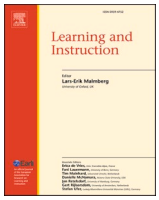
Learning and Instruction 101 (2025) 102229

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc



Relations between graphomotor self-concept and graphomotor skills: A longitudinal study in early school age

Joséphine Schwery Klingele [a,*], Martin Vetter [b], Lidia Truxius [c], Michelle N. Maurer [a,d], Judith Sägesser Wyss [a], Michael Eckhart [a]

[a] Institute for Special Needs Education, University of Teacher Education Bern, 3012, Bern, Switzerland
[b] Faculty of Participation Sciences, Department of Psychomotricity, Motologie and Movement Pedagogy, Ludwigsburg University of Education, 71634, Ludwigsburg, Germany
[c] Institute of Psychology, University of Bern, 3012, Bern, Switzerland
[d] Norwegian Reading Centre, University of Stavanger, 4021, Stavanger, Norway

ARTICLE INFO

Keywords:
Handwriting
Graphomotor skills
Self-concept
Early education
Longitudinal study

ABSTRACT

Background: While the positive impact of self-concept on writing is well established in proficient writers, its role in early handwriting development remains unclear.
Aims: By focusing on the graphomotor self-concept, this longitudinal study aimed to investigate the relations between the graphomotor self-concept, graphomotor skills, and handwriting legibility from the beginning of first grade to mid-second grade.
Sample: This study included 361 first-grade children (49 % girls) aged 6–8 years.
Methods: A graphomotor self-concept questionnaire and paper-and-pencil tasks were used to assess graphomotor skills and handwriting legibility.
Results: The results of the cross-lagged structural equation model revealed that after controlling for age, gender, and socioeconomic background, the graphomotor self-concept predicted graphomotor skills, whereas graphomotor skills predicted handwriting legibility.
Conclusions: These findings highlight the importance of promoting the graphomotor self-concept and graphomotor skills in early school-aged children. Both contribute substantially to handwriting development and thus to a successful start in school.

1. Introduction

Graphomotor skills are fundamental to the acquisition of handwriting (Downing & Caravolas, 2023). Forming letters requires precise fine motor control guided by visual processing, along with considerable practice and persistence (Achymy et al., 2022). Given the complexity and demands of handwriting acquisition, confidence in one's own graphomotor abilities — referred to as a positive graphomotor self-concept — may play a crucial role as well. Research on more proficient writers shows that self-concept, a key motivational belief, influences writing development (for an overview, see Camacho, Alves, & Boscolo, 2021). A positive self-concept is associated with greater willingness to exert effort, increased persistence when facing challenging tasks, and the pursuit of ambitious goals (Musu-Gillette et al., 2015), all of which contribute to improved achievement (Guay, Stupnisky, Boivin, Japel, & Dionne, 2019). However, our understanding of these dynamics in early school-aged children — particularly in first and second grade, when formal handwriting instruction begins — is still limited. It is reasonable to assume that, as in more proficient writing, individual differences in graphomotor self-concept in early development may influence children's motivation and persistence in handwriting tasks, thereby affecting their graphomotor development and proficiency. The present longitudinal study aims to clarify the relations between graphomotor self-concept and graphomotor skills, and how these contribute to handwriting legibility from first to second grade. The findings are expected to deepen our comprehension of early handwriting development and illuminate the potential importance of fostering a positive graphomotor self-concept as a key component of early handwriting

* Corresponding author. Pädagogische Hochschule Bern, Fabrikstrasse 8, 3012, Bern, Switzerland.
E-mail addresses: josephine.schwery@phbern.ch (J. Schwery Klingele), martin.vetter@ph-ludwigsburg.de (M. Vetter), lidia.truxius@unibe.ch (L. Truxius), michelle.maurer@phbern.ch (M.N. Maurer), judith.saegesser@phbern.ch (J.S. Wyss), michael.eckhart@phbern.ch (M. Eckhart).

https://doi.org/10.1016/j.learninstruc.2025.102229
Received 27 June 2024; Received in revised form 28 July 2025; Accepted 11 September 2025
Available online 1 October 2025

instruction.

1.1. Graphomotor skills and handwriting development

Graphomotor skills include precursors to handwriting and the ability to write letters (i.e., allographs) (Downing & Caravolas, 2023; Sägesser Wyss et al., 2024; Schilling, 2005). The key aspects of graphomotor skills are visuomotor integration and fine motor control (Bara & Gentaz, 2011). Visuomotor integration refers to the ability to reproduce shapes by relying on the coordination between visual perception and arm motor function (Beery et al., 2010), whereas fine motor control refers to precise coordination and control of eye, hand, and finger muscles (Chandler et al., 2021). Within the broader context of writing, graphomotor skills can be understood as low-level subprocesses in motor execution. Van Galen (1991) suggests in his psychomotor model of handwriting that handwriting is a multicomponent process coordinating several parallel processes from ideation to allograph and stroke production (i.e., motor execution). In this model, graphomotor skills can be understood as these low-level processing skills responsible for the execution of these motor processes to produce letter shapes. The model suggests that lower-level processes receive input from higher-level processes. Nevertheless, these processes do not occur in a sequential manner. Instead, they occur simultaneously, requiring temporary retention of information in an intermediary buffer, commonly conceptualized as working memory (Van Galen, 1991). For young children who are not practiced in these lower-level executions of motor skills, have to actively control these motor processes and are therefore working memory consuming (Maurer et al., 2023; Truxius et al., 2025). Therefore, it is essential for young children to automate and internalize motor processes such as graphomotor skills to free up cognitive resources that enable children to become more invested in other parallel processes of writing (Van Galen, 1991). A substantial body of research has been conducted on the role of motor processes in the development of writing skills. Children with well-developed visuomotor integration and fine motor skills, both indicators for graphomotor skills, tend to write more legibly and fluently later on (Duiser et al., 2014; Van Hartingfieldt et al., 2015), show improved spelling abilities (Maurer et al., 2023), and produce higher-quality written texts (Downing & Caravolas, 2023). These findings underline that practice in these lower-level processes might help children to become more engaged in higher levels of writing.

