Passive and Active Components of Working Memory and Transcription Skills among First-Graders

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Passive and Active Components of Working Memory and Transcription Skills among First-Graders

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Abstract

Transcription skills allow us to put spoken language into written text, and they entail handwriting processes and spelling knowledge. Handwriting and spelling are supported by different processes, but they are highly related. Additionally, both are directly supported by working memory (WM). The present study aims to examine how differently passive and active components of WM affect transcription (handwriting and spelling) among Italian beginner writers. We evaluated 395 Italian first-grade children (197 boys and 198 girls) with an average age of 6 years and 6 months (*SD* = 4.3 months) with five writing tasks (three handwriting tasks and two spelling tasks) and two WM tasks (passive components = span task; active components = selective span task). We computed a SEM analysis to investigate how differently the passive and active WM components affect the two spelling tasks both directly and *via* handwriting. Passive and active WM components directly affect handwriting; while spelling is directly affected by the active WM, and indirectly (*via* handwriting) by both WM components. These results confirmed the crucial role of handwriting in predicting spelling accuracy. In conclusion, current results show that the distinction between passive and active WM components is useful to understand how WM supports transcription processes.

KEYWORDS

Handwriting; primary school; spelling; transcription skills; working memory

Introduction

Writing is a complex ability that includes several processes. According to Hayes & Flower (1980) “writing consists of three major processes: planning, translating and reviewing” (see also Cornoldi et al., 2010). According to the model, the translating encompasses all the processes involved in converting heard or thought words into their written form. The automatization of transcription is the first step toward the development of expressive writing abilities. Transcription implies both handwriting processes and spelling knowledge (Abbott & Berninger, 1993; Berninger, 1999; Cornoldi, 2023). More recent models, such as the Not-So-Simple View of Writing (Berninger & Winn, 2006; Hayes & Berninger, 2014) and the Direct and Indirect Effects model of writing (Kim & Schatschneider, 2017), confirmed that transcription contribute to promote writing skills along with other cognitive processes: working memory, attention, planning, inhibitory control. In particular, literature (e.g., Hoskyn & Swanson, 2003; Swanson & Berninger, 1994, 1996) have demonstrated the huge involvement of working memory. However, the relationship between working memory and the two sub-processes of transcription (handwriting and spelling) is still little studied, and it needs further investigation and clarification.

The handwriting can be defined as all those subprocesses that allow children to produce a single or a sequence of graphemes, and its development requires time and practice (Cornoldi, 2023; Pontart et al., 2013). To write a single grapheme, the children had indeed to recall: i) the characteristics of the grapheme according to the specific font (e.g., block letters or cursive) through an allographic system; ii) the graphomotor pattern needed for the execution of the grapheme; iii) the executive parameters that grant the correct production of the grapheme (Cornoldi, 2023). Palmis et al. (2017) suggest that the automatization of handwriting skills in children is reached mainly at 10 years of age, since series of cinematic parameters change between 7 and 10 years of age.

Spelling can be defined as the ensemble of subprocesses employed by the writer to encode a heard or thought word and to convert it into a written form following the propter rules of a specific language; therefore, it involves the ability to recall, to recognize, and to mentally represent words (Coltheart et al., 1993; Cornoldi et al., 2010). According to the classic dual-route model, spelling depends on at least two different processes: the lexical and the sublexical processes (Coltheart et al., 1993). The first process permits to write the word by accessing directly to the word-specific section of long-term memory (Barry, 1994; Notarnicola et al., 2012); while the use of the sublexical route follows the phonological-to-graphemic conversion rules (Notarnicola et al., 2012; Patterson, 1986). Both processes are present in the early stages of spelling development, but their improvement follows different paths depending on language characteristics (Cornoldi, 2023; Notarnicola et al., 2012). For example, in the context of Italian language, the lexical process develops slowly and steady between 1^{st}-8^{th} grade, while the sublexical one grows quickly and reaches its highest efficiency between 3^{rd}-4^{th} grade (Notarnicola et al., 2012). In Italian, as in other transparent languages (such as German), the orthographic transparency is mostly granted for grapheme-to-phoneme correspondence (relevant in reading), but it is not always true in case of phoneme-to-grapheme transformation (relevant in writing). For example, in the Italian language, the grapheme “q” corresponds to the specific phoneme/k/, but the phoneme/k/could be transcribed into two different graphemes such as “c” or “q” (e.g., cuoio/kwjo/[leather] or quale/kwale/[which]). Whereas, in other case the two graphemes correspond to two separated phonemes (e.g., cesto/tʃesta/[basket] or quale/kwale/[which]). This peculiarity is due to the fact that the grapheme “c” corresponds to the phoneme/k/when it is followed by “a”, “o”, and “u”, and the phoneme/tʃ/when it is followed by “e”, “i”. So, it is easy to understand why the acquisition of transcription skills in Italian can be slower and harder than learning to read.

