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Keeping the line in transition years: Comparison of preschoolers and nine graders

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Abstract

The study deals with the graphomotor difficulties of children at the beginning and the end of primary school. The aim is to describe and analyze the occurrence of two manifestations of graphomotor problems: tremor and line continuity. The results of the redrawing of seven graphics were compared. Fifty-one (51) preschoolers and 22 nine graders participated in the research. The tremor was detected at 1/5 to 4/5 of preschoolers and at 1/5 to 3/5 of ninth graders; the prevalence of the tremor decreases with age. Significant differences were found in the number of interruptions in most tasks. Contrary to expectations, more interruptions were found among 9th graders. The result is interpreted based on declining experience with writing and drawing images larger than interlinear differences, experience interference such as writing through discontinuous cursive handwriting, favored by the majority of adolescents, and intervening personality characteristics such as perfectionism, and laziness.

Keywords*:* Adolescents; graphomotor skills; interruptions; preschool children; tremor.

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1. Introduction

The transition from kindergarten to elementary school is an important period for developing fine motor skills and graphomotor skills (Lin, 2019; Bonacina et al., 2021; Strooband et al., 2023). Children learn during their first years at school to develop their fine motor skills and become competent hand writers (Feder et al., 2005; Bautista, Habib, Eng & Bull, 2019; Shearer et al., 2021; McDougal et al., 2022; Obeid, DeNigris & Brooks, 2022; Neveu, Geurten, Durieux & Rousselle, 2023). Writing is a skill that must be developed (Kim, 2022; Sidhom & Orabi, 2023).

The development of graphomotor involves several partial skills, which determine the resulting drawing/writing performance (Danna et al., 2022; Lopez & Vaivre-Douret, 2022). According to Del Giudice et al. (2000), the subtle abilities determining drawing/writing performance can be divided into three groups: visual perceptual abilities, graphomotor abilities, and representational abilities. Moreover, performance depends on the neuropsychological development of the child. Vasileva (2015) presented a study aimed at a neuropsychological assessment of the relationship between graphic skills and the maturation of brain structures. In a group of N= 365 children (4-7 years old) she found out, that the most influential factor of graphic motor skills in the preschool period is age (results demonstrate a regular increase with the effect $F(2, 346) = 48.1$, $p<0.001$); but "the analysis of the results reveals some particularities in the development of kinetic organization of the movements which depend on the maturation tempo of premotor area in the frontal lobe in the left hemisphere. The development of the serial organization of the movements is an important component of the general formation of psychic functions and especially speech activity (spoken and written)" (Vasileva, 2015, pp. 20). A deficiency in any of the partial skills that determine the drawing/writing performance or the problematic maturation of brain structures that are responsible for the drawing/writing process can cause the child might have difficulty drawing and consequently writing, and as a result, he or she begins to fail at school. Early detection of children at risk is therefore essential.

Many authors point to the tendency that specialists and explorers predominantly pay attention to developmental problems at school age and the study of preschool age is insufficient (Vasileva, 2015, pp. 17; Brons et al., 2021; Amukune, Caplovitz Barrett & Józsa, 2022). Therefore, in our study, we focus on two age periods, both of which characterize the moment of the school transition stage: the pre-school age (i.e., before entering elementary school) and the 9th grade (i.e., before switching to secondary school). Early childhood (2–6 years old) is the period when children develop and refine a wide variety of movement skills that have been developed from birth. During the preschool and early elementary years, rapid changes lead to an improvement in children's motor proficiency due to growth and maturation. Vasileva (2015) and other authors from the field of neuropsychology draw attention to the asynchronous development of a child's brain and different abilities to determine drawing/writing skills.

Del Guidance et al.'s (2000) study shows other authors, that in various periods constructional abilities develop in the following order: visual perceptual abilities are increasing in pre-school age (the second wave of development is in later school years), representational skills develop during school attendance, and graphomotor skills evolve during the first year of schooling. For this reason, we chose preschool children and not first-grade pupils as a research group. In adolescence, the graphomotor performance should be stabilized, this period is represented in our study by 9th-grade pupils. Comparing these two age groups can provide valuable insights. According to recent research, the prevalence of graphomotor problems is quite high, although the authors disagree on a particular number. The literature suggests that the prevalence of dysgraphia in the school-age population ranges from 5-30% (Kushki, Schwellnus, Ilyas, & Chau, 2011; Rosenblum, Weiss, & Parush, 2004; Smits-Engelsman & Van, 2001). As with other specific developmental learning disabilities, dysgraphia and graphomotor disorders also differ depending on gender, drawing / writing skills (construction abilities) are different according to gender. Rosenblum et al. (2004), for example, report that 11-13% of female pupils and 21-32% of male primary school pupils have difficulty in writing. In preschool children, the gender difference was demonstrated by Vasileva (2015, pp. 20), who specifies "A statistical influence is detected by reference to the crude rating and the gender factor ($p <0.04$, providing $F = 4.207$). The higher rates are shown in the females than in the males. "

