

Writing: Hand and Paper or Keyboard and Screen

Aimee R. Natal

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School of Education, University of Bridgeport

Abstract

Elementary and adult students are required to keyboard and word- process much of their writing for school today. Using 14 research studies, this article explores whether handwriting still has a role to play for learning new material and the differences in the quality of writing when it is handwritten or typed on keyboard. The research involves seven studies of children and seven studies of adults.

Analysis of the results show that children learn new letters by handwriting them, learn to spell better by handwriting and write better quality compositions by hand than by keyboard, and write faster by hand.

The results of the studies with adults show that adults wrote by hand faster than they typed, and learned new letters by hand, with hardly any retention of knowledge of new letters when having learned them through keyboard. They also experience greater eye strain when reading from LCD screen, and based upon two European surveys, reported general feelings of favorability towards writing with pen on paper and reading lengthier materials on paper and not on screen.

Keywords: handwriting, keyboarding, writing, paper, digital

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Reading and writing are intertwined. There is nothing to read if it is not written first. In the last twenty years, the tools for reading and writing in the American classroom have shifted from the use of hardcopy books and papers, pens and pencils, to the inclusion of electronic keyboards, touchpads and screens. How has this technological inclusion (or is it intrusion?) changed the student's learning, for better and for worse? By pressing keys, is the student denied the kinesthetic actions found in handwriting which activate certain brain functions known to improve and increase memory? Through sharing the results of professional research and studies conducted and published in the last ten years, this paper probes for answers to these questions.

Many (but not nearly enough) studies were published in the last ten years about handwriting which are narrowed down here to fourteen: seven involve children from preschool age to grade six, and seven involve adults from the ages of 18 to 27 years. Summarized are the findings of each of these handwriting studies involving children, followed by the findings of each of the studies involving adults.

Seven Studies with Children

Starting with preschoolers, Longcamp et al (2005) tested 76, three to five year olds in three different preschools in France for letter recognition after being trained to copy them by hand or by typing them. They divided the students into two groups (38 children in each), one for handwriting and one for typing. Each group was then divided into three subgroups by age (older, middle and younger) and taught, for one half-hour for three weeks, twelve uppercase letters (of which the pre-test showed they had no prior knowledge and were unable to write).

For the keyboarding group, the keyboard was adapted to only display 15 keys and the children typed what they saw displayed on their computer screens. For the handwriting group, the children used a felt-tip pen and paper to copy the words from a piece of paper. At the end of the three weeks, and

again one week later, the 2 groups of children were tested on each of the 12 uppercase letters.

Longcamp's study showed that the subgroup of older children who learned the new letters by handwriting gave more correct responses in both post-tests than those older children who used a keyboard. The other two subgroups, both of children under 50 months of age, showed no significant difference, which the authors attribute to age, the low amount of time (1.5 hours total) the children spent learning the letters, and the fact that the learning was implicit. Direct instruction never occurred. Even so, Longcamp et al (2015) conclude that "writing movements may contribute to memorizing the shape and orientation of letters" (p. 70). They believe that the motor activity and kinesthetic feedback involved in the required movements performed while handwriting build internal models of the characters in the writer's mind, whereas typing does not.

Moving on to first grade, Cunningham and Stanovich (1990) report on an experiment they conducted with 24, six to seven year old early readers in California for spelling performance when writing by hand, using individual letter tiles, or by typing on a computer. Although this study was published in 1990 (not in the last ten years like the rest of the research discussed here), it is referenced so often that it warrants inclusion. As the title of this study states, their research showed that "writing beats the computer" (p. 159) for the first grade children learning to spell 30 words over the course of a week in their study.

However, in response to that, two years later, in 1992 in Florida, Vaughn et al (1992) replicated the previous study with double the number of students, all who had finished first grade. The results of their tests showed no difference between the three modalities used (handwriting, sorting letter tiles and typing on a computer) among students, whether they were labelled "learning disabled" or not. Thus the title of their study questions Cunningham's and Stanovich's: "Early Spelling Acquisition: Does Writing Really Beat the Computer?" and the authors and conductors of this particular study answered with "No" (p. 227). In their study, no one of the three conditions was more effective than the others

when it came to the spelling performance of the the 48 first grade students (24 of whom were Learning Disabled) in their study.

