

Features of Eye Gaze Interface for Selection Tasks

Takehiko Ohno

NTT Basic Research Laboratories

3-1 Morinosato Wakamiya, Atsugi, Kanagawa, 243-0198, JAPAN

takehiko@rudolph.brl.ntt.co.jp

Abstract

Eye gaze interface has potential as a new Human-Computer Interaction method, evident in the numerous kinds developed so far. However, in order to make sure that such an interface is both useful and convenient in daily life for a wide range of users, we need to undertake more indepth studies of human behavior in order to adapt the design to human factors. In this paper, a prototype system for a menu based interface is described and an experiment designed to analyze users' performance is reported. The results show that 1) the eye gaze interface is faster to operate than the mouse, 2) making selection by means of an eye mark takes longer than just reading menu commands, and 3) most errors are induced by lack of adequate visual feedback from the screen. Based on the results, two methods to reduce selection error and to improve the performance are discussed, and three facts that improve the usability of the eye gaze interface are presented.

1. Introduction

In the very near future, when one wants to control a computer it may be possible simply to glance at the display. This would make it unnecessary to learn how to control a mouse or operate a keyboard. Eye gaze interface would be the most common Human-Computer Interaction (HCI) method of the next decade.

There are two types of eye gaze interface [3, 4, 6]. One is command based, and the other is non-command based. In the command based interface, an eye mark is used to select a command from among a set of choices either in the form of a menu or of icons [1, 2]. People use the eye mark to select objects just as with other traditional pointing devices, such as mice, track balls, and touch panels.

In the non-command based interface, the user's eye mark does not select a particular target [4, 5]. Instead, its traces are analyzed and interpreted in order to detect the user's interests and intentions.

In our daily computer supported work, command based interfaces are used extensively. If it is possible to use an eye mark as a command based interface, there will be many potential application areas. However, several features of eye movement make the current state of the interface inadequate as a replacement for other pointing devices.

P-1 It is difficult to intentionally control eyes. We move our eyes all the time with no difficulty, but when we have to intentionally move and fix our eyes upon certain points, the resulting strain causes tiredness.

P-2 Precise eye control is difficult. We can select small icons or even pixels with a mouse. But it is difficult to select such small objects with precision using our eyes.

P-3 People perform two functions with their eyes when using the eye gaze interface: obtaining information from the display and operating the interface. The eye gaze interface should distinguish between these distinct functions.

When developing a useful eye gaze interface, it is insufficient simply to replace a traditional input device with an eye mark. Instead, we need to first understand the behavior of users, and identify the reasons they have difficulty in controlling the eye gaze interface. We can then develop a new interface based on these findings.

In this paper, we analyze users' behavior when using the eye gaze interface, compare this with the completion of menu selection tasks with a mouse, and based on the results, discuss the principal points to be considered when we develop an eye gaze interface. In particular, we focus on the common menu interface that is used in a variety of ways in the Graphical User Interface.

2. The Eye Gaze Interface System

Figure 1 represents an experimental environment that consists of an EMR-NC, a non-attachment eye mark recorder, and a Sun Sparc 10 (SS10) workstation. The

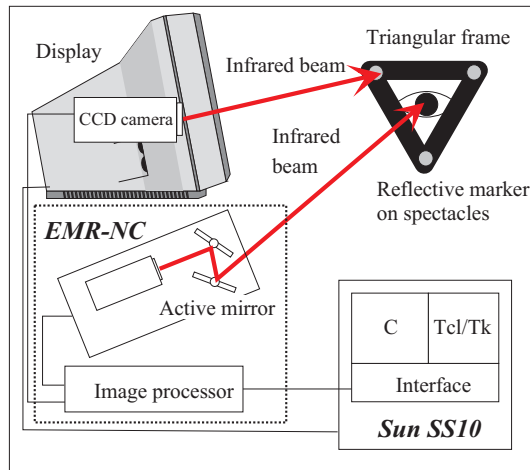


Figure 1. Overview of the eye gaze interface system with an eye mark recorder EMR-NC and a workstation Sun SS10.

