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The Effect of Handwriting vs. Keyboard Writing on the Learners' Reception of Words: Challenges and Benefits

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Abstract:

In this study, we were interested in determining how writing mode affects word memory and recognition. Handwriting using a pen on paper, typing on a regular laptop keyboard, and typing on an iPad touch keyboard were chosen as the three writing modes. Using a completely counterbalanced and in-subjects experimental design, 36 women ranging in age from 19 to 54 participated. Participants were asked to jot down words that were read aloud to them in each of the three writing modes using a wordlist paradigm. By handwriting, on a keyboard, and on an iPad virtual keyboard, we assessed our participants' verbal recall and recognition abilities. For the purposes of this study, the data were analysed using non-parametric statistics. This study's findings show that writing modality has an overall effect, and further analyses show that participants had much stronger free recall of words written in the handwriting condition than words written in either of the keyboard conditions. The writing mode had no influence on recognition in this circumstance. According to the results shown in the graph below, handwriting may have certain cognitive advantages over writing on a computer keyboard when it comes to word recall components. Findings are investigated for their educational and cognitive value in this study.

Keywords: Handwriting; keyboard writing; ergonomics of writing; word memory; cognition; educational implications of digitization embodied

1. Introduction

1.1 Background and motivation

Unlike other animals, humans are able to communicate through the written word (Preiss & Sternberg, 2005; van der Weel, 2011; Wolf, 2007). An inscription method has existed since the 4th millennium BC, when writing was developed, and it has always been done with the help of some form of item or technology, and it has always left a physical mark. Following the invention of the printing press by Johannes Gutenberg in 1440, manual inscriptions were replaced by mechanical typewriting. As digital writing devices take the place of mechanical writing instruments as the primary means of communication, handwriting is being disregarded even more frequently. It's a tendency that's also seen in the early stages of writing education (see, for example, Genlott&Grönlund, 2013; Trageton, 2003) that kids are learning to write by typing on virtual touch-screen keyboards or regular computer/laptop keyboards alongside traditional handwriting. In terms of the individual, cognitive, educational, and social implications of such a shift, we still don't know everything there is to know (Kiefer &Trumpp, 2012; Mangen, 2013; Mangen&Velay, 2010, 2014; Velay&Longcamp, 2013).

A variety of practical, pedagogical, and cognitive questions about writing are raised as a result of the marginalisation of handwriting. Putting our thoughts down on paper is a cognitive technology par excellence, according to Margaret Wilson (2008, p. 382): "For purposes of embodied cognition, this last example is perhaps most interesting not so much in terms of its archival functions [...] but for its functions in serving as an external memory device during ongoing cognitive processing [...]." Formalized (Wilson, 2008, p. 382) and formalised (Wilson, 2008, p. 382) formalised (Wilson, 2008, p. 382) formalised (Wilson, 2008, p. 382) formalised (Wilson, 2008, p. 382) Consider the following questions in light of this: Is there a role for digital writing tools in supporting and enhancing cognition? Does putting things down on a computer rather than by hand have an effect on our ability to recall what we have written? Does it matter if we type on an iPad with a virtual touch keyboard or a real keyboard on a laptop when it comes to memory performance? Some researchers (Chandler, 1992; Hensher, 2012; Keim, 2013, and McCullough 1996) have claimed that writing by hand is more stimulating to the mind than writing on the keyboard is. It is not yet

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clear how and to what degree such gaps occur, as well as what the cognitive and educational consequences of such variances would be.

A study in cognitive neuroscience comparing handwriting and keyboard writing (Longcamp et al., 2008; Longcamp, Boucard, Gilhodes, &Velay, 2006; Longcamp, Tanskanen, & Hari, 2006; Wamain, Tallet, Zanone&Longcamp, 2012) as well as the "embodied cognition" research paradigm (Calvo &Gomila, 2008) inspired this experiment. I According to this study, whether or not the words are written down by hand or typed in using a laptop keyboard has an impact on how well they are remembered.

Additional information is given on the haptics and the ergonomics of writing instruments.

