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THE EFFECTS OF EYE GAZE BASED CONTROL ON OPERATOR PERFORMANCE IN MONITORING MULTIPLE DISPLAYS

By

Allison Popola

B.S., Embry-Riddle Aeronautical University, 2009

A Thesis Submitted to the

Department of Human Factors & Systems

in Partial fulfillment of Requirements for the Degree of

Master of Science in Human Factors and Systems.

Embry-Riddle Aeronautical University

Daytona Beach, FL

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The Effects of Eye Gaze Based Control on Operator Performance in Monitoring Multiple Displays

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Allison Popola

This thesis was prepared under the direction of the candidate's thesis committee chair, Dr. Dahai Liu, PhD., Department of Human Factors & Systems, and has been approved by the members of the thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirement for the degree of Master of Science in Human Factors and Systems.

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Acknowledgments

The author would like to especially acknowledge her dedicated thesis chair, Dr. Dahai Liu, for all of his time and effort on this project. Thank you for the many hours spent on the phone, emails, brainstorming sessions, paper editing, and guidance that you provided over the past year. Aside from being the chair of the committee, he has also been an incredible professor and a great mentor and role model for the past four years.

The author would also like to thank Dr. Peter Squire for sharing his passion for research and being a very active role in the development and execution of this experiment. Without his daily efforts, this would not have been possible. He has been not only a thesis committee chair, but a mentor and excellent example during the author's transition from college student to workforce member.

Additionally, thank you to Dr. Beth Blickensderfer for her efforts as a committee member, sounding board, mentor, role model, professor, and friend. She has given so much time and has impacted so much not only on this study, but for the past 6 years.

Finally, the author would like to thank her parents, Ron and Debby Popola. Without their encouragement, support, patience, love, and guidance, this would never have happened. Thank you for your support in the completion of this degree and for teaching important life skills that brought me here.

This research was supported by the Naval Surface Warfare Center Dahlgren Division. The research was conducted in the Human Systems Integration (HSI) department in W62. The funding was provided through the Naval Innovation Science and Engineering Program (NISE), Section 219.

Abstract

This study investigated the utility and efficacy of using eye tracking technology as a method for selecting control of a camera within a multiple display configuration. A task analysis with a Keystroke-Level-Model (KLM) was conducted to acquire an estimated time for switching between cameras. KLM estimates suggest that response times are faster using an eye tracker than manual control – indicating a time savings. To confirm these estimates, and test other hypotheses a 2 × 2 within-subjects factorial design was used to examine the effects of Control (Using an eye tracker, or manual) under different Task Loads (Low, High). Dependent variables included objective performance (accuracy and response times during an identification task) and subjective workload measured by the NASA-TLX. The eye tracker under the specific experimental conditions was not significantly better or worse, however, further research may support that the use of the eye tracker could surpass the use of manual method in terms of operator performance given the time saving data from our initial task analysis using a Keystroke Level Model (KLM). Overall, this study provided great insight into using an eye tracker in a multiple display monitoring system.

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Introduction

Security operators are increasingly responsible for monitoring multiple screen feeds from numerous devices and may be required to shift control quickly among these devices when confronted with complex, asymmetric, threat situations under time pressures. This switching is done manually, which can take seconds; however, a threat event can occur quickly, leaving the operator with only a brief time window to respond.

Eye tracking technology could replace or supplement manual input when switching between multiple devices. Some benefits to using eye tracking technology are that it gives the operator freedom to switch control very quickly by using gaze; it frees up the operator's hands for other tasks, and may lower their workload. Research with eye tracking technology is well established among areas like helping the disabled, learning, web-design, and to provide knowledge on mental models and cognitive processes users go through when viewing a monitor. The purpose of this study is to investigate the effect of using eye tracking as an input method for switching/activating camera selection within a multi-display security operation scenario. In the following sections, a thorough review on eye tracking technology and its application is given in detail. The rationale and objective for this study is presented along with the hypotheses followed by the method and experimental design, and the results, discussion and conclusions are given in the end.

Literature Review

Eye tracking technology.

There are many different types of eye trackers. The one most commonly used today is a non contact method where light is reflected from the eye and sensed by the eye tracker or other optical sensor. By using the pupil-center/corneal-reflection method, the eye tracker determines where a user is looking. The optical methods for eye tracking are used frequently because they are non-invasive and inexpensive (Crane, & Steele, 1985). Eye trackers calibrate to the user by identifying different points on the screen that the user is looking at and then allows the user to use their gaze to perform actions that were once done manually. This project uses the eye tracker as an input method that will replace the need to type button presses on a keyboard. LC Technologies, Inc. provided the eye tracker used in this study. The eye tracker uses the participant's gaze to give control over camera pan-tilt zoon camera that the participant is viewing. Appropriate interaction techniques that incorporate eye movements into the user-computer dialogue in a convenient and natural way is a useful input medium achieved by measuring the visual line of gaze. Figure 1 shows a non invasive eye tracker that is fixed to the bottom of a computer monitor and uses infrared light reflected off the cornea to collect gaze movement and determine where on the monitor the user is looking. In Figure 2, the woman and young boy are wearing a head-mounted external eye tracker that collects information on where in the environment they are looking.

Figure 1: An example of a fixed eye tracking system mounted to a computer monitor (LC Technologies, 2009).

