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Eye-Gaze Tracking based Interaction in India

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Abstract

This paper presents a case study of using eye-gaze tracking based interaction for Indian computer-novice users. Introduction of interactive technologies were not synchronous in developed and developing countries, resulting in India a middle-aged population, who did not 'grow up' with technology and find existing computer interfaces and interaction devices counter-intuitive. We investigated how these users interact with an eye-gaze tracker, which has potential to be more intuitive than a mouse or touchpad. During the study, we designed and validated a new target prediction model and used the model in implementing a design bed. The design bed was used to develop interfaces for common computing tasks like shopping, banking, travelling and so on. Our study found that novice users can undertake pointing and selection tasks significantly faster using the eye-gaze tracker than mouse at a cost of higher but statistically non-significant cognitive load. We also conducted a longitudinal study which found users can reach their optimum speed (about 2 secs per selection) within approximately 20 minutes with less than 5% error rate.

Keywords: Eye gaze tracking, Target prediction, HCI in India, Neural Network

1. Introduction

Research on eye tracking dated back to late 18th century when Louis Émile Javal investigated saccadic movements in a reading task [9]. Edmund Huey pioneered in building the first eye tracker which was a contact lens connected with an aluminium pointer [9]. Present research on developing eye tracker investigates on reducing the cost of existing infra-red based trackers (e.g. Tobii [15] or FaceLab [6] Tracker) as well as increasing their accuracy [5]. In this paper, we investigated a novel application of eye-gaze tracking – using it as an input modality for Indian novice users. Introduction of interactive technologies was not synchronous in developed and developing countries. Information and Communication Technology (ICT) related digital divide has been already investigated in detail. Keniston [10] classified digital divide into four categories comparing the Indian context with USA and summarized ten lessons for successfully disseminating benefit of ICT in India. Smith and Dunckley [14] emphasized the need of correct cultural model to improve interaction experience of users in developing countries. Walton, Marsden and

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Vukovic [18] investigated cultural difference in more detail for South African students and pointed out key differences in interpreting hierarchical structures among native students.

In India, research on human computer interaction made significant contribution on developing multi-lingual systems for Indian languages and voice based interactive systems. Researchers in India already investigated eye-gaze tracking based interfaces for text typing [7, 13] and also investigated eye gaze patterns of elderly people [8] in particular during web searching [4]. However using eye gaze tracker as a primary input device for everyday computing tasks, at least in Indian context, is a novelty. Eye-gaze tracking systems are pretty intuitive to operate and have good potential to be incorporated into mainstream electronic devices. In Indian context, eye-gaze tracking system can even replace or augment the standard computer mouse or a TV remote as we found in our survey [3] that many elderly users did not find the computer mouse intuitive or found it difficult to read labels on a TV remote. The eye-gaze tracking research is advancing rapidly in terms of both reducing price and increasing accuracy of tracking. Indian universities have enough expertise to build customized accurate eye-gaze trackers using infra-red LEDs which can make it affordable to a lot of users. We have developed target prediction model that can help in pointing even using less accurate eye-gaze trackers. However, studies reported in this paper aims to investigate the potential of eye-gaze trackers as an input modality and do not report analysis on eye gaze patterns.