The relationship between handwriting and spelling has been extensively studied (Pontart et al., 2013; Roux et al., 2013). Although distinguishable, they are highly related: for example, handwriting is also affected by lexical and sublexical processes (Roux et al., 2013). On the other hand, the quality of handwriting improves with an improvement in spelling ability (Pontart et al., 2013). Additionally, in accordance with McCutchen (1996, 2000), it is possible to affirm that handwriting skills modulate and affect spelling, too. For example, the recent longitudinal study by Pritchard et al. (2021) identified handwriting skill as a specific and independent predictor of spelling ability.

The role of working memory in transcription skills

Working memory (WM) is a limited-capacity system which enables us to store and manipulate different types of information (both verbal and visuo-spatial) for a limited amount of time. The relationship between WM and writing, has been proved among children with typical (e.g., Rocha et al., 2022; Swanson & Berninger, 1994, 1996) and with atypical development (e.g., Graham et al., 2016; Re et al., 2014). However, the relationship between WM and the two sub-processes of transcription (handwriting and spelling) is less explored.

There is some evidence regarding the role of WM in the transcription process: WM has been shown to directly hold up both handwriting and spelling skills (Berninger et al., 2010). More precisely, WM correlates with the recall of graphomotor patterns and the simultaneous access to orthographic knowledge (De Vita et al., 2021; Hoskyn & Swanson, 2003; Peverly, 2006). Chenoweth & Hayes (2003) proved that burdening on the WM *via* an articulatory suppression task (i.e., asking the person to repeat a syllable endlessly during a writing task) affected transcription performance in adult writers; in other words, they demonstrated the importance of WM in transcription processes. These findings, suggest that WM could be involved somehow in the efficacy of the two transcription subprocesses (handwriting and spelling). Similar results were found by other authors (e.g. Service & Turpeinen, 2001) Furthermore, WM ensures the maintenance of the phonological representation of words, linguistic strings, and orthographic rules from long-term memory (McCutchen, 2000). Nevertheless, the relationship between WM and transcription, during early stages of writing skills acquisition, still requires further examination.

In beginner writers, most of the WM resources are used in recalling graphomotor patterns and orthographic rules because writing processes are still not automatized:, some authors suggest that a good automatization of handwriting and spelling skills reduces the involvement of WM resources (Berninger, 1999; McCutchen, 2000; Re et al., 2008; Re & Cornoldi, 2010). Other observed that until handwriting skills are not fully automatized, working memory resources have to be allocated between handwriting and spelling skills (Graham et al., 1997; McCutchen, 1996; Pontart et al., 2013).

Different WM processes can however support writing skills development. For example, Swanson & Berninger (1996) reported that translating abilities (i.e. written expression) are predicted by tasks involving maintenance and processing of verbal information (WM tasks), whereas transcription skills are predicted by short-term memory tasks (involving only maintenance) in children between 10 and 13 years of age. These results can be interpreted according to the WM model by Cornoldi & Vecchi (2000, 2003). Within this model, WM can be defined by two different dimensions: the horizontal and the vertical continuum. The first one, discriminates the different type of material (verbal vs. visual vs. spatial). Whereas the vertical continuum, identifies the different amount of attentional control needed. Thus, the authors affirmed that it is possible to distinguish between passive and active WM tasks. The passive ones require to simply recall an information previously presented, as, for example, the short-term memory span tasks. The active processing tasks, instead, entail storage and manipulation—modify, integrate, or update—of the information, as the complex WM span tasks. The distinction between these two components has been shown to be useful in understanding individual (e.g., Carretti et al., 2009; Lanfranchi et al., 2009) and age differences (Carretti et al., 2022). For what concerns writing abilities, it is possible to hypothesize that passive and active WM components could differently affect transcription skills in beginner writers, considering that they are still acquiring to automatize both handwriting and spelling. In the early grades of primary school, many of the actions children take when writing demand conscious attention and, therefore, effortful processes. Active working memory resources may be more involved in transcription skills at this stage compared to older children.