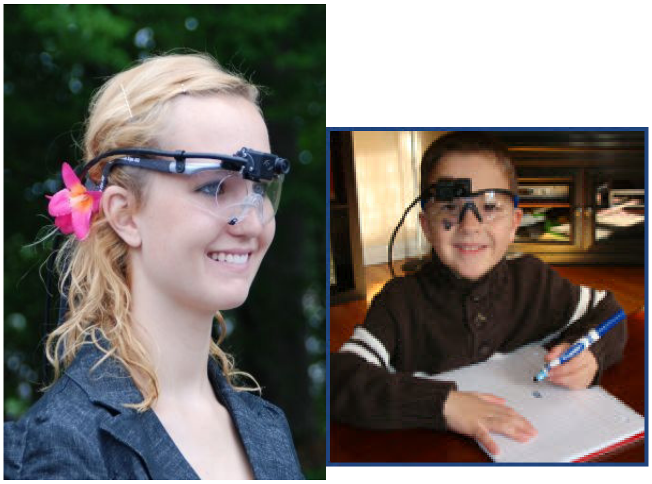


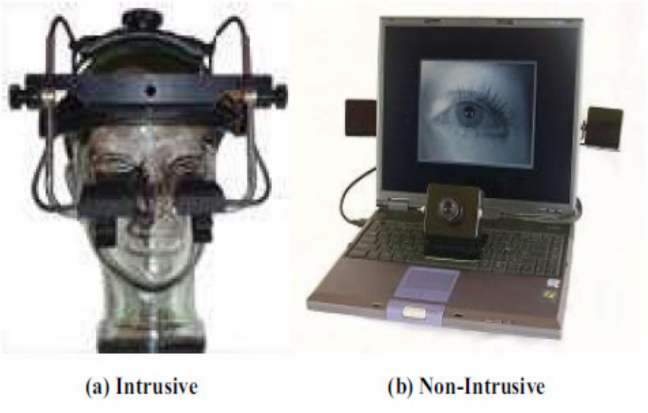
Figure 2: Examples of an external head-mounted eye tracker (ASL, 2011).

The early eye gaze trackers (EGTs) were developed for scientific exploration in the areas of ophthalmology, neurology, psychology, and other related areas to study oculomotor characteristics and abnormalities, and their relation to cognition and mental states (Morimoto & Mimica, 2005). Other uses for eye tracking technology can be found in gaze interaction with computers as a means for people with disabilities such as cerebral palsy or paralysis. Eye tracking plays a big part in Human Computer Interaction (HCI) by enhancing the design quality and providing a more user-friendly way to interact with a system. In addition, eye tracking technology can be used in aspects like fatigue driving monitoring, military applications, cognitive science, health care, advertising, and many other fields (Tunhua, Baogang, Changle, Shaozi, & Kunhui, 2010). LC Technologies creates eye tracking technology to be used in various fields like robotics for remote vision control, communication research and media psychology, science and education, human factors/industrial design, vision research, and more (LC Technologies, 2009). Eye tracking technology gives these users the ability to type and interact with a computer by using where they are looking instead of traditional input methods like a keyboard or a mouse (Aoki, Hensen, & Itoh, 2007).

Many current eye tracking systems rely heavily on still heads and clear eye pictures from the optical sensor that sends light to the eye and measures gaze by the reflection. This can present limitations because of the sensitivity and the need for a participant to remain still or to wear a device that maintains a constant separation between the camera sensor and the eye. For example, Andrew Gee and Roberto Cipolla from the University of Cambridge created a more flexible vision-based approach that can estimate the direction of gaze from a single, monocular view of the face. They explained that one can break down the two major components to gaze direction: the orientation of the head, and the orientation of the eyes within their sockets. There was a need for a more passive, vision-based approach that could tolerate large head movements and follow a person’s gaze at a distance using little or no calibration, and that could function in the same manner humans do naturally (Gee & Cipolla, 1994). This technique makes assumptions about facial structure and produces an estimate of head orientation. By using these assumptions and the facial tracking, their system can produce a real-time gaze estimate (Gee & Cipolla, 1994).

Eye tracking technology and human computer interaction.

Eye- movement tracking has been increasingly employed to study usability issues in the field of Human Computer Interaction (HCI) because it provides researchers with visual and display-based information processing (Poole & Ball, 2004). Eye tracking technology was used as a viable input method as well as a performance measurement tool for users when interacting with a computer. This is due to the fact that eye trackers can be calibrated to users very easily and are a nonintrusive alternate to traditional input methods. Figure 3 shows an example of a former more intrusive method, and a current non-intrusive method.


(a) Intrusive

(b) Non-Intrusive

Figure 3: Two eye tracking instruments; intrusive and non-intrusive varieties (Tunhua et al., 2010).

Using an eye tracker as a device for input would allow users to select objects visually present simply by using their gaze. The eye can move very quickly in comparison to other parts of the body. Theoretically, this means that if the operator's eye gaze can be tracked and effectively captured, no other input method can act as quickly (Zhai, Morimoto, & Ihde, 1999). Increasing the speed of user input to the computer is a major challenge in HCI research. Human observers presumably pay attention to objects they wish to select and since the observer pays attention to objects by fixating on them, it seems that the most natural input device from the user's point of view should be based on a device that can detect the user's line of gaze (Ware & Mikaelian, 1987). There is a strong tendency to look where one thinks, and patterns of eye movements and eye fixations can be indicators of the distribution of visual attention as well as indicators of cognitive processes (Bolt, 1981).

Eye tracking as a computer input has been investigated and considered an alternative or potentially superior pointing method for computer input (Zhai et al., 1999). In a study at IBM Almaden Research Center, eye tracking technology was explored as an input using a Manual and Gaze Input Cascaded (MAGIC) pointing method. The MAGIC pointing technique offered advantages such as reduced physical effort and fatigue on operators compared to traditional manual pointing, greater accuracy and naturalness than traditional gaze pointing, and possibly faster speed than manual pointing. The advantage is more significant for situations that prohibit the use of hands, for instance, when an operator is continuously occupied with other tasks. An interface that incorporates eye gaze as a pointing device would also help reduce fatigue and potential injury caused by repetitive movements that come along with operating a keyboard and pointing devices. Repetitive stress injury affects an increasing number of computer users. Using gaze movement to reduce the amount of stress to the hands can be very beneficial (Zhai et al., 1999). The experiment was designed where pointing and selection remained primarily a manual control task, but it was aided by gaze tracking. The goal was to use gaze to redefine the "home" position of the pointing cursor to be in the vicinity of the target, which was presumably what the user was viewing. The experiment design was a within-subject design utilizing nine participants where each participant performed the same task with three techniques: standard pure manual pointing with no gaze; the conservative MAGIC method, and the liberal MAGIC method. The hypothesis was that given the small scale of the experiment, the statistical power of the results would be on the weaker side. They found that participant completion time significantly varied among the techniques and that MAGIC pointing approaches do work. All participants were able to operate both techniques with minimal instruction. It was discovered that by the end of the experiment, participants that had less than 10 minutes of exposure to each technique were able to perform at a speed similar to their manual control skills. The liberal MAGIC pointing technique performed slightly faster than the conservative technique which performed faster than the manual pointing.

