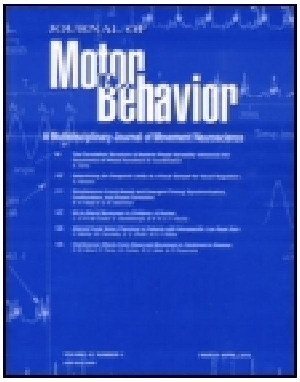

Journal of Motor Behavior
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vjmb20

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Version of record first published: 19 May 2011.

To cite this article: Sandra Sülzenbrück, Mathias Hegele, Gerhard Rinkenauer & Herbert Heuer (2011): The Death of Handwriting: Secondary Effects of Frequent Computer Use on Basic Motor Skills, Journal of Motor Behavior, 43:3, 247-251

To link to this article: http://dx.doi.org/10.1080/00222895.2011.571727

Journal of Motor Behavior, Vol. 43, No. 3, 2011

RAPID COMMUNICATION

The Death of Handwriting: Secondary Effects of Frequent Computer Use on Basic Motor Skills

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ABSTRACT. The benefits of modern technologies such as personal computers, in-vehicle navigation systems, and electronic organizers are evident in everyday life. However, only recently has it been proposed that the increasing use of personal computers in producing written texts may significantly contribute to the loss of handwriting skills. Such a fundamental change of human habits is likely to have generalized consequences for other basic fine motor skills as well. In this article, the authors provide evidence that the skill to produce precisely controlled arm–hand movements is related to the usage of computer keyboards in producing written text in everyday life. This result supports the notion that specific cultural skills such as handwriting and typing shape more general perceptual and motor skills. More generally, changing technologies are associated with generalized changes of the profile of basic human skills.

Keywords: computer use, fine motor skills, handwriting

The introduction of new technologies often goes along with mixed attitudes toward them: on the one hand, there is delight about the attained ease of life, but, on the other hand, there are worries about potential negative or even dangerous side effects. When the use of trains was established at the beginning of the 19th century, many people enjoyed the new comfortable way of traveling, whereas others worried about suffocating if carried at speeds of more than 20 mph (Harrington, 1994). In modern times, probably the most influential technological development was the invention of the personal computer. The impact of computer use on different aspects of human behavior has been the subject of numerous investigations whose results have been summarized in several reviews, for example, on the effects of computer use on children and adolescents (Subrahmanyam, Greenfield, Kraut, & Gross, 2001). The results of most of these studies show that the frequency of computer use is associated with differences in human behavior, even though they do not allow a general positive or negative verdict about the influence of computer use. The most popular subject of scientific inquiry associated with the widespread use of computer technology has been video gaming. A quite consistent finding is that playing video games is positively correlated with eye–hand coordination (Griffith, Voloschin, Gibb, & Bailey, 1983) or the surgeons' ability to operate laparoscopically (Rosser et al., 2007). In addition, positive correlations of video gaming have been found for various cognitive skills such as mental rotation (McClurg & Chaillé, 1987) or visual attention (Green & Bavelier, 2003). In a recent review, Dye, Green and Bavelier (2009) proposed that video games, in particular action video games, may provide an efficient training regimen for increasing the speed of perceptuomotor processing, but only few studies have presented evidence for a causal relationship between video gaming and perceptuomotor processing (Clark, Lanphear, & Riddick, 1987; Green, 2008).

With respect to possible negative outcomes of computer use, it has been speculated that the invention of computers and therefore the common use of keyboards to produce written texts may lead to the general loss of handwriting skills (Suddath, 2009). This may not be too disquieting in itself. However, there is reason to believe that analogous to the case of video gaming, there are implications of this development beyond the mere modification of the specific skill of handwriting. Using keyboards instead of pens could affect the human behavioral repertoire in a more general way, so that a broad class of basic motor skills rather than just handwriting could suffer.

Recently, we described a rather unexpected finding of an aging study that was related to differences in the amount of experience and practice with computers (Sülzenbrück, Hegele, Heuer, & Rinkenauer, 2010) and the associated differences in the amount of practice of handwriting. In contrast to a large body of research according to which aging is associated with a generalized slowing of cognitive and motor skills and abilities (Verhaegen & Salthouse, 1997) we found that older participants performed significantly faster ($n = 180$; M duration 29.15 ± 0.85 s) than their younger counterparts ($n = 177$; M duration 36.40 ± 1.01 s) in a particular subtask of a test battery for basic fine motor skills designed after the taxonomy of Fleishman (1972).

