education sciences

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Differences in Graphomotor Skills by the Writing Medium and Children's Gender

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Abstract: Factors of graphomotor skills may serve as indicators to determine a writer's handwriting proficiency or acclimation to different writing surface textures. This study examines differences in children's graphomotor skills based on types of writing medium and gender. Participants were 97 six-year-old Korean preschool children who had not received formal writing training prior to the study. Writing tasks were completed on a tablet screen and paper. Writing samples were analyzed using the Eye and Pen software to investigate spatial, temporal, and pressure exertion exhibited during the writing tasks. A repeated measures ANOVA revealed differences in graphomotor skills such as print size, writing speed, and writing pressure. Writing on a tablet screen decreased clarity of writing; print size and speed increased as the stylus slides across the tablet surface with relatively less friction, thereby decreasing the exertion of writing pressure. Analysis of writing differences according to gender indicated that boys generated larger print sizes than girls. Results suggest that while simple writing tasks may be feasible on the tablet screen, providing children with a larger writing medium and encouraging larger print sizes for writing practice, especially for boys, may be beneficial in the development of graphomotor skills among young learners.

Keywords: tablet screen vs. paper; graphomotor skills; beginning writers; gender difference

Citation: No, B.; Choi, N. Differences in Graphomotor Skills by the Writing Medium and Children's Gender. *Educ. Sci.* **2021**, *11*, 162. https://doi.org/10.3390/educsci11040162

Academic Editors: Jalal Nouri and Staffan Selander

Received: 14 February 2021
Accepted: 30 March 2021
Published: 1 April 2021

1. Introduction

The study attempts to examine how tablet PCs, as a new writing medium, contribute differently to young children's graphomotor skills compared to paper. Since prior studies exploring tablet PCs as education media have focused on the interactive characteristics of tablet PCs [1–4], the investigation of affects difference of surface texture of writing medium on children's graphomotor skills have been limited except for [5,6]. The present study aims to compare the characteristics of graphomotor skills among preschoolers using two types of writing medium. Gender was also included in the analysis because it was unclear whether it affected graphomotor skills.

1.1. Development of Graphomotor Skills

Early childhood is an important period of robust development for reading and writing abilities. In the viewpoint of conventional literacy, writing is identified as the ability to produce the standard phonemic symbols of a given language within a writing system and marks the onset of the ability to write when children enter elementary school; thus, the development of handwriting skills are also considered to begin at this time [7–9]. Based on this approach, research on the development of handwriting abilities, for younger children in particular, has been relatively limited. Conversely, emergent literacy considers a broad range of knowledge and understanding about print concepts, alphabetic knowledge, and early writing skills as the precursors to conventional reading and writing [10]. From this point of view, reading does not precede writing, but rather, both skills are thought to develop simultaneously. Scribbling or drawing are also considered to be a form of writing.

For beginning writers, the acquisition of handwriting skills is important. In fact, handwriting fluency (e.g., writing letters of the alphabet or copying text under timed conditions), has been shown to be contribute to the text quality for elementary school children [11] and young children [12]. When children lack adequate transcription skills such as handwriting and spelling, they consciously devote their attention to forming letters and spelling the words, taking away considerable attentional and cognitive resources from composing text [13]. As previous studies have shown, proficiency in handwriting, even as young children, may offer major advantages in writing development. Accordingly, an in-depth evaluation of the writing process may provide greater insight in understanding the development of handwriting in early childhood.

Graphomotor skills refers to the fine motor control involved in handwriting [14]. Such skills have been studied in the field of occupational therapy to better understand children struggling with handwriting, mainly focusing on the grip of a pen and the movement of the arms and shoulders [15]. At approximately 12 months of age, toddlers generally begin to show interest in utilizing a writing utensil such as a crayon to create marks on various spaces. The initial "hold" of a crayon using their palm gradually transitions to the use of their fingers. Around the age of four, children can generally use their thumbs, index, and middle fingers to grip a crayon. The movements involved in writing shift from gross-motor skills of the shoulder and elbow to fine-motor skills of the wrist and fingers. Towards the end of the fifth year, the development of graphomotor skills allows young children to draw most geometric forms and write letters or words. Although a substantial proportion of graphomotor skills develop during early childhood, preschoolers can still be deemed as unskilled writers. Handwriting is a slow and laborious process acquired until 9–10 years of age [7,8].