As a result of the current digital revolution, writing is being explored as a cognitive and sensory-motor activity. Writing on a computer keyboard requires a change in the haptics of handwriting, or the combination of our fingers and hands' active movement and our bodies' (passive) feeling of touch when we write, according to Mangen and Velay (2010). While there are physiological and ergonomic differences between handwriting and keyboarding, there also exist cognitive and phenomenological differences that must be taken into account. While we use both hands to type on a computer keyboard or touch screen, handwriting is among the most lateralized of physiological activities, with just a few people capable of writing with both hands at the same time. Handwriting can be a challenge for new writers since they have to use all their cognitive resources to generate individual letters instead of focusing on the text. As a result of this automation, cognitive resources are freed up to focus on the substance of a document (Feder &Majnemer, 2007). When it comes to writing, there is a distinct difference in the synchronisation of physical effort and visual attention between the two modes. You may find the page I'm talking about here: Inexperienced touch typists, on the other hand, are more likely to focus their visual attention on the keyboard than than the words they're typing on the computer screen (Johansson, Wengelin, Johansson, &Holmqvist, 2010). Our attention tends to focus on the tip of the pen while we are writing by hand since that's where the traces of the letters appear to come from While visual attention and sensorimotor activity are synchronised and continuous while writing by hand (Mangen, 2013), they are not when writing by keyboard. As a result, the process of inputting text using a keyboard is conceptually and physically distinct from the act of inputting text by hand (Mangen, 2013).

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Handwriting on paper necessitates a greater degree of precision and dexterity than writing digitally, according to the majority of experts (Mangen&Velay, 2014). Instead than relying on a computer keyboard, handwriting provides a more controlled and supervised translation of the writer's message. With handwriting, we seldom construct or apply an incorrect character (in relation to the intended letter and, assuming proper grammar skills are available, words), although technical errors are widespread with keyboard writing due to variations in motor control and coordination. Using digital tools to create text has resulted in an increasingly distant link between the physical, sensory-motor input of the writing process and the resulting audiovisual output (the written text itself) (Mangen&Velay, 2014).

A study that compares the cognitive and educational benefits of handwriting against typing has not been conducted, despite the above-mentioned technological inequalities. There is an impression that writing is primarily a mental activity based on current writing research (e.g. Alamargot and Chanquoy, 2001, 2012; Berninger, 2012; MacArthur, Graham and Fitzgerald, 2006; Torrance et al., 2012; Van Waes, Leijten, and Neuwirth, 2006; Van Waes et al., 2007; Van Waes et al., 2006). I There are three main processes in the writing process, according to Flower and Hayes (1981), who established the most frequently used cognitively-oriented writing model. These are: planning (creating an outline and defining goals), translating (creating text) and revising (i.e., text reading and editing). According to a recent empirical study (Olive &Passerault, 2012), written composition is a visuospatial activity in which working memory's visuospatial processes play an important role (Olive &Passerault, 2012).

In the digital age, writing has become more of a sensory-motor, tool-mediated activity that requires the dexterous use of writing implements (e.g., pens, pencils, keyboards, digital styluses) and writing surfaces (e.g., paper, computer screens) as well as a variety of writing surfaces (e.g., computer screens) (e.g., paper, cardboard, screens). It is possible that the diverse ergonomic and tactile affordances of these writing implements, as well as the writing surfaces, may have an influence on cognitive elements at different levels of abstraction. An examination of ergonomic elements of writing is therefore important, and the embodied cognition paradigm may be particularly beneficial for this.

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2. The theoretical framework

2.1 Embodiment of thought

Embodied cognition theory suggests that switching from handwriting to keyboard writing will have effects on a wide range of cognitive processes, from basic perceptuo-motor processing all the way up to higher level thought processes (Kiefer &Trumpp, 2012; Mangen, 2013; Mangen&Velay, 2010). Cognition is thought to originate not just in the brain (Fodor, 1983) or in a symbolic processing unit (Clark, 1997, 2008), but also in the nervous system's sensory and motor systems, a theory that has gained popularity in cognitive research in recent years (Calvo &Gomila, 2008). As a result of this concept of "embodied cognition," it may be said that the processes of sensory perception (such as sight or sound) as well as motor activity and mental processing are more closely linked and interdependent than previously thought. Embodiment theories have gained increasing empirical support in recent years, based on behavioural and neuroscientific studies (see Kiefer &Barsalou, 2011) that show how cognition is based on the reinstatement of both external and internal perceptions as well as bodily actions that produce simulations of previous experiences (Kiefer &Trumpp, 2012).

Under the phrase "embodied cognition," a wide range of theoretical contributions from several fields can be combined. The motor theories of perception are the most important cluster of theories for this paper's goals. First postulated by Liberman et al. (Liberman & Mattingly, 1985), motor theories of perception claim we cognitively duplicate movement and activities even when we see (or just hear, or only touch) something. Research in cognitive neuroscience and neurophysiology shows that when people are shown pictures of instruments that need certain movements (e.g., a hammer, scissors, a pen), the brain's motor regions (e.g., premotor and parietal areas; Broca's area) are active (Chao & Martin, 2000), There are many ways in which motor theories of perception can be used to support the idea that human cognition is "sandwiched" between perception (the input from our environment to our minds) and action (the output from our minds to the external environment), demonstrating the existence of underpinning motor-perceptual links.