The present study

On the basis of the literature, we aimed to extend previous studies investigating the role of passive and active components of WM on transcription abilities (handwriting and spelling) in beginner Italian writers. More precisely, we explored how differently passive and active components of WM directly affect handwriting skills, and how they directly and indirectly (*via* handwringing) affect children's performance in two different spelling tasks (a text dictation task and a picture-to-word writing task).

We expected, in line with Cornoldi & Vecchi (2003) model, that the passive components of WM will affect mainly the handwriting task, since the performance in these tasks is related to specific domain competence (the handwriting skills). Meanwhile, we hypothesize that active WM components will have an impact mainly on spelling tasks, as the student's performance in these two tasks depends on the integration of two different specific domain skills (handwriting and spelling skills).

Materials and method

Participants

Three hundred and ninety-eight first-graders were recruited for this study. Three children were not tested with the full battery of the tests because the teacher reported an intellectual disability. Therefore, the final sample included 395 students in the first grade (197 boys, 198 girls) with an average age of 80.22 months − 6 years and 6 months – (*SD* = 4.3 months; range 72–90 months). Thanks to the collaboration between two authors and some trained research assistants, 19 primary schools from different Italian regions were involved (17.72% North Italy, 40.51 Center Italy; 41.77% South Italy). Firstly, the schools were informed about the research project *via* a direct meeting with the school principal. After obtaining the principals' authorizations we asked the students' parents to sign an informant consent. This was delivered to each family thanks to the cooperation with the students' teachers. In addition to the informed consent form, the parents received a letter that explained the main purpose of the research project and explained that all data would be collected collectively in order to preserve their anonymity. At the end of the assessment and the data analysis, each school received a brief report in which the main results of the analysis were reported and easily explained.

Materials

Handwriting tasks

Handwriting abilities were evaluated using three standardized tasks included in an Italian standardized battery (Cornoldi et al., 2022). The tasks are designed to assess the child's handwriting fluency: Children are asked to write the highest number of graphemes possible throughout a limited time (one minute). In the first task, students are asked to write the graphemes ‘l’ and ‘e’ in italics, one after the other, without breaks. In the second and third tasks, participants were asked, respectively, to write the word “uno” (“one”) repeatedly and to write consecutive numbers in letters (i.e., one, two, three…). In the latter two tasks, the children were free to choose the font they preferred (block letters or cursive). The first and second tasks purely assess student fluency, while the third measures student integration between handwriting and orthographic skills (Cornoldi et al., 2022). For each task, the dependent variable was the number of graphemes correctly written by the child. It should be noted that in the first task (‘le’), we counted as valid only the couple of graphemes where the two letters were clearly distinguishable: for example, if the children wrote ‘leelelelelle’, we reported 10 graphemes, so those graphemes that did not respect the assignment were excluded. Meanwhile, in the case of the two other tasks (“one” and numbers in letters), we counted the word (“uno” or the word-number) even when they were misspelled. In these tasks, we reported the exact number of graphemes, including the wrong or additional graphemes. For example, “diciasette” (10 graphemes, incorrect) rather than “diciassette” [seventeen] (11 graphemes, correct); or “uni” (3 graphemes, incorrect) rather than “uno” [one] (3 graphemes, correct). Moreover, if children forgot a whole word or word-number, we did not include those missing graphemes in the total score. The test-retest reliability, reported in the manual (Cornoldi et al., 2022) is r = .77, r =.73, and r = .73 for “le”, “one”, and “numbers in letters”, respectively.