In a study conducted by Aoki and others at the Department of Industrial Engineering and Management in the Tokyo Institute of Technology, Japan, investigated the learning processes that participants undertake when using gaze technology as a computer input for the first time. The motivation for this study was to obtain useful insight into better design of gaze interaction interfaces, as well as to give advice on how to master gaze communication. The experiment design was a 7-day experiment using 8 Japanese students. The performance data collected fit a general learning model based on the power law of practice. This study focused on using typing tasks by gaze. The students had to type 110 sentences by gaze. The power law of practice was the mathematical model on learning. The experiment revealed that inefficient eye movements were dramatically reduced after only 15-25 sentences of typing, which is equal to approximately 3-4 hours of manual practice (Aoki et al., 2007).

HCI has become an important part of our daily lives. The movement of user’s eyes can provide a convenient, natural and high-bandwidth source of input (Kim & Ramakrishna, 1999). Non-intrusive eye gaze tracking that allows slight head movement was addressed in a study by Kim and Ramakrishna at the Kwangju Institute of Science and Technology, Korea, on computer vision and image processing techniques for measuring eye-gaze. Specifically, they discussed tracking eye movement, estimating gaze point, and provided experimental results from several experiments they performed pertaining to eye movement tracking. Results showed the practical feasibility of non-intrusive vision-based eye-gaze tracking methods involving eye movement tracking and gaze estimation by using them as one type of computer interface (and a substitute for a pointing device) (Kim & Ramakrishna, 1999).

Researchers at Xiamen University of China developed a real-time non-intrusive eye tracking method for HCI. They established a model to describe relative movement of pupil to nostrils. Results showed the effectiveness and efficiency of their method for tracking (Tunhua et al., 2010). Eye tracking technology has been used widely in HCI and is quickly expanding to other fields.

Safety and security operations.

Another field eye tracking can be applied is in security operations, particularly where operators must watch multiple monitors and respond quickly. The design of security applications needs to consider more than technical elements, but factor the human in as well. Almost all security systems involve human users in addition to technology; therefore, security should be considered and designed as a socio-technical work system (Brostoff & Sasse, 2002).

In a military investigation on an attack by American helicopters in February of 2010 that left 23 Afghan civilians dead, they found that the operator of an unmanned aerial vehicle (UAV) had failed to pass along crucial information. The suspected underlying cause for that mistake, according to Air Force and Army officials, was information overload. Operators monitor live video feeds while participating in dozens of instant-message and radio exchanges with intelligence analysts and troops on the ground. Operators may spend up to 12 hours on a shift monitoring multiple screens (see Figure 4 & 5). At George Mason University in Virginia, researchers measured the brain waves of study subjects they ran through a simulation of the work done in this type of scenario.

Figure 4: A military operator monitoring multiple screens (Shanker & Richtel, 2011).

The participants saw a video feed from one drone and the locations of others, along with instructions on where to direct them. The participants wore a cap on their head with electrodes that measured brain waves. As the number of drones and the pace of instructions increased, the brain waves showed sharp spikes in electrical activity (Shanker & Richtel, 2011). The type of multitasking associated with a position like this leaves the operator vulnerable to errors as a result of increased workload. Providing a way to decrease workload during these long high stress 12-hour shifts may prevent controller errors from happening. Figure 4 shows a typical control room with many screens and areas that operators would be working in. Implementing an eye tracker may aid in this information overload and help decrease errors made due to vulnerability.

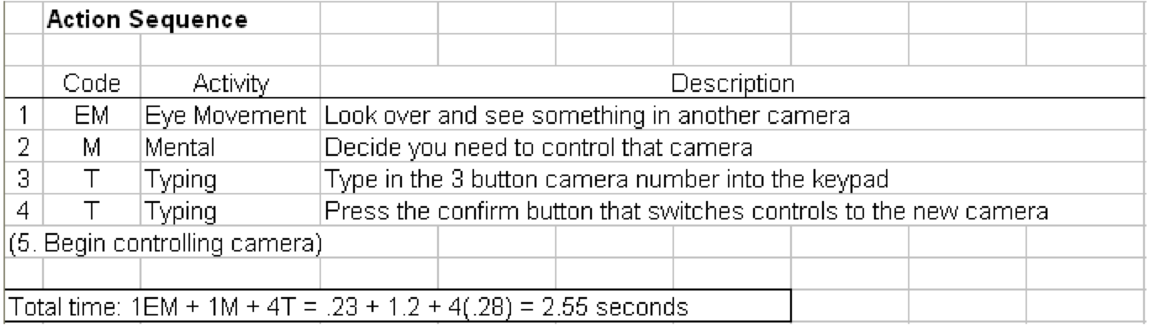
Figure 5: A room of control operators monitoring multiple screens of video feed (Shanker & Richtel, 2011).

Task analysis and KLM study

Using a Goals Operators Methods & Selection rules (GOMS) method, a comparison was done using a Keystroke-Level Model (KLM) to get acquire a baseline assessment of the time it takes to switch between multiple screens in security operations. GOMS has four variants: Keystroke-Level Model (KLM); the original formulation of GOMS created by Card, Moran, and Newell; a more rigorous version called NGOMSL; and a version that models overlapping human activities called CPM-GOMS (John & Kieras, 1996). The KLM is the simplest GOMS technique and its purpose is to estimate execution time for a task. Given the task and the method, the KLM uses pre-established keystroke-level primitive operators to predict the time to execute a task (John & Kieras, 1996).

A KLM was conducted for a security monitoring system developed in 2006 for Sears store security guards. The actions involved required mental decision making, flipping switches, and entering codes before the user gains control of a particular camera. With the eye tracker method of security monitoring, the user would simply look at another monitoring screen, and then gain control of that corresponding camera. KLMs for each of the methods were conducted to show the difference in the time that it takes a user to gain control of a camera. The procedure for the Sears system involved a user viewing many different monitors that each corresponded with a camera in that area of the store. To control those cameras, the user would flip on a switch on the control box and then using a handheld remote, type in the 3 digit code followed by a confirm button for the camera they would like to control. The KLM action sequence for the Sears system is shown in Table 1. The KLM technique was used to estimate execution time for a task by summing pre-established keystroke-level primitive operators. Two different manual methods were used: keyboard and mouse. In addition to the manual methods, a proposed eye-tracking method was modeled. Results from the KLM indicated timing differences between the methods. Specifically, the proposed eye-tracking method was the fastest (shortest response time), then keyboard, and finally the mouse (longest response time). Based on the initial KLM estimation, this experiment was designed to verify the estimates and show a proof of concept for using the eye tracker in this manner. The experimental study will leverage eye-tracking technology and use gaze-based information rather than manual input for switching between cameras.