When it comes to embodied cognition, this is perhaps the area where the most functional links between action and perception have been shown and where the notion is clearest (Velay&Longcamp, 2013). To the extent that alphabetic characters may be linked to specific handwriting motions even though they aren't physical objects, we can assume that motor-perceptual links play a role in their representation. It is necessary to create a graphic shape that is as comparable to the visual model as feasible in order to do these tasks. Handwriting actions are therefore linked to constant spatial information about a specific letter. Goodnow and Levine (1973) used the term "grammar of action" to describe the rigorous geographical and temporal limits that they imposed on their subjects (Velay&Longcamp, 2013).

Such mental simulations of movement are particularly important for the present experiment since everything written by hand leaves a record of movement, which makes them highly relevant. A "imprint of action," is what Longcamp et al. (2006) call a handwritten script, and they point out that, despite the wide range of handwriting styles, we can typically recognise it: It has been shown in a number of psychophysical investigations that the perceptual system can accurately derive production-related information from the visual trace [...]. Researchers including Tanskanen and Longcamp (2006) In the work of Longcamp, Tanskanen, and collaborators (2006) In the perception of handwritten traces, this data shows that we use information about the implicit motor principles involved in handwriting, supporting the idea that we do so.

In a nutshell, the kinesthetic processes involved in handwriting are distinct from the kinesthetic processes involved in typing on a keyboard. As a result, it is fair to expect that the continued marginalisation of handwriting will have major cognitive, educational, and cultural repercussions on an individual and society level.

2.2 Handwriting and keyboard writing; relationship to word memory

Writers must evaluate visual, proprioceptive (i.e., haptic/kinesthetic), and tactile information at the same time, according to studies on writing and drawing in neuroscience, and graphonomics specifically (Fogassi&Gallese, 2004). Learning the shape of each letter and honing one's graphomotor talents (the movement that results in the letter's shape) are critical to improving one's handwriting (Van Galen, 1991). There are clear neural network activation pattern similarities between seeing, reading, and writing letters in different languages and writing systems, for example, comparing logosyllabic systems (e.g., Chinese), Japanese ideograms, and alphabet systems, among others (Kato et al., 1999; Longcamp, Anton, Roth, &Velay, 2003, 2005; Van Galen, 1991). Brain imaging techniques have shown that neural networks can be differentially activated by the processing of different writing systems: logosyllabic writing systems appear to activate very distinct parts of the frontal and temporal areas of the brain, particularly regions involved in what is known as motor perception (Chen, Fu, Iversen, Smith, & Matthews, 2002).

Handwriting, in particular, relies heavily on the motor component, according to this study (Longcamp, Tanskanen, et al., 2006; Velay&Longcamp, 2013). To back up this argument, there are studies in the field of neurology showing that Letter memorization may be assisted by the movement of the hand when writing, according to certain studies. For example, in Japanese schools, children are sometimes taught to memorise kanji characters by repeatedly writing them by hand (Naka & Naoi, 1995). When writing difficult letters, many Japanese adults describe doing so with their finger in the air to help them recognise and remember their meaning. As a matter of fact, the Japanese call this phenomenon "kuusho" (Japanese for "kuusho") (Cibulka, 2013; Sasaki, 1987). Additionally, students' ability to retain graphic forms is facilitated when they are taught in handwriting (Naka & Naoi, 1995).

There are a range of purposes and contexts to which we write during the day. We write in order to remember something essential, which is one of writing's most crucial roles (e.g., shopping lists; note taking during reading or lectures; post-it notes). We should do more research on how writing affects our memories in light of how important writing is. Researchers employed the respondents' own handwritten notes to test the impact of writing modality on verbal memory for their own written content (i.e, writing with a pen on paper, typing with a laptop keyboard, or using a virtual touch-screen keyboard).

When it comes to chores like drafting grocery lists, taking notes during meetings, and reading for school or work, people are increasingly using tablets and smartphones instead of traditional desktops and laptops. The tactile and haptic feedback provided by touch-screen (or virtual) keyboards sets them apart from standard computer and laptop keyboards in several ways. A computer keyboard's tactile and haptic feedback is more noticeable than that of a touch-screen keyboard's, which is limited to the (optional) slight vibration enabled by force feedback and, in addition, does not allow the user to feel any tactile borders (or edges) between individual keys. This is more of a point of emphasis. Within-subject design was employed to boost ecological validity of the study by employing three different writing modes for each participant. With a ballpoint pen and paper or an iPad's touch screen keyboard, these included handwriting and typing.

