Enhancements to Eye Gaze Tracking Cursor Control using Electromyogram Signals

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Abstract

Eye gaze tracking (EGT) systems have been implemented previously in laboratory environments. However, they present usability obstacles that prevent their broad commercial acceptance. In response, a cursor control system was created that integrates an electromyogram-based control with EGT-based control. This system allows a user to perform small cursor displacements and left click operations by the monitoring and classifying of electromyogram (EMG) signals emitted during facial movements. This functionality will compensate for the limitations in cursor positioning accuracy and in click execution reliability experienced with EGT systems.

The EMG/EGT system, an EGT system and a mouse were tested using point-and-click trials. Trial time and error rate results underwent statistical and Fitts’ law analyses. Statistical analysis revealed that the EMG/EGT system was slower than the two other inputs, but was significantly less error-prone than the EGT-only system. Fitts’ law analysis showed that the EMG/EGT system was not well matched with Fitts’ model.

1. Introduction

The general mechanism used by the eyes to examine a visual scene consists of two types of eye movements: the saccade and the fixation. A saccade is a rapid, ballistic motion that moves the eye from one area of focus of the visual scene to another. After a saccade, a period of relative stability follows. This period is called a fixation, and it allows the eye to focus light on an area of the retina called the fovea. During a fixation, the eyes still exhibit small, jittery motions, usually less that 1° in size.

EGT techniques seek to determine the user’s line of gaze by taking video images of the eye in order to establish a relationship between the geometric orientation of visual features of the eye and the line of gaze. The most popular EGT technique at present uses the relative position of the bright eye (pupil) center and the center of the glint (corneal reflection) to determine the line of gaze [1-5]. Once the line of gaze is determined, the point of gaze (POG) is found by allowing the line of gaze to intersect with the plane of the scene being viewed (typically the computer screen). The mapping between screen coordinates and eye gaze direction is determined by a calibration procedure, performed in advance of the use of the EGT system.

The “raw” POG coordinates produced by the EGT system are generally processed further by some form of fixation identification algorithm, which will extract fixation coordinates from the POG coordinates. These fixation coordinates are then used to update the cursor position. Fixation identification algorithms can be classified by the manner in which they use spatial and temporal information to identify fixations [6]. Selections or clicks may be implemented by using a dwell time threshold or blinks. Dwell time is more natural to the user [4], and thus is more prevalent in its usage, but has disadvantages that will be detailed later in this section.

A seminal work in the field of EGT-based control of the cursor was that of Ware and Mikaelian [2]. The EGT technique that they employed required a dwell time of 400 ms. In their paper, they presented experiments to investigate the viability of eye gaze tracking as a pointing technique. The results showed task times of less than 1 s and that the data conformed to the Fitts’ law model. They also showed that task time and error rate increased significantly for target sizes less the 1.5° visual angle.

Hutchinson et al. described an eye-gaze-response interface computer aid (ERICA) in their paper [3]. The EGT technique that they employed required a dwell time of 2 – 3 s as a selection criterion, and the testing of their system produced some notable observations. These include: the bright eye effect was not observable in 5% - 10% of the candidates, the head must remain fairly stationary for the eye image to be captured, and there was a limitation in the accuracy of the system.

The work of Robert J.K. Jacob in this field is also worthy of note [4]. The fixation identification algorithm he used in his eye tracking cursor control system utilized a 100 ms temporal threshold to determine whether the POG points remained within a 0.5° dispersion threshold. In a preliminary evaluation, his eye tracking system was
used to perform object selection interactions with a dwell time of 150 – 250 ms. It was found to be quite effective in performing these tasks.

Sibert, in conjunction with Jacob and Templeman, provided a more formal evaluation of Jacob’s eye gaze tracking system [1, 5]. The evaluation consisted of two experiments that required participants to select circular targets with the EGT system, as well as, with the mouse. The EGT system used a dwell time of 150 ms as a selection criterion. The mean time selection results for both experiments showed that the EGT system was faster than the mouse and that the difference was statistically significant. Fitts’ law analysis of the results showed that the EGT interaction technique was not well represented by Fitts’ model, in the sense that there was little increase in trial time with the increase in trial distance.