Dictation task

The present task is included in the standardized Italian battery for the assessment of writing competence (Cornoldi et al., 2022) and consists of correctly writing a short text under dictation. The type of text varies with the grade level to reflect the typical texts that children are exposed to. The text for first-graders is composed of 51 words (252 graphemes), among which 4 are low-frequency words (8%) and 29 are complex words (41%). The complex words were the following: 5 words spelt regularly and with complex digraphs or trigraphs (e.g., “sci-”, or “gli-”); 8 words that contain double consonants or accents (e.g., “allora” [then] or ‘è’ [is]); 8 words with a spelling exception, such as words with an apostrophe (e.g., “l’aiuto” [the help]) or words that are homophones but not homographs (e.g., “ha” [has] and ‘a’ a simple preposition that are pronounced similarly in Italian). The dependent variable was the number of errors. The test-retest reliability for this task is *r* =.81.

Picture-to-word writing task

This task assesses the orthographic skills of beginner writers without dictation bias. When people are asked to write under dictation, their performance depends on several variables such as their orthographic competence and the examiner’s pronunciation (Cornoldi et al., 2022). Therefore, in the standardized Italian battery for the assessment of writing (Cornoldi et al., 2022) the dictation tasks are supported by other spelling tasks. For first-graders, the battery recommends this task. It consists of 27 black-and-white pictures of familiar objects (such as “casa” [home] or “martello” [hammer]) or animals (such as “cane” [dog] or “scoiattolo” [squirrel]). The child is asked to correctly write the name of the item pictured. The dependent variable in this task was the percentage of errors calculated considering the number of words written incorrectly and the number of words valid. The children’s answer could be identified as unacceptable if they do not write anything or if they write the wrong name (such as “belt” rather than “scarf”). The test-retest reliability is *r* =.54.

Passive working memory task

A forward word span task (taken from Carretti et al., 2022) was used to assess the passive component of WM. The child is required to remember eight lists of disyllabic regular and familiar words and write them correctly and in the right order. The length of the lists gradually increased from two to five words. The final score was obtained by summing, for each list, the number of words accurately written in the correct order of presentation (Max score 28). McDonald’s omega reliability, calculated in the current sample, is .81. According to the Cornoldi & Vecchi (2003) model, this could be defined as a passive WM task, since the child is asked to maintain verbal information.

Active working memory task

To assess active WM processes, the selective span task taken from Carretti et al. (2022) was administered. The task consists of eight trials during which children heard one or two lists of words (the length of each list increased from 2 to 3 words) and were required to recall the last word of each list. Each list was mad of disyllabic regular and familiar words. In the first and second trials, only a single 2-word list was presented, and in the third and fourth trials a single 3-word list was presented, therefore, there was only one word to recall. In the fifth and sixth trials, two 2-word lists were presented, and in the seventh and eighth trials, two 3-word lists were presented; therefore, there were two words to recall for each trial. For a better explanation, we report the following two examples: In the third trial, the children heard ‘sole, casa, pera’ (“sun, home, pear”) and were required to write the last word, which is “pear”; in the last trial, they heard (a) ‘mamma, casa, palla’ (“mum, home, ball”) and (b) pera, gatto, papà’ (“pear, cat, dad”), and were required to write the last word of each list, ‘ball’ and ‘dad’. The final score was calculated by adding the number of words written in the correct order of presentation (spelling errors were not considered). McDonald’s omega reliability, calculated in the current sample, is .89. According to the Cornoldi & Vecchi (2003) model, this task could be defined as an active WM task since the child is asked to maintain and manipulate verbal information. To carry out the task, only the last word of each list must be kept in mind, and all distractor words have to be ignored.

Procedure

All tasks were administered the authors (FDV and AMR) with the help of some trained research assistants and the students were tested in two sessions (two weeks apart). During the first session, we assessed the writing tasks, and it lasted approximately 1 h, including two breaks of approximately 10 min. The second session, instead, lasted 20 min, during which we administered the two WM tasks. In some cases, we did not collect the second session because the children were absent that day. So, for these two tasks we have 40 missing data, and in a single case in which the child did not understand the assignment in the selective span task (so in this task we have 41 missing data). There are also some missing data in the writing tasks, since the tasks were not considered valid because the children did not respect the assignment (in the case of handwriting tasks), or they made many omissions (in the case of spelling tasks). Ethical approval for the study was obtained from the Bioethics Committee of the University of Turin.

Data analysis

We used RStudio (RStudio Team, 2023) and SPSS 28 to run the analyses. First, we calculated a correlational analysis (Pearson’s r) to explore the relationship between all the writing and WM tasks.