The present study focuses on the lower-level motor subprocesses of writing as described in Van Galen's (1991) model and its relevance for handwriting legibility, which, alongside fluency, is a key characteristic of young children's handwriting (Mekyska et al., 2024). Handwriting legibility refers to the accuracy with which letters are formed, whereas handwriting fluency describes how quickly a pen moves across a page (Fitjar et al., 2022). Since handwriting legibility and fluency are closely related in young children (Fitjar et al., 2022), handwriting legibility might represent a reliable indicator for handwriting skills. Despite their fundamental importance, motor processes have received considerably less empirical attention compared to higher-level components of writing (Salas & Silvente, 2020). Targeted support in early handwriting instruction requires a comprehensive understanding of the underlying processes. In this context, it is essential to consider not only graphomotor skills and handwriting legibility but also the role of the graphomotor self-concept (Fogel & Rosenblum, 2022).

1.2. The graphomotor self-concept

The graphomotor self-concept refers to children's perceived ability to perform the fundamental motor processes involved in letter production (blinded for review) and is conceptualized as a domain-specific component of academic self-concept. Such domain-specific self-concepts begin to take shape in early school age through the interplay of individual learning experiences (mastery or failure of tasks) and influences from the social environment (Shavelson et al., 1976). This developmental phase is also marked by intensive learning processes related to handwriting acquisition. Children spend between 30 % and 60 % of their time in classroom engaged in fine motor activities, centered on writing and graphomotor tasks (Caramia et al., 2020). Against this backdrop, the graphomotor self-concept holds special significance in early school age. Despite its theoretical relevance, the role of the graphomotor self-concept in early handwriting development has not yet been empirically examined and therefore remains unknown. To assess how the graphomotor self-concept may relate to graphomotor skills and handwriting legibility in the early stages of handwriting acquisition, it is first necessary to understand how domain-specific academic self-concepts develop in early school age and how they are linked to achievement.

1.3. Relations between self-concept and achievement

In preschool and early school age, children's academic self-concept is typically overly optimistic and shows only a weak correlation with actual achievement (e.g., Arens et al., 2016). With increasing age, children's academic self-concept tends to decline and becomes more realistic, meaning it aligns more strongly with actual achievement (e.g., Weidinger et al., 2018). Furthermore, it becomes more stable, that is, more constant over time (e.g., Arens et al., 2022). Several explanatory approaches have been proposed to account for this developmental trajectory: First, upon school entry, children acquire new competencies in different academic areas and develop a more differentiated understanding of their strengths and weaknesses ("I am good at math but bad at French"), which leads to a more realistic self-concept (Chen et al., 2013; Dapp & Roebers, 2018). Second, middle childhood is marked by remarkable cognitive development, enabling children to reflect on their abilities and position themselves through social comparison (Harter, 2015). Third, external factors — particularly subjective feedback from teachers about success and failure and, objective achievement feedback such as grades — play a central role in the development of academic self-concept (Eccles, 1999). In summary, with school entry, children move to an environment in which external demands, individual developmental processes, and their interaction contribute significantly to the differentiation and adjustment of their self-concept (Harter, 2015).

Within the framework of longitudinal studies, for over three decades, self-concept research has explored whether good academic achievement is the cause of a positive academic self-concept, or conversely, whether a positive academic self-concept drives good academic achievement (Marsh & Köller, 2003). There is now broad consensus that the relations between academic self-concept and academic achievement cannot be explained by simple causality but rather through a model in which academic self-concept and academic achievement are reciprocally related (REM model; Guay et al., 2003; Marsh & Craven, 2006; Marsh & Martin, 2011). This means that academic self-concept predicts subsequent academic achievement (self-enhancement model), and academic achievement affects subsequent academic self-concept (skill-development model), whereby the relations are predominantly domain-specific, i.e., self-concept in a particular subject area is primarily linked to achievement in that same area (Marsh & O'Mara, 2008). The REM model has proven to be generalizable across various academic domains and cultures, as shown by several meta-analyses (Huang, 2011; Möller et al., 2009; Valentine et al., 2004). However, most studies were based on samples of students in late school age. Marsh and Martin (2011) argue that, for younger school children, empirical evidence to support the generalizability of the REM model is still insufficient. This assertion is supported by studies indicating that in younger children, only a unidirectional path in cross-lagged analysis is significant, whereas the reverse direction is absent (Arens et al., 2016; Skaalvik & Valås, 1999). However, the exact time point at which reciprocal relations emerge remains unclear (Dapp & Roebers, 2018).

In addition, evidence from writing research involving more proficient writers supports the importance of self-concept for the

development of achievement. These research studies show that self-concept, a key motivational belief, influences writing development (for an overview, see Camacho et al., 2021). A positive self-concept is associated with greater willingness to exert effort and increased persistence in writing tasks (Pajares et al., 2007). Such behavior, in turn, may lead children to invest more time in writing activities and to continuously improve their skills through practice (Graham & Weiner, 2012). Conversely, children with a negative self-concept are more likely to avoid challenging writing tasks, which can result in reduced practice and, consequently, lower writing proficiency (Danna et al., 2016). Given the scarcity of research in early school age, we examine the interplay between graphomotor self-concept, graphomotor skills, and handwriting legibility using a longitudinal approach.

1.4. The present study

The primary aim of the present investigation was to examine the longitudinal relations between graphomotor self-concept and graphomotor skills. Drawing on research with older students, both in self-concept and writing domains, which highlights the importance of self-concept for academic achievement, we assumed that early beliefs about one's own skills (self-concept) already play a significant role in early school years. It is hypothesized that graphomotor self-concept and graphomotor skills exert reciprocal influences on each other.