Graphomotor skills are assessed by evaluating various skills in writing such as writing speed, fluidity of movement, letter arrangements, spacing between letters, and the pressure used to write [15]. In particular, handwriting legibility and writing speed are key factors in assessing the acquisition of graphomotor skills [9,16]. Handwriting legibility refers to readability, which is affected by inconsistencies of letter size and spacing as well as inaccurate letter form [17]. The assessment of handwriting legibility is a traditional assessment based on the results of handwriting [9,16,18]. Unskilled writers have difficulty in adjusting the letter size compared to proficient writers, and proficient writers tend to write smaller [19,20]. Although writing speed alone is insufficient in determining whether one is proficient in writing [18], writing speed gradually increases with age as writing abilities improve [18,21]. In addition to handwriting legibility and writing speed, writing pressure is another factor of handwriting evaluation. Traditionally, the pressure transferred to the pen reflects the tension in the elbow, arm muscles, and hand when writing letters [22]. As children become adept in writing, muscle tension decreases. Taken together, information about the legibility, writing speed, and writing pressure is a meaningful indicator of handwriting proficiency. Generally, children who are unskilled at writing write more largely, irregularly, and slowly than adults who are proficient in writing.

With recent technological advancements, characteristic evaluations of graphomotor skills used in the writing process is now possible. Many studies have been conducted to measure the speed and pressure of the pen in the process of writing by recording the touched trajectory of a stylus on the tablet PC in real time, quantitatively analyzing the dynamic kinematics process [5,6,23,24]. Because proficient writers organize time and space better than unskilled writers, spatial and temporal information in the writing process could be indicators of writing proficiency [18]. In a study comparing the graphomotor skills between proficient and unskilled writers using the drawing task, unskilled writers drew at a faster rate, and there was no difference between the two groups in the size of drawing and pen pressure [24]. Spatial, temporal, and pressure data allow researchers to measure print size, writing speed, and writing pressure, thereby identifying features of graphomotor skills that determine the writer's proficiency and writing characteristics.

1.2. Writing and New Technology

The argument that information and communication technology should be actively incorporated in education to enhance the capabilities of digital media use of future generations is mainly supported by researchers in Nordic countries and Australia [25,26]. As remote learning continues across the globe in the era of COVID-19, the use of digital media in education has drastically increased. A tablet PC is one of the most important electronic devices in the field of education because it is intuitive, portable, and supports various learning applications [27,28]. While the facilitation of interactive learning using a tablet PC continues to gain much attention among educators and researchers in recent times, little is known about its educational effects as a medium of writing [5]. More importantly, whether writing should be taught to preschool and elementary school students using tablet screens is still uncertain [6].

Writing is media-dependent—a technology in itself in that cannot be used without a pencil or paper [29]. The intuitive and easy to learn interface of tablet PCs makes it possible for even very young children under 12 months to make a mark on the screen using their fingers [1]. Through the exploration of tablet PCs, young children develop a range of technical skills such as unlocking a device using different touch gestures such as tap, drag, or swipe [2]. Young children are highly motivated to participate in tablet PCs-based writing activities such as drawing images with fingers or digital paint brushes [3,4]. The differences experienced by the senses in the writing process due to the differences of texture between a paper and a tablet screen can affect children's motor sense and motor control. For instance, writing on a tablet screen with a plastic tip pen requires fine motor control for adjusting pen movements. Studies have reported that a tablet screen is smoother than paper because it has less surface friction [5,23]. Examining the impact of different surfaces on a writer's graphomotor skills may provide insight for educators in determining whether a tablet screen is an appropriate tool to use for preschooler's writing education.

1.3. Comparing Graphomotor Skills on the Tablet Screen to Paper

A tablet screen usually feels more slippery than paper, and a plastic-tip pen that is used with the tablet screen generates less friction than a ball-point pen on paper [5,23]. Skilled adult writers generally exhibited fast movements and strengthened pressure on the pen when writing on the tablet screen [23]. Ninth graders also found it challenging to write clearly on a smooth surface of the tablet screen [5].

