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Abstract: The article explores the relationship between handwriting and an individual's thought. University of Minnesota professor Christina Haas found in late 1980s that students do better job of planning their writing by hand, which started her fascination on understanding the connection between the mind and the hand. Anna Mangen of the University of Stavanger in Norway explained how handwriting unifies the hand , eye and attention at a single point.

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THE SCIENCE OF Handwriting

HOW WE LEARN

As we jettison the pen and pencil in a digital world, we are changing the way our brain thinks about writing

I am writing this article in bold, retroexperimental fashion, using a technique found rarely in the modern publishing world: handwriting, using pen and paper, those dead-tree tools seen by technophiles as historical curiosities, like clay tablets or Remington typewriters.

Why do such a thing in a keystroke age? In part I do so because handwriting is becoming a marginal activity, in society and in my life. We type more than ever before, and it's not uncommon to meet people who have ceased writing by hand altogether, their scripts withering like vestigial limbs.

I can't shake the feeling that my thinking is different--more measured, more rich--when mediated by hand rather than machine. People whom I ask often tell similar stories. The bulk of their words are delivered by keyboard, but they still make lists, take notes, outline texts or compose their thoughts by hand. They, too, feel handwriting engages the mind differently.

The feeling alone is certainly unscientific. It could be an illusion or confounded by factors, such as the difficulty of checking e-mail on paper, that have nothing to do with handwriting's cognitive properties. Skeptics might contend that modern children, weaned on keys and screens, will wield their devices to equal effect. As long as we write, what does it matter how?

So goes the conventional wisdom. Every other major millennial technological shift has occasioned hand-wringing concern: we worry about Internet addiction, friendships trivialized by social media, e-readers supplanting physical books, screens turning kids into stimulation junkies. Yet apart from writer Philip Hensher's lovely *The Missing Ink*, a book that plumbs handwriting's cultural history, the dwindling of this technology, central to civilization's rise, has gone largely unremarked.

As it turns out, only a few researchers have studied handwriting's relation to thought, and their findings are in early-draft form--but the draft suggests that us pen-clutching holdouts may be on to something. Pens and pencils do seem to engage our brain in a unique manner, especially as children. Whether these differences translate into nuances of adult thought is still unclear, and if you're looking for advice on whether a number-two pencil will best boost your brain, it doesn't exist. But society ought to be very careful about putting its pencils away for good.

Our Marvelous Hands

Given that writing is one of humanity's foundational achievements--Hammurabi's codes were not committed to memory, and Gutenberg could print only what was first handwritten--one might expect more scientific conclusiveness about its media. From the first modern writing studies in the 1970s until recently, researchers have focused on cognitive and linguistic aspects, such as revision strategies and memory. Brains mattered, not tools, nor the rest of our bodies. The medium was not the message.

"Researchers have been concerned with writing as a linguistic activity. It is, but it must also be accomplished in a material way," says Christina Haas, a professor in the University of Minnesota's writing studies department and editor of the journal *Written Communication*. In the late 1980s Haas found, to her surprise, that students seemed to do a better job of planning their writing by hand than by keyboard. It was a data point, not a conclusion; the study was small, and the students likely did not start typing during childhood, which would matter. Still, her result was intriguing.

"I thought, How can it be that the tool you use can influence what's happening in your brain?" Haas says. "I know this sounds simple, but it led me to the insight that people weren't talking about: it's the human body that intervenes between the tool and the brain." Central to that intervention are our hands, through which so many everyday interactions flow. (If you want to appreciate your hands anew, spend the next 15 minutes being mindful of their movements.) In a vision-centric society, hands tend to be overlooked, but their evolutionary importance is paramount.

Lucy, the australopithecine mother of our lineage, was not merely special because she stood upright but because doing so freed her hands. Over the next several million years these appendages gained exquisite versatility and precision, of use in crafting tools and also possibly in shaping language. Some researchers think gesture allowed language to evolve, imparting the representational richness necessary for syntax to arise. "That linkage between hand and mind is intimate," says anthropologist David F. Armstrong.

The importance of the hand-mind link is seen in developing children, for whom the ability to manipulate physical objects tracks uncannily with the acquisition of speech. It is also evident in the clinical literature, which contains many examples of patients with brain lesions that impair their handwriting also struggling to recognize letters by sight. For people who have trouble reading, tracing the outlines of letters with their fingers often helps.

"We use our hands to access our thoughts," says Virginia Berninger, an educational psychologist at the University of Washington. What our hands do with a keyboard is very different than with pen and paper. For most people, typing becomes automatic after a few months of instruction. Learning the precise geometries that make up handwritten characters, however, takes years. (The dominant hand is not alone, either. As interface expert Yves Guiard of Télécom ParisTech has shown, nondominant hands constantly and subtly adjust paper position just before letters are formed.) The geometries are so rich that forensic analysts take as axiomatic that no two people have the same script.

Visual feedback is also essential. Handwriting is messy in the dark. And that points to what literacy professor Anne Mangen of the University of Stavanger in Norway considers a central property of handwriting: it unifies hand, eye and attention at a single point in space and time. Typing on a keyboard, which Mangen calls "the abstraction of inscription," breaks the unity. The question is, Does it matter?