Second, we used a structural equation model (SEM) in order to test the direct effect of handwriting skills on the dictation and the picture-to-word writing tasks, and how differently the passive and active WM components affect the same tasks both directly and *via* handwriting skills. We tested a model that included the two WM measurements and a single latent factor, handwriting, since it has been demonstrated (e.g., Cornoldi et al., 2022; Re et al., 2023) that the following tasks 'le', 'one', and 'numbers in letters' are explained by the same latent factor. The model also included the two WM measures (span and in the selective span tasks) separately, as we aimed to identify the different roles of passive and active components of WM. The dependent variables were the number of errors in the dictation of text and the picture-to-word writing task, which both measures spelling abilities.

These analyses were performed using the lavaan package (Rosseel, 2012). We standardized all variables, and due to missing data, we used the Full Information Maximum Likehood (FILM) method to estimate the parameters. In addition, the overall goodness of fit of the model was evaluated following the cutoffs suggested by Jöreskog & Sörbom (1993): the chi-square (χ^2), the root mean square error of approximation (RMSEA < .08; Steiger & Lind, 1980), the standardized root mean square residual (SRMR < .10; Bentler, 1995), the comparative fit index (CFI > .95; Bentler, 1990), and the Non-Normed Fit Index (NNFI > .95; Bentler & Bonett, 1980).

Results

Correlations

Table 1 presents the descriptive statistics, while Table 2 reports the bivariate correlations between all variables. The findings showed: a significant correlation between the two WM tasks; a significant moderate correlation between the passive WM task and the three handwriting tasks ("le", "one" and numbers in letters); a significant moderate correlation between active WM and numbers-in-letters tasks; a significant negative correlation between passive WM and the two spelling tasks (dictation of text and picture-to-word writing) as well as between active WM and the two spelling tasks. Furthermore, the correlation analysis confirmed that writing tasks correlate among themselves; in particular, we observed a significant positive and moderate correlation between: "le" and "one"; "le" and numbers in letters; "one" and numbers in letters; dictation of text and picture-to-word writing tasks. In addition, there was a significant negative correlation between text dictation and all three handwriting tasks ("le", 'one' and numbers in letters), and the highest correlation value is between tasks dictation and numbers in letters. Finally, there was a significant negative correlation between picture-to-writing and number-in-letter tasks.

Table 1. Descriptive statistics (mean, standard deviation, skewness and kurtosis) of the handwriting, spelling, expressive writing and WM tasks.

	Mean	SD	Skewness	Kurtosis
Age	80.22	4.25	−0.12	2.23
"le"	43.01	17.84	0.77	4.76
"one"	43.95	15.93	−0.10	2.67
Numbers in letters	39.97	15.18	0.69	4.73
Picture-to-word writing task (% errors)	25.33	26.11	6.24	79.48
Dictation of text (nr of errors)	11.79	6.51	1.16	5.41
Span task	20.23	5.26	−1.03	4.19
Selective span task	8.75	3.36	−0.75	3.21

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Table 2. Correlations between handwriting tasks, spelling and vocabulary tasks and working memory tasks.

Tasks	1	2	3	4	5	6	7
1.“le”	1						
2.“one”	.35*	1					
3. Numbers in letters	.33*	.48*	1				
4. Dictation of text (nr of errors)	−0.12*	−0.15*	−0.42*	1			
5. Picture-to-word writing task (% errors)	−0.08	−0.10	−0.28*	.52*	1		
6. Span	.22*	.28*	.37*	−0.20*	−0.18*	1	
7. Selective span	.05	.07	.28*	−0.32*	−0.19*	.29*	1

Note. *$p < .001$.

Structural equation model

A structural equation model (SEM) was fitted to determine the direct and indirect effects of the passive and active components of WM on handwriting and spelling. We used a SEM analysis to investigate the relationships between handwriting, two spelling tasks (the text dictation and picture-to-word writing task), and passive and active components of WM.