Furthermore, this study aimed to examine the importance of graphomotor self-concept and graphomotor skills for the development of handwriting. Based on the writing model of Van Galen (1991) it was assumed that well-developed or automatized graphomotor skills facilitate more efficient handling of the cognitive processing demands involved in writing, which is in the long term reflected in improved handwriting legibility. Therefore, it was expected that graphomotor skills would serve as a significant predictor of handwriting legibility. In contrast, based on the demonstrated domain-specificity of academic self-concept (Marsh & Craven, 2006; Marsh & O'Mara, 2008), no significant predictive relations were expected between graphomotor self-concept and handwriting legibility.

To test these assumptions, a longitudinal design with three measurement points was implemented, spanning from school entry to mid-second grade. The analyses were based on a cross-lagged structural equation model, which allows for the examination of differentiated longitudinal reciprocal effects. To ensure the robustness of the results, key covariates were controlled: gender, as previous studies have shown differences in graphomotor skills between boys and girls (e.g., Maurer, 2023); age, as developmental differences may affect graphomotor skills (e.g., Sägesser Wyss et al., 2024); and socioeconomic status, which has also been discussed as a significant influencing factor on graphomotor skills (e.g., Eckhart & Sägesser Wyss, 2016).

This longitudinal study is the first to integrate different developmental stages of early handwriting acquisition with graphomotor self-concept, thus making an innovative contribution to writing and self-concept research. The study expands the current state of research in two ways: First, it examined students in early school age (grades 1 and 2), a group that has largely been neglected in previous longitudinal studies, although the early school years are a crucial developmental phase of domain-specific self-concepts and handwriting. Second, it investigated the domain of graphomotor skills — an academic area that has so far received limited attention in the context of longitudinal research on academic self-concept.

2. Method

2.1. Participants

The data presented here were derived from the research project *grafset*, to examine the effectiveness of graphomotor interventions, which was approved by the Ethics Committee of the Faculty of the University of Teacher Education Bern, Switzerland (Approval Number: 19s000201). The project was conducted from March 2021 to February 2024. The present study focused on a subsample that did not receive any graphomotor interventions. The study was designed as a longitudinal investigation with three measurement points and included children from both urban and rural areas in the German-speaking region of Switzerland. The subsample consisted of 361 children (49 % girls). The first measurement point took place at the beginning of the first grade, when the children were on average seven years old (SD = 0.39 years) (T1: October to December 2021). The second measurement point was six months later (T2: April to June 2022). The third measurement point was in the mid-second grade (T3: October to December 2022). There was minimal dropout from T1 to T3 (n = 3). However, there were some missing data due to the children's absences on test days because of illness.

In Switzerland, handwriting instruction begins in the first year of schooling. Children who experience difficulties in graphomotor skills receive educational support, such as psychomotor therapy. In this sample, 23 children (6.4 %) received additional educational support in the form of psychomotor therapy because of graphomotor difficulties. Additional educational support included special education (n = 73; 20.2 %), speech and language therapy (n = 40; 11.1 %), psychomotor therapy for socio-emotional and gross motor difficulties (n = 14; 3.9 %), special language support for children whose first language was not German (n = 37; 10.2 %), and occupational therapy (n = 8; 2.2 %). To assess the children's socioeconomic background, the parents' occupations were evaluated using the International Socio-Economic Index of Occupational Status (ISEI; Ganzeboom et al., 1992). The ISEI assesses occupational prestige in relation to both income and education levels. There was a wide range of socio-economic backgrounds, with scores ranging from 14.39 to 88.96. The average occupational prestige of the children's mothers was 54.61 (SD = 20.11) and that of the fathers was 54.06 (SD = 21.51). These results are slightly higher than the European average (Entorf & Minoiu, 2005). The majority of the children's first language was Swiss German or German (75 %).

To determine the minimum sample size required to investigate the research questions, a priori power analysis was conducted using the pwrSEM package (version 0.1.2; Wang & Rhemtulla, 2021). The results indicated that a sample size of n = 170 would be required to achieve 80 % statistical power at significance level of α = .05.

2.2. Procedure

Before data collection began, written consent was obtained from parents for their children to participate. The children provided their verbal consent on test days. At each measurement point, data were collected on two consecutive mornings (between 8:30 a.m. and 11:30 a.m.) by trained research assistants. On the first day, graphomotor skills and handwriting legibility were assessed. Graphomotor skills were assessed in a group setting within the classroom, while handwriting legibility was assessed individually in a separate room. The second day focused on testing the children's self-concept within the classroom. To ensure the test was comfortable and considered the children's motivation, endurance, and attention, each test was designed to take a maximum of 20 min.

2.3. Measurements

2.3.1. Graphomotor skills

Graphomotor skills were measured using the GRAFOS-2 Screening (Sägesser Wyss et al., 2024). In the GRAFOS-2 Screening children were instructed to copy eight shapes fundamental to letter writing (vertical line, horizontal line, circle, arc downwards, arc upwards, cross, square, and triangle) and four more complex shapes (rhombus, connected loops, horizontal eight, and drop). The accurate reproduction of shapes requires visuomotor integration and fine motor skills, which are

considered central aspects of graphomotor skills. In total, the children had to reproduce each of the 12 shapes as accurately as possible six times in predefined fields (1 cm^2). Accuracy was rated according to clearly defined criteria and evaluated by a total of eleven different raters across all three measurement points. Each shape was scored 1 (correct reproduction) or 0 (inaccurate reproduction). An example of the rating of a circle is its complete closure and the absence of "corners." The mean was calculated for each of the eight simple and four complex shapes separately. The inter-rater reliability between the different raters reached a value of Fleiss' $\kappa = .65$, which represents a substantial degree of agreement (Lanids & Kock, 1977). The internal consistency of the screening, as measured by Cronbach's alpha (α), was also high ($\alpha = .80$ for the eight simple forms; $\alpha = .78$ for the four complex shapes).