Numerous researches have examined how writing method (both handwriting and typing) affects elements of memory retention, identification, and recall, particularly in the field of neurology Memory for letters learnt by handwriting and keyboard writing were compared in two behavioural tests, one for toddlers and one for adults (Longcamp et al. 2005). (Longcamp, Zerbato-Poudou, &Velay, 2006). (Longcamp, Boucard, and et al., 2006). Both studies found that those who learned to write by hand subsequently had greater memory and visual recognition than those who learned to write on a keyboard. For the first time, fMRI results from Longcamp et al. (2008) showed that processing handwritten and typed characters' orientation did not depend on the same brain regions as in earlier studies. Many areas of the brain involved in visualising and executing actions, such as the left Broca's area and the bilateral inferior parietal lobules (IPLs), were more active in the handwriting condition than in the other conditions (Longcamp et al., 2008). It's likely that the sensory-motor actions involved in writing by hand lead to the ultimate recall of the character's form and/or orientation (Longcamp, Tanskanen, et al., 2006; Mangen&Velay, 2010).

Every one of these findings has something to do with the ability to recall single letters or character combinations. Single-letter memory may have limited ecological value for many everyday writing activities connected to functional memory or learning outcomes, and this may be the case at all levels of development. Only Smoker and colleagues (2009) have taken this line of investigation a step further by investigating possible links between writing modes and word-level memory. An experiment in which participants were asked to recall and recognise words that had either been written down by hand or typed on a computer keyboard was published in Smoker et al(2009) .'s Journal of Experimental Psychology: General. For the purpose of this investigation, the researchers conducted a between-subjects experiment in which 61 people participated. Handwriting on paper and typing on a standard computer keyboard were the two writing modes, with the keyboard condition being a regular computer keyboard. On a printout (in the case of handwriting) and on the left hand side of a computer screen (in the case of computer use), participants in both situations saw identical words (taken from the sixth grade Florida Comprehensive Assessment Test (FCAT)). Using paper

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or a computer, participants were instructed to copy the words exactly as they were listed, writing them down next to the originals. The assignment had no time limit, and the logbook recorded every minute of time spent on it. A distractor task was assigned to participants after the display of the stimuli. As soon as the distractor task was done, the participants were encouraged to write down on a blank sheet of paper as many words as they could remember in order to show their memory. It wasn't long after they completed the memory exam that the participants were asked to complete an FCAT vocabulary recognition problem. A five-minute time limit was also imposed on the recognition exercise.

The effect of writing medium on the identification test was substantial in a research conducted by Smoker and colleagues (2009), which indicated that memory on the recall task was close to significance in favour of handwritten words. Study results show that people are more likely to recall the meaning of words if they have written them down by hand rather than typing them in, according to Smoker et al.

An important part of the current study is a direct replication of Smoker and coworkers' work, although the design is completely counterbalanced within participants. Using a mechanical laptop keyboard and a virtual touch keyboard, we test whether individuals can better recall words written as part of lists when they are written by hand rather than typed. To test these two possibilities, a new experiment has been set up.

H1: “Our first hypothesis was that superior free recall of words written by hand would be observed when compared to words written on a physical laptop keyboard and words written on a virtual keyboard on an Apple iPad.”

H2: “We also anticipated that results on the word recognition test would differ depending on the writing modality used, more specifically, that participants would recognise more words if they had written them by hand rather than using a computer or iPad keyboard to type them in.”

3. Method

3.1 Ethical standards

Participants were required to sign an informed permission form before participating in the study, which was authorised by the Norwegian Social Science Data Services (NSD).

3.2 Participant and design factors

There were three writing conditions in the current study, and each participant was allocated to one of them. Students and teachers from a medium-sized Norwegian university participated in the study, which had 36 female participants. It was critical that all participants were fluent in Norwegian. According to the research, all of the participants had normal eyesight and hearing as well as no issues reading or writing. Thirteen people described themselves as "touch-typists," while three described themselves as "left-handed." When 36 individuals were utilised in a repeated measures design with three conditions, the power to detect a medium effect size (f = 0.25) was 0.9, according to a power analysis. Age, education, conventional keyboard typing speed (words per minute), keyboard experience (years), and touchscreen experience (years) are all shown here. Table 1 shows the results.