Specifically, handwriting was regressed on passive and active WM components, while spelling was regressed on both WM components and handwriting. This enables us to estimate both the direct and the mediated effects (*via* handwriting) of working memory’s components on spelling. The adequacy of the fit of the model was judged not good according to the criteria suggested by Jöreskog & Sörbom (1993): $\chi^2(8) = 29.95$, $p < .001$, RMSEA =.083, SRMR <.10, CFI = .95, NNFI =.88. Therefore, we computed the modification index (MI) to inspect whether the inclusion of additional parameters could improve the fit of the model (Whittaker, 2012). The highest value was observed for the covariance between the tasks of ‘le’ and ‘one’ (MI = 16.05, EPC= 0.18). From a theoretical perspective, the performance in both tasks depends merely on handwriting skills (Cornoldi et al., 2022). We tested the adequacy of this second model, including the covariance between ‘le’ and ‘one’, and the fit was judged to be good according to the criteria suggested by Jöreskog & Sörbom (1993): $\chi^2(7) = 13.26$, $p = .066$, RMSEA <.08, SRMR < .10, CFI > .95, NNFI >.95.

The results show that both WM components have a direct effect on handwriting: the span task (*β*

=.32; p <.05) and the selective span task (β = .19; p <.05). The span task has no significant effect on both spelling tasks, while the selective span task has a direct effect on both text dictation (β = −0.21; p <.001) and the picture-to-word writing task (β = −0.11; p = .05). In addition, a significant effect of handwriting has been observed on text dictation (β = −0.37; p <.001) and on the picture-to-word writing task (β = −0.24; p < .001). Finally, the findings show an indirect effect of active WM on text dictation (β = −0.07; p <.05) and on the picture-to-word writing task (β = −0.05; p < .05), and of passive WM on text dictation (β = −0.12; p <.05) and the picture-to-word writing task (β = −0.08; p < .05).

All model parameters are illustrated in Table 3 and Figure 1. Finally, the R-squared values for all endogenous variables are presented in the model in Table 4.

Figure 1. Direct and indirect effects of active and passive WM tasks and handwriting model on a text dictation task and picture-to-word writing task.*Note.* *p ≤ .050; **p ≤ .001.

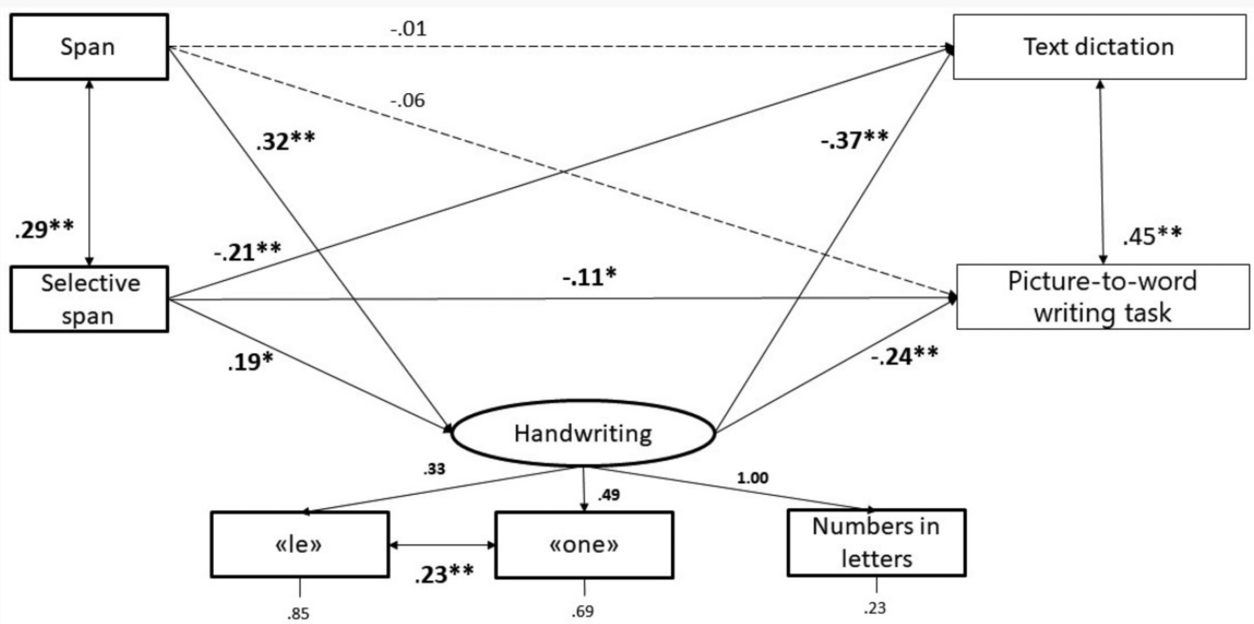

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Table 3. Estimated parameters of the structure equation model.