Continuing on with first graders, and also in Florida, Wagner et al (2010) published a handwriting study conducted with 98 first grade students and, in addition, with 88 fourth grade students. Wagner's study provides racial and economic breakdown of the students (many of the studies included here do not): 49% White and 43% Black and primarily middle and lower class. The students were given ten minutes to write (by hand) about which animal they would choose to be the classroom pet. Results showed that handwriting fluency was highly correlated to the other composition variables analyzed (macro organization, complexity, productivity and spelling and punctuation) in the 4th grade students' compositions in particular (p. 214). Thus the authors of this study conclude that a student who is a fluent hand writer is better at writing (content and form-wise), due to having more attentional resources to devote to planning and composing, and not spent on the physical activity involved in handling the writing utensil and painstakingly thinking about and forming each letter. They compared this to being similar to the fluent reader who does not have to struggle with decoding (p. 217). Thus for students who rely mostly on handwriting and not on keyboarding to complete assignments or write essays, this study confirms that fluency in the handwriting process itself is of utmost importance and needs to be mastered.

Keeping with the importance of fluency, across the pond in England, Connelly et al (2007) tested 312 students in two primary schools, ranging from the ages of four to eleven years old (178 were boys and 157 were girls) on the relationship between handwriting fluency and keyboarding fluency and the compositional quality of writing when using each. For their first study (of two), each student was given two minutes to handwrite and then to type the sentence, "The quick brown fox jumped over the lazy dog" (p. 484). Students were timed and scored for accuracy. The results showed that handwriting, on average, was always faster than keyboarding in these UK students across all age

groups (grades 1-6). In addition, a significant correlation was found between handwriting fluency and keyboarding fluency amongst the participants in this sample.

In their second study, the authors took the 48 students from grades 5 and 6 and sampled their writing skills by using the Weschler Objective Language Dimensions (WOLD) standardized writing test. Students were given 15 minutes to free write to both of two different prompts. For the WOLD handwriting prompt, students used a pencil and paper and for the WOLD keyboarding prompt, they used a blank MSWord document on a computer. Their compositions were scored in six areas: 1) ideas and development, 2) organization, unity and coherence, 3) vocabulary, 4) sentence structure and variety, 5) grammar and usage and 6) capitalization and punctuation. In this case, "the handwritten essays, on average, received higher WOLD total scores than the keyboarded essays....All the analytic scores for handwritten essays were significantly higher than the analytic scores for keyboarded essays." (p. 488-489). So not only did Connelly et al find that elementary students write faster with pen than with keyboard, they also linked fluency in handwriting to the ability to produce higher quality compositions.

Berninger (2009) and her three colleagues at the University of Washington published a study on children's ability to write the alphabet, sentences and essays using a pen and a keyboard. Widely referenced, this study took place over 4 years with the same 241 elementary students in grades two, four and six. The students' ethnicities in this urban public school in the Pacific Northwest were 65% white, 22% Asian, 7% black, and 1% Hispanic. Students were tested on three tasks. The first was to print all lower case letters in alphabetic order with a pen, and then to select each letter of the alphabet in order on a keyboard, and to do both as quickly and accurately as possible. The second was to write one sentence that began with the word "Writing" while using a pen and to write one sentence that began with "Reading" while using the keyboard. For the last task, the children were asked to write essays on provided topics for 10 minutes, one using pen and the other using keyboard.

Berninger's (2009) study found that second, fourth and sixth graders consistently composed longer essays by pen than by keyboard, and wrote faster by pen (p. 129), just like Connelly's study in England two years earlier. This was true for students whether they were labelled as "learning disabled" or were not. This led the authors to conclude that it should not be automatically assumed, by Special Educators especially, that children with TD (transcription disability) will benefit from using a keyboard to write. Also, Berninger (2009) claims that in beginning and developing writers, forming written words by hand leaves a stronger memory trace than does choosing letters on keyboard. "The motor act of writing is tactile...the finger movements involved in handwriting activate brain regions associated with cognitive, metacognitive and language processes. This activation may contribute to idea expression, sentence construction to express complete thoughts and longer essays." (Berninger, 2009, p. 136).