Table 1. Demographics, writing experience and writing skill

	Mean (SD)	Max, min	Median
Age	25.22 (7.98)	54, 18	22
Education	15.81 (2.70)	22, 12	15
Years of experience with keyboards	12.97 (6.19)	35, 4	12
Years of experience with touchscreens	0.89 (1.04)	3, 0	1
Age when started with keyboard writing	12.25 (5.32)	23, 3	12
Keyboard words per minute	61.00 (21.12)	118, 26	59

3.3 Instruments

We employed a word list paradigm to examine the influence of writing mode on a core cognitive outcome. Cognitive psychologists have long utilised word list learning to study episodic verbal memory (Tulving, 2002), a sort of verbal, consciously accessible memory for elements connected with events. To assess episodic verbal memory, we used word list learning in this study (Mayes & Roberts, 2001). Each step in the process of recalling what has been encoded and stored is regarded to be a separate component of the overall process of recalling previously learned knowledge (Mayes & Roberts, 2001). A larger demand is placed on attentional resources when subjects are asked to recollect the contents of a previously learned/encoded and stored word list than when subjects are presented previously learned words and asked if they were old or new (Naveh- Benjamin, Craik, Guez, & Dori, 1998). When it comes to retrieval and recognition, the tactics used during encoding might have a varied effect (Tulving & Thomson, 1973). Consequently, the retrieval processes on memory as they relate to list-learning throughout various forms of writing were evaluated in this study by evaluations of both word recognition and free recall.

There were three word lists used for the listening-to-writing exercise. It had 28 words, all of which had a similar semantic context and were divided into three unique semantic groups. Action verbs (for example, "paint"), animals (for example, "dog"), and food were the three main subjects of the lists (for example, "avocado"). We identified a similar number of items with one, two, and three syllables in each category on each of the word lists. There was a 6-second delay between each word captured digitally and processed, resulting in each list lasting around three minutes in length (see below). A full picture was created by including all 28 target words and their corresponding distractor words on each recognition checklist. There was no rhyme or reason as to the sequence in which the items on the checklist appeared.

Technically-oriented gear

On a Dell laptop with Windows 7, a set of KOSS SB/45 headphones were used to record each of the three-word lists and play them again. Apple's first-generation iPad running IOS 4 and its notepad software with the default font type and size were used to build a touch technology keyboard. Dell laptop with a full-size keyboard was utilised for the physical keyboard condition, with participants writing in Notepad in Windows XP with the window maximised and Lucida Console 10 point typeface as the default typeface. For the handwriting test, an A4 notebook and a normal blue ballpoint pen were used. An in-built microphone was attached to a digital video camera, which was mounted on a tripod, for each session's video recording. This made it possible to evaluate the recall sessions in the future.

Procedures

During the experiment, participants were required to enter a list of words using handwriting, a real laptop keyboard, and an iPad virtual touch keyboard, all of which were dissimilar from one another in every way possible. Before the session began, each participant received a set of headphones to wear throughout the event. Upon entering the room, they were informed that they would be hearing a series of phrases read out loud. Participants were told to jot

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down each word as soon as they heard it, one word at a time, as soon as they heard it. In each of the three scenarios, the same approach was taken. After completing the job of writing down all of the items on a given list, participants were informed that they would be asked to recall as many words as possible. Although participants were advised that they may use any approach to organise written words to increase memory and recall, such as establishing line breaks between each new word or organising words into columns or clusters while writing, they were also informed that they were free to do so.

Participants were instructed to scribble down the words that were read aloud to them while wearing headphones, then a second set of words was played back to them. Participant word lists were then put aside and participants were instantly asked to recollect as many words from the list as possible. To ensure accuracy, after each listening-writing session, participants were asked to check their written lists for the presence of the target and distractor terms. A lab assistant read aloud a set of target and distractor words for the recognition exam. There was a radical reversal of how writing strategies and word lists were provided across all disciplines.

When using a physical keyboard and writing by hand, participants should sit comfortably in front of the laptop and notepad. It was up to the iPad participants to choose whether or not to hold or place the tablet on a desk in front of them while they were doing the experiment. Participants were told to say aloud any and all words that came to mind as part of the free recall condition. As soon as they thought they could recall no more, the participants contacted the researcher and they were given an infinite amount of time to do so. People who recalled what they said and how they said it, as well as any interruptions to their mental process, were documented (words not in the list).

To test whether or not a participant recognised the words on a list of targets and distractor words, the experimenter read the list aloud to each participant. Participants were then asked to indicate whether or not each word in the list was one they had written down. To finish the task, the participant had to go through the process again for the other two writing technology conditions.

A speed typing exam (available at http://norwegian-speedtest.10-fast-fingers.com) was used to measure the participants' keyboard writing speed and whether or not they were touch

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typists after they completed all three conditions. The participants were also asked to indicate how many years they had spent using keyboards and touch-screen devices in order to better understand their writing abilities.

Analysis

Using a signal detection technique to evaluate discrimination performance, the d' (d-prime) measure of recognition memory performance was produced by balancing the percentage of recognition hits and false positives according to the proportion of recognition hits and erroneous positives (Macmillan & Creelman, 2005).