Gerth and colleagues compared writing performance according to writing medium among adults, school aged children, and preschoolers. In this study, writing speed was faster for all age groups on tablet screens [6]. Smoother tablet surfaces required supplementary control of handwriting movements, which may have presented an additional obstacle for beginning writing. While findings of this study were noteworthy, writing pressure, an important factor in evaluating graphomotor skills, was not addressed. Another comparative study of graphomotor skills among second and ninth graders also found that ninth graders had strategically adapted to writing on smoother tablet screen surfaces by increasing writing size, speed, and pressure [5]. Research on the differences in graphomotor skills of young children between traditional and new writing media is rather limited. For these reasons, the possible differences of writing pressure for young children across the two media types invites further exploration.

1.4. Gender Difference in Graphomotor Skills

While the developmental stages of graphomotor skills have received much attention, gender differences have received relatively little attention. A meta-study [21] of gender differences on letter size reported a tendency for boys to write larger than girls. Teachers recognize that the writing of girls is generally neater, smaller, and more legible [30]. In a previous study where children were asked to write like the opposite gender (i.e., girls were asked to write like boys and vice versa), children displayed the same pattern; boys reported that they imitated the writing of girls by making their handwriting smaller and

neater, whereas girls imitated the boys' writing by making their writing larger and less tidy [31]. Considering the results of these prior studies, print size of boys is expected to be larger than that of girls, and studies comparing gender differences in print size are required by empirical methods.

Gender differences in writing speed and movement have been more widely studied compared to print size. Rosenberg and colleague's meta-study suggests that gender influences writing speed, but conflicting findings have been reported on which gender writes faster [18]. The inconsistency in writing speed measurements may reflect variability due to methodological differences such as instructions given to the children on how to perform or in the type of writing assignments. Typically, writing speed is measured either by recording the amount of time required to write a specific text or the amount of text reproduced within a specific time period [18]. For example, a study by Graham found that girls from grade 1 to grade 9 write faster, based on the higher number of characters written per hour in the task of copying phrases during a given time limit [13]. Meanwhile, a study found that gender difference in writing speed varies depending on the age of the child, with girls aged 7 to 10 writing faster, but boys aged 11 writing faster [32]. Recently, studies of writing pressure have also been conducted [5], but little is known about the differences in writing pressure by gender. In the current study, we aim to identify any differences of writing pressure between the two gender groups.

1.5. Present Study: Numeric Writing Task

Prior studies used the task of copying symbols or words in order to measure graphomotor skills. Gerth and colleagues used the task of copying patterns, geometric forms, and a phrase [6]. Alamargot and Morin used the task of writing the participant's own name and letters of the alphabet recalled in the right order [5]. For preschoolers who are beginning writers, such tasks are not suitable. For example, the length and difficulty of the task of writing one's name vary and copying randomized phrases may also be difficult for preschoolers to execute. While copying shapes or patterns may be more appropriate for young children, a different set of meaningful symbols that young children are familiar with can also be considered: Arabic numerals. Arabic numerals are one of the most frequently encountered symbols and environmental prints in children's daily lives. Numeric writing is also an important ability because it is closely related to arithmetic [33,34]. The ability to recognize and write numbers is an important developmental task in the second half of early childhood. Thus far, a considerable amount of studies have focused on number recognition, but significantly less research has been carried out in addressing the phenomenon that occurs in numeric writing.

1.6. The Aims of Present Study

This study attempts to examine the differences of children's graphomotor skills when writing on a tablet screen vs. paper. As a writing medium, the most notable difference between a tablet screen and paper is the surface texture. Differences in roughness between the two media can impact a writer's experience as an affordance. In prior research, the development of graphomotor skills has been seldom explored. The present study aims to compare the characteristics of graphomotor skills (print size, writing speed, and writing pressure) among preschoolers (six-year-old children) using two types of writing medium. Gender was also included in the analysis because conflicting evidence makes it unclear as to whether gender affects children's graphomotor skills. The current study evaluates young children's graphomotor skills by repeated measurements of numeric writing on tablet screens and paper, respectively. Research questions of this study are as follows.