Last for the seven handwriting studies involving children is one published by Klein and Taub (2005) in Israel, conducted with 53, 6th grade teachers given nine, 6th grade student essays each. Each of the essays used in this study was previously assessed "by experts" and given a score of 80% (p. 137). The difference in the nine essays for Klein's experiment is that some were handwritten, some were typed, some neatly and some not. The results showed that the highest scored essays were the highly legible ones: "Presentation of very legible essays brought about a grade rise of 1-7%, whereas the assessment of the poorly written papers [less legible] was 9-23% lower" (p. 142) than the 80% score originally given by the specialists when the papers were all uniformly written via word processor with printer. This study shows that legibility in handwriting and uniform, traditional font and size when word processing matters, and that poor handwriting can influence the person grading a written composition negatively.

When considering the results of this and the six other studies involving children from preschool to grade 6, it is plain to see that keyboarding cannot just be taken for granted as the modus operandi for writing for elementary aged school students. (These seven studies were not carefully culled to only

show favorable results skewed towards handwriting, and were all this student could find when researching the subject.) Handwriting should not be viewed as outdated or even as optional for elementary students. This research shows that children learn new letters by handwriting them (Longcamp, 2005), learn to spell better by handwriting (Cunningham & Stanovich, 1990), and write better quality compositions by hand than by keyboard (Wagner, 2010 and Connelly, 2007), and write faster by hand (Connelly, 2007 and Berninger, 2009). How does this change once the child is an adult? Do the minds of adults fare better while keyboarding?

Seven Adult Studies

Mogey and Hartley (2012) set out to compare how first-year Divinity students (aged 18-21) at the University of Edinburgh responded to essay questions when handwriting their answers compared to when using a laptop. The 37 students were given their choice of one of three exam questions one week in advance, and whether they wanted to use pen and paper or laptop. Thirteen of the 37 students chose to handwrite their essays and 24 chose to word process them. The scorers used MS Word 2003 to count the number of words, sentences and paragraphs of each essay, as well as the Flesch Reading Ease formula for average number of syllables per word and words per sentence. In addition, the scorers used the Fog Index to determine the readability of each essay, which is based on the number of words with three or more syllables used. Thus all the essays were graded based on 13 stylistic measures in total. Mogey and Hartley (2015) found that there were no significant differences between the papers based upon whether they were handwritten or word-processed.

Looking at keyboarding only, Hayes and Chenoweth (2006) studied how the adult mind retains information when being distracted while typing. Twenty Carnegie Mellon students typed (transcribed) information about winemaking in Napa from one computer screen to another. Ten of them had to do so while saying out loud the word "tap" in time to a metronome set at 120 clicks per minute (articulatory suppression, the experimental condition), and the other ten did not have that distraction while typing

(the control condition). There were six test trials, each three minutes long. Following the trials, each participant was given a 23 question multiple-choice test about the text they had typed. The results show that those in the articulatory suppression group typed fewer words per minute with more uncorrected errors. Also, those in the control group answered more questions correctly on the comprehension/memory test after the trials. These results led the researchers to conclude "that working memory is involved in transcription and editing" (p. 146) and "articulatory interference reduces the long-term memory for the transcribed material" (p. 147). The authors believe understanding interference in writing processes will help to understand the development of writing in young students. They pose that if young writers are using their working memory for lower-level writing processes, such as handwriting or typing, then this decreases what is left for them to use for the higher-level processes. They stress the importance of automatization of the lower-level writing skills (just as Wagner did), which means that being fluent in handwriting or typing is essential.

In Israel, Weintraub et al (2010) recruited 63 adult volunteers who regularly use a keyboard (over 70% were university students and the rest, working professionals) for a handwriting and keyboarding study. Each participant was assessed four ways: copying a paragraph by hand, copying it by typing, handwriting a dictated paragraph and typing a dictated paragraph. There is a high correlation between copying and dictation performance so the researchers focused only on the speed and accuracy of the handwriting and typing of the copied (not dictated) texts. What they found is that their participants' handwriting speed was approximately 10% faster than their keyboarding speed, and there was no correlation between handwriting legibility and keyboarding accuracy. Using the Developmental Eye Movement (DEM) test, they found that "the better the horizontal or total eye movement was, the more accurate the keyboarding was" (p. 128). Weintraub (2010) says 12-21% of students are classified as having handwriting difficulties, and that it is often assumed that keyboarding should be their alternative. But the findings of his study suggest that this should not always be the

case, because students who struggle with handwriting due to fine motor difficulties may also struggle with keyboarding. This reinforces the importance of fluency in handwriting for academic performance for students, including adult ones. The fact that the adults typed slower than they wrote by hand also points to the importance of fluency in keyboarding or typing.