2.3.2. Graphomotor self-concept

We used a recently developed questionnaire to assess the graphomotor self-concept at early school age (author et al., under review). The questionnaire consisted of five items rated on a four-point Likert scale with circles of different sizes ranging from "strongly disagree" (smallest circle) to "strongly agree" (largest circle). Each item represented a statement about the child's individually perceived graphomotor achievement (e.g., "I can already write many difficult letters"), with the smallest circle representing a value of 0 and the largest circle a value of 3. Since early school-aged children often struggle to understand negatively worded items (Fletcher & Hattie, 2004), all items were phrased positively. Due to the lack of reading skills of children at that age, the questionnaire items were read aloud by the research assistants. The children were instructed to choose the circle that best represented their self-perception. Before administering the questionnaire, it was ensured that all the children understood the instructions. The criterion-related validity of the questionnaire was demonstrated ($r = .54$, $p < .001$) (author et al., under review). The internal consistency of the questionnaire, measured by Cronbach's alpha (α), was found to be satisfactory (T1: $\alpha = .75$; T2: $\alpha = .84$; T3: $\alpha = .78$).

2.3.3. Handwriting legibility

To assess legibility, the children wrote six different words in basic German-Swiss writing on a sheet of paper, based on which handwriting legibility was rated. The words included four words with six letters and two words with eight letters each. One of the co-authors independently rated each letter within a word by determining whether it could be identified correctly in isolation (score 1) or not (score 0), that is, without the contextual support of adjacent letters. For each word, the percentage of recognizable letters was calculated. A global, i.e., holistic approach is widely used in handwriting legibility research (see Rosenblum et al., 2003 for review). A second rater scored 50 % of the data to establish interrater reliability. The weighted Cohen's Kappa coefficient revealed good agreement between the two raters ($\kappa = .71$; Altmann, 1991). Internal consistency (Cronbach's alpha) was found to be satisfactory (T1: $\alpha = .79$; T2: $\alpha = .74$; T3: $\alpha = .77$).

2.4. Data analysis

In the first step, we examined the changes in the graphomotor self-concept, graphomotor skills, and handwriting legibility across the three measurement points performing a repeated-measures ANOVA in R (Version 4.4.1; R Core Team, 2024) with the Ime4 package (Bates et al., 2015). We also calculated correlations among all variables. The next step focused on the longitudinal relations between the graphomotor self-concept and graphomotor skills and their relevance in developing handwriting legibility. Following the methodological approaches of previous studies on the REM (e.g., Arens et al., 2016), we used a cross-lagged structural equation model over three measurements. The graphomotor self-concept was defined as a latent variable using all five items of the questionnaire for assessing the graphomotor self-concept. The graphomotor skills were represented as a latent variable based on the fundamental and complex forms. Handwriting legibility was determined as a latent variable using the legibility ratings of the six selected words. Cross-lagged structural equation models estimate cross-lagged paths that map reciprocal relations between variables across multiple time points (Kleinke et al., 2017). In addition, cross-lagged structural equation models include the cross-sectional relation between variables and autoregressive paths, which capture the stability of each variable over time. This modeling approach offers the advantage of accounting for prior achievement, thereby enhancing causal inference in longitudinal designs (Shadish et al., 2002). We used MPlus (Version 8.11; Muthén & Muthén, 2024) with a robust maximum likelihood estimator (MLR). The advantage of this procedure is that it is robust to non-normally distributed data (Kleinke et al., 2017), as was the case with the analyzed data. Violation of the normal distribution was moderate, as shown by the skewness and kurtosis presented in Table 1. In addition, the children's age, gender, and socioeconomic background (modelled as latent variables containing the mother's and father's ISEI scores) were controlled. The criteria for good model fit were defined by the comparative fit index (CFI $>.90$), the Tucker-Lewis index (TLI $>.90$), the root mean square error of approximation (RMSEA $\leq.06$) including its confidence interval, and the standardized root mean square residual (SRMR $\leq.08$) (Kline, 2015). In addition, the chi-square test was calculated ($\chi 2$). Data were examined for outliers using Mahalanobis distance. We identified two students in the study sample as multivariate outliers and excluded them from the analysis. Missing data, ranging from 2 % to 9 % across measurement points, were handled using full maximum likelihood estimation (FIML), which provides more efficient and less biased results compared to other methods, such as listwise deletion or mean estimation (Graham, 2009).

3. Results

3.1. Descriptive results and correlations

To obtain an overview of the development of the graphomotor self-concept, graphomotor skills, and handwriting legibility, we performed a repeated-measures ANOVA across the three measurement points. The investigation of the mean differences across measurement times showed

Table 1
Sample sizes (n), Means (M), Standard Deviations (SD), minimum (min), maximum (max), skewness and kurtosis for all analyses variables.

	n	*M*	*SD*	min	max	skewness	kurtosis
Graphomotor self-concept T1	334	2.086	.71	.00	3.00	−.69	−.24
Graphomotor self-concept T2	337	2.35	.70	.00	3.00	−1.27	.90
Graphomotor self-concept T3	344	2.41	.56	.00	3.00	−1.30	1.64
Graphomotor skills T1							
fundamental shapes	345	.56	.17	.15	.96	−.02	−.60
complex shapes	345	.14	.13	.00	.71	1.20	1.30
Graphomotor skills T2							
fundamental shapes	351	.66	.13	.13	1.00	−.24	.24
complex shapes	350	.26	.17	.00	.83	.61	−.23
Graphomotor skills T3							
fundamental shapes	344	.69	.14	.25	.98	−.65	.07
complex shapes	344	.26	.17	.00	.79	.72	.01
Handwriting legibility T1	328	.86	.09	.47	1.00	−1.05	1.44
Handwriting legibility T2	342	.89	.08	.61	1.00	−.89	.66
Handwriting legibility T3	337	.91	.07	.60	1.00	−1.27	1.62