The Scientific Letter

The beginnings of an answer lie, appropriately, with letter perception. Seeing either handwritten or typed letters naturally stimulates visual activity, but the former also produces motor activity, although we remain physically motionless. At the neurological level, a scripted letter is both visual and physical.

Marieke Longcamp, a cognitive scientist at Aix-Marseille University in France, refers to this phenomenon as an embodiment of perception and has investigated its consequences in a series of experiments that test children on their ability to recognize letters, a task of deceptive simplicity to a literate adult. Discerning and understanding that A and a are the same characters is only easy because we have practiced for so long.

When Longcamp trained children still learning the alphabet to write letters by hand, they more readily recognized the letters than when she taught them the appropriate keystrokes, as she described in a 2005 study. A year later Longcamp saw a similar pattern in adults, but with an interesting twist. Over several weeks she taught adults to handwrite or type unfamiliar Bengali letterforms. Immediately after training, handwriters and typers were equally adept at recognition

tests. After several more weeks, though, dramatic differences in recall emerged. Letterform knowledge accumulated by hand persisted, whereas typed learning dissipated.

Longcamp attributes this difference to the motor activity that seeing handwritten letters triggers. Because reading a scrawled character seems to activate the neurological instructions for penning it, the mere act of reading the letter replays it anew in our mind. "This memory doesn't exist in the keyboard," Longcamp says.

Those studies are not definitive; they involved just a few dozen participants, and the inevitable caveats attend. Yet they fit into a continuum of complementary findings, the next of which come from cognitive neuroscientist Karin James of Indiana University Bloomington. James is interested in functional specialization, which is the way parts of the human brain are fine-tuned to process faces, colors and motion without conscious thought.

Letters also attain specialization, but unlike colors and motion they are almost certainly not evolutionarily hardwired. Instead, James surmises, letter specializations develop during childhood, through exposure to language, raising the question of whether different types of exposure affect specialization.

James observed people's brains as they looked at letters and letterlike shapes in a pair of experiments in 2008 and 2010. When they have been taught to write those forms by hand, activity in functionally specialized letter areas is greater than when they have learned the keystrokes. Moreover, as she described in a 2012 paper, seeing handwritten letters not only triggers the expected motor activity but even heightens activity in purely visual areas. Hands help us see.

James attributes this facility not to Longcamp's mental-letter-replay mechanisms but to the way our hands produce subtly differing letterforms with every iteration. Even a practiced writer rarely produces two identical letters, and the effect is more pronounced in children. As James describes it, child letterforms are still "noisy relative to the model" and in aggregate make up a mental library of the many variations a single letter can take.

Letter recognition is a fundament of reading. It is also crucial to spelling, an ability that predicts many high-level language skills, such as translating ideas into text or expressing concepts clearly. "If this process is different according to writing mode, it can affect the whole reading process," Longcamp says.

Such millisecond-level neurological processing can cross into real-world relevance, as the work of Berninger at the University of Washington reveals. Berninger led an exceptionally thorough, five-year-long study of 128 children as they learned to write. She and her colleagues tracked their subjects on various cognitive and academic measures, from how their fingers tapped in sequence to spelling ability, memory and communication skills.

Key to a 2009 publication emerging from this study were the serially coordinated finger movements, which renowned psychologist Karl Lashley proposed, in the mid-20th century, as a foundation for

basic cognitive functions. In the 1990s they were shown to underlie handwriting as well. While performing them, students showed marked differences in brain activity usually related to language and working memory. The latter--one's capacity for keeping and organizing information in mind, such as an essay writer simultaneously grasping facts she intends to convey, her overall argument and a just completed sentence--is indispensable to complex reading and writing.

Outside the scanner, these activations in turn tracked with letter-forming ability, handwriting legibility and ultimately the students' fluency of expression. "It's legible, automatic handwriting, when you just ask kids to write the alphabet from memory, that was the single best predictor of not only spelling but the quality and amount they composed," Berninger says. She considers hands to be "the end organ of the language system."

The Next Chapter

Berninger emphasizes that her findings need to be replicated, but the studies consistently point to the importance for handwriting in child development. The message comes at an opportune time: the so-called Common Core standards, a set of guidelines issued in 2010 to unify state curricula in the U.S., has set off a national discussion about handwriting's place in school.

Much of the discussion involves cursive education, which went unmentioned in the standards, leading to its formal abandonment by Indiana and Florida. The ensuing backlash prompted eight states, including California and a chastened Indiana, to affirm cursive's importance. Cursive aside, the educational trend is nonetheless away from handwriting. It is taught less rigorously than in the past, and typing is ever more common in ever lower grades, a drift reflective of handwriting's dwindling in society at large. Kathleen S. Wright, handwriting product manager at Ohio-based education company Zaner-Bloser, says teachers often tell her about children who start school without ever having seen an adult write by hand.

