The Timing of Eye-hand Movements during Signature Simulations

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Abstract. An investigation of the eye and hand movement during the task of signature simulation was conducted. Three subjects' eye movements and hand movements were recorded using an eye-tracker and a digitizing tablet while they simulated signatures. The study revealed that eye gaze most frequently shifted within less than 17 msec of a pen velocity minimum. It is thought that the cognitive processes overseeing this movement control and the limitations of the visuomotor buffer could play an important role in the behaviour of simulating signatures and signature simulation quality.

1. Introduction

The relationship between eye and hand movements during the task of signature simulation has not been thoroughly investigated previously, particularly with respect to movement initiation and termination. Previous research on line copying has found that the eyes tend to move within 33 msec of the pen reaching a velocity minimum (Pepe & Sita, 2014). It has been proposed that the eyes may be receiving feed-forward information about the upcoming movement (Ketcham et al., 2006; Reina & Schwartz, 2003), or that there is a reciprocal exchange of information between the sensorimotor systems (Vercher, Gauthier, Cole, & Blouin, 1997). Although it has been proposed that this close eye-hand relationship may help improve the spatial accuracy of signature simulations (Pepe & Sita, 2014), the question of whether this relationship is evident during the task of signature simulation has never been investigated.

Previous studies have also found that the eyes frequently lead the hand in motor tasks (see Gielen, Dijkstra, Roozen, & Welton, 2009; Inhoff, Briihl, Bohemier, & Wang 1992; Truitt, Clifton, Pollatsek, & Rayner, 1997). The eyes are thought to lead manipulative action by around half a second and move on to the next object about half a second before the action is completed (Land, 2006). The presumed role of this half second buffer is to hold information for a brief time period, allowing a match between episodic input and continuous motor output (Land & Furneaux, 1997). This buffer would therefore allow simulators to check, or guide their written output and to look back to the exemplar signature in a 'just-in-time' manner (see Ballard, Hayhoe & Pelz, 1995) to transform the next part of the exemplar signature into a motor program before the visual information in memory had faded, therefore allowing the motor action to proceed (Ballard et al., 1995; Hayhoe, Bensinger, & Ballard, 1998; Land, 2006).

It is therefore of interest to explore the timing of eye and hand movements to help determine behavioural processes underlying signature simulations.

2. Methods

A total of three subjects were tested. Subjects sat on a kneel chair at a table with an attached PTZ-1230 12x12 Wacom Intuos 3 digitising tablet (FFT low-pass 12 Hz filter capturing at 200 Hz with a sampling accuracy 0.25 mm in the x and y direction) and inking pen for recording subjects' raw and digital pen data. Movalyzer version 6.1 was used to capture digitising tablet data. A Tobii X-120 eye-tracker was attached and centered under the table facing upwards at an angle of 68° captured eye movements of subjects. The sampling rate of the eye-tracker was 100 Hz with a spatial accuracy of ± 0.5°. An external Basler scA640-120gc digital camera recorded the scene at 100 frames per second and allowed for viewing of simultaneous eye-gaze position and pen position.

The scene camera had a resolution capture of 658 x 492 pixels and was positioned directly above the center of the writing area. A blank, white screen was placed perpendicular to the table and positioned behind the digitising tablet to enhance luminosity to increase the reliability of the eye-tracking sampling. A head rest was used to keep subjects' head positions stable throughout testing to maximize eye-tracking spatial accuracy. Gaze data was recorded in Tobii studio version 2.0.2 and analysed in Tobii studio version 3.0.3.

Once seated, subjects were adjusted to a comfortable sitting height. The eyes' viewing distance from the eye-tracker ranged between 54 cm and 62 cm depending on subject height. At 57.3 cm, 1° of visual angle equated to 1 cm on the page. Following the eye-tracker calibration in which subjects were required to look at 5 fixed calibration points on a blank page, subjects were required to have a practice attempt at copying the word 'practice'. This was to ensure a comfortable writing position and to make sure that the eye-tracker was tracking properly. Following this practice attempt, subjects were instructed to produce simulations of two different exemplar signatures.

Simulations were produced at least 5° below the exemplar, removing the ability of subjects to acquire visual information using parafoveal vision. An example of a completed signature simulation trial from the view of the scene camera is shown below in Figure 1.1.

Figure 1.1. A completed simulation trial.

Subjects were instructed to simulate the exemplar to the best of their ability. Subjects were informed that they would begin each trial following a verbal cue and were required to move their pen away from the pad following completion of their simulation to indicate the end of the trial. Prior to commencing, and following their simulation attempts, subjects were required to look at a reference point.

Two different exemplar signatures were simulated three times consecutively by each subject. The order of presentation of the exemplars was counterbalanced between subjects, eliminating any bias effects due to fatigue or familiarity.

Gaze data was collected from first initial pen-down movement to completion of the final pen-down movement. The time differential between gaze shifts and velocity minima, as well as pen and eye lead times were extracted by viewing each frame captured by the video camera during the simulation trials.

Pen strokes produced during the simulation attempts were defined by peak velocity profiles in Movalzyer. These are represented by the lines between the circles in Figure 1.2. The circles represent the locations of pen velocity minima.

