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## Problematic elements in the graphomotor skills of pupils in the early adolescence

**Irena Loudova\***, University of Hradec Kralove, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic  
**Jana Havigerova**, University of Hradec Kralove, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic

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### Abstract

Graphomotor skills (handwriting) are obviously required for full participation in school activities since students spend up to half of their classroom time engaged in paper and pencil tasks daily. The objective of the presented paper is to quantify the prevalence of graphomotor problems of early adolescent pupils, based on their graphomotor skills coding during the primary school attendance. The research was designed as a quantitative cross-sectional study. As the basic research method was used, the assessment scale and the assessment record sheet. The research sample included pupils in the early adolescence period, namely, ninth grade pupils (14–16 years old), sample group size  $n = 22$ . The results of the research showed that the problem with the visual–motor memory prevails in the sample group of pupils. This problem can be solved, for example, by presenting relevant models to pupils, who are diagnosed with a graphomotor disorder.

**Keywords:** Graphomotor skills, graphomotor problems, early adolescence, visual-motor memory

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\* **ADDRESS FOR CORRESPONDENCE:** Irena Loudova, University of Hradec Kralove, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic. *E-mail address:* [irena.loudova@uhk.cz](mailto:irena.loudova@uhk.cz) / *Tel.:* +420-603-195-166

## 1. Introduction

Early adolescent pupils can experience a range of learning disabilities that are important to diagnose and attend to as part of literacy instruction. The pupils with learning disabilities represent a very heterogeneous group of individuals in relation to severity of learning disabilities, reading and writing abilities and background. There is nothing to suggest that there is a particular cause of graphomotor problems, they are, however, becoming increasingly common among pupils in primary schools.

Graphomotor skills are a combination of cognitive, perceptual and motor skills which enable a person to write. For the position of graphomotor skills in the writing foundations, see Figure 1. The term graphomotor skills describes the more technical motor processes that are necessary for writing, colouring or drawing (Loose, Piekert & Diener, 1997), but the term is also stretched to include the interactive environmental factors of writing (Dehn, 1994). The significant aspects of writing with efficiency of movement and the critical role of visual monitoring when writing (Quenzel, 1994) are afforded just as little explanation.

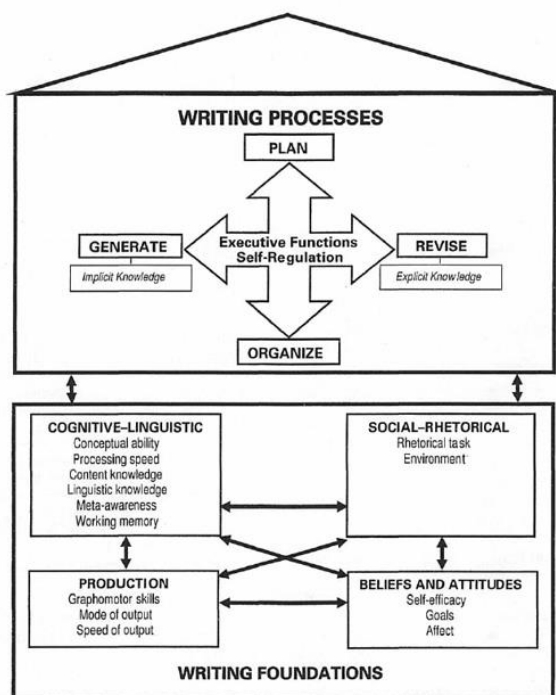


Figure 1. Model of written language production (Bashir & Singer, 2010)

The study of writing motor skills describes and research studies how graphic characters can be written by hand with efficiency of movement and the best way to learn this type of economic writing (Diaz Meyer, Schneider, Marquardt, Knopf & Luptowicz, 2017). The long-term objective of writing lessons is the acquisition of legible, efficient, fluid, fatigue-free and individual penmanship. Within this framework, the development of an even writing rhythm, quick writing speed and adequately low writing pressure, as well as the necessary transfer of these skills to writing letters, words and whole sentences, plays a central role (cf. *ibid.*).

Research into writing motor skills includes an interdisciplinary approach that links findings from motor skills, brain research, neuropsychology, the psychology of learning, pedagogy and writing ergonomics. The criteria for writing with efficiency of movement, e.g., using efficient movements to link letters, effectively lifting the pen when writing and simplifying letters, are derived from the

kinematic analysis of experienced, automated handwriting (cf. *ibid.*). Experienced writers carry out automated writing movements, i.e., they can subconsciously recall their memorised motor processes and as such can concentrate predominantly on the content of their writing.