	Z	p	β	95% CI	SE
Latent loadings					
HW =~ “le”	6.10	<.001	.33	.22, .43	.05
HW =~ “one”	9.16	<.001	.49	.38, .59	.05
HW =~ Numbers in letters	13.29	<.001	1.00	.85, 1.14	.08
Direct effects					
HW ~ Span	5.24	.001	.32	.20, .44	.06
HW ~ Selective Span	3.73	.002	.19	.09, .30	.05
Dictation of text ~ Span	0.08	.940	.01	−0.11, .12	.06
Dictation of text ~ Selective Span	−4.01	<.001	−0.21	−0.31, −0.11	.05
Picture-to-word ~ Span	−0.96	.336	−0.06	−0.17, .06	.06
Picture-to-word ~ Selective span	−1.97	.049	- .11	−0.21, −0.00	.05
Dictation of text ~ HW	−6.04	<.001	−0.37	−0.50, −0.25	.06
Picture-to-word ~ HW	−4.19	<.001	−0.24	−0.36, −0.13	.06
Indirect effects					
Span ~ HW ~ Dictation of text	−3.37	.001	−0.12	−0.19, −0.05	.04
Selective span ~ HW ~ Dictation of text	−3.15	.002	−0.07	−0.12, −0.03	.02
Span ~ HW ~ Picture-to-word	−2.95	.003	−0.08	−0.13, −0.03	.03
Selective span ~ HW ~ Picture-to-word	−2.76	.006	−0.05	−0.08, −0.01	.02
Covariances					
Span ~ ~ Selective span	5.86	<.001	.05	.19,.38	.05
Dictation of text ~ ~ Picture-to-word	10.51	<.001	.45	.36,.53	.04
“le” ~ ~ “One”	4.40	<.001	.23	.13,.34	.05

Note. β: standardized beta coefficient; CI: 95% confidence intervals; SE: standard error; WM: Working Memory; Handwriting: HW; Picture-to-word: Picture-to-word writing task.

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Table 4. R^2 for all endogenous variables of the model.

	R-Square

“le”	.11
“one”	.24
Numbers in letters	.99
Dictation of text	.23
Picture-to-word	.10
Handwriting	.18

Note. Picture-to-word = Picture-to-word writing task.

Discussion

The present study investigates how passive and active components of WM contribute to handwriting and spelling skills in beginner writers. As reviewed in the introduction, there are studies suggesting that WM is differently involved in writing depending on the complexity of the task (e.g., Ferrara & Cornoldi, 2019; Kim & Schatschneider, 2017; Swanson & Berninger, 1996). However, the different contribution of WM has not been analyzed in relation to transcription skills, in particular in early writers.

Following previous studies on other school learning abilities (e.g. reading comprehension - Carretti et al., 2005- and problem solving - Passolunghi & Cornoldi, 2008), we used as framework the Cornoldi & Vecchi, (2000, 2003) WM to understand how passive and active WM components affect differently the development of transcription skills. To tackle this issue, we assessed a wide sample of Italian first-grade children with three handwriting tasks (“le”, ‘one’ and numbers in letters), two WM tasks (span and selective span) and two different spelling tasks (dictation of text and picture-to-word writing task). Correlational analysis showed that WM is generally associated with the transcription tasks used in the current study. The use of SEM models, however, allows us to examine the different contribution of WM components. According to the Cornoldi & Vecchi, (2003) model, we anticipated that passive WM components would primarily influence the handwriting task due to their dependence on specific domain competence, namely handwriting skills. On the contrary, we theorized that active working memory components would predominantly affect spelling tasks, given that success in both tasks relies on the integration of distinct domain-specific skills: handwriting and spelling abilities.

Therefore, we tested a model in which passive and active components of WM were used as predictors, and their roles were tested both directly on spelling and indirectly through handwriting. To reduce the number of parameters, handwriting was defined as a latent factor defined according to a previous exploratory factor analysis (Cornoldi et al., 2022; Re et al., 2023). Structural equation models were used to analyze the model (see Figure 1). The results showed that passive and active WM directly influence handwriting; active WM has a direct and indirect (*via* handwriting) effect on both spelling tasks, while passive WM indirectly (*via* handwriting) has an impact on both spelling tasks; handwriting directly affects both spelling tasks.

