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Does handwriting on a tablet screen affect students' graphomotor execution? A comparison between Grades Two and Nine

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ABSTRACT

We sought to ascertain how handwriting with a plastic-tipped pen on the screen of a digital tablet affects graphomotor execution in students, compared with handwriting on paper with a ballpoint pen. We predicted that the modification to propriokinesthetic feedback induced by the screen/plastic tip combination would differently disturb younger and older students, who rely on perceptual feedback either to form letters (former) or to adjust movement execution (latter). Twenty-eight students from Grades Two and Nine were asked to handwrite the alphabet and their names and surnames under the two conditions. Kinematics were recorded using the tablet, controlled by Eye and Pen software. Results showed that handwriting on the tablet surface with a plastic-tipped pen primarily affected pen pauses in the second graders and pen movements in the ninth graders, suggesting a disturbance in segment trajectory calculation in the younger participants and reduced control of muscular adjustment in the older children.

1. Introduction

1.1. Writing and new technologies

The advent of new technologies in schools means that students are now having to write with different tools in different media, including keyboards, virtual keyboards (tablets), and pen or fingers on a tablet surface, and no longer just with pen/pencil on paper. While this new technological reality may arouse fresh interest in writing (Clark & Dugdale, 2009; Karsenti & Collin, 2013), it does not necessarily make the activity itself any easier. For example, keyboarding is less efficient than handwriting in at least three areas (for a summary, see Caporossi & Alamargot, 2014; Mangen & Velay, 2010; Matthewman & Triggs, 2004). (i) Keyboarding requires frequent shifts of attention between the screen and the keyboard, an aspect that does not exist in handwriting. In addition, with handwriting, the text is produced at the very place where the motor action is performed, so the writer can simultaneously consider the letter's formation and its textual context (Caporossi & Alamargot, 2014). (ii) Second, using readymade letters in keyboarding does not involve any graphomotor processing, unlike

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handwriting. The writer's task is therefore limited to spatially locating the specific letters on the keyboard and pressing the corresponding keys (Mangen & Velay, 2010). This difference in motor execution has an effect on reading, as the additional motor encoding that occurs during letter formation has been shown to promote the recognition of these letters, both in kindergarten children (Longcamp, Zerbato-Poudou, & Velay, 2005) and in adults (Longcamp, Boucard, Gilhodes, & Velay, 2006). (iii) The use of a keyboard can prove to be a costly alternative for children, as they consume cognitive resources searching for the keys they have to press, at the expense of written production. By comparing the handwriting and typing fluency of 300 children aged 4–11 years as they copied out a sentence, Connelly, Gee, and Walsh (2007) demonstrated the superiority of handwriting, regardless of age. In a second study with fifth and sixth graders, the authors showed that keyboarding can be as much as two years behind handwriting in development. Only students who have received keyboard training (i.e., touch-typing instruction) seem to benefit from the use of word processing software (see also Christensen, 2004; Rogers & Case-Smith, 2002).

This series of examples linked to the use of a keyboard clearly shows that while technology can provide new and stimulating tools for writing, it can also impose new cognitive constraints that are not immediately perceptible. There is a similar problem when children use digital tablets in class, writing on the screen with a plastic-tipped pen. The few studies to have observed the impact of tablet use on writing have focused mainly on the new learning methods offered by interactivity (Berninger, Nagy, Tanimoto, Thompson, & Abbott, 2015; Jolly & Gentaz, 2013). The question of graphomotor constraints introduced by the particularly smooth tablet surface does not seem to have been considered, probably because this tool has only very recently been introduced into the classroom. Nonetheless, we all seem to have difficulty writing on a smooth and slippery surface, such as when we sign our name on the back of a credit card (Wann & Nimmo-Smith, 1991). In the same way, writing with a plastic-tipped pen on the glass surface of a tablet produces a sensation of sliding over a slippery surface, which suggests that the fine motor control required for adjusting pen movements is disturbed.