In this context, the conscious control of movements typical of those learning to write plays a critical, even counter-productive role (cf. Quenzel & Mai, 2000). Subconscious automated writing is performed at a very high speed that cannot be monitored visually. As such, even the direction of attention to a detail of the letter is in itself sufficient to disturb automated execution considerably (cf. Marquardt et al., 1996; Quenzel, 1994).

There are five distinct areas of skills that must all work together in order for handwriting to take place.

1. Visual perceptual skills—the ability to see a letter or word and assign meaning or judge accuracy
2. Orthographic coding—the ability to store letters or groups of letters in memory and then retrieve them when needed
3. Motor planning and execution—also called “praxis”, this is the ability to carry out necessary motor movement
4. Kinesthetic feedback—the ability to know where a part of the body is in space (in the case of handwriting, the hand and fingers) for the purpose of carrying out necessary motor movement
5. Visual-motor coordination—the ability to correlate motor movement with visual perception (the ability physically to create letters and words on the paper)

When deficits occur in any of the individual areas of skill involved in the graphomotor process, problems may arise in several modalities, including handwriting, composition and even reading. Deficits can occur in any of these individual areas and, in most cases, will involve more than just one skill. The symptoms of graphomotor problems are as follows:

- Lack of a connection between memory and fingers: an individual with Graphomotor problems will find it difficult to remember the letter shapes and the muscle movement to make the shapes.
- Motor Problems: An individual with poor Graphomotor Skills will find it difficult to use muscles to hold the pen or move it in the manner needed to write on demand.
- Finger Agnosia: Some individuals with Graphomotor problems will lose track of where their fingers are when they are writing.

According to experts to improve graphomotor skills and handwriting readiness, teachers should incorporate activities aimed at improving fine motor control, isolated finger movements, fine motor strength, enhancing right-left discrimination and visual perception, promoting prewriting skills and improving orientation to printed language, while also promoting a fun atmosphere (National Research Council, 2012).

In our research we specially aim at visual–motor memory (VMM). The component skills that enable the motor activity of picking up a pen or pencil and drawing an alphanumerical symbol are both complex and diverse (Feder & Majnemer, 2007). Nonetheless, the fundamental challenge is one of learning how to generate motor commands that result in an effector (the hand) producing a graphical representation of a memorised shape (alphanumerical symbol). Thus, learning to write is contingent on a cognitive ability to remember visual patterns and recruit the appropriate neural circuit to translate these patterns from memory to page.

This psychological process is defined as VMM for symbolic representations (i.e., memory of a visual pattern and how to reproduce an approximation of the shape via the motor system). We believe that VMM must underpin the procedural aspects of learning to write and hypothesise that this cognitive skill is the pathway through which increased automaticity in handwriting emerges with practice. Namely, as pupils practice they become quicker to recall and execute the commands necessary to produce legible letter/word forms (Medwell & Wray, 2014). This ‘routinising’ should free up cognitive

resources for more abstract higher-order language processes (e.g., composition, syntax and spelling), which develop concurrently with learning to write (cf., Medwell & Wray, 2014, McCarney, Peters, Jackson, Thomas & Kirby, 2014). Thus, it is plausible that VMM ability may indirectly influence the rate of development of these non-motoric language processes.

## 2. Objectives and research questions

This paper focuses on the area of graphomotor skills and problems of pupils with a special focus on the developmental aspect. The research stems out from the 2018 specific research project 'Screening of graphomotor problems in preschool children', the aim of which was to develop a screening tool for the detection of children with graphomotor problems (hereafter GMP) in preschool age and to determine the prevalence of GMP in this age group from the perspective of educators.

The main objectives of the presented research were to quantify the prevalence of graphomotor problems of children, based on coding of graphomotor products of children and eventually to detect graphical elements that show the greatest occurrence of GMP indicators. Contribution in terms of strict science parameters are as follows:

- Description and analysis of graphomotor indicators of children in particular stages of development (in this paper the research sample were pupils in their early adolescence).
- The potential to identify children at increased risk of developing specific developmental learning disorders manifesting difficulties in drawing and writing.
- Provide a knowledge base for pre-graduate teacher education.

Based on the above-mentioned research objectives, the main research question was determined:

- What is the proportion of children with graphomotor difficulties in individual stages of development?

Subsequently, the following sub-questions were formulated:

- Does the ratio of individuals with GMPs vary from one cohort to another?
- What graphic elements are associated with the most prominent GMPs?

Research assumption: The prevalence quantified on the basis of the products of children will (in a statistically acceptable tolerance of  $\pm 5\%$ ) correspond to the prevalence quantified on the basis of GMP screening in the above-mentioned project in all observed stages of development of the individual (pre-school age, start of pubescence—sixth grade and beginning of adolescence—9 class).