1. Does the size of the print written by six-year-old children differ depending on the writing medium (tablet screen/paper) and gender (boys/girls)?
2. Does the writing speed of six-year-old children differ depending on the writing medium (tablet screen/paper) and gender (boys/girls)?

3. Does the writing pressure of six-year-old children differ depending on the writing medium (tablet screen/paper) and gender (boys/girls)?

2. Materials and Methods

2.1. Participants

For the current study, 113 preschool children aged 6 participated in this study. Preschoolers were recruited from four different cities (An-san, An-yang, Suwon, and Siheung) in Korea. Writing samples of 16 children whose writing was not recognized by the software program or samples of those who wrote more than one numeric number was excluded, and the remaining 97 children were included in the final analysis. As shown in Table 1, the average age of children was 79.06 months (SD = 3.43), with 39 boys and 58 girls. All participants were Korean native speakers. Ninety-one children were right-handed, 4 were left-handed, and 2 used both hands to write. All of the participants attended or graduated from a kindergarten or daycare center, and regularly used pencils and pens in their daily activities. Slightly lower than half of the children (n = 45) had prior experience in painting or writing on a tablet screen.

Table 1. General demographics and previous tablet screen use of participants (N = 97).

Variable			*N* (%)
General demographics	Age (Month)	Range Average age	73–84 79.06 (3.43)
	Gender	Boy Girl	39 (40.2) 58 (59.8)
	Preferred hand	Right hand Left hand Both hands	91 (93.8) 4 (4.1) 2 (2.1)
Experience in education	Educational institute	Kindergarten Daycare center	45 (46.4) 52 (53.6)
	Daily attendance (hrs)	3~8 h Over 8 h	81 (83.5) 16 (16.5)
Experience in using tablet screen	Drawing or writing	Yes No	45 (46.4) 52 (53.6)

2.2. Materials

In this study, a numeric writing task was assigned under two conditions: (1) Writing with a plastic tip pen on a tablet screen and (2) writing with a ballpoint pen on paper, which was placed on tablet screen. Materials used in the numerical writing task for the two conditions are shown in Figure 1. The writing utensils and tablet screen used for both conditions are shown in Figure 2. Children wrote directly on the tablet screen using a pen with a plastic tip without ink (Samsung S Pen Plus, shown in Figure 2A), and on an A4 sized sheet of paper attached to a tablet screen using a Wacom ballpoint pen (shown in Figure 2B). Under the paper condition, the paper was placed on the tablet screen to measure the movement trajectory of pen and writing pressure. Pens used under the two conditions were similar in size and shape, inducing a similar grip of the writing utensil for both conditions. A 15" Samsung Pen S laptop (shown in Figure 2C) was used as a tablet screen for both tasks. The Eye and Pen® [35] software recorded the temporal and spatial information of the pen (with or without pressure) in real-time on the tablet screen/paper.

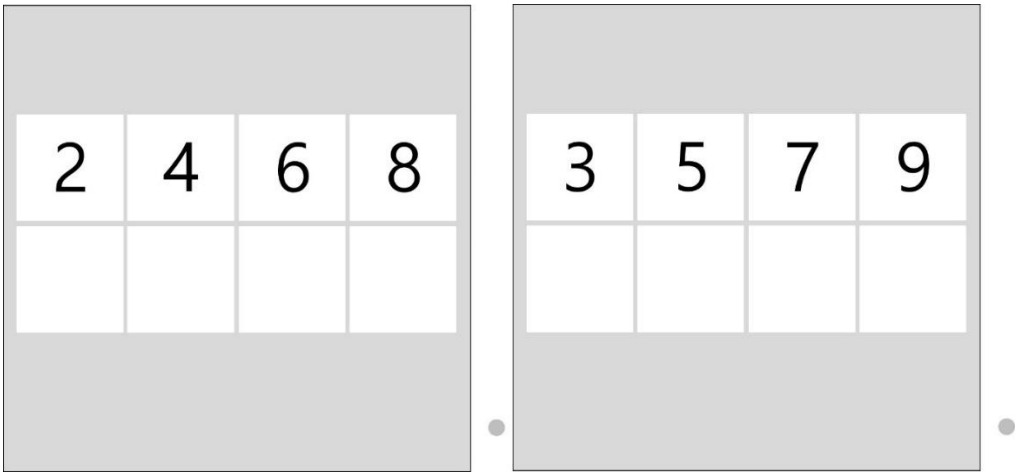

Figure 1. Writing tasks displayed on the tablet screen vs. printed on a sheet of paper for the numeric copying task.

