Application of Fitts' Law to Eye Gaze Interaction

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ABSTRACT

An experiment is described comparing the performance of an eye tracker and a mouse in a simple pointing task. Subjects had to make rapid and accurate horizontal movements to targets that were vertical ribbons located at various distances from the cursor's starting position. The dwell-time protocol was used for the eye tracker to make selections. Movement times were shorter for the mouse than for the eye tracker. Fitts' Law model was shown to predict movement times using both interaction techniques equally well. The model is thus seen to be a potential contributor to design of modern multimodal human-computer interfaces.

Keywords

Eye tracking, cursor control, Fitts' Law

INTRODUCTION

The major issue in designing efficient human-computer interfaces is matching natural capabilities of humans with interaction techniques on computing systems. Since the emergence of graphical user interfaces (GUIs), prediction of the time for humans to execute computer input tasks has been a key focus in HCI research. To reveal the limits in human performance, reliable speed-accuracy models for human movement are needed. As today's human-computer dialogues get more "direct" due to application of the principles of multimodality, this need becomes even stronger.

A model of human movement, known as *Fitts' Law*, predicts that the time (*MT*) to move to a target is linearly proportional to $\log_2(2A/W)$, where W is the width of the target and A is the amplitude of the movement, or the distance from the home position to the target center. This logarithmic expression is often referred to as a task's *index of difficulty* (*ID*). Formally, the most widely adopted variation of Fitts' Law is:

$$MT = a + b \log_2(A/W + 0.5) \qquad (1)$$

where a and b are empirical constants determined through linear regression. Numerous investigators have shown Fitts' Law to be a powerful predictor of movement time in HCI using conventional GUI techniques, such as the mouse or joystick (see, e.g., [1]). Up to now, however, much fewer research has been conducted to test the application of the model to the interaction based on the user's eye movements as direct real-time computer input. Ware and Mikaelian were the first to carry out Fitts' Law analysis on the movement times obtained in a simple target selection task using an eye tracker [3]. Equation 1 was shown to hold for the eye tracker as well. Unfortunately, the range of *ID*s employed in [3] was very narrow. This was partly due to the fact that target width was kept constant in this study. One might then question the validity of Fitts' Law for eye gaze interaction. The present study was conducted in an attempt to test the validity of the conclusion by Ware and Mikaelian concerning the suitability of Fitts' Law for eye gaze interaction. Given the limitations of [3], the experimental conditions were chosen such as to ensure a more appropriate range of *ID*s.

METHOD

Six undergraduate students from Siauliai University (all male) volunteered to participate in the experiment without compensation. All subjects were regular users of the mouse in their daily work, but none of them had any prior experience with an eye tracker. All subjects had normal or corrected vision. The experiment was conducted on a PC Pentium MMX 200 using either a standard serial mouse or the eye tracker for input, and a 14" monitor for output. The eye tracker used was an ion-e™ system from Eye Control Technologies (Oregon, USA). To increase the stability of the cursor position with respect to the point of gaze, the minimum amount of smoothing (in number of frames of past comparison) performed by the built-in adaptive averager was set at 4, whereas 25 served as the maximum. These values were close to those considered optimal by the manufacturer of the eye tracker. The dwell-time protocol was used for issuing the selection command equivalent to the left click action with a mouse. According to this protocol, a selection event occurs when the point of gaze remains within a specified area on the screen for a specified amount of time referred to as dwell time. In the present experiment, the eye tracker's setting for dwell time was chosen to be 250 ms (pilot runs had shown this value to be reasonable for the task at hand).

Subjects sat at a table on which the display rested, and viewed the display at a distance of approximately 60 cm. Subjects performed a simple target acquisition task. Each trial was proceded by appearance of the dialog box with an "OK" button to confirm that the subject was ready to proceed. This allowed subjects to rest their eyes and/or recalibrate the system (when they felt the calibration was no more appropriate) at any time between trials. After subjects had positioned the cursor over the button using their eyes, a target (vertical ribbon) appeared 20 mm from the right edge of the display screen. Simultaneously, a square (26 mm x 26 mm) home box appeared to the left of the target. The cursor in the form of an arrow was also seen on the display. The centers of both the target and the home box were located on the same imaginary horizontal line in the middle of the screen. To proceed with a trial, subjects had to move the cursor using their eyes only into the home box and keep it there. If the cursor remained over the home box continuously for 250 ms, the measurement of total positioning time was initiated. This was accompanied by a beep to give an audio feedback to the subjects. They then manipulated their eyes until the cursor was positioned inside the target ribbon. To end the trial, subjects had again to gaze steadily at the target ribbon to make the cursor stay within its boundaries continuously for 250 ms (this duration being determined by the dwell-time setting of the eye tracker). Successful completion of the trial was again signaled by a beep. Subjects were instructed to try to complete the whole sequence of actions as quickly as possible. Total target acquisition time was defined as the amount of time between the moment the timer had been started and the moment it stopped minus the 250-ms dwell time on the target.