EMR-NC was developed jointly by NAC Co. and NTT Basic Research Laboratories. To record the eye mark, users wear a lightweight triangular frame that is attached to a pair of spectacles. The EMR-NC detects the triangular frame by using two cameras, one on either side of the display, and controls an active mirror to track their eye position. This mechanism makes it possible to track users' eye marks with a high accuracy, of about 0.3 degrees, and it allows users to move their heads freely. Eye mark data is recorded 30 times per second (30Hz) and sent to the SS10 in real-time. There are C libraries to control the EMR-NC and we have developed experimental interfaces with C and Tcl/Tk.

3. The Selection Method of The Item

In a command based interface, users have to select a command from among a number of possible options by using certain methods. But if a command is activated just because users look at it, it will cause a serious problem. When they search the screen to find an appropriate command, many commands will be executed to cause chaos. This problem is known as the "Midas Touch problem" [2]. In recent studies, many methods have been proposed to overcome this problem but without complete success. To use the eye gaze interface for ordinary tasks, these remaining problems should be solved. The following describes three major methods and their respective problems.

S-1 The use of response time to activate commands. The response time is about 0.5 to 1 second. During selection, the system can provide some visual feedback to avoid

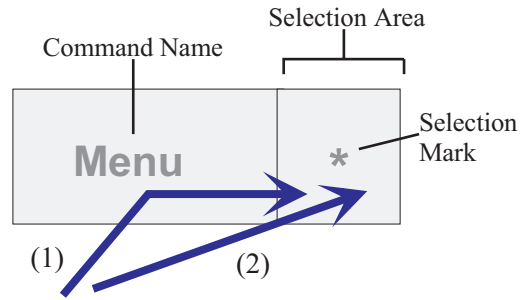


Figure 2. Quick Glance Selection Method

users' mis-selection. For example, "Eyecon", which is an eye shaped icon interface that starts to close its eye when it is gazed on, is used to indicate to users that the selection process is in operation [1]. With this method, it is important to use an adequate response time. If it is too short they may select an unintended item while simply looking for the one they want. If it is too long, the waiting time will make them irritated and reluctant to use the interface.

S-2 The use of an eye gesture such as a wink. The system has to detect whether the users' winks are physiological or intentional selection behavior.

S-3 The use of other methods in combination with the eye mark. One such example might be pressing the space bar or a mouse button. The reliability of this method is higher than the other two, but users need to operate both the eye mark and other devices.

Selection with the eye mark is sometimes very hard work. We observed that subjects could not continue the task after a half-hour trial. This was not, however, because of their use of the eye mark recorder. When we asked subjects to use eye mark recorder while they were performing ordinary tasks, they could continue for more than one hour without any stress or fatigue. One of the reasons is that the eye movement required for a selection task is very unusual for the subjects. They have to direct the eye mark to the target and gaze at it for a while, or blink their eyes to select a command.

To reduce the burden on the user and improve the usability of the interface, I propose a new selection method, called the "Quick Glance Selection Method". A prototype system using this method was developed and an experiment was conducted to compare its performance with that of a mouse.

3.1. Quick Glance Selection Method

The *Quick Glance Selection Method* proposed here provides a fast and simple way to select a target. Users do

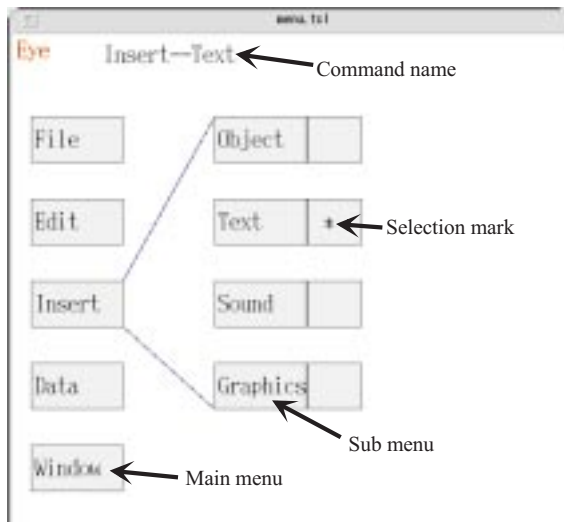


Figure 3. Screen image of the menu selection task.

not have to make intentional eye movements to select their target. Instead, they just glance at it. This is similar to a normal graphical user interface where they glance at a target to select with the mouse.

