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Eye movements during the handwriting of words: Individually and within sentences



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ABSTRACT

Handwriting, a complex motor process involves the coordination of both the upper limb and visual system. The gaze behavior that occurs during the handwriting process is an area that has been little studied. This study investigated the eye-movements of adults during writing and reading tasks. Eye and handwriting movements were recorded for six different words over three different tasks. The results compared reading and handwriting the same words, a between condition comparison and a comparison between the two handwriting tasks. Compared to reading, participants produced more fixations during handwriting tasks and the average fixation durations were longer. When reading fixations were found to be mostly around the center of word, whereas fixations when writing appear to be made for each letter in a written word and were located around the base of letters and flowed in a left to right direction. Between the two writing tasks more fixations were made when words were written individually compared to within sentences, yet fixation durations were no different. Correlation of the number of fixations made to kinematic variables revealed that horizontal size and road length held a strong correlation with the number of fixations made by participants.

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1. Introduction

During writing, perceptual, motor, and cognitive processes interact. Handwriting is understood as a process that is characterized by spatial and kinematic parameters (Tucha, Tucha, & Lange, 2008).

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Accompanying movements like writing, the eyes alternate between fixations (maintaining a visual gaze on a location) and fast saccadic movements between fixation points (Crawford, Mendendorp, & Marotta, 2004), however how often they occur and to which aspects of the written trace or its surrounds they are located has not been reported. Regarding the role of vision in handwriting, it is common knowledge that writing can occur quite easily without vision. However, Van Doorn and Keuss (1993) found that when completing handwriting tasks most individuals visually track their ongoing work, suggesting that vision plays an important role in handwriting. It has also been reported that in the absence of vision or under altered visual conditions, handwritten text contains more errors, with more repetitions, deletions, insertions and substitutions of both letters and strokes, and that the speed, spacing, sizing and spatial arrangement of the words along the line are effected (Feder & Majnemer, 2007; Smyth & Silvers, 1987; Van Doorn & Keuss, 1992; Van Doorn & Keuss, 1993). This suggests that there are two distinct functions for vision in the control of handwriting; the overall spatial arrangement of words on a horizontal line and the accurate production of movement sequences. Where overt visual attention is paid to handwriting the speed of handwriting has been reported to decrease (Marquardt, Gentz, & Mai, 1996). This is thought to be related to the automated movements associated with handwriting, typically averaging 4–6 Hz, being too fast for the eyes to foveate (Marquardt et al., 1996). Instead, vision's role in handwriting is proffered to be used to guide the hand, a role that increases in importance with the speed of movement (Marquardt et al., 1996; Van Doorn & Keuss, 1993). Siebner et al. (2001) reported that writing under normal circumstances uses mainly feed-forward mechanisms to adjust the kinematics of writing movements and that sensory feedback (including vision) is only required to monitor the approximate range of the movement and not the distinct details.

In most situations fixations and saccades are used together to locate and observe what we are attending to and to gather visual information for the purpose of guiding behavior. Eye movements have been studied during many everyday activities involving body movements; driving and steering a car (Land & Lee, 1994), food preparation (Land & Hayhoe, 2001), pointing and drawing (Gowen & Miall, 2006; Reina & Schwartz, 2003; Tchalenko, 2007), tracing (Gowen & Miall, 2006), playing sports (Land & Furneaux, 1997; Land & McLeod, 2000) and building with blocks (Ballard, Hayhoe, & Pelz, 1995). For many of these tasks, the major role of the eye movements involved appears to be two fold; in one instance, vision is used as a guiding aide, locating reference areas or targets that may assist or be involved in precuing parameters for future movements, and in the other instance, the eye functions as part of the feedback mechanism, relaying visual feedback about movements performed.

Reading is closely associated with writing as we often need to read what we have written. Much research has been conducted examining eye gaze during reading and an extensive review by Rayner (1998) covers much of the important work in this area. Reading requires particular eye-movement strategies which allows an individual to acquire visual information and process it, giving meaning to the text (Land, 2006). It is thought that when reading, top-down processes dominate gaze shifts as cognitive skills required for lexical interpretation influence eye movements (Avallone, De Stefano, Gambone, & Marcelli, 2009; Rayner, Xingshan, Williams, Cave, & Well, 2007). During reading the eye moves between two and five times per second in order to bring the text into foveal vision (Land, 2006; Salthouse & Ellis, 1980). Rayner (1998) posits that the mean fixation duration during silent reading tasks is approximately 225 ms and 275 ms for oral reading tasks. During the first 50–70 ms of a fixation it has been hypothesized that the information needed for reading is obtained (Land, 2006), however longer or more difficult words produce longer fixations as the lexical and linguistic information takes longer to process (Land, 2006; Rayner et al., 2007). When reading English, typically the eyes move in a linear pattern of fixations, moving from left to right allowing the words to be interpreted by the reader (Land, 2006). An effect often called the 'preferred viewing location' outlines that in reading most readers initially fixate about half way between the beginning of a word and the middle of the word (Rayner, 1979; Deutsch & Rayner, 1999; McConkie, Kerr, Reddix, & Zola, 1988; Rayner, Sereno, & Raney, 1996).

Eye-tracking techniques can be used to explore issues regarding the cognitive processes that may occur during the real time production of graphomotor output (Pepe, Rogers, & Sita, 2012). There are only a small number of reported studies on eye movements in activities closely related to writing, where the hand uses a stylus to create a drawn artefact; these are drawing, tracing, copying, sketching and signature forgery. In signature simulation tasks, (Pepe & Sita, 2014, chap. 6; Pepe et al., 2012) it

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