This particular subtask, line tracing, serves to assess the basic fine motor skill of executing precisely controlled smooth arm–hand movements. The tip of a pen is inserted into a groove that is countersunk into a metal board, and the course of this groove has to be followed with the pen from beginning to the end without the pen touching the walls of the groove. Not only were younger participants significantly slower than their older counterparts, it took them almost 8 s longer to perform the task compared to the norm values for their age group from a sample investigated about 30 years ago (Hamster, 1980).

The suspicion that this result may reflect a cohort effect of expertise in handwriting, which is closely related to the tracing task, was addressed in a post hoc analysis of the data. For this analysis we assumed that frequent computer use is

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associated with a decreased use of handwriting in everyday life. We classified participants according to their self-reported computer use as computer users and nonusers. No difference in tracing time was found between older computer users ($n = 111$) and older nonusers ($n = 43$), 29.39 ± 1.12 s and 27.38 ± 1.53 s, respectively. However, we found a significant difference in tracing time between younger computer users ($n = 140$) and nonusers ($n = 7$), with computer users being much slower (37.32 ± 1.12 s) than nonusers (28.80 ± 3.87 s). This pattern of results is consistent with the notion that frequent computer use, which replaces handwriting in the production of written text, negatively affects the speed of precise arm–hand movements in younger adults but not in older adults, who, in the absence of computers for most of their lives, all made extensive use of handwriting throughout their lifespan.

To investigate the relation between experience with handwriting or keyboard-typed text and basic fine motor skills more systematically, we invited young participants who differed in their preferred tool for producing written texts (keyboard vs. pen) and therefore in their expertise in handwriting and typing. They were tested on a set of basic fine motor skills based on a taxonomy proposed by Fleishman (1972): aiming, steadiness, precision and speed of arm–hand movements, manual and finger dexterity, and wrist–finger speed. We expected group differences to emerge specifically for the skill that is associated with the execution of continuous precisely controlled arm–hand movements, but not for any other basic fine motor skill.

Method

Participants

Two groups of participants took part in this quasiexperimental study. Participants were selected on the basis of self-declared amount of time per week spent on typing texts on a keyboard of a computer and the amount of time spent with handwriting activities. The computer group consisted of 12 right-handed individuals (7 women, 5 men) with a mean age of 25.3 years ($SD = 0.37$ years). The handwriting group comprised 8 right-handed individuals (6 women, 2 men) with a mean age of 23.6 years ($SD = 1.27$ years). The two groups differed significantly in the time spent producing written text with the help of a computer (computer: 19.4 ± 2.94 hr/week; handwriting: 2.4 ± 0.64 hr/week), $t(12.6) = 5.63$, $p < .001$, and in time spent with the production of handwritten texts (computer*:* 3.1 ± 0.89 hr/week; handwriting: 10.1 ± 1.91 hr/week; $t(18) = -3.65$, $p < .01$).

Task and Procedure

Different basic fine motor skills were assessed by means of a series of five tests of a standardized psychomotor test battery, the Motorische Leistungsserie (MLS; Schuhfried GmbH, Mödling, Austria), developed by Schoppe (1974). The MLS consists of a test board (300 × 300 × 15 mm) with two pens connected to it, one on the right and one on the left side. Measurements are based on contacts between pens and test board, which close electrical circuits (Neuwirth & Benesch, 2004). Data collection was controlled by an IBM-compatible microcomputer using the Vienna Test System software (Schuhfried GmbH, Mödling, Austria). For all participants, the five tests of the MLS were run using first the right hand and then the left hand.

The five psychomotor tests are described briefly. The steadiness test serves to assess arm–hand steadiness during maintenance of a constant position of the arm and the hand. The tip of a pen with a diameter of 1.5 mm had to be inserted into a hole with a diameter of 5.8 mm and to be held there without touching the side wall of the hole for 32 s. Line tracing measures the precision and speed of continuous smooth arm–hand movements and resembles the track tracing test of Fleishman (1954). The pen had to be placed perpendicularly into the starting position of a groove and had to be navigated through the course of the groove without touching the side walls. The aiming test measures the skill to make rapid repeated small-scale movements. Participants had to successively hit 20 linearly aligned round contact fields of 5 mm diameter and 4 mm distances in between with the pen as fast as possible without hitting the test board outside of the target areas and without missing a target. The pegboard test captures manual and finger dexterity. Participants had to take each one of 25 pegs out of a box placed in 300 mm distance from the test board and stick it into one of 25 holes (in 5 mm distance from each other) aligned vertically (starting with the highest and moving successively downward) on the side of the test board as rapidly as possible. The tapping test measures wrist–finger speed. Participants had to tap on a square contact area of 40 × 40 mm with the pen as frequently as possible in 32 s, and the number of taps was recorded.