This study has the character of piloting with not a very large research group, so it will not analyze the calculations depending on gender, it is the limit of this study and the topic for future research. One of the issues discussed is also the relationship between graphomotor problems and intelligence. The study of Del Giudice et al. (2000, pp. 366) performed on a group of N = 80 preschool children (3-5 years old) and N = 80 school-age children (8-9 years old) show that "total scores were highly related to IQ, showing that the battery [testing visual perceptual, visual engine and graphics-engine abilities] was consistent with general intelligence performances. " The correlation can be interpreted

by the fact that both skills share some similar sub-skills (e.g., vituperative abilities, memory, executive functions, etc.). So, there is no reason to consider intelligence as an intervening variable.

An important question in the study of graphomotorics is how to measure graphomotor skills, especially how to measure them at preschool age, which, as mentioned above, has remained until recently rather in the background of researchers' interest. The graphic performance of children is reflected in the so-called constructional tasks, where the child draws spontaneously and/or copies drawings (Del Giudice et al., 2000). The methods for measuring the graphics performance and the sub-skills that make this performance can also be divided into two groups - tests based on spontaneous drawing analysis and tests based on template drawing. In our study, we work with stimulus material of the second type - graphic performance analysis according to templates. This group of tasks is recommended for testing graphic design skills in preschool age (Vasileva, 2015, pp. 23), also recommends the following types of tasks for the development of graph skills: "drawing of figures following a sample, completion of began figure, writing elements from letters within a margined space, outlining figures by connecting sets of dots," etc.

De Giudice et al. (2000) used the following series of tasks in their study: visual scanning tasks, visual perceptual tasks, representational tasks, visual motor coordination tasks, and executive (graphomotor) tasks. Since we do not operate with partial assumptions of graphomotor performance in our study, we have chosen our own set of tasks, which by their nature correspond to visual-motor tasks. The author of the templates is an important Czech special pedagogue Jiřina Bednářová (Bednářová & Šmardová, 2006; Bednářová & Šmardová, 2011). Note: In the research of the graphic performance and the subskills that make the above-mentioned possible, a grip that can also play a role, may indicate difficulties on the one hand and thus influence the course and outcome of the child's graphic activity. Although there are sufficiently valid and reliable grip measurement tools (Burton & Dancisak, 2000, who recommend using the Schneck and Henderson Grip Scale with a five-level scoring system for assessment for preschoolers), we have only tentatively recorded pathological grip, and we did not work with this information furthermore. For further research, more accurate grip measurement may be an additional element for analyzing moderators or mediators of graphical performance, its determinants, and context.

1.1. Purpose of study

This study has two aims: (1) to quantify the percentage of children in school transition periods (pre-school children and 9th-grade pupils) with risk of graphomotor problems; (2) to determine how two manifestations of graphomotor problems differ at preschool and 9th-grade pupils. The study is a nonexperimental quantitative pilot.

2. Materials and Methods

2.1. Data collection tools

Drawing templates laid out on an A4 size paper; respondents always have to draw a picture on a blank A4 paper so that it is as close as possible to the original template. Young children are said that this is a “copier game”. The templates have forms that imitate the basic forms of the letters: coil (sweeping and petty), knots (overhead, downward, and bidirectional), pinnacles, and scoops.

Graphomotor difficulties are operationalized as (1) *Tremor*: the result line in the task is not merely a clear solid line, but contains slight or pronounced “ripples”, it is an external manifestation of the uncertainty of guiding the movement of the pencil on paper, while the cause of the tremor is not addressed; the variable reaches values of 0 (clear fixed line = no tremor), 1 (at times slight ripple of the line = slight tremor), 2 (at times strong ripple or in the whole task slight/strong ripple of the line = strong tremor). (2) *Interruptions:* the number of movement interruptions during the task solution, the number of evident stops with the writing tool lifting, reaches values of 0 (the task was performed in one continuous move by the assignment), 1 ton (n = a number of the move interruptions).