In 2008 MIT published a French study conducted by Longcamp et al (her research involving preschoolers previously discussed above) using functional MRI scans of adult participants' brains while they wrote by hand first and then by keyboard. Six men and six women (average age of 26) took part in the experiment. For one hour, once a week for three weeks they learned 10 letters from the Bengali and Gujarati alphabets by hand or by keyboard. Each of the 10 letters was written on paper, or its key selected with the right hand on the keyboard, 20 times each session. Results showed that when the participants were tested 1, 3 and 5 weeks later, those who had learned the letters by hand had higher correct response rates than those who learned using a keyboard. The typed scores got worse as time went on, so much so, that at the 5 week mark, the "response accuracy for typed characters approached chance level" (p. 806). The fMRI data showed that the middle temporal gyrus of the brain was more activated during handwriting, as well as the left Broca's area. Whereas with typing, only one, very limited area (the right supramarginal gyrus) was activated. Longcamp (2008) concludes this shows that the motor activity involved in handwriting is reactivated in a person's brain when they visually process new or familiar letters, and that this is lacking if a person only presses a key on a keyboard.

The next two studies involving handwriting and adults are not based on the results of tests, but the results of surveys given to adults, in Italy first (Fortunati, 2013), and then in Finland (Taipale, 2013). Both papers are based on participant answers to these two questions:

- 1). Describe the differences you find when using a pen and using a computer. Describe what you like and dislike about both these modalities.
- 2). Describe which differences you find in reading paper and reading on a screen. Describe what you like and dislike about both these

modalities. (Fortunati, 2013, p. 44 and Taipale, 2013, p. 535).

Twenty-four adult graduate students answered in Italy and 25 in Finland. In response to question one, students from the studies at both universities agreed that writing on paper is more immediate, personal, portable and free (Fortunati, 2013 and Taipale, 2013). The Finn responses added that when writing by hand, they are more creative and also remember more of what they have written. Respondents from both studies agreed that the positive aspects of keyboarding are speed and automaticity of editing due to built-in editing software (Fortunati and Taipale, 2013). The Finns noted an additional benefit to keyboarding: uniform legibility.

In response to question two, the answers by students from both studies once again lined up regarding student perceptions of the differences between reading on paper and reading on screen. For short articles, screen was preferred but for lengthy texts, such as books, paper was preferred (Taipale and Fortunati, 2013). Being able to hold the book or paper with pen in hand, ready to underline or otherwise annotate was important and desirable to both Italian and Finnish respondents (Taipale and Fortunati, 2013). In addition, the Italians noted that reading on paper requires no electricity, charged battery or access to the Internet, and the Finns noted easier portability of papers and books and a more "focused and sustained practice" than when reading on a screen (p. 539). Reading on a screen provided one benefit, according to the Italians: being able to read in the dark, but it also caused more eyestrain and distractions, by way of advertising banners and links and graphics (p. 48). The question remains as to whether these 49 European adults respondents' answers are indicative of the rest of their age group, and whether non-academic respondents would respond similarly in their countries, not to mention how Americans adults' answers would compare.

The last of the seven studies involving adults included here is also focused on the act of reading from a screen. Though not specifically about handwriting, it is included because when we speak of

students typing using keyboards, these keyboards are always connected to a screen at which the student is looking, or from which they are reading or copying. When we speak of handwriting, no such additional stimuli is taking place. So when comparing handwriting with keyboarding, the presence of the screen in connection to the keyboard should not be left out.

In this study, the effects of reading books from two e-readers and paper book were analyzed by Benedetto et al (2013) at Universite Paris using 12 volunteers whose average age was 27 years old. Each participant wore an infrared video-based eye tracker and had normal vision. They each read from a Kindle Paperwhite e-reader (E-ink display), the Kindle Fire (which is LCD) and a paper book. The three sessions took place over 30 days, with one session at the same time of day, every ten days, lasting for about 70 minutes. Each student was tested prior to each session using the Visual Fatigue Scale (which measures eye blink, lack of which contributes to dry eye, the most common symptom of Computer Vision Syndrome) and the Critical Flicker Fusion test (measures sensory perception using Hertz). They were then retested for both of these at the end of each session. In addition, they were given a comprehension test and subjective preference scale to complete at the end of each session. Benedetto found that prolonged reading using the LCD screen causes greater eye strain or visual fatigue than does reading from the E-ink e-reader or the paper book (p. 4). It "reduces the size of the pupil and the frequency of eye blink, and increases the perceived visual fatigue" (p. 6).