The feature of the *Quick Glance Selection Method* is that the target is separated into two parts; command name and selection area (Figure 2). When they wish to select a command, they look at the selection area instead of gazing at the command name. There are two ways to select the target. One way is to look first at the command name (Figure 2(1)). The selection mark in the selection area will then appear as a visual feedback, and when they look at the selection area, the selection is completed. With this approach, they need two saccades to select their target. Beginners who do not know the location of the menu items use this method.

Another way is to look at the selection area directly (Figure 2(2)). When users already possess knowledge of the location of menus, they can just look at the target. This requires just one saccade.

4. Experiment: Comparison of Eye Mark and Mouse

An experiment of using hierarchical menu selection tasks was conducted to compare the performance of the eye mark with that of a mouse. Figure 3 shows the screen image of the task. A command name was displayed at the top of the screen that asked subjects to select from menus presented to them. First, they selected the first command from the main menu, and then a sub menu was displayed on the right side. Then they made a selection from the sub menu to complete

Method	Mouse	Eye mark
Main menu	0.0%	0.5%
Sub menu	0.0%	9.1%

Table 1. Error rate of the menu selection task.

the task. When they used the mouse, they simply clicked on the main and sub menus to make a selection. When they used the eye mark, they looked at the main menu to make a selection, and then, they looked at the selection area of the sub menu to select the second command. Before selecting a sub menu, they could select another main menu to cancel the previous selection.

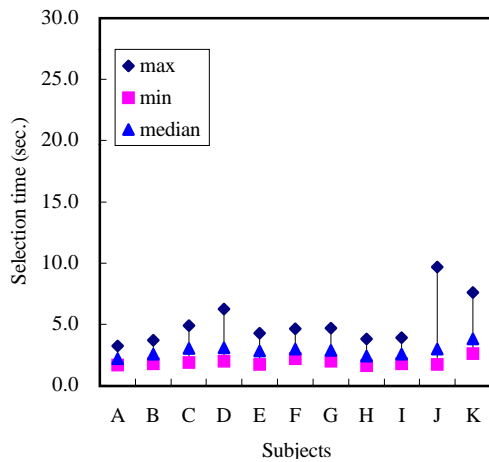
Subjects 11 subjects participated in this experiment. They were Macintosh or Windows users who used computers almost every day. They could manipulate mice at high speed.

Tasks Subjects were given 15 practice trials. Each trial consisted of mouse and eye mark selection tasks. Following that, there were four data collection sessions. For each session, they had 14 selection tasks with the mouse and 14 tasks with the eye mark. There were 56 trials in total for each device. Eye mark data and selection time were logged by a workstation.

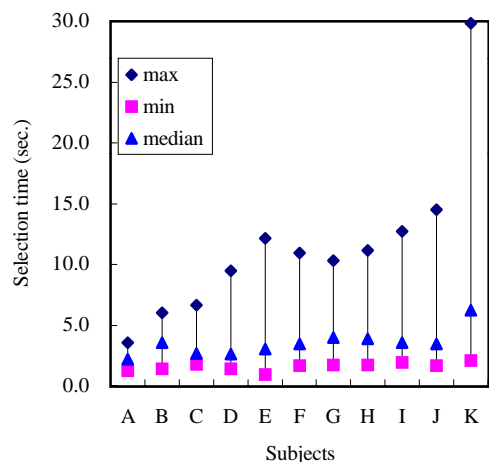
5. Results

The results show that it is possible to select a command with the eye mark faster than with the mouse. Figure 4 shows the selection time for all subjects. Subject E, the fastest of all, could select a command in 0.92 seconds with the eye mark and in 1.72 seconds with the mouse. The difference in the minimum time was small between subjects and between devices. The difference in the median time between subjects was also not very great. The selection time of the slowest subject was less than 1.8 times that of the fastest. But there was a great difference between the maximum times for devices. In the worst case, subject K took 29.8 seconds to select a command with the eye mark, and 7.6 seconds to select with the mouse.