2.2. Participants and Ethics

The research sample was obtained through the availability of a nonprobability sampling method (Nestor & Schutt, 2015, p. 115). Nine grade pupils´ parents and children from two preschool units of kindergarten were approached by a cooperating teacher to sign informed consent of the child's participation in the anonymized research. Out of the 79 parents addressed, 76 expressed written consent. The testing took place from April to June 2019. The children were tested face-to-face in a separate room (teacher's workroom). The administrator always introduced herself to the whole class, then summoned the children one by one to a separate test room. The administrator gradually

submitted individual templates to the respondents and exchanged clean papers, on which the children made their own "copies" of the templates. Every child received a small motivational reward after completing all tasks. Testing of one child took approximately 10 minutes.

Three children, whose parents agreed with their participation, were not present at school due to illness (2) and participation at the competition (1) was not tested. Data from 73 respondents were thus obtained from a total of 79 addressed children. *The G0 respondents* were preschool children in the strict sense, ie children in the last year of preschool education who participated in the enrollment in April and started primary school in September, N_{G0} = 51, average age 6;6. *The G9 respondents* were adolescents who attended the 9th grade at the time of testing, attended the single entrance examination for secondary schools in April, and entered secondary school in September, N_{G9} = 22, average age 15; 2. A total of 43 boys and 30 girls participated in the research see Table 1.

Table 1

Research sample subgroups (grade and gender): Descriptives (N=73)

gender	G0	G9	*Total*
1 boy	29	14	*43*
2 girls	22	8	*30*
Total	*51*	*22*	*73*

3. Results

Each task was assessed in terms of tremor (0-1-2) and number of interruptions (0-count). The result was converted to a binary scale, the operationalization of a child at risk. The percentage of children with non-zero performance was quantified, and the min-max shows the range of children with non-zero performance, i.e., children at risk.

Table 2

Tremor and number of interruptions: Group Descriptives (N_{G0}=51, N_{G9}=22)

Tremor	G0 % no problem	G0 % at risk	G9 % no problem	G9 % at risk	Interruptions	G0 % no problem	G0 % at risk	G9 % no problem	G9 % at risk
Min-max	21,6-66,7	33,3-78,4	40,9-81,8	18,2-59,1	Min-max	47,1-88,2	11,8-52,9	22,7-54,5	45,5-77,3
Mean	48,5	51,5	55,2	44,8	Mean	72,3	27,7	43,5	56,5

It is apparent from Table 2 that tremor as a risk factor appears on average in about half of the research group of both preschoolers and nine graders. Interruptions appear as a risk factor in only about one-fourth of preschoolers and half of nine graders.

Table 3

Tremor and number of interruptions: Group Descriptives (N_{G0}=51, N_{G9}=22)

Picture to copy	Tremor Mean G0		Tremor Mean G9	Interruptions Mean G0		Interruptions Mean G0
sweeping coil	0.569	≈	0.591	0.216	<	1.000
petty coil	0.569	≈	0.545	0.196	<	0.682
overhead knots	0.667	≈	0.636	0.765	<	1.455
downward knots	0.863	>	0.591	0.706	<	1.409
bidirectional knots	0.961	>	0.773	1.941	<	2.409
pinnacles	0.353	>	0.182	0.255	<	3.000
scoops	0.392	<	0.545	1.765	<	2.409

From Table 3 we can see that the average tremor values in the preschool group are approximately equal for tasks 1, 2, and 3, higher for tasks 4, 5, and 6, and surprisingly lower for task 7. Table 3 further shows that the average values of the number of interruptions in the group of preschoolers are surprisingly lower, ie. in all the monitored tasks, the 9th-grade pupils achieved an average higher number of interruptions in all tasks.

Table 4

Differences in TREMOR preschoolers versus nine graders: Mann-Whitney U test (N=73)

Independent Samples T-Test	W	p	Rank-Biserial Correlation	95% CI Lower	95% CI Upper
sweeping coil	546.000	0.844	-0.027	-0.307	0.258
petty coil	576.000	0.845	0.027	-0.258	0.307
overhead knots	571.500	0.895	0.019	-0.265	0.300
downward knots	673.500	0.148	0.201	-0.087	0.457
bidirectional knots	648.000	0.248	0.155	-0.133	0.419
pinnacles	648.000	0.186	0.155	-0.133	0.419
scoops	496.000	0.364	-0.116	-0.386	0.172

Table 4 documents the test results of the two groups' comparison in terms of the variable tremor for each template. From the results, we can see that no statistically significant difference between the group of preschoolers and the group of n graders was found in any of the tested templates.