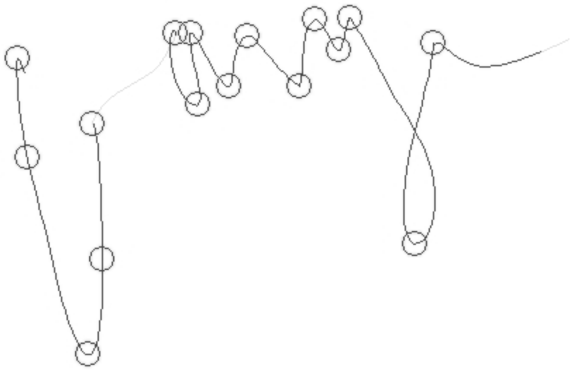

Figure 1.2. An image of a simulation trial showing the locations of velocity minima of the pen.

Gaze shifts that occurred when the pen was in-air were excluded from the analysis. In addition, when the pen was stationary, the only fixations included in the analysis were the fixations just prior to initial pen movement, or immediately after the pen movement had ceased. This was to control for excessive numbers of gaze shifts being made during moments the pen was stationary.

3. Results

The relationship between the observed gaze shifts and strokes are shown in Table 1.1. Lead-time referred to either i) the time that the eye led to pen (before the pen caught up to the position, or relative position of the eye), or ii) the pen led the eye (before the eye caught up to the position of the pen).

Table 1.1.
Summary of the eye and pen data for each subject during signature simulations

Subject	Average number of pen strokes produced	Average stroke duration (msec)	Average number of gaze-shifts made during pen-down movement	Average time gaze shift occurred from a pen velocity minima (msec)	Approximate average eye lead-time in front of pen (in strokes) on exemplar	Estimated eye lead-time (msec) on exemplar	Estimated lead-time (msec) on copy		Average number of strokes per gaze shift
							eye	pen	
1	13.0	191	7.00	39.6	2.18	419	n/a	n/a	1.86
2	45.3	240	24.7	44.1	1.82	445	n/a	n/a	1.83
3	35.2	212	8.50	41.8	n/a	n/a	418	604	4.10

There appeared to be a close temporal relationship between gaze shifts and pen velocity minima. The data revealed that this was not simply due to low average stroke durations. Gaze tended to shift most frequently within less than 17 msec of a pen velocity minimum. Figure 1.3 below shows a summary of the amount of time that elapsed between gaze shifts and pen velocity minima for the simulation trials.

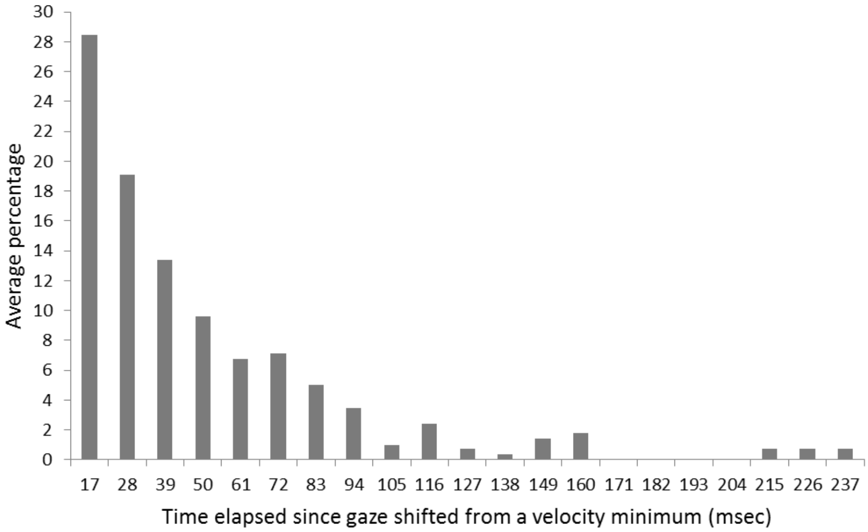

Figure 1.3. Average time elapsed between a gaze shift and a velocity minimum.

4. Discussion

The subjects' gaze frequently shifted around moments of pen velocity minima. This is evidence of a close temporal relationship between the eye and hand movements in relation to movement initiation and termination. Previous studies have reported similar relationships in tracing and drawing and other graphical tasks (Gielen, Dijkstra, Roozen, & Welton, 2009; Gowen & Miall, 2006; Ketcham et al., 2006; Reina & Schwartz, 2003). De'Seperati and Viviani (1997) suggest that there may be some general principles of operation common to the distinct modules responsible for setting up the motor output to the hand and the eye. It is possible that the timing of these movements serve to optimize the recurring cognitive processes involved in the task. From a quality of output point of view, this eye-hand behaviour makes sense. It seems logical to make gaze shifts at moments when the pen is moving slowest, as this allows adequate time for visual processing of the next stroke from the original image, or checking and/or guiding spatial output of the written trace. One presumed problem with making gaze shifts mid-stroke when the pen is moving quickly is that cognitive suppression (Irwin & Carlson-

Radvansky, 1996) and the time taken to visually process newly fixated area (see Rayner, 1998) may affect the accuracy of output by affecting the module responsible for setting up the motor output to the eye and hand.