Table 1.
KLM action sequence of a Sears security guard procedure.



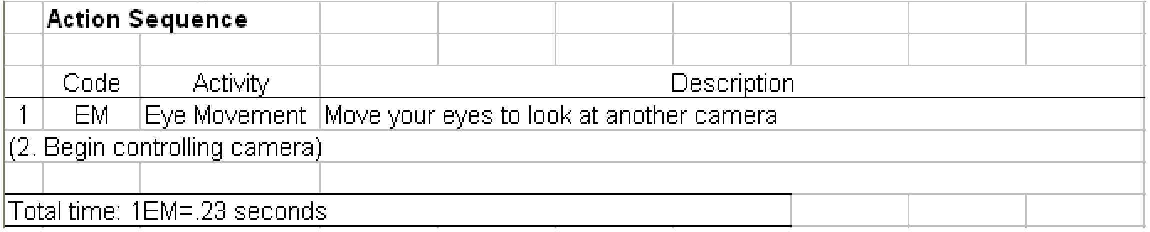
Action Sequence

	Code	Activity	Description
1	EM	Eye Movement	Look over and see something in another camera
2	M	Mental	Decide you need to control that camera
3	T	Typing	Type in the 3 button camera number into the keypad
4	T	Typing	Press the confirm button that switches controls to the new camera
(5. Begin controlling camera)			

Total time: 1EM + 1M + 4T = .23 + 1.2 + 4(.28) = 2.55 seconds

The procedure for using an eye tracking system would alleviate all of the keystrokes needed in the original Sears procedure for gaining and switching control among different cameras by allowing the user to simply look between the camera monitors and gain control over the cameras. The KLM action sequence for using the new eye tracking method is shown in Table 2.

Table 2.
KLM action sequence for using an eye tracker to switch between screens.



Action Sequence

	Code	Activity	Description
1	EM	Eye Movement	Move your eyes to look at another camera
(2. Begin controlling camera)			

Total time: 1EM=.23 seconds

The KLM provided estimates that using an eye tracker to replace the button presses in a monitoring system will save time. The goal of this study was to use the original estimates from the KLM to discover if the time saved would have an impact on accuracy, response time, and perceived workload.

Objective.

The goal of this study is to leverage eye tracking technology and use eye gaze information as an input method for switching between multiple monitoring devices, in order to reduce response time and operator workload, more specifically, to investigate the feasibility and effectiveness of using eye tracking technology in a monitoring task scenario. More specifically, there are four major aims for this study;

- Explore the benefits of using eye tracking as an input method to replace manual input when switching control of monitoring devices.
- Determine the difference between the time it takes to respond to a threat using an eye tracking input method and using a manual input method.
- Determine the perceived workload in users when using an eye tracking input method and using a manual input method.
- Obtain useful insight into using gaze communication interfaces that can compliment or replace current methods of input.

Statement of hypotheses.

Hypothesis 1: Interaction Effect: There will be an effect of response time between control type and task load. Specifically, there will be lower response times overall when using the eye tracker, and this will be evident mainly at a high task load level

Hypothesis 2: Interaction Effect: There will be an effect of accuracy between control type and task load. Specifically, accuracy will increase when using the eye tracker, and this will be evident mainly at a high task load level.

Hypothesis 3: Interaction Effect: There will be an effect of workload between control type and task load. Specifically, workload will decrease when using the eye tracker, and this will be evident mainly at a high task load level.

Hypothesis 4: Task Load: Task load will have a significant effect on response time. Specifically, it was predicted that response times will increase as the task load increased.

Hypothesis 5: Task Load: Task load will have a significant effect on accuracy. Specifically, it is predicted that the accuracy would decrease as the task load increased.

Hypothesis 6: Task Load: Task load will have a significant effect on the perceived workload. Specifically, participants would express higher workload as the task load increased

Hypothesis 7: Control Type: Control Type will have a significant effect on response time. Specifically, it was predicted that response times would decrease when using the eye tracker.

Hypothesis 8: Control Type: Control Type will have a significant effect on accuracy. Specifically, it is predicted that the accuracy would increase when using the eye tracker

Hypothesis 9: Control Type: Control Type will have a significant effect on the perceived workload. Specifically, participants would express lower workload when using the eye tracker

Method

Participants

A call for participation was sent to civilian employees, and 16 volunteers signed up to participate (10 women, 6 men, $M_{\text{age}} = 33$ years, age range: 20-49 years) through a department-wide email at the Naval Surface Warfare Center- Dahlgren Division (NSWCDD). There were 6 additional participants, recruited in the same way as described above, which provided pilot rating values: 3 women, and 3 men. All participants were allowed to wear corrective eyewear if necessary, resulting in normal or corrected to normal vision for all participants.

Apparatus

This study took place on Dahlgren Naval Support Facility in the Human Performance Lab run by the Human Systems Integration Branch. The equipment used in this study was a desktop machine with a mounted eye tracker (as seen in Figure 6), four pan-tilt zoom networked cameras, a keyboard that allowed participants to control the cameras, a total of 8 display screens that were used to present targets in the workspaces, and office furniture used to set up the workspaces that each camera viewed.

Figure 6: The computer and eye tracker from LC Technologies used in this experiment.

The eye tracker in the HPL laboratory functions by using light that shines through the pupil and reflects off of the retina, causing the pupil to appear white. The bright pupil effect enhances the camera's image of the pupil in order for the system to locate the center (See figure 7). The gazepoint is calculated based on the relative positions of the pupil center and corneal reflection in the image of the eye. The accuracy of the EyeGaze Edge predicts gazepoint with an average accuracy of a quarter inch or better.