Table 5

Differences in INTERRUPTIONS preschoolers versus 9th-grade pupils: Mann-Whitney U test (N=73)

Independent Samples T-Test	W	p	Rank-Biserial Correlation	95% CI Lower	95% CI Upper
sweeping coil	340.500	< .001	-0.393	-0.608	-0.124
petty coil	390.000	0.006	-0.305	-0.541	-0.024
overhead knots	336.500	0.002	-0.400	-0.613	-0.132
downward knots	450.500	0.133	-0.197	-0.454	0.091
bidirectional knots	436.000	0.120	-0.223	-0.476	0.064
pinnacles	300.500	< .001	-0.464	-0.660	-0.209
scoops	480.500	0.284	-0.143	-0.410	0.145

Table 5 demonstrates the test results for the comparison of the two groups for the interruptions variable for each template. From the results, we can see that a statistically significant difference between the group of preschoolers and the group of nine graders was found in copying coils, overhead knots, and pinnacles. From Table 3 we know that in all these tasks the 9th-grade students reached an average higher number of interruptions than preschoolers did.

4. Discussion

This study had two objectives. The first objective of the study was to quantify the estimated prevalence of children in school transition periods (preschool children and 9th-grade pupils) at risk of graphomotor problems. Graphomotor problems were operationalized as tremors and interruptions in simple graphomotor tasks. The study showed that tremor in the line occurs in preschoolers in the range of 33.3-62.7%, and 9th-grade pupils in the range of 18.2-59.1%, depending on the template. The literature suggests that the prevalence of dysgraphia in the school-age population ranges from 5-30% (Kushki, Schwellnus, Ilyas, & Chau, 2011; Rosenblum, Weiss, & Parush, 2004; Smits-Engelsman & Van, 2001). The percentage is about 11-13% of pupils and 21-32% of primary school pupils have trouble writing (Rosenblum et al., 2004). Our results show a higher prevalence than reported in the literature, but we have to consider that we are deducing by a single indicator (in this case tremor) in a single task.

Looking at the results in more detail, the lowest percentage of children whose line has the tremor mark when drawing straight lines. When tasks require curve drawing, the percentage of children whose line shows a tremor increases by two to three times. This is an interesting result because classic arguments for cursive handwriting were based on the beliefs that are easier for children to make curved lines than straight ones, that the cursive movements follow naturally from scribbling, and that cursive is fewer pen lifts than manuscript and is faster (Schwellnus, Cameron & Carnahan, 2012). On the contrary, based on the results of this piloting, it appears that the curves are more difficult and the straight lines are easier and that the tremor in the straight lines can therefore more reliably indicate difficulties in graphomotor. Since the percentage of children with a tremor in a straight-line task is the lowest, we also consider tremor in straight lines as the most reliable indicator of the risk prevalence of graphomotor problems. However, only further research can support the correctness of this opinion.

The most difficult in terms of tremor in this study was bidirectional knots containing four alternately upper and lower knots flowing sequentially. In addition, the tremor in this task can be influenced by the interaction of emotions

- the task is difficult, and the first error or hesitation occurred after the first knot, which could trigger negative emotions (starch, rage, tension, etc.). Negative emotions deactivate motor-skill areas in the brain, anxiety affects movement in both gross and fine motor tasks (Causer, Holmes, Smiths, & Williams, 2011); under load, tremor appears in part of the pediatric population (Pešová & Šamalík, 2006).

Interruptions as a risk factor in the drawing appear in preschoolers in the range of 11.8-52.9% and nine graders in the range of 45.5-77.3%. This is about the same range as for the tremor for preschoolers, while for the 9th-grade pupils, the result shifts to almost twice the minimum and maximum values than for tremors, compared to preschoolers. How is it possible that the interrupted line showed such a high (almost double) percentage of drawings of the 9th-grade pupils? Suppose that the proportion of children with graphomotor difficulties is the same in the population of 9th-grade pupils. The higher occurrence of interruptions in drawings according to our models must then be the result of the participation of other intervening variables. One such variable may be the size of the original in this study, which was about 10 cm in height. Graphomotor exercises of this size are standard in preschool age, while in primary school children practice basic shapes in the first grade, in the third grade the font between rows, while the inter-row height decreases gradually from 14 to 10 mm (the result of the actual measurement of n = 14 Czech copybooks accredited by the Ministry of Education for primary education). Therefore, we believe that the 9th-grade pupils probably had quite fine-motor movements to a greater extent than interlinear spaces, which could have contributed to a higher number of interruptions while drawing larger templates.