The primary benefit of using the EGT techniques previously described for cursor control is the speed advantage they provide over using a mouse [1, 5]. However, this approach has some drawbacks. One such drawback is the so-called “Midas Touch” problem [4], which originates when eye gaze dwell time is used to issue a left-click operation. During a human-computer interaction session, situations may arise where a user may only desire to stare at an icon to examine it, rather than to select it. If this user is utilizing an EGT input system that issues left-clicks when the point of gaze dwells in a small area for specific period of time, unintended selections may result. Another disadvantage is the limited accuracy of the approach. This limitation results from the fact that the eye only needs to focus incoming light anywhere in the fovea to achieve the higher level of visual acuity available in that region of the retina. However, this still allows variations of about 1° of visual arc in the direction of gaze [4]. The lax nature of this physical constraint limits the accuracy with which the line of gaze can be estimated. There is also the issue of POG offsets that may occur after the original calibration of the EGT system. These offsets are caused by minor movements of the head from its original calibration position. Morimoto and Mimica have shown experimentally that the calibration mapping of a remote eye gaze tracker decays (becomes less accurate) as the head moves away from its original position [7]. Therefore, the only ways to restore the accuracy of the EGT system are to either place the head of the user back to its original position or to recalibrate the system at the present position of the user’s head.

Researchers have proposed and implemented a number of mechanisms to compensate for the drawbacks of EGT-based inputs. An example of this is a mechanism that would allow for expanding targets proposed by Miniotas et al. [8]. This mechanism would seek to mitigate the effects of the limited accuracy inherent with eye gaze tracking, by increasing target size to a “pointing-friendly” size while the user’s gaze is within the boundaries of the target. In their experimental evaluations they used three levels of an expansion factor (1, 2, 3), and had movement time and error rate as dependent measures. Statistical analysis of the results showed a statistically significant decrease in movement time and error rate with expansion factor. The primary disadvantage of target expansion is that the spatial penalty incurred by using this mechanism is permanent, that is, the extra space consumed during the expansion can only be occupied by non-interactive objects.

Other researchers have taken the approach of integrating eye gaze tracking with another input modality as a compensatory mechanism.

A gaze-speech multimodal interface is a system that can produce improved human-to-computer interaction if the two input modalities are integrated efficiently. A user would be required to adhere to a general protocol in order for an interaction procedure to be recognized by such a system. Typically this would mean that a user would gaze at an object of interest then utter a specific word or phrase to initiate the procedure (e.g. click, drag, move, or drop) to be performed on the object. A study on how to optimally integrate these modalities for object selection tasks was performed by Zhang et al. [9]. It was found that one-word phrase used in conjunction with a eye operative region around the fixation point of 1.5 cm resulted in the highest recognition rates and smallest selection times. This study showed that gaze-speech interfaces can overcome the susceptibility of gaze-based interaction to unintended selections, as well as, improve the accuracy and speed of speech recognition systems, by allowing for simpler vocabularies. However, these interfaces did not improve the limited spatial accuracy inherent in EGT systems.

Zhai et al. produced a bimodal form of cursor control, which used mouse input for small cursor movements, along with click operations, and gaze input to perform large cursor excursions [10]. Their approach was called manual and gaze input cascaded (MAGIC) pointing. Two MAGIC pointing techniques were developed: conservative and liberal. The two techniques were compared to a mouse input using point-and-click trials. The results showed that the difference between techniques was statistically significant, with mean task completion times of 1.4 s for mouse input, 1.52 s for conservative MAGIC input, and 1.33 s for liberal MAGIC input. The results suggest that the liberal MAGIC technique is faster than the mouse for point-and-click tasks, while not being susceptible to the disadvantages typically associated with gaze-based interaction. The results also showed that the MAGIC techniques matched the Fitts’ law model relatively poorly. This technique again demonstrates that if an EGT-based input is properly integrated with another form of input
they can produce a very efficient form of human-computer interaction. However, this technique is not suitable for individuals who are unable to use their hands.

Surakka et al. have developed an HCI system that utilizes the two modalities of voluntary gaze direction (EGT) and voluntary facial muscle movement (EMG) to perform object pointing and selection tasks [11]. The voluntary facial movement of frowning was used to perform object selection by monitoring the EMG signals from the corrugator supercilii. The analysis revealed that the mouse was faster than the new system in performing object pointing and selection over short distances. However, the regression slopes derived from Fitt’s law analysis suggest that the system may be faster than the mouse over long distances, that is, beyond 800 pixels. This approach is similar to gaze-speech interfaces in that it overcomes the unintended selection problem encountered with an EGT system, but does not deal with its limited accuracy problem.