Figure 2. Writing materials (stylus pens and a tablet screen) used in the two conditions.

2.3. Measures

Patterns of graphomotor skills expressed during the writing process were recorded and analyzed using the Eye and Pen® [35] software. Calculation methods of the numerical data derived from the handwriting samples are described below.

- Print size was calculated by measuring the length (in centimeters) of the pen's trajectory resulting from the process of writing all four numbers given in the task.
- Writing speed was calculated measuring by the average speed of the pen movement in centimeter per second (cm/s) of the pen's trajectory resulting from the process of writing all four numbers given in the task.
- Writing pressure: Writing pressure refers to how hard the pen is pressed down on the writing medium during the writing process. Writing pressure exerted during the writing task was derived for each individual number and the average pressure value for all four digits combined. Pressure values were measured in a range that can be measured on the tablet screen used in this study (0–4096).

2.4. Procedure

This study was reviewed and approved by the Institutional Review Board of Seoul National University (IRB No. 1912/001-014). Prior to obtaining the consent signatures for participation in the study, parents were informed of the research topics, methods, procedures, potential risks, rights, and conditions. The task was conducted in four cities during January and February 2020. As the academic year of Korean schools commence in March, the study was executed in January and February, just prior to participants' entry to primary school. Children born in 2013 were selected for the study with consent from

legal guardians to participate in the study. Out of the 113 children initially evaluated for data collection, a total of 97 children were included in the final dataset. Individual children participated in the numeric writing task, face-to-face with a researcher. Preschoolers were tested individually in a quiet room at the kindergarten or their home. Half of the participants started with condition (1), the other half with condition (2). Children were asked to write in their usual handwriting and speed. The order of the handwriting task conditions (on the tablet screen and on paper) was alternated from one participant to the next (i.e., counterbalanced within-participants design). Each child participated in both tablet screen and paper conditions. There was no time limit on completing the writing task, but the entire process took less than five minutes.

2.5. Data Analysis

Data derived from the graphomotor skills assessment including the spatial and temporal features of writing and pen pressure were analyzed using the Eye and Pen® [35] program. Graphomotor skills were measured by recording children's writing performance of all four digits shown in the tasks.

Collected data were analyzed using the SPSS program to compute percentiles, means, and standard deviations, and a repeated measures ANOVA was also conducted. The three graphomotor skills (dependent variables) were analyzed individually. There were two independent variables: (1) Writing medium (tablet screen vs. paper), a within-subjects factor; and (2) children's gender, a between-subjects factor.

3. Results

3.1. Differences in Print Size by Writing Medium and Gender

A repeated measures ANOVA (RMANOVA) was conducted to test our hypotheses that the print size written by preschoolers would differ by writing medium and gender. Writing medium was a within-subjects factor, and gender was a between-subjects factor.

In Table 2, the distance traveled by the pen to form four numbers was longer on the tablet screen (M = 34.92, SD = 8.41) than on paper (M = 30.88, SD = 7.20). Larger prints were more often written by boys (M = 35.05, SD = 6.90) than by girls (M = 31.46, SD = 5.40). As shown in Table 3, the main effect of writing medium was significant, F (1, 95) = 7.06, $p < 0.001$. The main effect of gender was also significant, F (1, 95) = 8.21, $p < 0.01$. There was no significant interaction between writing medium and gender.

Table 2. Graphomotor skills data on numeric writing: Mean (standard deviation) print size by writing medium (tablet screen/paper) and gender (boys/girls).