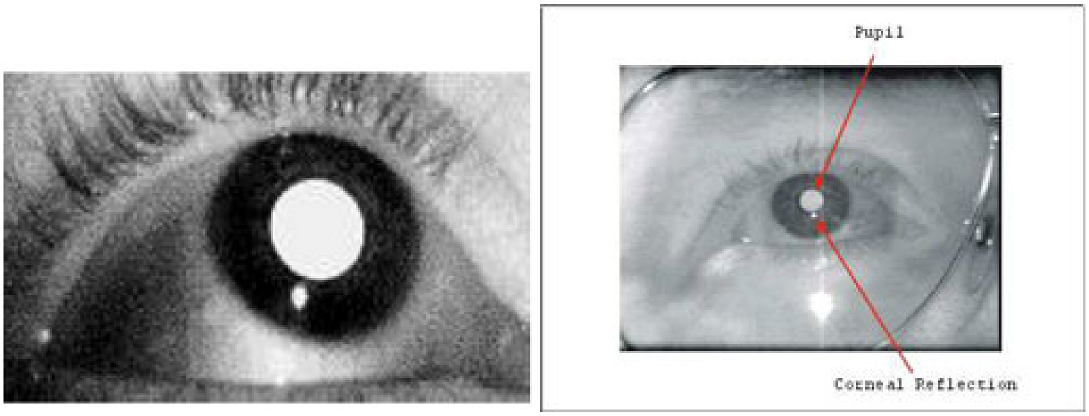


Figure 7: A replicated image of the eye tracker locating the pupil of an eye ball by reflecting light off the cornea (LC Technologies, 2009).

The EyeGaze systems allow users to perform a broad variety of functions including: generating speech, environmental control (lights and appliances), typing, and running both mouse- and keyboard-controlled applications on the *Edge* screen. Additionally, users can use their *Edge* as a keyboard and mouse interface for their own computer. Selections are made by looking at boxes or "keys" displayed on the EyeGaze System's screen (LC Technologies, 2009).

Procedure

Participants were recruited and each given a block of one hour. Within that hour, they had an introduction to the study, read the literature and signed the informed consent form, calibrated the eye tracker, participated in a training session where they got familiar with controlling the cameras, and then they went through the four conditions of the experiment.

Eye tracker calibration was done in approximately 15 seconds. The system prompted each user to follow small targets across the computer monitor in order to capture an accurate reading of the user's line of gaze. Interacting with the eye tracker was nonintrusive, and the eye tracker did not physically come in contact with the user.

After calibration and instruction on using the eye tracker, each participant was exposed to the experimental conditions. Each of the participants was acting as a security operator. As security operators they were responsible for monitoring four workspaces that had been set up to look like offices. Each office had one actor in it. The actors were present in the workspaces to cue the participant that targets and distracters would be displayed on the computer monitors. Targets and distracters were displayed using two letters; a capital 'D' and a capital 'G.' These letters were chosen because it is easier to see than selecting other similarly featured letters like 'T' and 'L.' It was also more beneficial to select letters that are close to each other on a standard keyboard. The 'D' and 'G' share a lot of similar features (Duncan & Humphreys, 1989), which requires the participant to read and correctly identify the letter that they see. To see an example of a participant viewing the display, see below in figure 8.

Figure 8. A participant watching the four workspaces and looking for targets and distractors on the display screens within each space.

Actors were used in this study to provide a visual cue in a workspace where the next event was going to take place. Events were displayed one at a time, on both computer monitors in each workspace. Events were initialized when the actor moved from one side of the workspace, paused at each of the computer monitors, and ended at the opposite side of their workspace. Participants were able to scan from left to right in each office scene and switched control from camera to camera by either a manual means or by using the eye tracker, depending on what condition they were in, and in all four conditions they recorded what they saw by pressing the ‘D’ or ‘G’ key on the keyboard.

After participants completed each condition, they rated their perceived workload using the NASA-TLX index. Hart and Staveland’s NASA Task Load Index (TLX) (Hart & Staveland,

1988) method assesses workload on six 7-point scales. After all of the conditions were completed, participants filled out a weighting form so that each of the subscales could be rated and then analyzed after data collection. After the weighting form, the participants filled out a short questionnaire that was created to gain more insight subjectively to what the participant liked and thought about the conditions. The procedure can be seen below in Table 4.

Table 3.
The experimental procedure.

Step	
1	Sign Informed Consent
2	Experimenter explained the task
3	Calibrated the eye tracker
4	Went through practice with the controls on the keyboard
5	Performed their first condition
6	Filled out the NASA-TLX questionnaire after the condition
7	Repeat until the fourth condition is over
8	After last NASA-TLX questionnaire, participants were given a weighting form to rate the subscales of the NASA-TLX
9	Participants filled out a short questionnaire about the experiment overall

Independent Variables

There were two within-subjects independent variables used in this study. The first variable was the type of input method participants used during the scenarios. There were two different types of inputs methods for this study. The manual input method was the control condition and the eye tracker input (automated input) method was the experimental condition. The second variable was the varying levels of task load. There were two levels of task load; low, and high. In the low task load there were 32 events that occurred during the trial, in the high task load there were 46 events.

Dependent Variables

There were three dependent variables in this study. The first was the detection response time (RT). The second was accuracy, to be measured by taking the percent of correctly identified targets. RT and accuracy were collected by the software by capturing the button presses from the keyboard. The times were rounded up to the second to account for the human variability that there was when beginning each condition. The conditions were started by the experimenter counting down and on ‘start’ each actor began the PowerPoint presentations that the events were on and the experimenter pressed the start key on the participant’s keyboard. The third dependent variable was perceived workload which was measured by using the NASA-TLX.

Experimental Design

The experiment utilized a 2 (Control: Manual, Eye Tracker) x 2 (Task load: Low, High) within-subjects, factorial design. The factorial design consisted of two factors each with two levels and the experiment took on all possible combinations of these levels. Control refers to the method used to activate a camera: manual (via a keyboard) or automated (via eye tracker). Task load refers to the number of target and distracter events within the security scenarios. The control and task load conditions can be seen below in Table 3. Condition order across participants was determined by using a Latin Square to ensure that each condition was counterbalanced.

Table 4.
The Control Type/task load break down.

