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Adapting to the surface: A comparison of handwriting measures when writing on a tablet computer and on paper

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ABSTRACT

Our study addresses the following research questions: Are there differences between handwriting movements on paper and on a tablet computer? Can experienced writers, such as most adults, adapt their graphomotor execution during writing to a rather unfamiliar surface for instance a tablet computer?

We examined the handwriting performance of adults in three tasks with different complexity: (a) graphomotor abilities, (b) visuomotor abilities and (c) handwriting. Each participant performed each task twice, once on paper and once on a tablet computer with a pen.

We tested 25 participants by measuring their writing duration, in air time, number of pen lifts, writing velocity and number of inversions in velocity. The data were analyzed using linear mixed-effects modeling with repeated measures.

Our results reveal differences between writing on paper and on a tablet computer which were partly task-dependent. Our findings also show that participants were able to adapt their graphomotor execution to the smoother surface of the tablet computer during the tasks.

1. Introduction

Handwriting involves the skilled coordination and timing of activities of multiple joints (e.g., hand, arm, shoulder) in order to generate planar movements of a pen tip (e.g., Latash, 1993, p. 212). Writing is organized in a specific sequence, first, individual letter strokes are chunked into production units which are then, with the appropriate timing, transformed into trajectories of the pen tip that, in turn, must be adjusted on the basis of proprioceptive and tactile feedback to produce a smooth writing movement (Tresilian, 2012, p. 723). These lower-level processes of handwriting, such as graphomotor execution, need to be mastered first in handwriting acquisition, because they demand conscious attention to the writing process and a close sensory guidance of the pen during writing (Grabowski, 2010). Despite its importance in handwriting acquisition only a few writing models include graphomotor execution as a fundamental skill of writing (Kandel, Peereman, Grosjacques, & Fayol, 2011; Van Galen, 1991). Therefore, our study focusses on the graphomotor execution and how it is influenced by the writing surface, namely the smoother writing surface of a tablet computer compared to more familiar paper.

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1.1. Depicting the handwriting process

Previous studies in handwriting research primarily focussed on the product of writing – the quality and the speed of production (Berninger et al., 1992; Graham, Harris, & Fink, 2000; Medwell & Wray, 2007, 2014; Rosenblum, Weiss, & Parush, 2003; Weintraub & Graham, 1998). The quality of handwriting refers to the consistent size and the legibility of letters and words. The speed of production mostly relates to the number of letters or words written in a certain amount of time (e.g., the number of letters written correctly in 15 s during a given task such as writing the alphabet or copying the sentence "the quick brown fox jumps over the lazy dog"; [Berninger et al., 1992, 1997; Graham & Weintraub, 1996; Medwell & Wray, 2014]). However, handwriting is not simply a product of distinct hand and finger movements, but it "is rather understood as a process that is characterised by spatial and kinematic parameters" (Tucha, Tucha, & Lange, 2008, p. 146).

1.2. New technologies in handwriting research

Recently a shift from a product-oriented to a process-oriented approach in handwriting occurred. With the advent of graphic digitizers and tablet computers, researchers can track the process of handwriting directly instead of being restricted to the final product (Medwell & Wray, 2007; Rosenblum et al., 2003; Tucha et al., 2008). These media provide a reliable and objective measure of the dynamic parameters of handwriting performance (Marquardt & Mai, 1994). The surface of a graphic digitizer or tablet computer is usually smoother when compared to paper. Consequently, the writer needs to adapt the graphomotor execution during writing to generate a regular and fluent handwriting movement. Previous studies have shown that skilled writers are able to adapt their handwriting movements to different writing surfaces (e.g., when producing a signature on the smooth surface of a credit card) through a modulation of pen pressure (Wann & Nimmo-Smith, 1991) or a modulation of writing height (Denier van der Gon & Thuring, 1965). The early study of Denier van der Gon and Thuring (1965) showed that adults' writing times stay constant but the height of letters changes when the friction between pen and writing surface is decreased. In other words, participants wrote faster and bigger when the writing surface became noticeably smoother. The authors show that such adjustments of handwriting performance have a delay of about 100 ms. We suspect that this sensitivity to the writing surface is tuned through the motor components of handwriting which leads to an adaption of graphomotor execution via proprioceptive and tactile feedback (Tresilian, 2012, p. 723). Therefore, our study investigates how experienced writers adapt their graphomotor execution to the smoother writing surface of a tablet computer in comparison to paper.

1.3. Comparing different writing surfaces

To our knowledge, there were very few studies that investigated if it makes a difference to write on a tablet computer or on paper. For instance, Alamargot and Morin (2015) asked second and ninth graders to write the alphabet and their names and surnames on a tablet computer and on paper. Both groups wrote less legible letters in the name-surname task and larger letters (in the alphabet and name-surname task) on the tablet screen than on paper. Further, the ninth graders showed faster writing speed and higher pen pressure while the second graders exhibited more pauses during writing on the tablet computer than on paper. Alamargot and Morin (2015) suggested that the two surfaces differently influenced the writing of younger and older pupils. More specifically, the ninth graders compensated for the smoother surface by producing larger letters and by increasing their pen pressure and pen speed which is similar to the behavior observed in adults (Wann & Nimmo-Smith, 1991).

However, previous research has shown that children differ in handwriting performance compared to adults. For instance, the study by Bourdin and Fayol (1994) directly compared spoken and written language production of children and adults in French. Participants had to recall word lists in oral or written mode. Their results show that children, compared to experienced writers such as most adults, performed better for oral recall than written recall while there was no difference in recall mode for adults. Bourdin and Fayol argued that children are not fully automatized in low-level skills of writing (e.g., spelling and graphomotor skills) which reduces the working memory capacity available for the memory task. Recently, Grabowski (2010) replicated the results of Bourdin and Fayol (1994) for German, even though the orthography of German is more predictable than the French orthography and would therefore pose fewer demands on the cognitive system of young writers. Similar to Bourdin and Fayol (1994), Grabowski (2010) concluded that the lack of graphomotor automization (not spelling differences) is responsible for a slower performance of children compared to adults. Since children's movement execution during handwriting is not yet automatized, we hypothesize that modifications in writing conditions, for instance a smoother writing surface such as a tablet computer, might influence children's handwriting performance in a different way compared to adults' handwriting movements. Therefore we decided to investigate handwriting performance on different writing surfaces of experienced writers rather than children.

1.4. Handwriting measures

Tablet computers and digitizers provide handwriting measures such as writing and pause duration, writing velocity and the number of inversions in velocity (NIV) that capture the dynamic processes during writing (Adi-Japha & Freeman, 2001; Kandel & Perret, 2015; Sumner, Connelly, & Barnett, 2014; Tucha et al., 2008; Wicki, Hurschler Lichtsteiner, Saxer Geiger, &