		Boys		Girls		Total	
		N	***M* (*SD*)**	***N***	***M* (*SD*)**	***N***	***M* (*SD*)**
Print size (cm)	Tablet screen	39	37.19 (9.55)	58	33.39 (7.24)	97	34.92 (8.41)
	Paper		32.90 (7.91)		29.53 (6.40)		30.88 (7.20)

Table 3. Results of repeated measures ANOVA: Print size by writing medium (tablet screen/paper) and gender (boys/girls).

Source	*SS*	*df*	*MSE*	*F*
Between subjects				
Gender	600.44	1	600.44	8.21 **
Error	6949.35	95	73.15	
Within subjects				
Writing medium	776.33	1	776.33	17.46 ***
Writing medium × Gender	2.18	1	2.18	0.05
Error	4224.23	95	44.47	

** $p < 0.01$, *** $p < 0.001$.

Figure 3 presents sample data that show different print sizes. The top two were written by a boy and the bottom two were written by a girl. The two on the left were written on a screen, and two on the right were written on paper. Although all of the numbers presented in the writing tasks were of the same font and size, boys produced larger prints than girls overall, and all of the participants wrote larger prints on the screen than on paper.

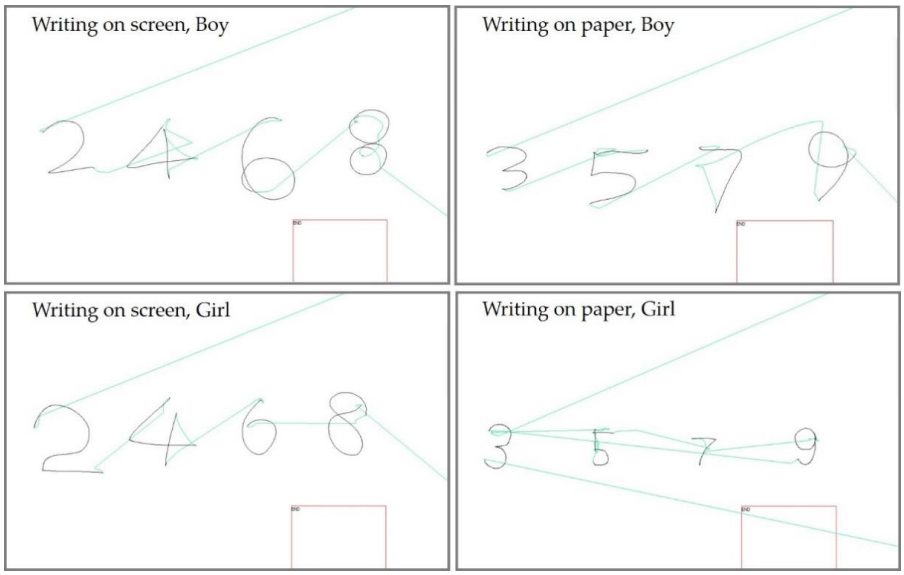

Figure 3. Examples of a print size comparison by writing medium (tablet screen/paper) and gender (boy/girl). Note: Eye and Pen® [35] software screen capture materials.

3.2. Differences in Writing Speed by Writing Medium and Gender

A repeated measures ANOVA (RMANOVA) was conducted to test our hypotheses that writing speed of preschoolers would differ by writing medium and gender. Writing medium was a within-subjects factor, and gender was a between-subjects factor.

In Table 4, the pen moved faster on the screen (M = 7.51, SD = 2.90 cm/s) than on paper (M = 5.26, SD = 2.21 cm/s). As shown in Table 5, only the main effect of writing medium was significant, F (1, 95) = 89.92, $p < 0.001$. There was no significant interaction between writing medium and gender.

Table 4. Graphomotor skills data on the numeric writing: Mean (standard deviation) writing speed by writing medium (tablet screen/paper) and gender (boys/girls).

		Boys		**Girls**		**Total**	
		N	***M* (*SD*)**	***N***	***M* (*SD*)**	***N***	***M* (*SD*)**
Writing speed (cm/s)	Tablet screen	39	8.13 (3.01)	58	7.10 (2.77)	97	7.51 (2.90)
	Paper		5.73 (2.54)		4.94 (1.93)		5.26 (2.21)

Table 5. Results of repeated measures ANOVA: Writing speed by writing medium (tablet screen/paper) and gender (boys/girls).