The error rate for all the subjects (Table 1) shows that there were no errors when selecting with the mouse and rarely when selecting from the main menu with the eye mark. However, there were many errors when selecting sub menus with the eye mark, amounting to a rate of about 9.1%. Since the selection task of the the main menu and the sub menu are similar processes, the reason for the difference is that subjects cannot cancel the selection from the sub menu.



(a) Selection task with mouse.



(b) Selection task with eye mark.

Figure 4. Menu selection task time

5.1. Error Classification

For everyday usage of the eye gaze interface, 9.1% selection error is too great and should be reduced. Causes of the error were classified into three types.

- E-1** Wrong selection of the menu. Users wanted to select one menu, but the eye mark moved over an unwanted menu and it was selected.
- E-2** Unconscious glancing at the selection mark. Users looked at the selection mark when it was displayed.
- E-3** Wrong positioning of the eye mark. When users looked at the target, the eye mark was not in the menu region on the screen, but outside the menu. They moved their eyes to try to select the menu and the wrong menu was selected.

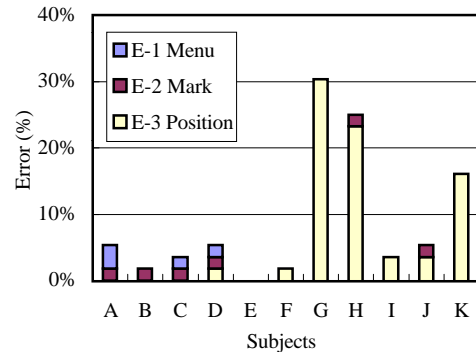


Figure 5. Types of eye mark selection error

Figure 5 shows the error rate for the three types. The error rates of subjects G, H, and K were above 10%, and the average for the remaining subjects was 4.0%.

81.8% of the errors were caused by **E-3**. In this case, users could not select the menu. If a given menu is activated, they could understand the current position of the eye mark. But when there was no visual feedback from the screen, they moved their eye mark around the menu to try to select it, and another menu was wrongly selected. This may cause a feeling of fatigue and lack of control. If it is possible to find a solution to **E-3**, the error rate will be reduced by 81.8%, to about 1.7%. The selection time will become much shorter, too. The method for reducing the selection error will be discussed in Section 6.

5.2. Difference of Eye Mark Operation Time

Selection by using the eye mark is unusual and it may result in lack of control and fatigue to the user. When users start to select a menu by the eye mark, they first look at each menu (obtaining information task). When they find the target, they select it by gazing at the menu (selection task).

To find the difference between obtaining and selection tasks, we compared the operating time of the two process when the users employed the *Quick Glance Selection Method*. The eye mark data of subject A was used because the variance in the selection time using the eye mark was the smallest and the difference in the error rate was only about 5.4%.

Figure 6 shows the average operation time for both the obtaining information task and the selection task. The obtaining information task is 0.10 seconds faster than the selection task ($p < .001$). This is because, when users select a menu, they first look at the name of the menu (this process is the same as the obtaining information task), visual feedback is displayed, and after confirming the feedback, they finish gazing at the target. This process is more complicated than obtaining information. When they use the mouse to select a

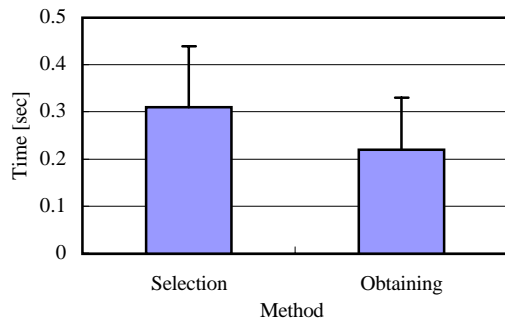


Figure 6. Operation time of subject A.

menu, they simply move the mouse cursor to the menu and do not have to confirm whether their selection is correct or not. This may initially result in poor levels of control.

