Forskningsrapport «Penn på PC – Lærer elevene mer?»

Background:

This study was part of a research collaboration between NTNU in Trondheim and Ulstein VGS (upper secondary school) in Ulsteinvik (Møre og Romsdal). The school had received means to invest in personal computers for all pupils who started in the first grade the year they turned 16 (in 2022). The project leader and other teachers at the school decided to invest in PCs with both a keyboard and the possibility to use a digital pen on a touchscreen. Since such computers are more expensive, the school was interested in collaborative (brain) research that could justify the additional cost.

Handwriting stimulates the brain:

In the NU-lab at NTNU Dragvoll [1], we study brain development with high-density electroencephalography (HD EEG) and functional near-infrared spectroscopy (fNIRS). The electrode nets used in EEG consist of 128 (infant)/256 sensitive electrodes that record electrical activity in the brain. Since 2015, the lab has been involved in a research collaboration with Microsoft Europe that has resulted in international publications in 2017 [2] and 2020 [3]. First, we showed that drawing by hand and typing on a keyboard leads to entirely different brain activity in students. Then, we showed that, since cursive handwriting activates the brain to a larger degree than typing on a keyboard does, the brain is much more engaged in communicating information between its active parts when students and 12-year-old adolescents write or draw by hand.

The lab’s brain research on handwriting has been accessed and downloaded over 150K times. It has also received a great deal of media attention, both in Norway: Dagsrevyen; Praktisk info med Jon Almaas, TV2; Schrödingers katt, NRK1 [4]; Gemini/forskning.no/Science Norway [5] and internationally: e.g., SVT and Child Trends News Service [6]. We are also involved in the new documentary series “Avlogga” (NRK1) that will be aired in the autumn of 2024, where two journalists and young fathers go completely offline for a whole year, and we measure the effects on their brains in terms of attention and creativity. On January 26th, 2024, our third publication came out, showing widespread neural network activity for handwriting only [7].

Our findings consistently show that, when we use our hand to write or draw, the sensory-, motor-, and sensorimotor areas of the brain are much more active. Using the sensory systems to carefully control hand movements to produce complex forms and letters, seems to put the brain in a state that promotes learning and remembering. Based on our findings [2,3], twenty US states have recently passed a bill that reintroduces handwriting tuition in public schools by law from January 1st, 2024. Similar discussions about reintroducing a minimum of handwriting tuition in primary schools are presently taking place in several countries in the West, for example in Sweden and Canada.

The present study:

The aim of the study was twofold. First, we set out to replicate previous brain results in an experimental task in the lab showing that handwriting, but not typewriting, gives rise to widespread synchronized neural oscillations in the alpha-theta frequency band in a subset (N=40) of 16-year-old pupils attending the first grade of upper-secondary school. Then, the whole cohort (n=146) took part in a classroom task where they watched a prerecorded lecture on the immune system while half of the pupils took notes by hand whereas the other half took notes using a keyboard [8]. Notetaking strategies were investigated in terms of number of words written and the use of drawings, as well as possible differences in grades on a classroom test between the two notetaking groups.



Figure 1. A 16-year-old pupil from Ulstein VGS participating in the brain experiment in November 2022 at the NU-lab at NTNU Dragvoll. The participant is wearing a sensor net consisting of 256 sensitive electrodes and uses a digital pen to alternately write given words in cursive on a touchscreen or to type them using the provided keyboard (just visible under the participant’s arm). Before arriving at the lab, pupils had given their informed written consent, and they were aware that they could withdraw from the study without consequences.



Figure 2. Brain sources PM (parietal midline), CM (central midline), CL (central left), OpM (occipital midline), PR

(parietal right), and PL (parietal left) visualized as connectivity networks consisting of hubs (≥4 departures/arrivals), nodes (≤3 departures/arrivals), and the connectivity lines between them. The colour and thickness of the connectivity lines represent the strength of the brain connectivity, where red lines indicate more activity than orange and yellow lines. **A**. A participant’s brain during handwriting reveals solid neuronal connections between PM, OpM, and PR and between OpM, CL, and PR. **B.** The same participant, during typewriting, reveals less connectivity within the brain, where the connectivity lines are fewer in number, less prominent, and in less vibrant colours than during handwriting. Figure reproduced from Sara Lyster’s Master’s thesis from NTNU (2023) [9].

EEG study measuring network connectivity during handwriting and typewriting:

The brain activity of forty right-handed 16-year-old pupils was measured with HD EEG while participants wrote 27 different words presented one at a time in a semi-randomized order by hand using a digital pen on a touchscreen and typed the words on a keyboard (see Figure 1).

As in our previous studies [3,7], analyses of temporal spectral evolution (TSE) and brain connectivity showed important differences in oscillatory and neural network activity when participants wrote by hand as opposed to when they used a keyboard. For writing by hand, brain areas in the parietal and central regions (the “sensorimotor” areas in the brain) showed event-related synchronized activity in the theta range. In addition, widespread alpha-theta connectivity was found for handwriting, but not for typewriting (see Figure 2). The oscillatory activity and neural connectivity patterns found in precisely these brain regions are known to be crucial for memory formation and for encoding of new information and, therefore, are likely beneficial for learning.