We were able to assess if the data were normally distributed by doing the Kolmogorov-Smirnov test on a single sample. The following variables deviated statistically significantly from normalcy based on the Kolmogorov-Smirnov test: Handwriting data was negatively skewed, whereas data from the keyboard exhibited a flattened distribution and data from the Pad condition was right-skewed ($p=.001$; skewness: 0.721). When it came to recognition, the data from the Pad condition was right-skewed ($p=.001$; skewness: 0.721). Nonparametric statistics were utilised throughout the investigation as a consequence.

The omnibus analyses of differences between rankings in the groups for free recall and recognition were evaluated using Friedman's related samples analysis of variance. Planned follow-up samples were compared with related samples in each group using the Wilcoxon statistical test. Z-scores and the square root of N, as specified in Rosenthal (1991), were used to determine effect sizes (r) as published in Rosenthal (1991). (1991). We used a non-parametric Spearman rank-order correlation analysis to examine the relationship between a number of different performance metrics, such as memory, typing speed, keyboard usage experience, and the use of touch-screen technology. Mann-Whitney U tests were also employed to examine if there were any differences in memory performance between touch-typists and non-touch-typists. The data was analysed with the help of the SPSS 22 statistical software tool.

4. Results

"In Table 2 , we show descriptive statistics for free recall and recognition in the three different writing modalities:"

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Table 2: Performance

	Free recall		Recognition (d′)	
	Mean (*sd*)	Median	Mean (*sd*)	Median
Handwriting	15.33 (*4.67*)	15.0	2.91 (*0.56*)	3.04
Keyboard	13.89 (*3.64*)	13.0	2.78 (*0.51*)	2.79
iPad	13.64 (*4.54*)	12.5	2.67 (*0.78*)	2.72

sd: standard deviation;
d′: d-prime

The only statistically significant omnibus group difference was seen for free recall (p.049). Free recall was considerably better in the handwriting condition than in both the keyboard (p =.024, r =.37) and iPad (p =.050, r =.32) conditions, as well as in the iPad condition. According to our calculations, both of these impact sizes (r) are of medium importance (Cohen, 1988). A lack of statistical significance and a lack of indication of a potential trend toward significance were observed by researchers in their study.

Spearman rank order correlation analyses were used to assess if keyboard or touch technology skill/experience was linked to the free recall effect. Memory for lists produced on the iPad touch screen and years of experience with touch displays (rho =.329, p =.005) were shown to have a positive connection (rho =.329). There was no correlation between years of keyboard experience, writing speed, or age at which one first learned keyboard writing (rho = -.049, p =.785), and recall for lists produced on the standard keyboard. Neither touch-typists nor non-touch typists (N = 23) showed any difference in the ability to remember words input on the keyboard (Mann-Whitney U = 138, p =.721).

5. Discussion

Writing by hand is linked to better free recall of written content compared to text generated by traditional keyboards on computers and virtual keyboard devices, such as those found on iPads. The study's hypothesis 1 (H1) is supported by this finding. No differences in word recognition ability were seen between writing techniques, contradicting our second hypothesis (H2) on recognition memory. So our findings are incompatible with the fundamental idea that keyboard writing (whether on a virtual or traditional keyboard) diminishes or worsens memory for the material that is typed. However, our findings imply that handwriting may have certain cognitive benefits that are not totally preserved when writing on a computer for aspects of word memory. It is impossible to provide a definitive explanation for the observed pattern because the study was exploratory in nature; however, drawing on relevant empirical and theoretical research on similar aspects of writing, the following speculations are offered in an attempt to shed some light on our findings. As a result, they might serve as a starting point for further studies.

However, our findings only partially duplicated those of Smoker et al. (2009), who indicated that writing mode influences episodic memory. When it comes to writing mode, however, there were only statistically significant impacts on recognition and memory in the Smoker trial. Furthermore, years of expertise with touch screens were linked to better memory recall on the iPad, but competence and experience with traditional keyboards were not linked to greater memory recall for word lists generated on conventional keyboards. Participants' level of automaticity, albeit solely in the touch keyboard input mode, may have had a role in the outcomes based on the positive connection between lists generated on the iPad touch keyboard and years of familiarity with touch keyboards. According to our findings, several participants in our study had less than a year of experience writing on virtual keyboards while having at least four years of experience writing on conventional keyboards. It's likely that the lack of experience with virtual keyboards contributed to this conclusion, to put it another way. It is possible that participants' expertise with touch keyboard writing allowed them to rehearse (orally; quietly) prior words throughout the trial, explaining why there was an impact of experience in the touch screen keyboard condition but not in the traditional keyboard condition A touch keyboard has no tactile feedback to help distinguish between distinct keys, unlike a regular keyboard, which has tactile feedback to help distinguish between keys. Force feedback is another common feature of touch keyboards (in the form of vibration). Knowledge of and experience with a virtual keyboard that offers force feedback may contribute more to automaticity of skill and, as a consequence, reduced cognitive load than knowledge of and experience with a normal physical keyboard, according to the research on cognitive burden.