Data Analysis

Two-sided Mann–Whitney tests were performed for each dependent variable of the test battery to compare the means of both groups. Nonparametric tests were chosen because several of the performance measures did not yield normally distributed data. For the comparison of group means of residuals of the regression analyses we computed one-sided t tests. Degrees of freedom were corrected if homogeneity of variance was not given. The probability level for statistical significance was $p < .05$.

Results

The results of the five tests (see Table 1) showed that the type of daily writing activity was associated with a specific difference in the speed of precise arm–hand movements. Although the sample size was small, we found a significant group difference in the time required to complete the line tracing test. This difference was significant only for movements with the right hand, with the computer group performing 36% slower (M duration 31.33 ± 3.35 s) than the

TABLE 1. Means and Standard Errors of Performance Measures in the Psychomotor Tests

Variable		Computer group		Handwriting group		
		M	*SE*	*M*	*SE*	Test statistic (*z*)
Steadiness *N* errors	Right hand	5.75	1.33	9.63	4.03	0.70
	Left hand	9.83	2.87	9.63	3.42	0.08
Line-tracing Duration of test (s)	Right hand	31.33	3.35	20.06	2.22	–2.39*
	Left hand	28.08	4.74	22.51	1.57	–0.77
Number of errors	Right hand	22.50	3.04	19.38	1.46	–0.27
	Left hand	29.42	3.08	25.75	4.43	–0.23
Aiming Duration of test (s)	Right hand	7.89	0.49	8.56	0.77	0.69
	Left hand	8.34	0.68	8.73	0.54	1.20
Number of errors	Right hand	0.33	0.19	0.38	0.26	0.51
	Left hand	2.08	0.76	1.25	0.45	–0.32
Pegboard Duration of test (s)	Right hand	40.89	1.86	42.04	2.27	0.69
	Left hand	42.58	1.28	45.17	1.87	1.16
Tapping Number of taps	Right hand	211.17	5.61	206.13	4.25	–0.58
	Left hand	186.25	5.35	178.00	6.17	–1.39

Note. Nonparametric statistical tests were used, and the normal approximations of the test statistic are given.
*$p < .05$.

handwriting group (M duration 20.06 ± 2.22 s; $z = –2.39$, $p < .05$, $d = 1.21$). The difference in speed was accompanied by a nonsignificant difference in accuracy, again in favor of handwriting group. Thus there was no speed–accuracy trade-off. In the tapping test the handwriting group was slower than the computer group, but this difference failed to reach statistical significance as did all other group differences.

To confirm that the difference in the duration of line tracing between the two groups could indeed be attributed to the preferred tool for writing texts and not to other factors, we conducted additional regression analyses with the duration of line tracing as the dependent variable. We successively added the potential confounding variables age, gender, number of errors in line tracing, and the total duration of weekly writing activity as predictors. In the final regression analysis, we then added the relative amount of time spent writing texts on a computer, which we computed for each participant as the ratio of hours spent writing on a computer divided by the total time spent writing. After each step of the regression analysis we compared the means of the residuals between the computer and handwriting groups. In Figure 1, group differences are depicted for the comparison of duration without any confounding predictors (*none*) as well as for the residuals of the regression analyses (note that the number of predictors used to determine the residuals increases from left to right). As Figure 1 shows, we found significant differences between the computer and handwriting groups for the comparison without confounders, with a difference in duration of 10.65 s ($t(18) = 2.50$, $p < .05$), and also when we successively added the predictors age (11.07 s, $t(18) = 2.44$, $p < .05$); gender 10.08 s ($t(18) = 2.29$, $p < .05$), number of