Classroom test to investigate if handwritten notes give better test grades than typewritten notes:

The teacher team at Ulstein VGS recorded a 20-minute lecture on the immune system and prepared an exam consisting of 15 open-ended questions. After the winter break during the spring semester of 2023, the whole cohort of 140 pupils watched the video lecture in their respective classrooms and under supervision of their usual teacher. Half of the pupils were assigned to take lecture notes by hand, preferably using the digital pen and the touchscreen on their school PC. The other half of the pupils were instructed to take lecture notes using the keyboard on the school PC. Lecture notes were digitally stored and used in the analysis. After watching the video, the whole class took part in a distractor task for about half an hour led by the teacher in charge. They then all took the digital exam where the first 8 questions were more of a factual nature, while the remaining 7 questions were considered as more conceptual and inferential. Possible top score was 15 points, one point per question.

Two teachers individually marked the same 41 exams. The interrater reliability varied a lot between questions, from 0.16 to 0.86 (where 1.0 means 100% agreement between raters). At 0.49, the overall interrater reliability was moderate. The two teachers then discussed the given grades and agreed on a joint final grade for each of the 41 pupils. One of the teachers, the project leader, then continued to mark the remainder of the exams.

When taking notes, pupils typed significantly more words (range: 6-383, M: 189±90, N=63) than they wrote by hand (range: 3-242, M: 115±47, N=72), as confirmed by an independent samples *t*-test, *t*(133)=6.0, p<0.001. None of the pupils who typed their notes had made any drawings, whereas pupils who used a pen produced a total of 147 drawings (range: 0-7, M: 2.0±1.9).

The best grade obtained was 11.75 points (out of 15). One pupil had a score of 0 points, one scored only 0.25 points and two more 0.5 points (all boys). The mean test score was 6.0 points, both for pupils who took notes by hand (N=76) and for pupils who typed on a keyboard (N=70) and with large SDs of 2.7 and 2.9 for handwriting and typing, respectively. When testing for significant differences in point scores between factual and conceptual questions for the two types of notetakings, no such differences were found.

It was clear that girls (N=63) performed significantly better on the school test than boys did (N=83), *t*(144)=3.1, p<0.001. Girls received an average test score of 6.8 points, while boys only had 5.4 points. Girls outperformed boys both on factual and conceptual questions. Also, when including only girls, test scores were 6.8 points irrespective of whether they took handwritten (N=35) or typewritten notes (N=28).

There may be several reasons why the present study was not able to show that taking handwritten lecture notes leads to better performance on a school test than taking typewritten notes. The video lecture was quite short, the test consisted of just 15 questions (8 factual/ 7 conceptual questions) and was taken half an hour after the lecture finished. Not all pupils took lecture notes and some only noted down a few words. The interrater reliability was moderate, and the test results were generally rather poor and variable, with an average score of 6±2.8 out of 15 points. Girls had better scores on the school test than boys and seemed to be more engaged in the experiment and perhaps more dutiful overall. But when the effect of handwritten vs. typewritten notes on the test scores was tested for girls only, the groups may have become too small.

Conclusion:

In the present study we replicated our previous brain results by showing that writing by hand, but not typing on a keyboard, leads to increased functional coherence connectivity in the brains of 16-year-old high-school pupils [3,7]. The neural connectivity patterns found in large parts of the brain during handwriting only, are known to be crucial for memory formation and for encoding new information and, therefore, are likely beneficial for learning in the classroom.

In the school test, we were not able to replicate the results from a study from 2014 [8] where researchers reported that university students who took notes on laptops performed worse on conceptual questions than students who took notes longhand. The students watched five TED talks and answered a total of 50 questions. We propose to improve the school test by adding more questions (especially conceptual, inferential and/or application in nature) and by carrying out the experiment under more stringent conditions, and to test a new cohort of pupils who started high school in August 2023.

Links:

1. [NuLab - Nevrovitenskapelig utviklingslaboratorium - Institutt for psykologi - NTNU](https://www.ntnu.no/psykologi/nulab)
2. [Frontiers | Only Three Fingers Write, but the Whole Brain Works†: A High-Density EEG Study Showing Advantages of Drawing Over Typing for Learning (frontiersin.org)](https://www.frontiersin.org/articles/10.3389/fpsyg.2017.00706/full)
3. [Frontiers | The Importance of Cursive Handwriting Over Typewriting for Learning in the Classroom: A High-Density EEG Study of 12-Year-Old Children and Young Adults (frontiersin.org)](https://www.frontiersin.org/articles/10.3389/fpsyg.2020.01810/full)
4. [Teknologien som forandrer oss – 3. Er det håp for hjernen? (Sesong 1) – NRK TV](https://tv.nrk.no/serie/teknologien-som-forandrer-oss/sesong/1/episode/3)
5. [Why writing by hand makes kids smarter (sciencenorway.no)](https://partner.sciencenorway.no/children-and-adolescents-natural-sciences-ntnu/why-writing-by-hand-makes-kids-smarter/1752480)
6. <https://www.ivanhoe.com/positive-parenting/how-handwriting-stimulates-the-brain/>
7. [Frontiers | Handwriting but not Typewriting Leads to Widespread Brain Connectivity: A High-Density EEG Study with Implications for the Classroom (frontiersin.org)](https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1219945/abstract)
8. [Psychological-Science-2014-Mueller-0956797614524581-1u0h0yu.pdf (cpb-us-w2.wpmucdn.com)](https://cpb-us-w2.wpmucdn.com/sites.udel.edu/dist/6/132/files/2010/11/Psychological-Science-2014-Mueller-0956797614524581-1u0h0yu.pdf)
9. [NTNU Open: An HD-EEG study of high school students showing widespread brain connectivity when handwriting but not when typewriting](https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3074575?show=full)