"Everybody in the writing community says it's better to begin writing by hand," says behavioral scientist Thierry Olive of the University of Poitiers in France. "When you type, you don't have movement." Yet once students are old enough, can pens and pencils be dropped, like training wheels on the way to typing's 10-speed bicycle? On this question, research goes fuzzy. Writing in the adult sense is more than letterform and character recognition. It is a mentally recursive process, an ever shifting, feedback-looping interplay between thoughts and knowledge.

In some circumstances, the text-manipulating powers of word-processing programs seem to aid complex thought. The programs also offer a sheer speed that, for some people, ultimately feels more true to mind than handwriting. David Slomp, a literacy education instructor at the University of Lethbridge in Alberta, thinks this automaticity is what matters: as long as the letters flow, keyboarding is just fine. And just as Stephen Peverly, an educational psychologist at Columbia University's Teachers College, can offer anecdotes about students swapping laptops for notebooks because they better remember handwritten notes, some studies suggest the opposite.

There is, however, one aspect of writing that hints at a unique role for hands. Writing also seems to have spatial properties, a dimension revealed in experiments on writing with distractions. Texts

composed while writers trace shapes with one hand, for example, engaging their brain's spatial processes, are uniquely disorganized compared with texts composed with background noise flashing on a screen and contain fewer new ideas. Minds encode the relative locations of words and paragraphs, a blueprint of thought without which text may be less differentiated, a pile of beams rather than a scaffold.

Here, it seems, is a possible intersection for handwriting's physical aspects and higher-level properties. Perhaps hand-formed letters, inscribed more deeply in our mind, are building blocks for sturdier mental architectures. However speculative and untested a hypothesis, it resonates with many people's experiences. Often, Haas says, students reported that "somehow with the computer, I can't get a sense of my text. They used that term, over and over. Maybe they were not understanding the structure of their text." The benefits of pen and paper may then be traced, at least in part, to what they offer as interfaces: the ability to easily make squiggles and arrows, to write between lines, to integrate text with diagram. For all the effort expended on programs for brainstorming and mind-mapping and outlining, those functions remain clumsy on computers. One's writing experiences and preferences are ultimately personal, varying by situation and mental habits. Such is the case with people I interviewed for this article: Marieke Longcamp types for work but takes notes by hand. Christina Haas types documents that can be composed quickly but switches to handwriting for deep thinking. Thierry Olive types his articles but writes in his journal. Both David Armstrong and anthropologist Sherman Wilcox, his collaborator, type almost exclusively, although Wilcox edits by hand. So does John Hayes, a founder of modern cognitive studies of writing.

As for myself, coming to the end of an article that, by the time you read it, will have been written and edited by hand, typed in editor-friendly digital format, then edited again, it is difficult to say what precisely would differ if I had typed from the beginning or composed every last iteration by hand.

Frequently I outline longer articles by hand, so the essential structure would likely be similar. I do think, though, that there is something special in how a pen rests in the hand and moves across paper, to Mangen's sense of meditative flow arising from motor and sensory unity. I don't have that sense, as I do on-screen, of manipulating text blocks but rather words and sentences.

The text itself also feels somehow more complete, especially those parts derived from handwritten notes and hand-annotated reference material. I feel that I know the text more than usual. Years from now I will likely remember this story more fully than those I have typed, which sometimes I encounter online with no memory at all of writing.

Is that sentiment scientific? Not in the least. Would you have the same experience? Not necessarily. Could it be ascribed in part to the extra days that handwriting required or the subject's closeness to my heart? Quite possibly. But I can report, in this nonconclusive, N of 1 study, with no controls or standardized metrics or objective behavioral outcomes, that writing by hand felt good, even right.

FAST FACTS

Suspicious Minds

1> People who believe in one conspiracy theory are likely to espouse others, even when they are contradictory.

- 2> Conspiracy ideation is also linked with mistrust of science, including well-established findings, such as the fact that smoking can cause lung cancer.
- 3> Mere exposure to information supporting various fringe explanations can erode engagement in societal discourse.

AN EVOLVING ALPHABET

Legend for Chart:

- A - Hieroglyphic
- B - Proto Sinaltic
- C - Phoenician & Paleo-Hebrew
- D - Early Greek
- E - Greek
- F - Latin
- G - Modern Hebrew

A	B	C	D	E	F	G
	A					
	B					
	E					
	K					
	M					
	N					
	O					
	R					
	S					
	T					

Brain activity differs when printing or typing letters. In one study, subjects who saw letters they had earlier printed, but not typed, had more activity in the left inferior frontal gyrus (near right), a speech area, and in the left anterior cingulate cortex (far right), involved in decision making and attention, among other things.

According to one view, the modern alphabet evolved from Egyptian hieroglyphics, and the pictograms' meaning may have served as a mnemonic tool. For example, the modern Hebrew letter aleph is believed to have been derived from a word meaning "ox" (alp) and bet from a word meaning "house."

(Further Reading)

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◆ The Missing Ink: The Lost Art of Handwriting. Philip Hensher. Faber and Faber, 2012.

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ILLUSTRATIONS BY CELIA JOHNSON

BRANDON KEIM is a freelance journalist specializing in science, environment and culture. Based in Bangor, Me., and Brooklyn, N.Y., he henceforth resolves to not just carry a notebook and pen but to actually use them.

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