The approach we propose involves integrating EGT and EMG inputs in such a way that an enhanced form of cursor control results. For our hybrid EMG/EGT system incremental positional commands will be derived from the EMG subsystem to effect small cursor displacements within a restricted neighborhood of the current cursor location. Similarly, only the EMG subsystem will be used to determine when the user commands a click operation. On the other hand, when the user needs to perform a long cursor displacement on the screen, the EGT subsystem will be employed. Such a system seeks to compensate for two of the shortcomings of EGT inputs (limited accuracy and unreliable left-click operation) by using EMG-based cursor commands for small cursor displacements and left-clicks, while attempting to maintain the inherent speed benefits of the EGT-based interaction.

2. Methods

2.1. EMG Subsystem Implementation

When a surface electrode is placed on the skin above a contracting superficial muscle, it will receive electrical signals emanating from several muscle fibers associated with different motor units. The spatio-temporal summation of these electrical signals results in what is called an electromyogram (EMG) signal. The purpose of the EMG subsystem is to monitor EMG signals emitted from muscles in the face and to translate these EMG signals, corresponding to prescribed muscle contractions, into cursor actions. Figure 2-1 displays the placement of five Ag/AgCl electrodes attached to the head of the user. The figure indicates that electrodes were placed over the right frontalis muscle, the left temporalis muscle, the right temporalis muscle, and the procerus muscle, respectively. The additional electrode was placed over the right mastoid as a reference.

The hardware components of the EMG subsystem are presented in Figure 2-2. The set of four EMG signals were input into Grass® P5 Series AC preamplifiers. The ADC64™ DSP/AD board (Innovative Integration, Simi Valley, CA) performed analog-to-digital conversion on each signal at a sampling rate of 1.2 kHz, and then applied an EMG classification algorithm to these digitized signals in real-time. The board was connected to the computer’s processor through the PCI bus. The output of the classification algorithm was sent to the host cursor control application via hardware interrupts.

The desired relations between cursor actions, facial movements, and muscle contractions for the EMG subsystem are given in Table 2-1. The purpose of the EMG classification algorithm was to determine if a facial muscle contraction had occurred and if so, which specific muscle was the source of this contraction. Given the one-to-one correspondence between muscle contraction and cursor action shown in Table 2-1, the output of an effective muscle contraction classification algorithm can be used to provide real-time cursor control.

Table 2-1 Relations between cursor actions, facial movements and muscle contractions
<table>
<thead>
<tr>
<th>Cursor Action</th>
<th>Facial Movement</th>
<th>Muscle Contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Left Jaw Clench</td>
<td>Left Temporalis</td>
</tr>
<tr>
<td>Right</td>
<td>Right Jaw Clench</td>
<td>Right Temporalis</td>
</tr>
<tr>
<td>Up</td>
<td>Eyebrows Up</td>
<td>Right Frontalis</td>
</tr>
<tr>
<td>Down</td>
<td>Eyebrows Down</td>
<td>Procerus</td>
</tr>
<tr>
<td>Left-Click</td>
<td>Left &amp; Right Jaw Clench</td>
<td>Left &amp; Right Temporalis</td>
</tr>
</tbody>
</table>

It had been observed previously that the four muscles being monitored possessed distinct EMG spectral characteristics, and that this spectral information would be useful for performing classifications [12, 13]. Empirical observations suggested that Mean Power Frequency (MPF) values would be a suitable way of representing the spectral data for this input configuration, and it was decided to use MPF values as a feature input into the classification algorithm. The MPF is derived from PSD values as a weighted average frequency in which each frequency component, f, is weighted by its power, P. The equation for the calculation of the MPF is given by:

\[
MPF = \left( \frac{f_0 \times P_0 + \ldots + f_k \times P_k + \ldots + f_{N-1} \times P_{N-1}}{P_0 + \ldots + P_k + \ldots + P_{N-1}} \right) (2-1)
\]

where \( k = 0, 1, 2, \ldots, N - 1 \), and \( N = 256 \).

EMG recordings, taken from a test group of five individuals, revealed the each muscle type had a characteristic range of MPF values. The frontalis muscle had the majority of its spectral content below 200 Hz, with an MPF in the range 40 Hz – 165 Hz. The temporalis muscles had a significant portion of their spectral content above 200 Hz, with an MPF in the range 120 Hz – 295 Hz. The procerus muscle had an intermediate spectral content when compared to the frontalis and temporalis muscles, with an MPF in the range 60 Hz – 195 Hz.