Note. The ranges of values: graphomotor self-concept (0–3); graphomotor skills (0–1); handwriting legibility (0–1).

significant changes for all measures over time. A significant improvement was found for the graphomotor self-concept between the first and third measurement points ($F(1,301) = 49.054$, $p < .001$, $\eta_p^2 = .140$). Post-hoc analyses using the Bonferroni test showed significant changes between the first and second time points ($p < .001$). No significant difference was observed between the second and third time points ($p = .196$). Graphomotor skills also improved significantly over time ($F(2,642) = 139.933$, $p < .001$, $\eta_p^2 = .304$). Post-hoc analyses showed that graphomotor skills improved significantly between the first and second time points ($p < .001$) and the second and third time points ($p = .034$). Handwriting legibility also showed significant improvements over the three measurement points ($F(1,295) = 81.421$, $p < .001$, $\eta_p^2 = .216$). Post hoc analyses revealed significant improvements between the first and second measurement points ($p < .001$) and the second and third measurement points ($p < .001$). Table 1 presents the descriptive statistics for the full sample. To obtain an overview of the relations among all the included variables, we calculated the correlations between the control, predictor, and outcome variables (see Table 2).

3.2. Relations between the graphomotor self-concept, graphomotor skills, and legibility

To investigate the longitudinal relations between the graphomotor self-concept and graphomotor skills, and their significance in the development of handwriting legibility, we calculated a cross-lagged structural equation model, controlling for age, gender, and socioeconomic background. Fig. 1 illustrates the significant paths in the cross-lagged structural equation model. The fit indices showed good model fit ($\chi 2 = 23.826$, $df = 807$, $p < 0.001$; CFI = 0.925; TLI = 0.916; RMSEA = 0.031 [90 %-CI: 0.026–0.035]; SRMR = 0.051). The factor loadings for all items were significant ($p < .001$) and well-defined (between .5 and .7), except for item 2 for the graphomotor self-concept at T1 ($p = .39$; see Table 3).

In the model (see Fig. 1), the horizontal arrows (autoregressive paths) represent stability over time. The results showed significant stability estimates for the graphomotor self-concept, graphomotor skills, and handwriting legibility (Table 4). Crucially, the stability coefficients for the graphomotor self-concept increased over time (T1–T2: $\beta = .29$; T2–T3: $\beta = .53$). The curved double-sided arrows represent the cross-sectional relations. The results showed a significant correlation between graphomotor skills and handwriting legibility at all measurement points (T1: $r = .52$; T2: $r = .44$; T3: $r = .34$). There was no correlation between the other latent variables. The diagonal arrows represent the cross-lagged paths between the variables. The graphomotor self-concept at T2 significantly predicted graphomotor skills at T3 ($\beta = .25$). In addition, graphomotor skills were found to predict handwriting legibility (T1–T2: $\beta = .24$; T2–T3: $\beta = .25$). Prior graphomotor self-concept did not demonstrate any associations with later handwriting legibility (see Fig. 1 and Table 4).

4. Discussion

The present longitudinal study aimed to gain a deeper understanding of the interplay between graphomotor self-concept, graphomotor skills, and handwriting legibility over a period of 18 months, from the beginning of first grade to mid-second grade. Using a longitudinal design with three measurement points, the reciprocal longitudinal relations between graphomotor self-concept, graphomotor skills, and handwriting legibility were analyzed through a cross-lagged structural equation model, controlling for age, gender, and socioeconomic status. The results showed that, at the beginning of first grade, graphomotor self-concept and graphomotor skills developed largely independently. However, in the transition from first to second grade, graphomotor self-concept was statistically significantly associated with later graphomotor skills, although the effect size was small. Similarly, graphomotor skills had a statistically significant, yet modest, impact on later handwriting legibility, whereas graphomotor self-concept did not directly affect handwriting legibility. This study is the first longitudinal investigation to connect different developmental stages of early handwriting acquisition with early beliefs about one's own skills (self-concept). The focus was on early school age, a key developmental period in which both domain-specific self-concepts and handwriting are formed.

4.1. Developmental changes in graphomotor self-concept, graphomotor skills, and handwriting legibility

The results of the repeated measures ANOVA showed a general improvement in graphomotor self-concept, graphomotor skills, and handwriting legibility over the entire study period. These findings underscore the importance of early school age as a phase of intensive and dynamic development. The increase in graphomotor skills and handwriting legibility aligns with previous studies that have demonstrated improvements in these areas during the early years of schooling (e.g., Truxius et al., 2025). The observed increase in graphomotor self-concept can be interpreted in at least two ways. On the one hand, it is consistent with the assumption that academic self-concept is initially overly positive at the beginning of school (Dapp & Roebers, 2018). On the other hand, it contradicts findings indicating a decline in self-concept during the early school years (Harter, 2015). According to Harter (2015), young children initially have an exaggeratedly positive self-concept, which begins to decline with school entry as their self-perceptions become increasingly realistic. In contrast to these findings, longitudinal studies have shown that this decline typically does not begin before the age of 8–10 years (Dapp & Roebers, 2018; Weidinger et al., 2018). In summary,

Table 2
Pearson correlations among all variables.

