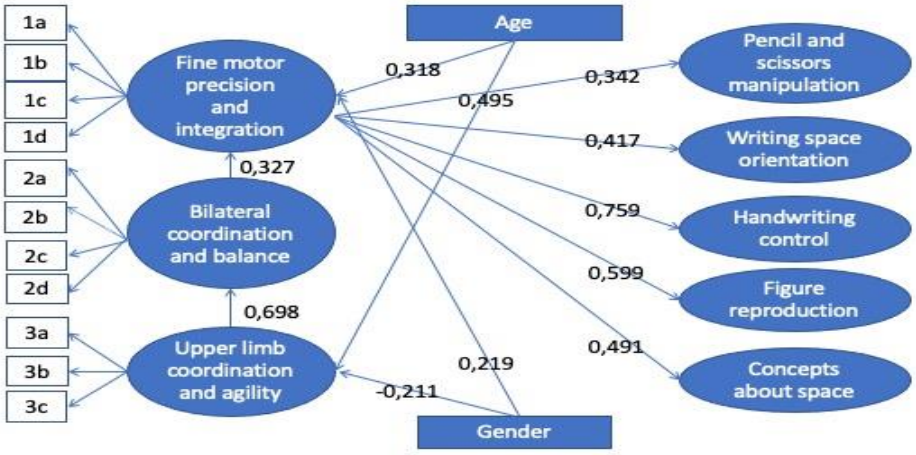

Figure 1: A path model on the correlation between gross and fine motor skills and graphomotor skills.

Moreover, the higher the age in months, the higher the score of upper limb coordination and agility; fine motor precision and integration are also higher.

Regarding gender (dummy with values 1 for boys and 0 for girls), boys have significantly higher fine motor precision and integration (positive estimated parameter that is equal to 0.495), and significantly lower upper limb coordination and agility (negative estimated parameter that is equal to -0.211), compared to girls.

This model shows the main importance of fine motor skills on the handwriting readiness of preschool children and the significance of their reinforcement in kindergarten.

Discussion

This study investigated the correlation between gross and fine motor skills and graphomotor skills of preschoolers. The results showed that upper limb coordination and agility influence bilateral coordination and balance which, in turn, influences fine motor precision and integration. Fine motor precision and integration influence all five graphomotor factors. The higher impact seems to appear in

handwriting control and figure reproduction. Furthermore, it appears that gross and fine motor skills are strongly connected to each other, and to graphomotor skills.

The findings of our study seem to be in accordance with the literature; gross motor skills are the basis for the development of fine motor skills (Douret & Auzias, 1993· Gallahue, 1996· Gallahue et al. 2011· Rigal, 2009). The correlation between these two domains of motor skills appears to be strong during preschool ages, where, the findings of Oberer et al. (2017) showed that the various motor skills are interrelated and that, in early childhood, all motor tests (whole-body coordination and dexterity) contain a common factor, despite obvious differences in the quality and demands of the tests. It appears that the preschool child's ability to control and move his or her body as a whole is related to the development of sophisticated motor control of the hands, which makes him or her capable of dexterous movements. Yakimishyn & Magill-Evans (2002) report that supporting the development of young children's basic motor skills is the basis for the development of their fine motor skills that will enable them to skillfully manipulate school tools. Indeed, Roebers and Kauer (2009) argue that motor tests (gross or fine) require the use of executive skills. Thus, for children to draw a line through a path or walk balancing on a line successfully, they need to mentally plan the exact point on which they need to move to or maintain, and according to Oberer et al. (2017) to recall and use their strategies. In the case of our study, the factors of upper-limb coordination, agility, bilateral coordination, and balance seem to be the ones that significantly influence the fine motor precision and integration factor.

Fine motor skills involve those factors that help control the hand movements involved in accurate writing (lateral dominance, kinesthetic control, finger touch, motor planning) (Feder & Magnemer, 2007). These subtle dexterous movements applied to the manipulation of graphic and design tools serve to acquire the graphomotor skills necessary for early learning (Ratzon, et al., 2007) and thus contribute to successful graphic movement. In our study, the fine motor precision and integration factor was found to have a statistically significant effect on all five graphomotor motor factors assessed (pencil and scissors manipulation, writing space orientation, handwriting control, figure reproduction, and concept about space).

Conclusions

The strong relationship shown between gross, fine motor, and graphomotor skills in preschool children in our study confirms the importance of this particular period for the motor development and the development of children's basic motor skills (Gallahue & Donnely, 2003) and graphomotor skills. To be able to write, the child must first learn to control his or her fine movements to then produce the letter traces (Lamber, & Espérer, 2002). According to the American Psychiatry Association (2013), 30-50% of children with motor impairments have learning difficulties in the areas of reading and writing.

Therefore, during the preschool period, most children master the basic motor repertoire as well as object control and specific graphomotor skills (Margalit, 1998; Pavri, & Monda-Amaya, 2000; Rigal,

2009) that will help in their smooth transition from kindergarten to primary school (Bart, et al., 2007; Pianta, et al., 1999; Stipek & Byler, 1997),

Exercising young children in movement activities and games that strengthen their torso, shoulders, and hips creates a solid muscular base. For example, strengthening and stabilizing the shoulder girdle and arms can be a prerequisite for the use of scissors and writing tools. We, therefore, need to provide children with early support in kindergarten programs to enable them to cope with more complex motor skills required in later grades, such as handwriting, and to contribute to their cognitive and psychosomatic readiness for primary school and everyday challenges. Furthermore, as Bart et al. (2007) point out, early assessment of children's motor skills before they enter school could allow the creation of appropriately designed motor interventions to facilitate the transition for children with weaker mobility.

Thus, it is of great importance for preschool teachers to design specific activities that develop and enhance all and each of these skills in unison (gross motor, fine motor, and graphomotor skills).

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