Source	***SS***	***df***	***MSE***	***F***
Between subjects				
Gender	38.36	1	38.36	3.72
Error	980.58	95	10.32	
Within subjects				
Writing medium	242.13	1	242.13	89.92 ***
Writing medium × Gender	0.73	1	0.73	0.27
Error	255.81	95	2.69	

*** $p < 0.001$.

3.3. Differences in Writing Pressure by Writing Medium and Gender

A repeated measures ANOVA (RMANOVA) was conducted to test our hypotheses that writing pressure of preschoolers would differ by writing medium and gender. Writing medium was a within-subjects factor, and gender was a between-subjects factor.

In Table 6, greater pressure was exerted by the pen on the screen (M = 3003.62, SD = 494.12) than on paper (M = 3202.37, SD = 593.16). As shown in Table 7, only the main effect of writing medium was significant, F (1, 95) = 15.32, $p < 0.001$. The main effect of gender and writing medium by gender interaction was not significant.

Table 6. Graphomotor skills data on the numeric writing: Mean (standard deviation) writing pressure by writing medium (tablet screen/paper) and gender (boys/girls).

		Boys		Girls		Total	
		N	*M* (*SD*)	*N*	*M* (*SD*)	*N*	*M* (*SD*)
Writing pressure	Tablet screen	39	2919.10 (476.98)	58	3060.45 (501.36)	97	3003.62 (494.12)
	Paper		3168.57 (558.48)		3225.09 (619.14)		3202.37 (593.16)

Table 7. Results of repeated measures ANOVA: Writing pressure by writing medium (tablet screen/paper) and gender (boys/girls).

Source	*SS*	*df*	*MSE*	*F*
Between subjects				
Gender	456,499.26	1	456,499.26	0.98
Error	44,276,057.53	95	466,063.76	
Within subjects				
Writing medium	1,999,547.56	1	1,999,547.56	15.32 ***
Writing medium × Gender	83,889.52	1	83,889.52	0.64
Error	12,398,841.83	95	130,514.13	

*** $p < 0.001$.

4. Discussion and Conclusions

This study compared young children's writing on the tablet screen and on paper to discover the potential of a tablet PC as a new educational medium. Previously, studies exploring tablet PCs have focused on the interactive characteristics of tablet PCs [1–4]. However, investing the differential effects of surface roughness of writing medium on children's graphomotor skills needs to be expanded e.g., [5,6]. To add to this, among the studies examining the effects of surface roughness of writing medium on the development of graphomotor skills in children, only one study by Gerth and colleagues [6] investigated young children. However, this study was unable to provide information on the significance of writing pressure. In addition, relatively little research has examined the impact of gender on graphomotor skills. The current study used a tablet screen, a digital pen, and software to measure print size, writing speed, and writing pressure during numeric writing. Writing samples and subsequent writing performance data of 97 six-year-olds were collected and calculated to determine whether children's graphomotor skills differed by writing medium or gender.

The main results are as follows. First, preschoolers' graphomotor skills vary depending on writing medium. In other words, young children write larger, faster, and exert less pressure when writing on the tablet screens than on paper. The results of this study are consistent with that of a prior study reporting that letter sizes were found to increase when writing on the tablet screen [5]. In addition, the results of this study are consistent with prior studies showing that writing speed increases on a tablet screen than writing on paper for adults [6], ninth graders [5,6], and preschoolers [6]. These results are attributed to the difference of surface texture between the tablet screen and paper as a writing medium: The

smooth surface of the tablet screen causes the pen to slide, resulting in larger character production and increase in writing speed.

Preschoolers exerted less writing pressure when writing on a tablet screen compared to paper. In general, high writing pressure indicates greater muscle tension [22], and pressure decreases as writing skills improve. Results of decreased writing pressure on the tablet screen can be interpreted as a lack of adaptive control for beginning writers. These outcomes are consistent with other studies in which adults [23] and ninth graders [5] (proficient writers) increased their writing pressure on the tablet screen, while second graders (unskilled writers) failed to control writing pressure and adapt to the writing medium [5].