## 3. Methods

### 3.1. Participants

The research group consisted of early adolescence pupils, namely, ninth grade pupils, file size  $n = 22$ , see Table 1. Only pupils whose parents/guardians agreed on their enrolment in the research and who were present at school at the time of research administration were recruited for the research. Research data were denominated—respondent names will never be associated with specific outputs, results will be published as results for the entire research group, individual samples will never contain any child identification data.

**Table 1. Sample group**

Gender	Total number	Age (average)	Right handed	Left handed
Female	14	15	12	2
Male	8	15	7	1

### 3.2. Research methods

The research was conceived as a quantitative cross-sectional study. The basic research method was the assessment scale and the assessment record sheet of our own design. The principles of the creation of relevant research tools in the field of quantitative methodology and psychometrics were applied in construction. The scale and sheet were created on the basis of existing tools used for diagnosis and development of reading and writing disorders from pre-school age. In particular drawings, the level of processing of individual graphomotor elements on the scale evaluating the quality of the graphic elements as a whole, were assessed (based on the similarity of the original model—size, shape or angle). The scale was evaluating the tension (fluency, interruption, tremor and pressure). The course of execution (performance) was not recorded or evaluated, i.e., the holding of a writing instrument, the release of the hand, and the dexterity were not recorded, only the final product was assessed.

The obtained were processed by standard mathematical-statistical procedures (descriptive statistics, tests to verify the normality of research data distribution, tests to verify the reliability of the research tool and tests for comparing multiple samples).

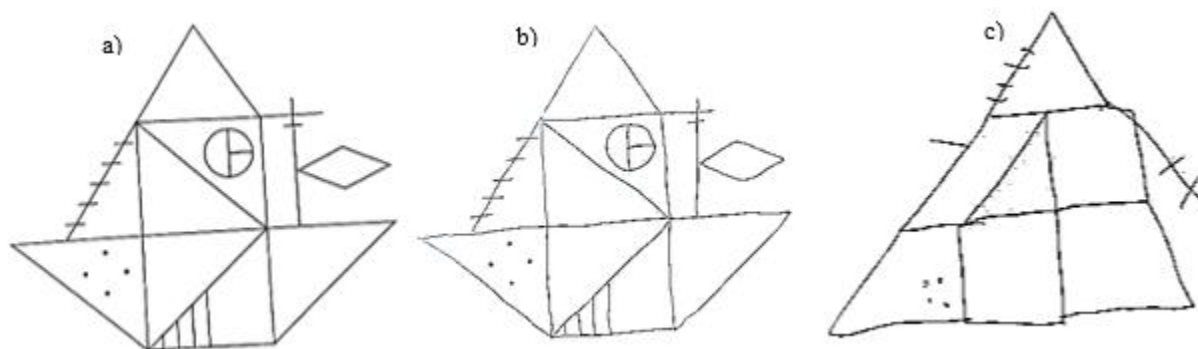
### 3.3. Procedure

A set of graphic templates with progressively increasing difficulty was distributed to selected group of pupils. More difficult developmental groups of elements were incorporated:

a group of elements requiring distance (spiral, arcs, teeth, etc.),

a group of elements based on ovals and containing crossing lines (upper and lower loops, garlands, arcades, etc.).

For each VMM trial, the accuracy with which participant's drawing (their input path) depicted the target shape (the reference path, see Figure 2) was evaluated.



**Figure 2. Illustrative example of VMM deficiency: a) original model, b) copy of drawing with original model, c) copy of drawing without original model (Bednarova, 2006)**

## 4. Results

The calculations were made to compare drawing performances and their properties based on the self-report method HPSQC. Self-report data test relies on the individual's own report of their

symptoms, behaviours, beliefs or attitudes. Self-reports are commonly used in psychological studies largely because much valuable and diagnostic information about a person is revealed to a researcher based on a person’s report on himself or herself. In the research sample the respondents achieved a total sum of HPSQC scale on average  $15 \pm 4.5$  points (min= 9, max = 27 points).

The results of the *U*-test (Mann–Whitney test for comparison of two groups) showed that pupils who achieved higher scores in self-assessment of graphomotor problems (attained a higher tremor and higher number of interruptions in the task 3 (upper loop)).