The EMG classification algorithm derived three features from each PSD estimate calculated for each EMG input to assist in determining which muscle(s) was the source of a contraction. These features were: the maximum PSD magnitude, the sum of all the PSD magnitudes for a given estimate, and the MPF value for the estimate.

The cursor actions left, right, up and down are produced by the predominant contraction of a single muscle. For a single muscle contraction to be correctly classified by the algorithm, a criterion placed on each feature, for the electrode (muscle) in question, must be satisfied. These criteria are:

i. The maximum PSD magnitude must exceed the threshold set for that electrode.

ii. The sum of the PSD amplitudes for the given electrode must exceed the PSD sums of the other electrodes.

iii. The MPF must fall into a range consistent with the muscle associated with the electrode.

The criteria required for the classification of the simultaneous contractions of the left and right temporalis muscles, which corresponded to a left-click, are similar to the criteria presented for the single muscle contraction.

### 2.2. EGT Subsystem Implementation

The eye tracking system used for our EGT subsystem was an R6-HS Remote Optics system manufactured by Applied Science Laboratories (Bedford, MA). This system produced POG estimates at 120 Hz and sent these estimates to the display PC (the computer that interacted with the user) via the serial port of the PC. The cursor control application running on the display PC received these values via hardware interrupts.

The fixation identification algorithm utilized temporal and spatial criteria to determine whether or not a fixation had occurred. More specifically, the algorithm extracted a 100 ms moving window (temporal threshold) of consecutive POG data points (POGx, POGy), and calculated the standard deviation of the x- and y-coordinates of these points. If both standard deviations were less than the coordinate thresholds associated with 0.5° of visual angle (spatial threshold), then it was determined that the onset of a fixation had occurred, and the centroid of the POG samples received during the 100 ms window was used as the coordinates to represent the fixation (Fx, Fy). If it was determined that a fixation had not occurred, then the window was advanced by one data point and fixation identification was performed again.

### 2.3. Information Fusion and Cursor Update Algorithm

In order to produce a seamless form of cursor control, an algorithm had to be created to define how the outputs of the EMG and EGT subsystems were to be integrated. This information fusion and cursor update algorithm determined the effective cursor position as a merging of the incremental EMG commands (\( \Delta x, \Delta y \)) and the absolute coordinates of a qualified EGT fixation (\( F'x, F'y \)) as defined by equations (2-2) and (2-3):

\[
C_x[n] = \begin{cases} 
C_{x[n-1]} + \Delta x[n] & \text{If EMG update} \\
F'_x[n] & \text{If EGT update}
\end{cases} \tag{2-2}
\]

\[
C_y[n] = \begin{cases} 
C_{y[n-1]} + \Delta y[n] & \text{If EMG update} \\
F'_y[n] & \text{If EGT update}
\end{cases} \tag{2-3}
\]

where \( C_x \) and \( C_y \) represent the x- and y-coordinates of a cursor position and \( n \) represents a discrete index used to describe the progression of cursor updates through time.

The merging of the outputs of the two subsystems implied that the current cursor position (\( C_x[n], C_y[n] \)) may
be updated by either the EMG or EGT subsystem at any
time.

An EMG subsystem update involved changing the
previous cursor position \( (C_x[n-1], C_y[n-1]) \) by an
increment of \( \Delta x \) or \( \Delta y \).

An EGT subsystem update involved replacing the
previous cursor position with the absolute coordinates of
a qualified fixation \( (F'_x, F'_y) \). A qualified fixation was
determined by taking every new fixation centroid \( (F_x, F_y) \)
identified by the fixation identification algorithm, and
testing it to determine if it signified a new point of user
attention, or if it simply was the continuation of previous
fixation. This was done by measuring the distance
between the current qualified fixation position \( (F'_x, F'_y) \) and
the \( (F_x, F_y) \) under test. This distance was compared
to the Euclidean distance defined by the standard
deviations in \( x \) and \( y \) of the POG points that resulted in
the new fixation \( (F_x, F_y) \). If the distance from \( (F'_x, F'_y) \) to
\( (F_x, F_y) \) was greater than this threshold, then \( (F_x, F_y) \) was
acknowledged as representing the new point of user
attention, and it became the new qualified fixation point
\( (F'_x, F'_y) \).