Control/Task Load	***Low***	***High***
Manual	32	46
Eye Tracker	32	46

The targets and distracters were set up by a script for each condition and the time between each event happened was random. Each time a target or distracter was displayed, it stayed on the computer monitor for 10 seconds and then disappeared. The participant was given the time constraint to be representative of a real life threat situation where they would not have unlimited time to respond. The events occurred in pairs of two because there were two monitors in each workspace. An actor moved from one side of their workspace to the other, stopping briefly at each of the two computer monitors as they displayed a target or a distracter. After the last one was displayed, the actor waited just outside of that side of the workspace and watched the clock until they made their next move back to the other side. See below in Figure 9.

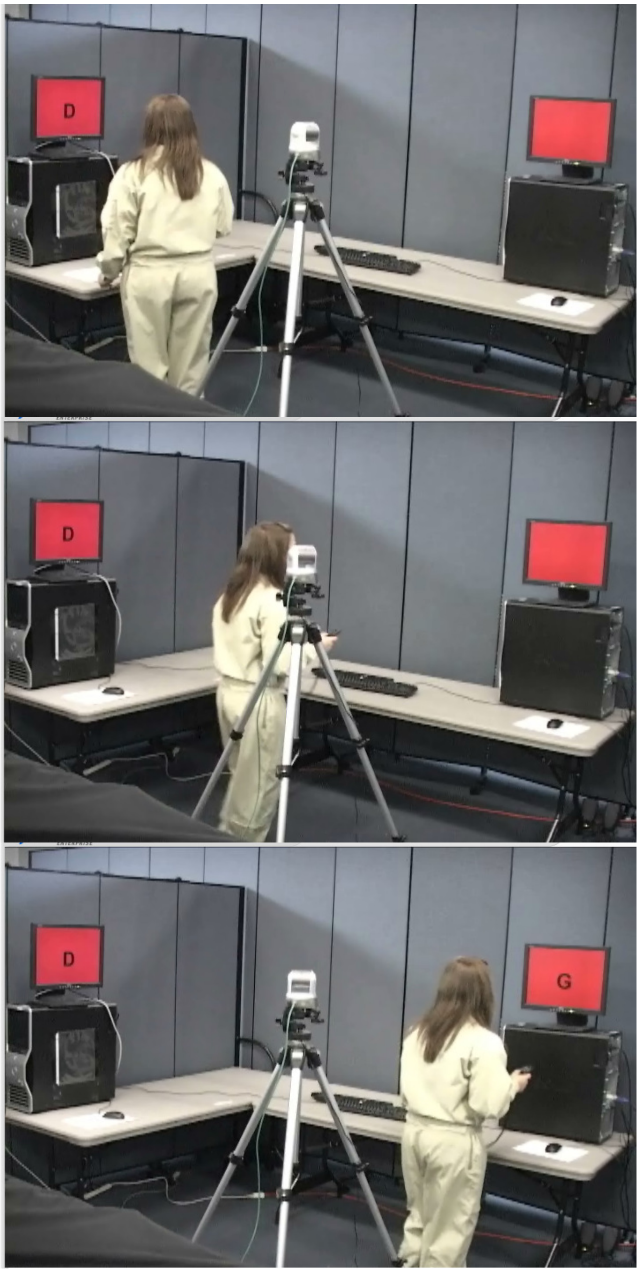


Figure 9. An actor during one event, stopping first at the first monitor, then stopping again at the second monitor, then exiting the space and waiting for the next event to occur.

Results

This experiment examined the effects that task load, and control type had on participants' accuracy in an identification task, response times, as well as their perceived workload. An analysis of variance (ANOVA) on each of the three dependent variables (accuracy, response times, and the perceived workload data) was conducted, with alpha level set at 5%.

Accuracy

Results did not show any significant main effects or interaction for accuracy. The means and standard deviation for these data can be seen below in Table 5. Table 6 shows the effects and significance for accuracy, and Table 7 shows the standard error and upper and lower bounds with a 95% confidence interval. There was no significant difference between using the eye tracker and using the manual method for control, indicating that the use of the eye tracker may be a viable replacement option. There was no significant effect of task load on accuracy, *F*(1, 15)=.027, *p*=.871. There was no significant effect of control type on accuracy, *F*(1, 15)=.156, *p*=.698. There was also no significant interaction between task load on accuracy, *F*(1, 15)=.941, *p*=.347.

Table 5

The means and standard deviation for accuracy.

Accuracy			
Condition Type	**Mean**	**Standard Deviation**	***N***
High Task Load, Eye Tracker	94.4375	8.7481	16
High Task Load, Manual	95.6875	7.49861	16
Low Task Load, Eye Tracker	96.9375	7.2431	16
Low Task Load, Manual	94.0625	13.0408	16

Table 6

The effects for accuracy.

Accuracy					
Factor	***df***	**Mean Square**	***F***	**Significance**	**Partial Eta Squared**
Task Load	1	3.063	0.027	0.871	0.002
Control Type	1	10.563	0.156	0.698	0.01
Task Load x Control Type	1	68.063	0.941	0.347	0.059

Table 7

Standard error and upper/lower bounds for accuracy.

	Grand Mean	**Task Load**		**Control Type**		**Task Load x Control Type**			
		High	Low	Eye	Manual	High Eye	High Manual	Low Eye	Low Manual
Std Error	1.267	1.88	1.788	1.402	1.833	2.187	1.875	1.811	3.26
Lower Bound	92.58	91.056	91.69	92.7	90.967	89.776	91.692	93.078	87.114
Upper Bound	97.98	99.069	99.31	98.675	98.783	99.099	99.683	100.797	101.011

Response Time

Results did not show any significant main effects or interaction for response time. The descriptive statistics and effects are reported below (Tables 8-10). There was no effect for response time on control type with $F(1,15)= 2.547$ $p= .131$, which indicates that the combined response times for each of the control types were not statistically different. There was no significant interaction between task load and control type with $F(1,15)= 1.429$ $p= .251$. Although there were no significant interactions seen the predicted direction for the effects were seen: response times longer with high than low task load conditions, and longer with manual than automated control.

Table 8

The means and standard deviation for response times.