The difference will be reduced if they repeat the task and learn the position of menus because when they know the position of the menu, they do not have to confirm whether or not the selected menu is correct.

6. Reducing Selection Error

When users gaze at the menu, it should be selected. However, the results of the experiment showed that they sometimes could not select correctly. There are two reasons for incorrect selection: (1) the eye mark was not on the rectangular menu area when the users looked at the menu. When they looked at the menu, the eye mark was sometimes outside the menu; and (2) the accuracy of the eye mark recorder was decreased during the task. Two methods to reduce these problems are discussed now.

6.1. Effects of Eye Mark Cursor

When users start to select a menu and it is not selected, they find that the position of the eye mark is not on the menu. However, they cannot find where they should look to select it because they cannot find the current position of the eye mark. If a cursor on the screen indicates the position of the eye mark, users can find the direction in which they should move their eyes, and thus can finish their selection. To confirm whether the use of a cursor would improve the selection task performance, I built a prototype environment and conducted an experiment.

Tasks Three subjects participated in the experiment and there were four data collection sessions. Each session had 14 trials with and 14 trials without the eye mark cursor.

Results Figure 7 shows the number of errors and the median selection time with and without the eye mark cursor. When

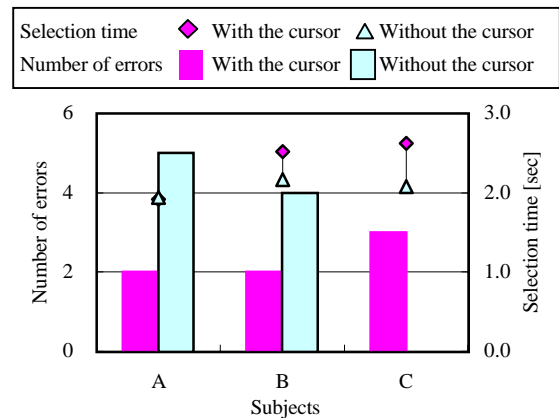


Figure 7. Number of errors and the median selection time with and without the eye mark cursor.

the eye mark cursor was used, the number of the errors was reduced for subjects A and B, but not for subject C. The selection times of subjects B and C with the eye mark cursor were slower than without the cursor. These results showed that the eye mark cursor did not improve selection task performance.

The reason for these results is that, when the cursor was shown on the display, the users' task changed from just gazing to moving the cursor onto the target. **P-1** and **P-2** (above) make it difficult to control the cursor. It was hard to control the cursor with eye movements, especially when the accuracy of the eye mark recorder was poor and the cursor was in a different position from the one at which the users were gazing.

6.2. Improving Eye Mark Recorder Accuracy

When I analyzed the eye mark data, I found that their absolute position slipped out a bit with subjects G, H, and K. If the eye mark recorder can detect the distance of the gap, it should be possible to correct the absolute position and maintain the accuracy.

"*Active Calibration*" is one of the techniques we have developed to correct for accuracy during the task. It detects situations where the eye mark recorder cannot track the position of the eye mark correctly, calculates the error distance and fixes it in the next trial. The feature of this method is that users do not have to suspend their task in order to re-calibration. When the error is large, fixation points will not reside on a menu item but at a place somewhere between two menu items. In such a case, *Active Calibration* is used to calculate the center of gravity of the fixation points and to compute the distance between the center of gravity and the center of the menu expected to be selected, inferred from

the user's selection. If the selection is incorrect and the system cannot infer the correct menu, it will calculate the distance wrongly. However this will be fixed in the next *Active Calibration*.

An experiment was conducted to confirm the effect of *Active Calibration*.