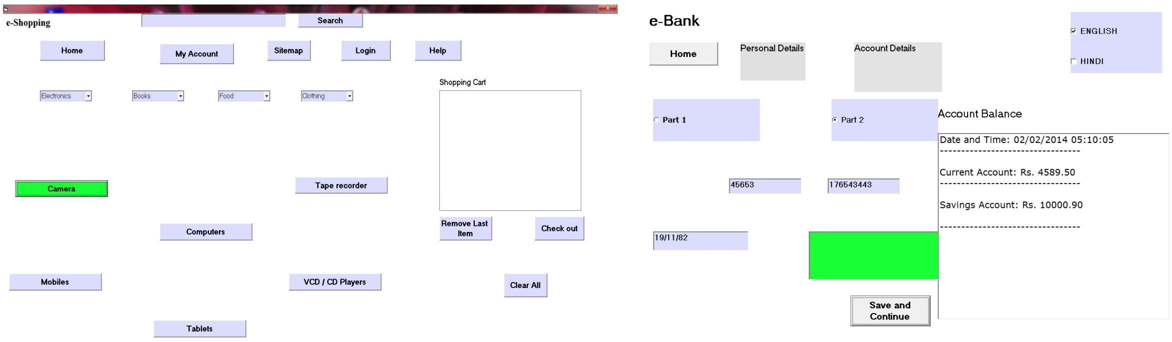
2. BACKGROUND

This research is part of the IUATC (www.iu-atc.com) consortium which is developing next generation wireless network and associated applications for British and Indian rural population. The consortium is developing a range of applications for farmers, rural health centres, schools, universities and so on. One biggest challenge of all these applications is to tackle the huge diversity of population in both India and UK. Our research concerns about personalizing user interfaces and user interaction. We conducted extensive survey in India and Europe and identified key differences in human factors and requirements from HCI points of views [3]. Our study found that there is a significant difference in education levels and cognitive abilities (in terms of scores in cognitive tests) between Indian and EU elderly population, which prompted us to develop more intuitive and intelligent technologies for Indian users. We have also found that EU middle-aged and elderly users have more exposure to computer related technologies than their Indian counterparts. We have developed a user modelling web service to personalize font size, colour contrast, line spacing and other static features of interfaces [1] as well as a target prediction model [2] to personalize dynamic interaction. However personalization of interface and interaction can not alone solve all issues as many Indian users found regular interaction devices like computer mouse or TV remotes hard to use. This paper reports a couple of user trials to evaluate users' performance and preference for eye-gaze tracking based interaction, which is more intuitive than mouse as users can control an electronic interface simply by looking at it. The study is conducted in India instead of a developed country as it is much easier in India to recruit participants who are not expert computer mouse users. Non-expert users reduce the effect of prior experience when we compared eye-gaze tracking based interaction with conventional mouse. A more detailed literature survey on existing eye-gaze tracking system can be found in a separate paper [2] and relevant literature to our studies have been addressed in discussion sections.

3. THE PROPOSED SYSTEM

We have developed a design bed incorporating a target prediction technology [2]. The target prediction technology analyses instantaneous velocity, bearing and acceleration of cursor movement and uses a neural network to predict next intended target. The design bed uses 18 point font size and big buttons to facilitate interaction by people with age-related impairment. The design bed is used to develop interfaces for everyday computing tasks like electronic shopping, banking, travelling and so on (figure 1). Each interface tries to reduce information overload by only providing minimum required details. Users do not need to precisely point on target, the target prediction technology automatically sets focus on a button when a pointer reaches near it. The green buttons in figure 1 depict such predicted targets. However the predicted button is not selected automatically, the user needs to give a second input in terms of a key press, mouse click or blink to make the final selection. A video demonstration of the system can be watched at http://youtu.be/4bx2OWZk_dM

The interfaces were evaluated using the Inclusive User Model of Cambridge University to make sure it is accessible to people with moderate visual and motor impairment. Figure 2 below shows the perception of the eShopping interface for people with age-related blurred vision and red-green colour blindness. It may be noted that the interface remains legible to these users. The blue lines depict possible cursor trace while a user with tremor in hand using a computer mouse. It may be noted that even such a user has little chance to wrongly select a target due to large inter-button spacing.



☑ ENGLISH
☐ HINDI

○ Part 1
● Part 2

45653
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Date and Time: 02/02/2014 05:10:05

Current Account: Rs. 4589.50

Savings Account: Rs. 10000.90
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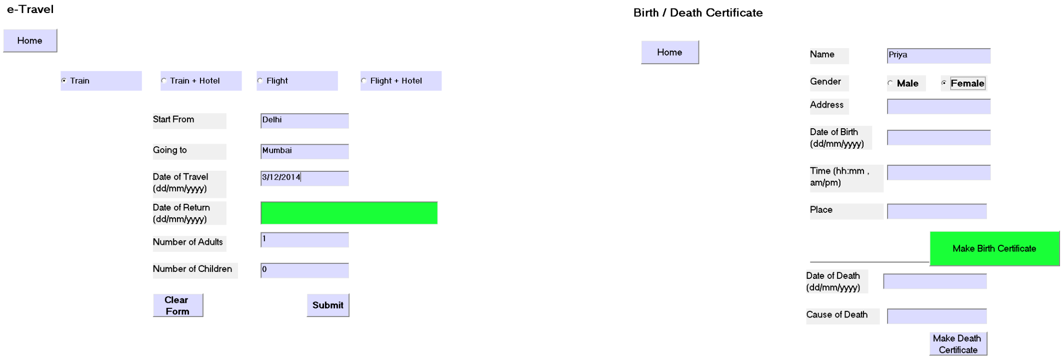
a. Electronic shopping Interface

b. Electronic Banking Interface



● Train
○ Train + Hotel
○ Flight
○ Flight + Hotel

Start From Delhi
Going to Mumbai
Date of Travel (dd/mm/yyyy) 3/12/2014
Date of Return (dd/mm/yyyy)
Number of Adults 1
Number of Children 0