	1	2	3	4	5	6	7	8	9	10	11
1 Age	–										
2 Gender	.168**	–									
3 Ses	−.010	.007	–								
4 Grsc T1 [a]	.053	.005	−.001	–							
5 Grsc T2 [a]	.003	.055	.034	.264**	–						
6 Grsc T3 [a]	.029	−.049	.050	.323**	.449**	–					
7 Graph T1	−.007	−.272**	.095	.028	.007	.127*	–				
8 Graph T2	−.006	−.274**	−.016	.058	−.068	.015	.492**	–			
9 Graph T3	−.073	−.263**	.172**	.029	.099	.111*	.310**	.449*	–		
10 Leg T1	−.069	−.118*	.142*	.039	.015	.093	.411**	.332**	.284**	–	
11 Leg T2	−.005	−.193**	.019	.085	.044	.115*	.346**	.419**	.303**	.376**	–
12 Leg T3	−.129*	−.378**	−.041	.177**	.026	.155**	.369**	.387**	.412**	.352**	.513**

Note.
Grsc = Graphomotor self-concept; Graph = Graphomotor skills; Leg = Handwriting legibility; Ses = Socioeconomic background.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.
[a] Spearman correlations.

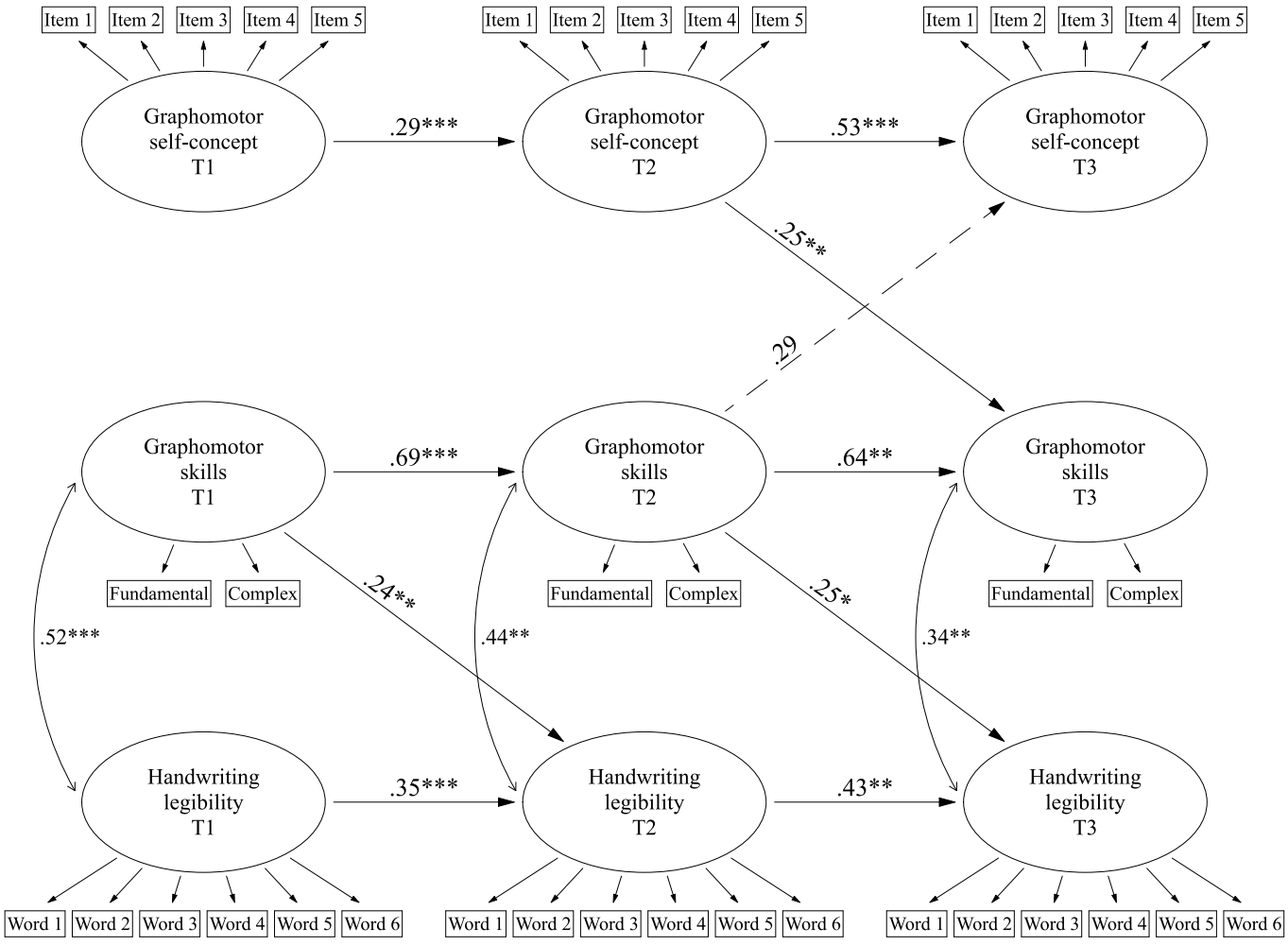


Fig. 1. Cross-lagged structural model showing the longitudinal relations between the graphomotor self-concept, graphomotor skills, and handwriting legibility across three measurement points from the first grade to the second grade. *Note.* Standardized path coefficients (straight lines) and cross-sectional relations (curved lines) are displayed. All full lines indicate significant relations (*$p < .05$, **$p < .01$, ***$p <. 001$); the dashed line indicates a trend ($p < .1$). For the sake of clarity, the indicators of the latent variables (i.e., the manifest variables) and error variances are not shown.

while a decline in academic self-concept is well-established in the research literature, its onset varies across studies. The present study examined children aged 7 to 8, corresponding to first and second grade in Switzerland. Within this time frame, no decline in academic self-concept was observed.