When considering the results of this and the six other studies involving adults and handwriting and keyboarding (and reading from a screen), like the research studies with child participants, this research shows that when learning new information, handwriting promotes greater retention of the knowledge. While Mogey & Hartley (2012) found no difference in the quality of essays handwritten or typed by the Scottish Divinity students, and while Hayes & Chenoweth (2012) showed how detracting interference can be while typing, Weintraub et al (2010) found that adults wrote by hand faster than they typed. Longcamp (2008) found that adults, too, learned new letters by hand, with hardly any

retention of knowledge of new letters when having learned them through keyboard. Benedetto (2013) found that adults reading from LCD screens experience greater eye strain than when reading from a paper book, and Fortunati (2013) and Taipale (2013) reported adult feelings about the differences between writing by hand on paper and keyboarding with screen, and with reading paper articles or books and reading via screen. The adults in their surveys were generally more favorable toward the non-technological methods.

When combined together, this research on children and adults shares these things in common: both adults and children learn new letters by learning to write them by hand. The physical action involved in pressing a key already marked with the new letter does not activate the same regions in the brain which lead to learning and memory, as using the hand and pen/(cil) to write the character does. Both the children and adults in these studies tended to write faster by hand than by keyboard, and also wrote better quality compositions when writing by hand and not keyboarding. Only one study showed otherwise, and it was neutral- neither the handwriting nor the keyboarding papers showed any significant differences and that was Moge (2012) study on 37 university student essays. In addition, the importance of fluency in the lower-level skills of writing by hand or typing by keyboard was demonstrated for both children and adults. If a child or adult has not had adequate instruction and practice in making the writing action automatic, their writing quality suffers due to increased brain function having to focus on this lower-level skill rather than higher order thinking. This goes for both handwriting and keyboarding. The fact that handwriting is faster for many children and adults shows that typing has not become second nature to them, but instead is laborious and taking away from their thought processes. The research by Wagner(2013), and Connelly (2007), respectively, especially shows that if writing by hand is difficult for a person, then typing by keyboard may not be any better. Likewise, for the child or adult who has become a fluent hand writer, they are more likely to also become fluent at typing. So the answer for those struggling with handwriting is not to stop handwriting

and instead use a keyboard (except for those students with physical issues which preclude the ability to write by hand), but to work to become fluent at handwriting.

Most students now use computers in school and at home. As many of the adult survey respondents noted, word-processing has the benefit of automatic editing for spelling and punctuation, and uniformity of text. The importance of legibility and spelling were both touched upon in these research studies. Messy handwriting can influence the person grading a paper negatively, which is when using a computer and printing out a paper has its benefit. But for children, automatic spell-check in word processing has its downside if the child wants to be able to spell that word correctly, independently of any technology and based only upon her own memory. Learning to spell by writing the words by hand gives the brain an advantage and leads to long-term memory. Letting a computer fill-in or correct and replace the words has no such effect. Last, there is also the issue of the difference in the strain on the eyes when students read and write with paper, or read and write from screens. The more staring at backlit screens, namely the LCD kind, the more eye strain and visual fatigue the student experiences. Reading from and writing on paper books and articles or a whiteboard strains the eyes to a much lesser degree.

To go forward, I would conclude after studying this research that schools should continue to teach children how to write by hand, and how to spell words by hand, and have them write their own compositions by hand. If the computer is used, it could be used in the final drafting process. For students who are expected to compose their rough drafts or do their assignments or homework on computer, it is imperative that the actual act of typing is mastered, and not just dabbled in, so that they are fluent keyboarders. Fluency is important here. Just as the reader who struggles with decoding suffers in comprehension, the writer who struggles with finding keys or with the laborious formation of letters by hand suffers in quality of thought and expression. For future research, it would be

interesting to survey American university students as Fortunati and Taipale did in Italy and Finland with the same questions regarding their perceived differences between digital reading and writing and that done via paper and pen/(cil). Likewise it would be interesting to test the differences in annotating when done electronically versus by pen in hand with paper or book. Last would be to study the differences between print and cursive handwriting to see if cursive handwriting is important in any way, or just an embellished form of handwriting itself (which we know is proven to be important in the learning process).

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