The results of this study should be taken with a grain of salt; more empirical research comparing the cognitive consequences of different keyboards will assist in better understanding the possible impact of haptic and tactile affordances on sensorimotor and cognitive processes while writing. Aiming to better understand the processes at work, future studies in writing should look to untangle the precise correlations between various components of cognitive processing, such as cognitive load, sensorimotor affordances of the input mode (i.e. writing modality).

Even while our results do not support H2, there are several possible explanations for our findings that participants were able to recall more words written by hand on paper than those typed on a laptop or iPad keyboard. One possible explanation is because writing by hand requires a different set of sensorimotor/graphomotor processes than writing on a keyboard. There must be a graphomotoric process of creating the shape of each letter from scratch while writing by hand in order to finish a phrase. This process is known as graphomotorics. Handwriting may have allowed for a more comprehensive encoding of the words into long-term memory, which may have resulted in an enhanced free recall as measured by the free recall test in our experiment. Smoker et al. (Smoker et al., 2009) observed that participants in the handwritten condition performed better than participants in the keyboard writing condition, and this finding is comparable in some ways. Using one-way ANOVA to see if memory was better for handwriting or typing, Smoker et al. (2009) found that memory on a recall task approached significance for handwritten words where the present study found a significant difference between writing modalities in favour of handwriting on the free recall measure and no significant difference for recognition (see their table 1 for details). Combined, these studies suggest that the embodied character of handwriting can boost memory in a number of different ways. When words are formed by hand, a stronger memory trace may be underpinned and contribute to better recall due to the kinesthesia contained in the sensorimotor process. But this does not explain why there was no difference in recognition performance between handwritten and keyboard writing in the current study.

Writing by hand differs from writing on a keyboard in the relationship and combination of sensorimotor input (i.e., the [physical] act of writing) with the visual feedback that results from this input. This may be one further explanation for the higher free recall of words written by hand on paper. When writing by hand on paper (or any other material substrate), the point of inscription, which is the tip of the pen on the substrate's surface, is typically the focus of visual attention. Handwriting leaves a "imprint of action" or spatial-temporal continuity between sensory and motor action and (audio) visual output (Longcamp, Tanskanen, et al., 2006). Such an integration of spatial and temporal information in both location and time is likely to lead to increased cognitive processing, which will ultimately improve elements of memory and recall. Writing on a keyboard, writers may vary between focusing their visual attention on the keyboard (and, therefore obtaining visual information from the characters on keys) and focusing their visual attention on the screen, depending on their level of automaticity or proficiency. Because their visual attention is mostly focused on the computer screen, which is a different area from their "motor area" it is likely that they are proficient keyboard writers (i.e., the keyboard). Keyboard writers may receive visual feedback about their haptic and tactile input that differs from the feedback provided while writing with a pen and paper in terms of kind and level of detail. Cognitive tests may demonstrate a deterioration in the solid mental representation of letters and words as a result. Nevertheless, it's conceivable that separating the sensory input's visual manifestation (the screen) from its motor domain (the keyboard) leads to less spatial information rivalry between the two areas, resulting in a better mental representation of the input. There is no reason to believe that these possibilities can explain why the benefit of handwriting was shown solely when it came to free recall rather than word recognition ability.

The usage of colour is another potential consideration from an aesthetic standpoint. While typing, keyboard writers' visual attention is divided between the text they are creating and the keyboard they are using. Keyboards distinguish between "motor region" (or input area) and "visual presentation area" where letters are shown from a visual-spatial point of view; the keyboard has both) (the screen; or output area). There are less visual and sensory inputs about the writer's writing process while utilising a keyboard, which may result in less accurate mental representation of the text being typed. When writing on a computer rather than a pen and paper, some experts believe that this separation causes the writer to interact with the written text less and as a result, they have a lower visual memory of the word.

Individuals differ in how long they spend staring at the keyboard as they write. When writing, some people pay more attention to the keyboard than the words on the page because they have undergone touch-typing instruction or because they regularly switch between gazing at the keyboard and the computer screen when they are proficient at typing. We discovered that being a self-described "touch typist" has no impact on the ability to retain information. Our findings become less consistent with visual feedback as an explanation. In future investigations, eye movement tracking might be employed to determine the impact of visual information on memory and retention. This would be a good way to explain things.