Several explanatory approaches may account for this development: *First*, the observed increase in graphomotor self-concept may be attributed to improvements in skills. First-grade children spend an estimated 30 %–60 % of their school time engaged in fine motor activities, with writing and graphomotor tasks playing a central role (Caramia et al., 2020). The extensive amount of practice and associated learning gains likely contributed significantly to the strengthening of graphomotor self-concept. *Second*, school-related organizational conditions might have also played a role in the positive development of graphomotor self-concept. In the Swiss education system, children do not receive summative feedback in the form of grades until midway through second grade. In the initial phase of schooling, qualitative feedback is predominant and typically emphasizes individual progress (Arens et al., 2016). These positive evaluations by teachers can foster the development of positive self-concept (Dapp & Roebers, 2018).

Furthermore, the cross-lagged structural equation model showed high levels of stability for all constructs examined (graphomotor self-concept, graphomotor skills, and handwriting legibility). This stability was reflected in strong autoregressive paths, indicating that each construct was highly predictive of its own future values. For instance, graphomotor skills emerged as the strongest predictors of their own subsequent development. Particularly noteworthy is the marked increase in the stability of graphomotor self-concept from the end of first grade to mid-second grade. Children who showed high confidence in their graphomotor abilities at the end of first grade generally maintained this confidence by mid-second grade. This finding is consistent with previous studies highlighting developmental changes in academic self-concept (e.g., Marsh et al., 2015). As cognitive maturation progresses, children in early school age increasingly engage in social comparison processes, which contribute to the stabilization of self-concept (Harter, 2015). This result suggests that individual differences in graphomotor self-concept solidify early. It further implies that interventions aimed at strengthening graphomotor self-concept should be implemented as early as possible, as the stability of a construct limits the extent to which it can be changed through external influences, such as interventions (Adachi & Willoughby, 2015).

4.2. *The role of graphomotor self-concept for subsequent graphomotor skills*

The longitudinal relation between graphomotor self-concept and graphomotor skills showed that both constructs initially developed independently during the first year of school. A unidirectional

Table 3
Standardized factor loadings of the manifest variables.

	Measurement point		
	T1 λ	T2 λ	T3 λ
Graphomotor skills			
fundamental shapes	.77	.60	.62
complex shapes	.65	.61	.74
Graphomotor self-concept			
Item 1	.65	.70	.61
Item 2	.39	.69	.63
Item 3	.73	.74	.70
Item 4	.74	.79	.73
Item 5	.55	.68	.63
Handwriting legibility			
Word 1 [a]	.71	.48	.53
Word 2 [b]	.58	.61	.65
Word 3 [c]	.77	.53	.62
Word 4 [d]	.57	.53	.46
Word 5 [e]	.71	.70	.77
Word 6 [f]	.45	.57	.57

Note. The fundamental shapes are circle, arc downwards, arc upwards, cross, square, triangle; The complex shapes are rhombus, double loop, horizontal eight, drop.
For all $p \leq .001$.
[a] Ameise [ant].
[b] Lineal [ruler].
[c] Rakete [rocket].
[d] Tomate [tomato].
[e] Badehose [swimsuit].
[f] Krokodil [crocodile].

longitudinal effect emerged between the end of first grade and mid-second grade: a higher graphomotor self-concept at the end of first grade predicted better graphomotor skills in mid-second grade. This finding supports the self-enhancement model, which posits that academic self-concepts serve as motivational resources and positively influence future academic achievement (Marsh & Craven, 2006). This change in the interaction between graphomotor self-concept and graphomotor skills is consistent with previous longitudinal studies showing that the association between academic self-concept and academic achievement tends to emerge over time (Chen et al., 2013; Skaalvik & Valås, 1999; Weidinger et al., 2018). In line with our hypothesis, these findings highlight the importance of graphomotor self-concept in early handwriting acquisition. However, contrary to expectations, no reciprocal relations were found. While graphomotor self-concept predicted later graphomotor skills, the reverse — an effect of graphomotor skills on later self-concept — was not statistically

Table 4
Standardized path coefficients.

	β	SE	*p*
Graphomotor self-concept T1 → Graphomotor skills T2	.109	.090	.227
Graphomotor self-concept T2 → Graphomotor skills T3	**.258**	**.080**	**.001**
Graphomotor self-concept T1 → Handwriting Legibility T2	.071	.075	.346
Graphomotor self-concept T2 → Handwriting Legibility T3	.051	.061	.403
Graphomotor skills T1 → Graphomotor self-concept T2	−.098	.122	.422
Graphomotor skills T2→ Graphomotor self-concept T3	.296	.172	.086
Graphomotor skills T1→ Handwriting Legibility T2	**.248**	**.081**	**.002**
Graphomotor skills T2→ Handwriting Legibility T3	**.256**	**.122**	**.037**
Handwriting Legibility T1→ Graphomotor self-concept T2	.025	.099	.800
Handwriting Legibility T2→ Graphomotor self-concept T3	−.058	.156	.709
Handwriting Legibility T1→ Graphomotor skills T2	.139	.112	.214
Handwriting Legibility T2→ Graphomotor skills T3	.009	.142	.947

Note. Significant paths in bold ($p < .05$).

significant. This finding initially aligns with meta-analyses suggesting that reciprocal relations between academic self-concept and academic achievement typically emerge only from around the age of nine, a point at which children are capable of realistically assessing their abilities (Marsh & Martin, 2011; Valentine et al., 2004). As the sample in this study consisted of younger children, the absence of a significant reciprocal path may be attributable to developmental factors.