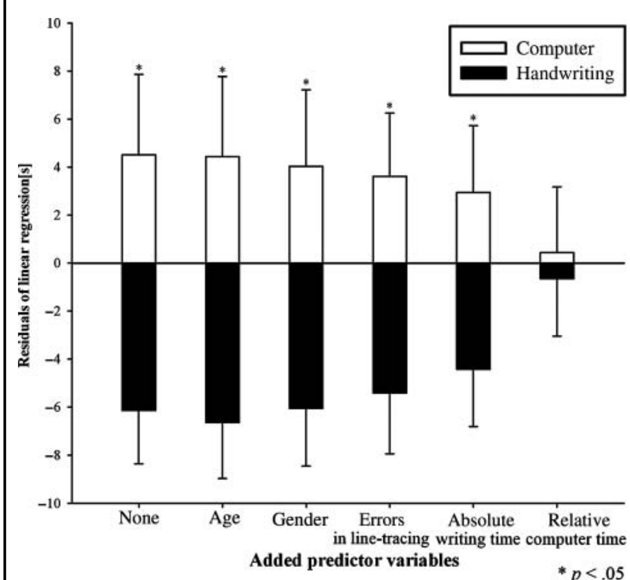

FIGURE 1. Mean residuals (with standard errors) of the duration of the line-tracing test in the handwriting and computer groups. The leftmost bars show the residuals without corrections for potential confounders: zero corresponds to the grand mean and the sum of absolute positive and negative values is the group difference. With every step to the right, we successively added the predictors age, gender, number of errors during line tracing, total amount of weekly writing activity, and relative amount of time spent writing on a computer to regression analyses for the duration of the line tracing test as the dependent variable. Significant group differences are marked by asterisks.

errors during line tracing 9.02 s ($t(18) = 2.34$, $p < .05$); and total amount of weekly writing activity (7.37 s, $t(18) = 1.87$, $p < .05$). Only when we further added the relative amount of time spent writing texts on a computer as a predictor was there no more significant group difference in the residuals (1.08 s, $t(18) = 0.28$, $p > .20$). This result indicates that the group difference in speed during line tracing can indeed be attributed to a difference in the relative amount of time spent writing texts on a computer and therefore to the preferred tool used for writing texts.

Discussion

Taken together, our findings clearly show that there are indeed specific differences in basic fine motor skills depending on the amount of time spent typing and handwriting texts. Individuals who primarily used keyboards and computers to produce written texts exhibited slower performance in a task measuring the precision of continuous arm–hand movements than people who regularly practiced the skill of handwriting. This finding is in line with research providing empirical evidence for a relation between the use of cognitive tools and human skills, for example, showing associations between frequent computer use to play video games and different motor skills (Griffith et al., 1983; Rosser et al., 2007) as well as various cognitive skills (Green & Bavelier, 2003; McClurg & Chaillé, 1987) or linking the frequent use of calculators with lower arithmetic skills (Campbell & Xue, 2001; Rustemeyer & Stoeger, 2007), although the causality of this relation remains to be clarified. More importantly, the results presented here imply that the use of computers not only affects the specific skill of handwriting, but also similarly affects fine motor skills and thus more general features of the human behavioral repertoire.

It remains to be elucidated whether the generalized changes that we observed reflect changes in psychomotor abilities. In contrast to skills, which refer to the level of proficiency attained in specific tasks by practice and experience (Fleishman & Bartlett, 1969), abilities are conceived to reflect characteristic traits of an individual that are stable over time and determine his or her capacity to successfully perform various tasks or activities (Schmidt & Lee, 1999). They are thought to be determined by genes and various environmental factors that shape the development of the neuromotor apparatus and to be only marginally modifiable by practice. However, it is likely that the development of abilities depends also on major behavioral requirements, such as the regular use of a pen for drawing and writing by hand. From this perspective different ways of producing written text are not only associated with more or less practice of handwriting, but also with the presence or absence of persistent behavioral requirements that are likely to shape the neuromotor foundations of skilled performance. Therefore, an impact of culturally mediated writing habits on basic motor abilities seems to be possible.

Our finding supports the claim that the frequent use of modern technologies, and especially of cognitive tools such as computers, electronic organizers, or in-vehicle navigation systems, may lead to fundamental changes in basic psychomotor and cognitive skills. These changes are likely due to a reduced expertise and training of specific skills, resulting from tasks being taken over by cognitive tools. This lack of practice not only selectively impairs the specific untrained skill, but can also affect a broader range of human skills. Future researchers should investigate the influence of modern technologies on human abilities to raise awareness of the potential losses that come along with new technologies and the associated impact on individuals and society. The resulting culturally mediated loss of basic human skills may lead to an increasing dependency on new technologies, which in turn could further deteriorate human skills and potentially also influence human abilities. However, researchers planning to investigate individuals who prefer handwriting to typing should hurry—this endangered species may soon become extinct.

ACKNOWLEDGMENTS

The authors thank Petra Wallmeyer and Daniel Caputo for running the experiment.

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Submitted January 5, 2011
Revised March 8, 2011
Accepted March 8, 2011