A fully within-subjects repeated measures design was used. Controlled variables were target amplitude (A = 26, 52, 104, and 208 mm) and target width (W = 13 and 26 mm) fully crossed with one another. Target height was held constant throughout the experiment at 144 mm. Each A-W combination initiated a block of 8 trials. Twelve randomized blocks were administered over five days (12 blocks per session/day) for a total of 480 trials per subject. In order to compare target acquisition times using the eye tracker with those obtained in a conventional GUI, exactly the same experimental conditions were tested on the same subjects using the mouse.

RESULTS

To accommodate learning effects, Student-Newman-Keuls test on mean acquisition times over multiple sessions showed no improvement after the second day of testing. Therefore, the data analysis was based on Sessions 3 to 5. The grand mean for selection time during cursor positioning with the eye tracker was 687 ms, whereas that obtained during control with the mouse was 258 ms. Selection time is seen to be longer for the eye tracker than for the mouse by a factor of 2.7. This disagrees with the results obtained in Sibert and Jacob's study [2] where selecting with an eye tracker was faster than selecting with a mouse. Ware and Mikaelian [3] did not test performance of their subjects with a mouse. No within-study comparison therefore can be made with their eye tracker performance. On the whole, substantial differences in the experimental setup and the range of A-W conditions tested preclude making valid across-study comparisons. Table 1 summarizes Fitts' Law performance characteristics calculated under Equation 1 for the two techniques of target acquisition under the present investigation. Although a negative intercept obtained for the mouse data presents some theoretical flaw [1], it is reasonably close to zero to be attributed solely to random variability in the data, not to the presence of some uncontrolled variations. Furthermore, appearance of negative intercepts is not uncommon in past research applying Fitts' Law in HCI tasks [1].

Table 1. Goodness of fit of Fitts' Law model

Device	r^a	SD^b	a (ms)	b (ms/bit)
Eye tracker	0.9910	29.2	298	176
Mouse	0.9914	20.5	-21	126

$^a p < 0.0001$. ^{b}Standard deviation.

CONCLUSION

The results of this study suggest that for target acquisition using eye movements directly as input, Fitts' Law model gives as good fit to the data as that obtained during control with the mouse. The model has therefore proven its potential as a valuable aid for designers of modern human-computer interfaces seeking to predict the performance of eye movement-based target selection techniques prior to implementation of the designs. In terms of the speed of performance, the eye tracker has not been found to be superior to the mouse, as opposed to the result reported in [2]. A possible explanation for this slowdown in performance might be a greater degree of response damping introduced by the adaptive averager. In particular, the users reported having the impression of the cursor lagging behind their gaze. On the other hand, the pilot runs revealed that reducing the amount of smoothing tended to cause more frequent overshoots which in turn led to increased selection times. Further work is needed to find the amount of smoothing that would give the best performance. The optimal limit for the dwell time on target also has yet to be found. Usage of a bigger monitor in future studies perhaps would allow to extend the range of *ID*s even further.

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REFERENCES

1. MacKenzie, I.S. Fitts' law as a research and design tool in human-computer interaction. *Human-Computer Interaction 7*, 1992, 91-139.
2. Sibert, L.E., and Jacob, R.J.K. Evaluation of eye gaze interaction, in *Proc. Human Factors in Computing Systems, CHI 2000,* (The Hague, Netherlands, April 2000), ACM Press.
3. Ware, C., and Mikaelian, H.H. An evaluation of an eye tracker as a device for computer input, in *Proc. Human Factors in Computing Systems and Graphics Interface, CHI+GI '87,* (Toronto, Canada, April 1987), ACM Press, 183-188.