In this study, preschoolers were found to produce larger prints more quickly on the smooth surface of a tablet screen, failing to make adjustments such as increasing pen pressure. This result is in line with Gerth and colleagues' work [6] comparing young children's graphomotor skills using two types of writing media. As Gerth and colleagues [6] reported, tablet screens may be more challenging for young children to write on. However, this can be complemented by the context in which tablet screens are used. Although tablet screens may have disadvantages when writing large amounts of text, such as multiple sentences or a paragraph, they may be an appropriate writing medium for smaller amounts of writing, such as drawing simple pictures or writing a few words. Tablet screens may be useful in the context of brainstorming and creating mind maps or playing quiz games in the classroom. Considering the limitations of expression through writing as compared to oral language for young children, tablet screens seem to be suitable for children's writing characteristics. Results also suggest that the size of tablet screens is important; screens must be large enough in order to be effectively utilized as a writing medium in early childhood education. Tablet PCs are likely to be used as a substitute for paper in the same context such as magnetic boards and blackboards as variations of writing media. Further research using a qualitative approach is needed to consider the use of tablet screens as a writing medium in early childhood education.

Second, print size in young children's writing varies by gender. In other words, boys generally produce larger prints than girls. Gender difference is in line with prior studies on print size [30,31]. Based on empirical experimentation, this study confirmed that print sizes of boys and girls were significantly different. However, writing speed and pressure do not vary by gender. Previous studies reported conflicting findings on writing speed in regard to gender difference [13,36,37]. Previous studies reporting gender differences in writing speed did not measure the dynamics of the writing process, but calculated writing speed either by recording the amount of time required to write a specific text or the amount of text reproduced within a specific time. In contrast, this study measured the writing speed of the pen in real-time using the task of copying four digits, rather than letters or phrases. Due to these methodological differences, it is possible that the results of this study were inconsistent with those reported in previous studies.

Studies on graphomotor skills noted differences between ability (proficient vs. unskilled writers) and age (older vs. younger writers). However, studies examining differences in gender were insufficient. This study found that boys write using larger font sizes than girls, but there are no significant differences of writing speed and pressure between the two groups. These results suggest that it may be appropriate to provide a larger writing medium for boys in the early stages of writing development, as they may find the task of writing in small, tight spaces to be more challenging. Further exploration of the sub-factors of graphomotor skills are necessary to understand the characteristics of young children as writers.

The following limitations need to be considered in the interpretation of the findings reported in the current and subsequent studies. Whether participants have prior experience with a tablet screen may have affected the control of the pen's movement in the tablet screen condition. That is, children with more experience using a tablet screen as a writing medium are more likely to have better control over smooth screen surfaces. In this study,

approximately half of the children previously had opportunities to draw or write on tablet screens, and differences in prior exposure to these tools were not controlled for. Moreover, young children actively write or draw on tablet screens with their fingers, an element that has not been investigated in the study. While the study was designed to observe differences between writing with a pen on a tablet screen or paper, this research gap can be seen as a limitation, given that the manipulation of the touch screen by using one's finger is a more intuitive and the most common method of operating a tablet screen for children. These limitations need to be considered in subsequent studies to refine the quality of assessment in the use of tablet screens and paper as a writing medium.

The study sought to examine how tablet PCs, a new digital medium widely used and introduced early on in young children's lives, contribute differently to young children's graphomotor skills compared to the more traditional forms of writing medium such as paper. Although previous research in writing proficiency was mainly conducted on school-aged children, the development of graphomotor skills is just as important for young children who have not yet begun formal schooling. The effects of gender differences were insufficiently explored in previous studies; thus, more attention should be afforded to the developmental process of graphomotor skills in this regard. Based on the study findings, short and simple writing activities on the tablet screen may be useful in the context of early childhood education. Additional research in understanding young children's graphomotor development and the use various electronic media as learning resources may provide new opportunities and innovative ideas to foster future writing proficiency.

Author Contributions: Conceptualization, B.N. and N.C.; Investigation, B.N.; Methodology, B.N. and N.C.; Software, B.N.; Supervision, N.C.; Visualization, B.N.; Writing—original draft, B.N.; Writing—review & editing, N.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the Institutional Review Board of Seoul National University (IRB No. 1912/001-014, 9 December 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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