In the second place, the manner of the accomplishment could have been influenced by the interference of experience, in which case, in our opinion, the experience/habit of some 9th-grade pupils could lead to the use of cursive handwriting that is discontinuous. Why? All 9th-grade pupils in the research group had a written template for learning continuous writing (they all were encouraged to write words in one move in the 1st grade). In the Czech school system, however, the similarity of writing to the template is required by the 3rd grade, until when writing is graded. From the fourth grade onwards, pupils can write in any way; Czech children create their manuscripts from the fourth grade. In our 9th-grade pupil's group, 72.7% (!) use cursive handwriting for dictations. We did not find out whether there is a relationship between the spontaneous use of cursive handwriting and tremor in tasks with rounded continuous moves, but this is a hypothesis suitable for further research.

Last but not least, the number of interruptions in the drawing of 9th-grade pupils could be more strongly intervened in the drawing process by some personality characteristics. We mean, for example, perfectionism, the pursuit of efficiency or laziness - it is easier and more reliable to interrupt moves for some tested tasks to achieve the optically correct result (in the same drawing). For pinnacles and scoops, interruptions are obvious at the vertices (spikes and arcs). For other pictures, there were no clear areas for stopping and linking in the template, but 9th-grade pupils may already have the feeling of making an interrupted line so that they may have the impression the resulting interrupt shape will not be visible and are therefore more freely interrupting moves to achieve a better result. The interruption allows the hand or pen position to be moved to a position that facilitates accurate movement. Let us remind you that the instruction did not explicitly state that the tasks should be solved as “single lines”.

5. Conclusion

From the results of this study, the section on interruptions, one might also conclude that the prevalence of age-related problems even increases from approximately ¼ to nearly ½ children (minimal preference preschoolers → 9th-grade pupils: tremor 33.3 → 18.2; interruptions 11, 8 → 45.5), which would sound alarming. However, based on the suggested interpretations, we conclude that the number of interruptions in this study is not a reliable indicator of the prevalence of difficulties. It could only happen if the respondents were told in the instruction that they should copy the drawing in a single line.

The second research question focused on the differences between preschoolers and 9th-grade pupils in the monitored graphomotor indicators. Regarding tremors, the prevalence in both studied groups was approximately the same for all the tasks tested (no statistically significant difference was found). Let us repeat that tremor as a risk factor appears on average in about half of the research group of both pre-schoolers and 9th-grade pupils. Interruptions as a risk factor occurred in only about one-quarter of preschoolers in contrast with half of the 9th-grade pupils - the differences were statistically evident in coils, overhead knots, and pinnacles. To accomplish all these picture templates, 9th-grade pupils demonstrably needed more moves than preschoolers did. The discontinuity (frequent interruptions) of the drawing lines in nine graders could be caused by the interference of the following: (1)

9th-grade pupils use to write with in-line spacing and not-so-large shapes, (2) 9th-grade pupils can create their manuscript from grade 4, a significant percentage prefer discontinuous cursive handwriting, (3) personality characters such as perfectionism or laziness (it is easier to achieve the perfect shape by interruption when the respondent notices that the move is not perfect), (4) the respondents were not told that the drawings should be made as "single lines".

It is desirable to monitor graphomotor difficulties from preschool age. They may indicate several less or more serious problems (memory disorders, visual disturbances, learning disorders, organicity, epilepsy, etc.). Especially in the school educational process, they may be involved in underachievement or failure in the performance of a pupil and may be negatively impacted by their experience and behavior. The results of our study show that the prevalence of graphomotor problems based on tremor tracking in line copying can be nearly 50% in both preschool children and ninth-grade adolescents. It has also been shown that the number of line interruptions is probably an unreliable indicator of graphomotor difficulties. To better assess its possible use for this purpose, it should be emphasized when assigning tasks that these are tasks whose solution should be a single line. New research questions have also arisen, among which the most interesting are the more detailed assessment of the differences between straight- and rounded-line drawings and the differences in their potential to predict children 's graphomotor difficulties and to verify whether there is a correlation between cursive handwriting preferences and several interruptions in tasks requiring more single movement. We consider the issue of graphomotor difficulties and possibilities of early identification of children at risk to be always actual and open to new research.

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