Response Times			
Condition Type	**Mean**	**Standard Deviation**	***N***
High Task Load, Eye Tracker	4.8125	1.37689	16
High Task Load, Manual	4.9375	1.43614	16
Low Task Load, Eye Tracker	4.125	1.14746	16
Low Task Load, Manual	4.75	1.12546	16

Table 9

The effects for response times.

Response Times					
Factor	***df***	**Mean Square**	***F***	**Significance**	**Partial Eta Squared**
Task Load	1	3.063	3.419	0.084	0.186
Control Type	1	2.25	2.547	0.131	0.145
Task Load x Control Type	1	1	1.429	0.251	0.087

Table 10

Standard error and upper/lower bounds for response times.

	Grand Mean	Task Load		Control Type		Task Load x Control Type			
		High	Low	Eye	Manual	High Eye	High Manual	Low Eye	Low Manual
Std Error	0.252	0.311	0.241	0.268	0.288	0.344	0.359	0.287	0.281
Lower Bound	4.119	4.212	3.924	3.898	4.231	4.079	4.172	3.514	4.15
Upper Bound	5.193	5.538	4.951	5.04	5.457	5.546	5.703	4.736	5.35

Perceived Workload

Results did not show any significant main effects or interactions for the NASA-TLX data. There was no main effect for task load, with $F(1,15)= 1.858$ and $p= .193$, nor was there a main effect for control type with $F(1,15)= 3.006$ and $p= .103$. The results do not show an interaction between the condition type or the task loads, *F*(1,15)= .227 *p*= .640. The descriptive statistics and effects are reported below (Tables 11-13).

Since no significance was found when using the aggregate scores of the NASA-TLX based on pair wise comparisons, further analysis was required on the six subscales separately. An ANOVA was run on each of the subscales. The subscales are listed in Table 14 with the significance. For Effort, participants rated that more effort was needed during the manual conditions than in the eye tracker conditions, with a p value of .058. For Performance, participants rated that they felt their performance was higher during the manual conditions than during the eye tracker, *p*=.012, this could be for a number of reasons; they felt that they could rely on the button press because it was more familiar, or they had bias towards using technology and it being unreliable. For frustration, participants rated that they were more frustrated during higher task loads, *p*=.002, participants also rated that they were more frustrated during the manual conditions, *p*=.013, probably due to the fact that they felt rushed and had to perform more actions each time there was an event. For temporal demand, the participants rated that they did feel that they were more rushed during higher task loads, *p*=.004, which shows that the task load manipulation was enough to show a difference between low and high. For mental demand, there was a trend towards an effect in task load. Participants rated that the manual conditions were more mentally demanding than physical, but not significantly, *p*=.075. For physical demand, participants rated that there was a significant difference in physical demand between task loads. At a higher task load, they felt more physical demand, *p*=.023, but there was no significant effect between the condition types for physical demand.

Table 11

The means and standard deviation for the NASA-TLX data.

NASA-TLX			
Condition Type	**Mean**	**Standard Deviation**	***N***
High Task Load, Eye Tracker	10.3	2.83742	16
High Task Load, Manual	10.7792	2.68535	16
Low Task Load, Eye Tracker	9.7208	2.7651	16
Low Task Load, Manual	10.4583	2.20986	16

Table 12

The effects for the NASA-TLX data.

NASA-TLX					
Factor	***df***	**Mean Square**	***F***	**Significance**	**Partial Eta Squared**
Task Load	1	3.24	1.858	0.193	0.11
Control Type	1	5.921	3.006	0.103	0.167
Task Load x Control Type	1	0.267	0.227	0.64	0.015

Table 13

Standard error and upper/lower bounds for perceived workload.

	Grand Mean	Task Load		Control Type		Task Load x Control Type			
		High	Low	Eye	Manual	High Eye	High Manual	Low Eye	Low Manual
Std Error	0.598	0.668	0.569	0.652	0.594	0.709	0.671	0.691	0.552
Lower Bound	9.04	9.115	8.877	8.621	9.353	8.788	9.348	8.247	9.281
Upper Bound	11.59	11.964	11.302	11.4	11.884	11.812	12.21	11.194	11.636

Table 14
Subscale ANOVA descriptive information.

	Effort	Performance	Frustration	Temporal	Mental	Physical
Control Type	0.058	0.012	0.002	-	-	-
Task Load	-	-	0.013	0.004	0.075	0.023

Discussion

Under these specific experimental conditions, the eye tracker did not outperform the manual in terms of accuracy, response time, or perceived workload. Although, statistical significance was not obtained, the directions of the findings are aligned with the initial predictions, and the time saving estimates from the KLM. There are several reasons for why statistical significance was not found.

Accuracy

The control type and task load did not have a significant effect on participant's accuracy. The accuracy was greater than 90% for correctly identifying targets and distracters. The high-level of accuracy suggests a ceiling effect, and indicates that participants were able to correctly respond to target and distracter events using both eye-tracking and manual conditions under high and low task loads. It might be possible that accuracy would decrease as the number of surveillance cameras increased, or if multiple events begin to occur simultaneously. The purpose of this preliminary study, however, was to examine the effect of control type on response rate and verify the initial KLM estimates.

Response Time

The KLM estimated 2 sec difference in response time between eye-tracking and manual control. Contrary to the KLM estimates, and our predictions, response times between automated and manual were not statistically different. However, the general pattern/trend of the predictions, and the partial significant of the findings were obtained. Response times were faster during low than high task load conditions; and also faster with eye-tracking than manual control. This may have happened due to the eye tracker software system itself. Although this guess is not backed up by the objective data, rounding to the nearest second might have been an issue and milliseconds may have mattered in this instance. The use of the camera was not in the KLM prediction, but in future studies, other eye-tracking metrics should be considered to better understand time differences before the eye tracker camera is moved.

NASA-TLX

A pair wise weighting form was used to find weights for each of the subscales that the NASA-TLX measures. After finding the aggregate score for overall workload in each of the conditions, the data showed no significant differences or interactions between the task load and the control type. It was anticipated that the NASA-TLX workload assessment would show significant lower perceived workload overall in automated conditions. A short questionnaire followed the NASA-TLX assessment where participants were asked to rank the condition with the lowest workload condition to the highest workload condition, and also stated what their preferred condition was. Overall participants seemed to agree that they found the manual conditions to be more difficult because there were more buttons to press. However, they preferred the manual conditions if the eye tracker had been unresponsive or difficult to use during their automated conditions.