Tasks Six subjects participated in the experiment. The task consisted of 14 trials with *Active Calibration* (calibration task) and 14 trials without *Active Calibration* (no calibration task). The tasks were mixed and the subjects were not instructed about *Active Calibration*.

Results *Active Calibration* was valid for three subjects and was not used for the remainder because there were no inaccuracies. The selection time for the valid users' calibration tasks was 38% to 170% faster than for no calibration tasks (average of 104%). The selection time for the invalid users' calibration tasks was 0.9% to 6.2% faster than for no calibration tasks (average of 3.1%). This data shows that *Active Calibration* significantly improves the selection performance.

7. Discussion

Three features of the above experimental results can help to improve the usability of the eye gaze interface.

Natural eye movement in the selection task. In the experiment related to the menu selection with the eye mark, it took longer to select the menu with the eye mark than by just looking at the menu. Moreover the indication of the eye mark pointer was insufficient to reduce the error, and the selection time became longer than the task without the pointer. When the eye movement has a specific function instead of just looking at the display, the operation time may become longer and users cannot maintain effective control. To avoid this problem, we should reduce the difference between the natural eye movement and the operation. This concept is used in the *Quick Glance Selection Method*. As shown in Figure 2, a selection mark is indicated in the selection area. This mark assists the user to find focus on the selection area easily. We have not yet confirmed the effect of the mark experimentally, but subjects reported that it is effective.

Selection cancellation mechanism. After the experiment, some subjects reported feeling frustrated when they selected a sub menu. This was because they could not cancel the selection. The difference in the error rate in Table 1 also show the necessity of being able to undo the selection. We should consider providing the eye gaze interface with an effective cancellation method in a future study.

Eye gaze interface robustness. In the experiment, there

was a wide variance in performance levels among users. Figures 4 and 5 showed that some subjects could not use the eye gaze interface well. We need a robust interface if we use the eye gaze interface in conventional environments. The solution to this problem definitely involves improving the eye mark recorder and supporting software would also prove effective. *Active Calibration*, which improved the accuracy of the interface, is one example of a way to support robustness. It is also effective to prepare a mechanism to detect situations that cannot be controlled and then help the user. The eye mark cursor was not effective in the experiment, but if it is displayed when users lose control, they can find their current position and recover the situation.

8. Conclusions

An eye gaze interface experiment was conducted. Based on the results, I presented three factors we should consider when designing the interface. The design methodology of the eye gaze interface is not yet established, and this result is a preliminary step in developing it.

Acknowledgment

Support for this research is gratefully acknowledged from Dr. Ken-ichiro Ishii, the executive manager of the Information Science Research Laboratory in NTT Basic Research Laboratories. Hisao Nojima, Dr. Satinder P. Gill and members of the Mental Process Research Group gave me invaluable comments regarding this paper.

References

- [1] J.P.Hansen, A.W.Anderson and P.Roed. Eye-Gaze Control of Multimedia Systems, in Y.Anzai, K.Ogawa and H.Mori(eds), *Symbiosis of Human and Artifact. Proceedings of the 6th International Conference on Human Computer Interaction*. Elsevier Science Publisher, 20A, 37-42, 1995.
- [2] R.J.K.Jacob. What You Look At Is What You Get: Eye Movement-Based Interaction Techniques, *Proceedings of CHI'90*, ACM Press, 11-18.
- [3] R.J.K.Jacob, J.J.Leggett, B.A.Myers and R.Pausch. Interaction Styles and Input/output Devices, *Behaviour and Information Technology*, 12, 69-79, 1993.
- [4] J.Nielsen. Noncommand User Interfaces. *Commun. ACM*, 36(4), 83-99, 1993.
- [5] I.Starker and R.A.Bolt. A Gaze-Responsive Self- Disclosing Display, *Proceedings of CHI'90*, ACM Press, 3-9.
- [6] B.M.Velichkovsky and J.P.Hansen. New Technological Windows into Mind: There is More in Eyes and Brains for Human-Computer Interaction, *Proceedings of CHI'96*, ACM Press, 496-503.