It therefore seems timely to analyze the effects of screen surface on handwriting, by comparing the two handwriting media (i.e., paper and screen). Moreover, as handwriting control develops with age, notably with the mastery of motor programs at around 9 or 10 years of age, these possible effects probably vary according to the student's level of development.

1.2. Development of handwriting skills and graphomotor execution

Handwriting movements are complex, and their mastery takes time. Assuming that handwriting acquisition begins formally at school at around 5–6 years, proficiency in handwriting is not definitively acquired before 14–15 years (Accardo, Genna, & Borean, 2013; Blöte & Hamstra-Bletz, 1991; Rueckriegel et al., 2008; Ziviani & Wallen, 2006). During this developmental period, movement control shifts from a retroactive mode, based on the interpretation of sensory information (visual and propriokinesthetic feedback), to a proactive mode, based on central motor programs. Elaborated for each letter, these programs generally emerge at around 9–10 years (Blöte & Hamstra-Bletz, 1991; Chartrel & Vinter, 2006, 2008; Schmidt & Lee, 2005; Vinter & Chartrel, 2010; Zesiger, 1995) and provide the instructions needed for the motor control system to produce integrated movements (Paillard, 1990; Ziviani & Wallen, 2006). It is only at around 14–15 years that motor programs become completely automated (Ajuriaguerra, Auzias, & Denner, 1971; Rueckriegel et al., 2008).

Before 9–10 years of age and the acquisition of motor programs, handwriting is slow and laborious. Considerable pressure is exerted on the pen, reflecting significant muscle tension, as well as the use of the shoulder and elbow to write (Bara & Gentaz, 2011; Chartrel & Vinter, 2004). The letters children form are often large, and have an irregular or rough appearance. The handwriting process is punctuated by pauses needed to calculate letter segments, based on sensory information. At the developmental level, Accardo et al. (2013) have shown that pause duration, which decreases significantly between 6 and 11 years, represents a sensitive indicator of changes in handwriting skills. Adopting another perspective, Paz-Villagrán, Danna, and Velay (2014) compared handwriting pauses in dysgraphic children aged 8–11 years with those of proficient children aged 7–9 years. These authors found that pauses that are either too numerous or too long are an indicator of dysfluency or poor handwriting. Beyond 9–10 years of age and the acquisition of motor programs, letter size, the amount of pressure exerted on the pen, and the frequency and duration of pauses between two segments decrease, while the speed, fluidity and legibility of letter formation increase (Accardo et al., 2013; Bara & Gentaz, 2011; Chartrel & Vinter, 2006, 2008; Freeman, 1914; Meulenbroek & Van Galen, 1988; Vinter & Chartrel, 2010; Vinter & Zesiger, 2007; Zesiger, Deonna, & Mayor, 2000; Ziviani & Wallen, 2006).

Thus, in young writers who have not yet acquired any motor programs, perceptual feedback plays an essential role in controlling handwriting movements (Ziviani & Wallen, 2006). Chartrel and Vinter (2006) showed that when they were blindfolded, students aged 8–10 years increased their propriokinesthetic feedback by putting more pressure on the pen and by making the letters larger and increasing pen speed. In adults, while the proactive control of movement limits recourse to sensory feedback, it does not totally replace it. Deprivation of visual and/or propriokinesthetic information has been shown to disturb movement kinematics. By asking university students to handwrite the letter sequences *gegegeg* and *nenenen* with and without visual feedback, Van Doorn and Keuss (1993) highlighted an increase in pressure, speed and letter size in the absence of vision. Increased pressure augments the contact with the paper, and thus the amount of proprioceptive information available (see also Van Doorn, 1992; Van Doorn & Keuss, 1992). The proprioceptive system therefore continues to contribute to the proper execution of motor programs and the effective production of movements in adults. By studying pointing gestures in deafferented patients, Bard, Turrell, Fleury, and Teasdale (1999) showed that the motor system has the ability to