Frustration levels did not come out significantly different in the self reporting, but during data collection it was apparent that many struggled with using an eye tracker, especially if it was their first time interacting with one. Even when the eye tracker was calibrated, it was inconsistent at times and participants would get off task when trying to recover from an eye tracker error. It was clear that even though learning effects were controlled for, there did seem to be a big learning curve for participants with our particular eye tracker and experimental setup.

Limitations

The sensitivity of the eye tracking system utilized in this study caused temporary inconsistencies during the five minute conditions. The eye tracker illuminated the eye with an infrared light and the position of the eye was then gathered from looking at the pupil and the reflection off the retina. The system was very sensitive to head movements if the eye was out of the camera's range or if the camera was not focused on the eye. Using a less sensitive eye tracking device could mitigate the sensitivity to head movements or distance, however, the use of different technology would bring about other issues; there will always be a trade off with sensitivity and consistency.

There are many limitations with self reporting. Drawing conclusions based on self reported data is difficult because each participant rated workload based on their own thresholds of workload. Some problems with the NASA-TLX are the context effects, range or anchor effects, and issues with using or not using a weighting process (Hart, 2006). The weighting scheme was introduced to take individual differences of the subscales into account when computing an overall workload score. A weighting scheme was used for this study, but individual analysis was done on the subscales when significance was not found with that overall score. This index uses one question for each of the subscales, which is great for how long it takes to administer, but poor because it may not provide a reliable rating of that specific scale. For instance, one question on frustration will be less reliable than multiple questions on various aspects of frustration and how it is impacting workload. Some ways that other researchers have mitigated these problems was to add more subscales, or delete or redefine existing subscales to improve the relevance to the target or task. Taking this approach may increase the fit; however, it may compromise the validity, sensitivity, and reliability of the index (Hart, 2006).

Practical Implications

This study showed that implementing an eye tracker into a monitoring task when switching control between cameras performs the same compared to a current manual method of switching control in terms of accuracy, response times, and perceived workload in an experimental scenario. The benefit is that with future research and more understanding, this method may surpass the manual method. A situation in which an operator is required to both monitor and control multiple devices could potentially benefit by this research. For example, in the case of security operations where an operator must monitor UAVs while also multi-tasking, the operator is left vulnerable to errors as their pace increased and they became overloaded with information. Implementing an eye tracker may reduce workload, aid with the information overload, and decrease errors made to vulnerability. Some applications for this technology solution can also be used in the Ground-Based Operational Surveillance System, a tower-based elevated sensor system used to enhance the ability to detect hostile troop movement in Iraq; The Department of Homeland Security's "virtual-fence," a series of networked microwave towers that will hold sensors, cameras and communications equipment; helping agents monitor the border to detect movement and keep out illegal immigrants and drug smugglers; The Shipboard Protection System Program which uses organic tools to rapidly assess asymmetric threats and defend against terrorist attacks like the one that severely damaged the USS Cole in 2000; and Dahlgren's Virtual Perimeter Monitoring System, used to assist in the detection of physical intrusions, chemical and radiological attacks, and other threats to Navy personnel and bases.

Recommendations for Future Research

Using information from this study on the practicality of using an eye tracker as a method of input can be used across domains. It is applicable in any situation where an operator must monitor multiple screens and gain control over cameras quickly. This application could be used in environments like ship control bridges, air traffic control rooms, Unmanned Aerial Vehicle (UAV) control rooms, building or base wide security, as well as border security. Reducing operator workload and creating a more efficient transition between controlling cameras would be beneficial in all of those domains.

The first recommendation for future research if using the eye tracker used in this study was the only option would be to determine a new baseline and find out under a simpler task if using the eye tracker would in fact save time compared to using actual buttons to switch control.

The second recommendation would be to remove the human variability associated with having live actors needed for each condition. If the process could be automated, the need for humans, stopwatches, and other sources of potential mistakes would be removed.

More recommendations would include to try a new style of eye tracker to see if the sensitivity and calibration could be a potential source for error or investigating more camera feeds and have the participant responsible for monitoring more than four workspaces. The current system was designed for more cameras to be integrated and would potentially show more time saved if the workload was greater.

The sample size of participants was a convenience sample, and no one was a prior operator; a suggestion for future research would be using real security operators in order to gain better feedback for what it is that operators need.

A preliminary KLM study was conducted, but more interviews on the matter and a full task analysis should be used if operators are going to be studied. The manipulation of high and low task load was sufficient based on the subjective data from participants. Future research including the same type of manipulation of high and low task load scenarios but incorporating different types of targets and distracters may show more about of the best situations for eye tracker utilization.

Conclusion

This study investigated the effects of using an eye tracker as a method to replace manual means of switching control of a camera. The use of eye tracking technology is comparable to using the manual method in terms of accuracy, response times, and workload. This experiment provided great insight into using eye gaze to switch control between cameras in an identification and monitoring task. Specifically, some of the feedback from participants showed that trust in technology may be a big factor in whether or not operators would respond positively or negatively to a new piece of technology like an eye tracker being introduced to their station. In the future, more research is needed to see if implementing this type of technology would in fact reduce the workload on operators, and increase their performance. Data analysis for this experiment included running ANOVAs to find main effects and interactions, and although not all hypotheses were supported with significance, there were clear reasons for why the results turned out the way that they did.

The potential benefits that using an eye tracker in a monitoring scenario would be to aid the operator and decrease workload, to increase situation awareness and accuracy for detecting a threat, to improve the ease of use for a system. From the literature review on eye trackers and human computer interaction, it can be seen that eye tracking as an input device may help reduce the physical effort and fatigue on operators, especially in situations that prohibit the use of hands or where an operator will be preoccupied with another task. The literature also shows that a person’s attention is focused where they are looking and a device that could use that information and an input device that is based on that concept would be preferred. This research was able to serve as a proof of concept for both the software and the application of an eye tracker for this type of scenario. Under these specific conditions, the eye tracker method did not perform significantly better or worse, however, further research may support that the use of the eye tracker could surpass that of the manual method in terms of operator performance given the time saving data from our initial KLM estimates.

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