There appeared to be occasional moments the eye would overshoot the position of the pen by close to half a second. Equally as often, the eye would lag behind the pen before making a saccade to catch back up to the pen's tip. Fixations following the pen on the line recently drawn may be part of a visual feedback mechanism controlling ongoing alignment of the pen with the pen trace and fixations made ahead of the pen are presumably used as a point of reference necessary to guide future pen movement (Tchalenko, 2007). The presence of these two eye behaviours suggests vision is able to adopt both a feedback and a feed-forward role during signature simulations.

The eye was observed to lead the pen by up to half a second when comparing pen position on the copy and eye position on the exemplar. This is likely to be necessary to transform visual information held in working memory into a motor program (Fleischer, 1986; Miall, Gowen, & Tchalenko, 2009). If information is held in a memory buffer for the time between a gaze shift and completion of the current motor act, the results would indicate that the memory buffer during this task is close to half a second long. This means that the simulator may only have half a second to fixate downward, guide the pen's movement and fixate back up to the exemplar in time to load the next stroke so that pen movement does not cease and line quality can be maintained. It is therefore suggested that the temporal limitation of the memory buffer is, in part, responsible for the commonly observed trade-off between the spatial quality and line quality during signature simulations.

Future studies should attempt to validate the current study's findings using a greater number of subjects and attempt to determine how the temporal limitations of the visuomotor buffer can affect signature simulation quality and experts judgments about authenticity.

References

Ballard, D. H., Hayhoe, M. M., & Pelz, J. B. (1995). Memory representations in natural tasks. *Journal of Cognitive Neuroscience, 7*(1), 66-80.

De'Sperati, C., & Viviani, P. (1997). The relationship between curvature and velocity in two-dimensional smooth pursuit eye movements. *J Neurosci, 17*(10), 3932-3945.

Fleischer, A. G. (1986). Control of eye movements by working memory load. *Biol Cybern, 55*(4), 227-238.

Gielen, C. C., Dijkstra, T. M., Roozen, I. J., & Welten, J. (2009). Coordination of gaze and hand movements for tracking and tracing in 3D. *Cortex, 45*(3), 340-355. doi: 10.1016/j.cortex.2008.02.009

Gowen, E., & Miall, R. C. (2006). Eye-hand interactions in tracing and drawing tasks. *Hum Mov Sci, 25*(4-5), 568-585. doi: 10.1016/j.humov.2006.06.005

Hayhoe, M. M., Bensinger, D. G., & Ballard, D. H. (1998). Task constraints in visual working memory. *Vision Res, 38*(1), 125-137.

Inhoff, A. W., & Wang, J. (1992). Encoding of text, manual movement planning, and eye-hand coordination during copytyping. *J Exp Psychol Hum Percept Perform, 18*(2), 437-448.

Irwin, D. E., & Carlson-Radvansky, L. A. (1996). Cognitive Suppression during Saccadic Eye Movements. *Psychological Science, 7*(2), 83-88. doi: 10.2307/40062915

Ketcham, C. J., Dounskaia, N. V., & Stelmach, G. E. (2006). The role of vision in the control of continuous multijoint movements. *J Mot Behav, 38*(1), 29-44. doi: 10.3200/jmbr.38.1.29-44

Land, M. F. (2006). Eye movements and the control of actions in everyday life. *Prog Retin Eye Res, 25*(3), 296-324. doi: 10.1016/j.preteyeres.2006.01.002

Land, M. F., & Furneaux, S. (1997). The knowledge base of the oculomotor system. *Philos Trans R Soc Lond B Biol Sci, 352*(1358), 1231-1239. doi: 10.1098/rstb.1997.0105

Miall, R. C., Gowen, E., & Tchalenko, J. (2009). Drawing cartoon faces--a functional imaging study of the cognitive neuroscience of drawing. *Cortex, 45*(3), 394-406. doi: 10.1016/j.cortex.2007.10.013

Pepe, A., & Sita, J. (2014). Gaze-shifts and Pen Velocity Minima during Line Copying with Consideration to Signature Simulation. In M. Horsley, B. Knight, & R. Reilly (Eds.). *Current Trends in Eye Tracking Research* (pp. 101-106). Switzerland: Springer international. doi: 10.1007/978-3-319-02868-2

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychol Bull, 124*(3), 372-422.

Reina, G. A., & Schwartz, A. B. (2003). Eye-hand coupling during closed-loop drawing: evidence of shared motor planning? *Hum Mov Sci, 22*(2), 137-152.

Tchalenko, J. (2007). Eye movements in drawing simple lines. *Perception, 36*(8), 1152-1167.

Truitt, F. E., Clifton, C., Pollatsek, A., & Rayner, K. (1997). The perceptual span and the eye-hand span in sight reading music. *Visual Cognition, 4*(2), 143-161.

Vercher, J. L., Gauthier, G. M., Cole, J., & Blouin, J. (1997). Role of arm proprioception in calibrating the arm-eye temporal coordination. *Neurosci Lett, 237*(2-3), 109-112.