2.4. Design of Experiment

An experiment was designed to test whether the
EMG/EGT-based input would produce lower error rates
and comparable task times to those recorded for EGT-
based input in point-and-click trials. Also, this
experiment would use the error rate and task time
measures to compare the performance of EMG/EGT-
based input to that of a mouse in completing the same
trials.

A purpose-specific program was created for this
experiment using Visual Basic, and each trial was
displayed on a 19” monitor. The participant was seated
in front of the monitor, such that the eye to screen distance
was approximately 29”. The layout of an example trial is
shown in Figure 2-3. Each layout contained a square icon
labeled “HOME” and a circular icon labeled “TARGET”. There were
three target diameters [48 pixels (1.1°), 66 pixels (1.5°), 96
pixels (2.2°)], three pointing distances [286 pixels (6.5°), 578 pixels (7.2°)],
and four angles of approach (NE, SE, SW, NW) for this
experiment. These factors were crossed to produce 36 (3
target diameters x 3 distances x 4 angles) unique trial
conditions. The placement of the two icons was arranged
in such a way that the center of the screen would always
bisect the distance between them.

2.5. Data Analysis Methods

The two dependent variables of trial time and error
rate were analyzed separately using mixed design
ANOVAs. This was done to investigate the effects of the
various factors on each variable. These analyses were
accompanied by orthogonal contrasts for the cursor
control technique factor for both error rate and trial time.

One of the most popular methods for evaluating the
point-and-click performance of cursor control devices is
to use Fitts’ law analysis. Fitts proposed that the
information processing capacity of the human motor
system was analogous to Shannon’s formulation of
channel capacity used in the transmission of information
[14, 15]. Specifically, he argued that a movement task’s
difficulty, represented by its index of difficulty (I), could
be expressed as:

\[
I = \log_2 \left( \frac{2A}{W} \right)
\]

where \( A \) is the distance or amplitude to move to a
target, \( W \) is the width or tolerance of the target region in
which the move terminates, and \( I \) is quantified in bits.

![Figure 2-3 Example point-and-click trial layout for experiment 1](image-url)
On this basis, Fitts conjectured that the average movement time (T) for a set of tasks with different amplitude and width values would be constant, provided I was constant for all these tasks. This concept may be expressed as:

\[ \frac{I}{T} = C \]  

(2-5)

where C is a constant with units of bits per second.

C may be interpreted as the capacity of the human motor system to execute a specific class of motor responses, and later became known as the index of performance. Fitts extended his analogy to the case where I takes on different values, and suggested that T and I would have a first order relationship expressed mathematically as:

\[ T = a + bI \]  

(2-6)

where a is the T intercept for a task of I = 0, and b (= 1/C) is the slope of the relationship.

Mackenzie made modifications to Fitts’ law so as to improve its accuracy in modeling the performance of input devices in point-and-click tasks [16]. His modifications resulted in a reformulation of I:

\[ I_e = \frac{1}{\log_2 e} \left( \frac{A}{W_e} + 1 \right) \]  

(2-7)

where \( I_e \) is called the effective index of difficulty, and \( W_e \) is the effective width of the target.

\( W_e \) is a modified value for the width of the target derived from the distribution of the selection points about the target center for a number of trials. The equation for \( W_e \) is given by:

\[ W_e = 4.133 \times S_x \]  

(2-8)

where \( S_x \) is the standard deviation of the distances between the selection points and the target center, resolved along the task axis.

\( W_e \) gives a better indication of the spread of user selection points than the fixed dimension W. Therefore, Mackenzie’s modified Fitts’ law model can be expressed as:

\[ T = a + b \log_2 \left( \frac{A}{W_e} + 1 \right) \]  

(2-9)

When applying Fitts’ Law analysis to the evaluation of a cursor control system in point-and-click tasks, a movement time value is obtained by averaging all the movement times taken for tasks of a given I. Provided that there are tasks with different I values, then a number of (I, T) ordered pairs will be available. These ordered pairs are used to produce a linear regression line that represents the performance capabilities of that cursor control system. Fitts’ law analysis was applied to the EMG/EGT system to investigate whether or not it would provide a good model for the evaluation of system performance, and thus provide a means of comparison with other cursor control systems. The uncertainty as to how well the hybrid system performance would match Fitts’ model was rooted in the fact that empirical evidence presented in human-computer interaction literature has provided conflicting conclusions as to how well eye tracking matches Fitts’ model [1, 2, 5]. However, it has been shown that EMG-based cursor control correlates well with the model [13].