The present findings support that WM directly holds up the development of transcription skills in beginner writers (Berninger et al., 2010; McCutchen, 1996; Swanson & Berninger, 1994, 1996). The passive WM component is involved in the maintenance of the executive graphomotor patterns, since they are not fully acquired yet, while the active one is necessary to recall and manipulate graphomotor information from long-term memory required to correctly write the words they need. This result extended to earlier age the results by De Vita et al. (2021). In their study, the relationship between WM and handwriting performance in third-fifth grader children was tested, and they found that children with good WM abilities performed better than children with low WM abilities in several writing tasks, including handwriting tasks.

Furthermore, the present study confirmed that the development of spelling competence is endorsed by handwriting skills (Pritchard et al., 2021) and by WM (Hoskyn & Swanson, 2003; Peverly, 2006). The present results, despite their correlational nature, aimed to investigate a more specific hypothesis, focusing on WM components that sustain this learning task. Our findings are in line with previous studies affirming that WM resources coordinate the recall and execution of graphomotor patterns and simultaneous access to orthographic knowledge (De Vita et al., 2021; Hoskyn & Swanson, 2003). It has been observed that both passive and active WM affect directly the handwriting fluency. Additionally, they clarified that active WM aspects directly and indirectly (*via* handwriting) affect spelling competence, while passive ones only indirectly (*via* handwriting) affect spelling performance. Since the relationship between passive WM component and handwriting is stronger, this may suggest that improvement in handwriting depends more on automatization processes. Whereas the fact that spelling is more associated with active WM component may suggest that its acquisition require more resource-demanding processes, such as for example the generalization the orthographic rules. It is interesting to note that the contribution of active WM components changes depending on the complexity of the spelling task: higher for the dictation task, lower for the picture-to-word task in which the access to word is cued by the picture. The presence of a visual prompt may therefore facilitate the retrieval of the representation of written word (see for example, O'Brien et al., 2022).

Although the present investigation exposes interesting results, some limitations should be acknowledged. First, the passive and active WM components were evaluated with two tasks that depend on writing, too, rather than choosing an oral WM assessment. Therefore, handwriting and spelling competencies were involved and could affect WM performance. However, the choice of administering two written span tasks was made since they were collected in schools, which gave us permission to implement only group sessions. To reduce the impact of transcription in the lists of the WM span tasks we included disyllabic regular, and familiar words only. This choice was made in accordance with the results obtained by Bourdin & Fayol (1994). The authors made four different study to clarify the differences in children' oral and written recall of words in a WM span. The authors concluded that that transcription skills (handwriting and spelling) affect children's performance in the written recall, but the two performances were approximately comparable when the children were asked to recall familiar and regular words. Moreover, in our study, in these two tasks we ignored the accuracy, so the misspelled words were counted as corrected if the children would recall them in the right order of presentation. Finally, the present research considered only first-grade children, it might be beneficial to enlarge these findings by involving a sample of older students. It could reveal new information and knowledge about the different role of passive and active WM components in transcription skills (handwriting and spelling) throughout development. However, the choice for this target (Italian first-grade children) was made because we wanted to explore the contribution of passive and active WM components in transcription during the early stages of acquisition of these skills.

Conclusion

These results confirm the important role of WM among beginner writers, illustrating the direct and indirect effects of passive and active WM components on transcription skills in first-grade Italian children. The study clarifies that spelling performance is directly affected by handwriting and active WM components, while it is indirectly influenced (*via* handwriting) by both passive and active WM components. In addition, it corroborates the importance of handwriting skills in predicting the accuracy of spelling tasks.

From a practical point of view, these findings highlight how WM constraints can exacerbate handwriting and spelling difficulties. Therefore, educators should prioritize and enhance transcription skills, considering that complex task demands can further challenge the writing process. Our results suggest that providing visual cues for words could alleviate WM burden.

Furthermore, these findings are of relevance to clinicians working with students at risk of specific learning disabilities. It is crucial for specialists to recognize how children with low WM may struggle with acquiring spelling skills, and how this can impact their performance in demanding tasks such as writing from dictation, which heavily rely on WM resources.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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