**Table 2. Tasks tremor versus self-report of graphomotor problems via HPSQC: Mann–Whitney *U* (*N* = 22)**

Tremor	<i>U</i>	Sig.	Mean rank 0	Mean rank 1	Interruptions	<i>U</i>	Sig.	Mean rank 0	Mean rank 1
Task 1	48.0	0.654	11,70	10,36	task 1	39.0	0.837	11.33	12.25
Task 2	36.5	0.219	12,46	9,06	task 2	44.5	0.484	11.03	13.63
Task 3	19.0	0.010	14,27	7,40	task 3	62.5	0.019	10.03	18.13
Task 4	31.5	0.140	12.58	8.44	Task 4	40.0	0.774	11.28	12.50
Task 5	26.5	0.962	11.03	10.83	Task 5	52.0	0.195	10.61	15.50
Task 6	38.5	0.277	12.29	9.28	Task 6	52.0	0.195	10.61	15.50
Task 7	40.0	0.345	12.56	9.83	Task 7	56.0	0.098	10.39	16.50
Task 18	43.5	0.547	11.65	9.94	Task 18	43.0	0.594	11.11	13.25
Task 27	56.0	0.804	10.69	11.50	Task 27	34.0	0.902	11.61	11.00
Task 28	62.0	0.602	10.33	11.89	Task 28	26.5	0.962	11.03	10.83

Looking at the descriptive statistics of task 3, we can see that the most significant difference is in the number of upper loop interruptions. This task could thus serve as a good screening tool for facilitating the detection of adolescents with graphomotor difficulties and the risk of dysgraphia.

**Table 3. Tasks 3 (tremor and number of interruptions) versus self-report of graphomotor problems via HPSQC: Descriptive statistics (*N* = 22)**

	TASK 3 tremor		TASK 3 interruptions	
GM problems	0	1	0	1
Mean	0.61	0.75	0.94	3.75
Median	0.50	0.50	1	4
Std. Deviation	0.69	0.95	1.21	2.62
Minimum	0	0	0	1
Maximum	2	2	4	6

Furthermore, the results of the self-assessment were positively correlated (spearman correlation) with the variables of similarity in task 18 (similarity of a copy of a picture in a square—equilateral and uneven triangle—without guiding points), similarity in task 27 (drawing a copy of a complex figure) and similarity in task 28 (drawing of a complex figure by heart), see Table 4.

**Table 4. Similarity of shapes when redrawing complicated figures: Spearman correlation (*N* = 22)**

Task	rho	Sig.
TSK18_simil	-0.431	0.051
TSK27_simil	-0.167	0.469
TSK28_sim	0.451	0.040

Calculations were made to compare the drawing performances and their properties based on the teacher’s tip (four children were identified by the teacher as children with graphomotor problems). The results of Chi-square and Cramer V indicated that pupils who were detected with difficulties showed a larger tremor in the task 5 (saw-teethotic difficulties) reached a higher tremor in the task

3 (upper loop). Furthermore, the results showed that there is a statistically significant difference between the two groups in task 3 (upper loop) and task 35 (transcription of printing fonts into written script). Pupils identified by the teacher as those with graphomotor problems showed greater tremor in task 3 and had more grammatical errors in transcription. Other differences were not statistically significant.

## 5. Discussion and conclusion

The concept of VMM is consistent with contemporary theories on the embodied nature of cognition (Glenberg, Witt & Metcalfe, 2013). However, further empirical investigation is required: longitudinal research looking at whether rate of language acquisition (writing and reading) is mediated by VMM ability would help to increase our understanding of the degree to which VMM contributes to writing and reading development. In addition, research across a wider age range might be expected to find the strength of the relationship between VMM and language abilities varying with time. Specifically, once automaticity of handwriting rises above a certain threshold it might be expected that the relative contribution of VMM to wider language ability will diminish (cf. Medwell & Wray, 2014).

If VMM is the cognitive process within which the critical shift from effortful to proceduralised/automatic production of letters occurs (cf. *ibid.*), then we have identified a key cognitive component that supports the early stages of written language acquisition. It should be noted that our data are correlational, and therefore we cannot address the issue of causality. It is reasonable to suggest that reduced VMM capabilities might have a negative impact on reading and writing skill, but it is also equally plausible that poor reading and writing skills (produced by genetic and/or environmental factors) cause reduced VMM capabilities. In reality, it is probable that these factors form a complex dynamical system where their development is mutually dependent. This viewpoint is consistent with recent theories which suggest that multiple deficits contribute to complex disorders such as dyslexia (van Bergen, van der Leij & de Jong, 2014).

Graphomotor difficulties, seen as slow and effortful output and spacing, are believed to affect all other composing processes. The effort and conscious control required to move the ideas from pupils' minds through their hands to the page is great enough to usurp resources otherwise devoted to higher level cognitive processes, such as planning and meaning making (Lahey & Bloom, 1994).

In summary, the graphomotor tasks employed for studying fine motor control showed the possibility of characterising the fine motor impairments. The implication of our findings is that an evaluation of participants' simple geometric drawings (straight lines and loops) provides insight into the deficits that affect pupils' drawing performance. Based on these findings, we can adapt relevant teaching methods in the class, where pupils with psychomotor difficulties are identified.

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