At the same time, a statistical trend toward a reciprocal relation was observed (see dashed line in Fig. 1). The effect of graphomotor skills on later graphomotor self-concept in the transition from first to second grade was just below the threshold for significance and can be interpreted as a statistical trend. This statistical trend may indicate the beginning of a shift toward a reciprocal relation — an emerging process that begins to develop at this age but is not yet fully established. Two factors might have limited the statistical detectability of this reciprocal effect: *First*, graphomotor self-concept showed increasing stability toward the end of the school year. While a stable self-concept is considered a prerequisite for influencing future achievement (Arens et al., 2016), high autoregression or stability reduces the likelihood of detecting significant cross-lagged paths (Guay et al., 2003). It is therefore plausible that the potential influence of graphomotor skills on graphomotor self-concept was masked by this high stability (e.g., Chen et al., 2013). *Second*, the relatively long intervals between measurement points might have contributed to the fact that short-term changes in the interaction between graphomotor self-concept and graphomotor skills were not adequately captured. Previous studies with shorter time intervals between measurements (e.g., Weidinger et al., 2018) suggest that long intervals may obscure developmental changes in the relations between academic self-concept and academic achievement. Although meta-analyses involving older students did not find a moderating effect of time interval (Huang, 2011; Valentine et al., 2004), shorter intervals may be particularly important in elementary school age, when academic self-concept is still forming, to capture developmental trajectories more precisely. In light of these findings, it is crucial that future studies track the development of academic self-concept and academic achievement from the beginning of schooling until at least the end of third grade, ideally with multiple measurement points per school year, to accurately map nuanced developmental progressions.

4.3. The importance of graphomotor self-concept and graphomotor skills for handwriting legibility

As hypothesized, graphomotor skills at the beginning of first grade proved to be a significant predictor of later handwriting legibility. This result aligns with numerous studies in writing research that emphasize the central role of graphomotor skills in the development of legible handwriting (e.g., Downing & Caravolas, 2023; Duiser et al., 2014; Van Hartingsveldt et al., 2014). In contrast, no significant relations were found between graphomotor self-concept and later handwriting legibility. This finding also aligns with our expectations and can be explained by the domain specificity of academic self-concepts: self-assessments tend to have predictive value only when they are closely related in content to the achievement outcome (Möller et al., 2009). In the present study, the items used to assess graphomotor self-concept primarily referred to the subjective perception of reproducing letter sequences, but not to qualitative aspects such as precision or legibility. These differences between the self-concept measure and the evaluated achievement criterion (legibility) may thus explain the absence of a relation.

4.4. Limitations and future directions

Finally, some limitations need to be considered. *First*, we assessed children's graphomotor self-concept to investigate how early motivational beliefs affect children's engagement in a graphomotor task and later achievement. Even though self-concept represents an important

motivational belief for early learning other motivational beliefs might be involved as well. Future studies might investigate the importance of interest and attitude. Given the demonstrated importance of graphomotor self-concept for the development of graphomotor skills, it seems particularly relevant for future research to develop targeted pedagogical interventions aimed at promoting graphomotor self-concept in early school age and systematically evaluate their effectiveness (O'Mara et al., 2006). *Second*, it should be noted that Item 2 on the graphomotor self-concept questionnaire behaved differently from Items 1, 3, 4, and 5 at the beginning of first grade, showing lower factor values. This item, "My hand almost writes letters by itself", assesses the extent to which children are able to reproduce letter sequences in an automated way. As only 75 % of the children in the sample had German as their first language, the phrasing of this item possibly posed a challenge for some children at the beginning of first grade. This hypothesis is supported by the fact that Item 2 behaved more coherently with the other items from the end of first grade onward, likely indicating an improvement in language comprehension over time. *Third*, the study focused exclusively on handwriting legibility, without considering fluency. To obtain a complete picture of handwriting, future studies should examine both legibility and fluency. Moreover, the generalizability of the present findings should be tested through replication studies using samples from other educational systems and cultural contexts.

4.5. Practical implications

The present findings highlight key points for educational practice. The observed increase in the stability of graphomotor self-concept in this study supports the assumption that motivational beliefs about one's own abilities develop early. The educational implication is that proactive measures to support positive, and to counteract negative developments in graphomotor self-concept should be initiated at the earliest opportunity.

The results concerning the longitudinal relations between graphomotor self-concept and graphomotor skills demonstrate that handwriting instruction should address both the development of graphomotor skills and the strengthening of graphomotor self-concept simultaneously. This can be achieved through a motivating approach to handwriting acquisition that includes constructive feedback and individual praise (Craven et al., 2003), self-directed learning experiences, and opportunities for students to actively shape their learning process (Sägesser Wyss et al., 2021). Reflection phases, whether through self-reflection or in dialogue with peers and teachers, should also be an integral part of instruction (Marsh & Craven, 2006).

Furthermore, the findings of the present study are particularly relevant considering the importance of handwriting legibility for further academic learning. For example, this is evident, in relation to the presentation effect. Numerous studies have shown that identical content is rated significantly lower when presented illegibly (for an overview, see Graham et al., 2011). It can therefore be assumed that an early focus on graphomotor skills — through a varied and engaging range of practice opportunities — has a positive effect on legibility, which in turn forms a key foundation for long-term academic success.

5. Conclusion

This longitudinal study highlights the relevance of graphomotor self-concept for the development of graphomotor skills. For the first time, longitudinal evidence suggests that reciprocal relations between graphomotor self-concept and graphomotor skills may begin to emerge during the transition from first to second grade — earlier than previously assumed. In addition, the study confirms the central importance of graphomotor skills for handwriting legibility. Overall, the findings indicate that targeted educational interventions aimed at promoting both graphomotor skills and positive graphomotor self-concept during the school entry phase might be promising for supporting writing competence and, which in turn, may contribute to long-term academic success.

CRediT authorship contribution statement

Joséphine Schwery Klingele: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Martin Vetter:** Writing – review & editing, Supervision. **Lidia Truxius:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michelle N. Maurer:** Methodology, Writing – review & editing, Visualization, Supervision. **Judith Sägesser Wyss:** Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition. **Michael Eckhart:** Writing – review & editing, Visualization, Resources, Funding acquisition.

Acknowledgments

This work was supported by the Swiss National Science Foundation (SNSF) [grant number 189187].

Data availability

Data will be made available on request.

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