3. Results

Both the trial time and error rate data were found to be substantially non-normal in their distributions. This resulted in the logarithmic transformations of both the trial time [\( \log_{10}(X) \)] and error rate [\( \log_{10}(X + 1) \)] data sets.

The tests of between-subjects effects for trial time revealed a significant effect for cursor control technique (p < 0.0005) and the contrasts for these effects revealed that the EMG/EGT technique was significantly slower than both the mouse (p < 0.0005) and EGT (p < 0.0005) techniques. A bar chart representing the transformed mean trial time data is given in Figure 3-1. Also, in order to give the results a “real world” context, the marginal means of the cursor control techniques for the untransformed trial time data are given in Table 3-1.

The tests of between-subjects effects for error rate also displayed a significant effect for cursor control technique (p < 0.0005), and the contrasts for these effects revealed that the EMG/EGT technique had a significantly smaller error rate than the EGT technique (p < 0.0005). The contrasts also showed that the error rate produced by the EMG/EGT technique was comparable to that of the mouse (p = 0.206). A bar chart of the transformed mean error rate data is given in Figure 3-2, and the marginal means of the cursor control techniques for the untransformed error rate data are given in Table 3-2.
Figure 3-1 Bar chart showing mean trial time performance for cursor control techniques used in the experiment, after logarithmic transformations

Table 3-1 Marginal means of cursor control technique factor for untransformed time data

<table>
<thead>
<tr>
<th>Cursor Control Techniques</th>
<th>Mean (s)</th>
<th>Std. Error (s)</th>
<th>95% Confidence Interval Lower Bound (s)</th>
<th>Upper Bound (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>9.84</td>
<td>0.38</td>
<td>0.20</td>
<td>1.76</td>
</tr>
<tr>
<td>EMG/EGT</td>
<td>4.68</td>
<td>0.38</td>
<td>3.91</td>
<td>5.46</td>
</tr>
<tr>
<td>EGT</td>
<td>3.07</td>
<td>0.38</td>
<td>2.29</td>
<td>3.85</td>
</tr>
</tbody>
</table>

Figure 3-2 Bar chart showing mean error rate performance for cursor control techniques used in the experiment, after logarithmic transformations

Table 3-2 Marginal means of cursor control technique factor for untransformed error rate data

<table>
<thead>
<tr>
<th>Cursor Control Techniques</th>
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<th>Std. Error</th>
<th>95% Confidence Interval Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>0.014</td>
<td>0.245</td>
<td>-0.489</td>
<td>0.517</td>
</tr>
<tr>
<td>EMG/EGT</td>
<td>0.135</td>
<td>0.245</td>
<td>-0.368</td>
<td>0.637</td>
</tr>
<tr>
<td>EGT</td>
<td>3.976</td>
<td>0.245</td>
<td>3.474</td>
<td>4.479</td>
</tr>
</tbody>
</table>

4. Discussion

Statistical analysis of experimental data indicated that EMG/EGT users were slower than EGT users in performing cursor control tasks (4.68 s mean trial time for EMG/EGT compared to 3.07 s for mean trial time for EGT).

The benefit of using an EMG/EGT input instead of an EGT input can be found by comparing the mean error rate results for the two inputs (0.135 errors/trial for EMG/EGT and 3.976 errors/trial for EGT). This statistically significant difference in error rate can be attributed to the different approaches employed by the users of either system when selecting the smaller target sizes. EGT users utilized a shifting of eye gaze in the region of these smaller targets, in order to compensate for its inaccuracy. This often resulted in unintended left-clicks being issued in the region surrounding the target. When EMG-based input was used to compensate for the lack of accuracy of EGT-based input, it enabled the user to have incremental control of cursor movement, and it allowed the user to no longer be dependent on the eye tracking input to perform selection operations. These two advantages provided by EMG/EGT control resulted in a more reliable icon selection mechanism, especially suited for high resolution environments.

The results of Fitts’ law analysis indicated that the ballistic nature of eye movements was not well modeled by this law, and the strong influence of these movements on the EMG/EGT technique made EMG/EGT a poor match for the model ($r^2 = 0.474$). This was despite the fact that the EMG modality on its own had been shown to correlate well with Fitts’ model [13].

4. Conclusion

A novel EMG/EGT cursor control system that compensates for the inaccuracy and unreliable left-click limitations possessed by an EGT system has been created and tested. This EMG/EGT mode of interaction is not well modeled by Fitts’ law.

5. Acknowledgments

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6. References