Last but not least, it is important to keep in mind that the current experiment participants were adults with previous writing experience in both languages. Most of them were taught to write by hand rather than via the use of a computer. Some schools are now using digital tools instead of or in addition to conventional handwriting instruction in order to teach students how to write. More and more youngsters are writing on their computers rather of writing with a pencil and paper outside of school. It's possible that having participants who were "keyboard-first" authors in a study like the one under discussion might have yielded different results. Some intriguing discoveries have been discovered in Chinese studies of children despite the fact that research on this area is still scarce, particularly in terms of longitudinal studies of children whose language and writing system are comparable to those of the current study (i.e Norwegian). Rather than learning to read and write in the traditional logographic style, Chinese schoolchildren are increasingly using pinyin-based electronic devices. With the exception of the visual qualities of logographic Chinese letters, Pinyin is a system that connects phonemes with English alphabetic symbols. Chinese children's capacity to learn to read would be harmed, according to Tan et al. (2013). Authors evaluated primary school students in three Chinese cities to see if they were able to read Chinese characters using a pinyin input technique and observed that the overall incidence rate of severe reading difficulty looked to be substantially greater than previously reported. Using digital writing tools in conjunction with the pinyin input technique appears to have a significant negative impact on Chinese children's reading performance: The interference with Chinese reading acquisition, which is characterised by fine-grained analysis of visual features of characters, pinyin typing appears to be damaging in itself. Children's reading skills increase when they practise handwriting, though. A study by Tan and coworkers (2013, p. 1122) The capacity of Chinese youngsters to recognise characters will almost certainly be harmed more by the use of a keyboard than by studying an alphabetic language. This is due to the fact that the former necessitates a more complex and detailed visual-spatial mapping and more repetitions than the latter. The question of whether replacing keyboard writing for handwriting for children whose linguistic system is alphabetic rather than logographic is an important one to examine.

6. Conclusion, constraints, and future outlooks are all addressed in this section.

The following are some of the study's shortcomings. If a ceiling effect is to blame for the absence of changes in recognition conditions, it is plausible that this is so. An even greater negative skewness of -1.02 indicates that this ceiling effect was particularly prominent in the handwriting condition, suggesting that true differences in recognition across the three recognition modalities may have been concealed by this effect. Using non-parametric statistics further weakens the statistical ability to discover actual differences since the ceiling effect covers such differences and reduces their significance. A drawback of the study is that only the encoding conditions were changed in terms of modality. Since the encoding and retrieval circumstances were not compatible, we did not explore the encoding specificity principle, but rather evaluated all memory performance using an oral report (i.e. no oral recital of the stimuli). As a result, the research doesn't look at how different modalities connected with encoding affect memory or recognition. Our findings might have been influenced by the use of visual feedback, such as looking at a growing list of words written down and memorising them. We may reasonably assume that participants in the two keyboard writing conditions had more time to memorise their lists than participants in the handwriting condition while writing in the two keyboard writing conditions... (where the writing process takes longer, hence leaving less time for visual memorization of written words). Because we didn't account for "time on task," this is something we'll look at more in future studies. The participants in this study were also adults with prior experience in both written and oral formative forms of written and spoken communication. Therefore, our findings do not necessarily apply to children and novice writers, nor do they apply to handwriting or keyboard writing in general. For this experiment, we don't know if it would have been different if the participants had learnt to write on a keyboard instead of by hand. Because various writing forms have varied affordances in this regard, our study has another possible flaw: that we didn't control for spatial organisation when respondents wrote down the lists. However, just one person ordered words geographically according to their semantic significance when writing. Every other person only wrote one word per line. For this reason, it is plausible that working memory effects may have been present when all recall procedures were completed within a few hours of encoding.

As the writing process becomes more digital, it is important to recognise the importance of writing devices and the substrates on which they are written in the act of writing (e.g., paper vs. screens). Even while writing requires delicate finger and hand motions that are intertwined with attention, perception, and cognitive processes, it is also a tool-mediated talent. There are major differences between writing by hand and typing on an electronic keyboard when it comes to sensory motor and kinesthetic awareness. Results from this study show that it is crucial to analyse the function of sensorimotor and kinesthetic processes involved in writing since these processes differ considerably between handwriting and keyboard writing. Subjects were able to recall more words that they had written by hand when compared to both the iPad touch and laptop keyboard conditions. This study shows that different technologies may alter cognitive results in different ways when it comes to writing, as seen here.

In order to better understand how digital technology affects writing's cognitive components, further empirical study is needed. Material and ergonomic elements such as the interaction between sensorimotor execution and psychological processes, as well as the cognitive outcomes of distinct writing modalities are critical to consider when building writing technologies, according to our findings. The better performance in the handwriting condition in this study is not attributable to the fact that people had grown up learning to write with a pen and paper rather than a computer keyboard, according to the findings of this study. To determine whether or not this is a generational issue, or whether something more basic, less time-limited, and age-specific is at play, there is a need for further empirical research, particularly longitudinal research including children and young people.

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