Name Priya
Gender ○ Male ● Female
Address
Date of Birth (dd/mm/yyyy)
Time (hh:mm , am/pm)
Place
Date of Death (dd/mm/yyyy)
Cause of Death

c. Electronic Travelling Interface

d. Birth/Death Registration System

Figure1. Interface designed using the target prediction design bed

4. USER TRIALS

The following sections report the following two user trials.

1. The first trial compares cognitive load and selection time for a standard computer mouse and eye-gaze tracking system for the electronic shopping application
2. The second trial presents a longitudinal study to investigate the effect of learning on eye-gaze tracking based interaction.

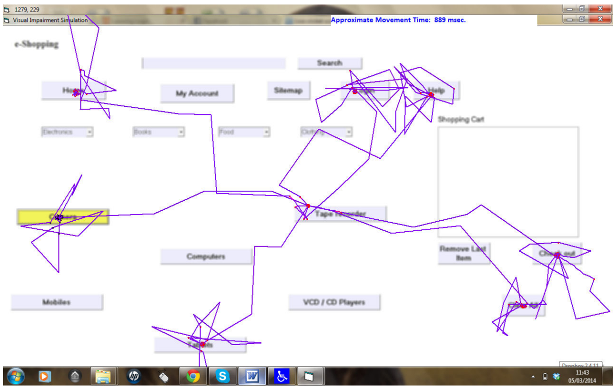


Figure 2. Simulation of interaction by users with moderate visual and motor impairment

4.1. Comparison of Eye-gaze Tracker and Mouse

In this user trial we have compared users' cognitive load and selection times between eye-gaze tracking and mouse for an online shopping task using the eShopping interface discussed above.

We collected data from participants who are not regular computer users. The study aims to find how easy or difficult users perceive and perform with eye gaze tracking based system in comparison to mouse, which is still now the most commonly used computer input device. Vertegaal [17] already compared eye-gaze tracking and mouse based interaction for pointing and clicking tasks and found that eye-gaze tracking with dwell time based selection is faster than mouse but eye-gaze tracking also generated higher error rate.

4.1.1. Participants

We collected data from 8 users (average age 57 years, 6 male, 2 female). Participants were interviewed about their prior experience of using computer and only allowed in the trial if they never used computer regularly before. A few users occasionally used computers and but still did not consider themselves as expert users. The study was conducted at Delhi and Kolkata, India.

4.1.2. Material

We have used a Windows 7 HP computer with 54 cm × 33 cm monitor having 1920 x 1080 pixels resolution to record users' performance with the eShopping system. We used a Tobii TX2 eye-gaze tracker to record eye gaze. We have used a beizer curve [12] based filtering algorithm [2] to smoothly move the mouse cursor inside the screen. For eye-gaze tracking based interaction, the blank space button in a standard Logitech keyboard is used for selecting target. A standard Logitech mouse was used to record performance with mouse. We used the NASA TLX score sheet to measure cognitive load.

4.1.3. Procedure

The users were instructed to buy a few items using the eShopping interface (Figure 1a) using mouse and eye-gaze tracker. The mouse based interaction did not involve target prediction system while the eye-gaze tracking based system had the target prediction on. After repeating the process a few times, they were instructed to fill up the TLX score sheet. The order of input options (mouse and eye-gaze tracker) was randomized to minimize order effect.

The process of buying an item involved following steps:

1. Pointing and clicking on one of the combo boxes on top (figure 1a).
2. Pointing and clicking on the button having the desired item (like camera, computer etc., refer figure 1a). On clicking a button, the interface shows a list of cameras, computers and so on.
3. Pointing and clicking on the button having the desired product like a particular computer brand or a particular book.

4. Repeating above steps to add more items to shopping cart.
5. Pointing and clicking on ‘Check Out’ button at the right sides of the screen (Figure 1a).
6. Repeating the whole procedure (steps 1-5) two to three times using both mouse and eye-gaze tracker.

4.1.4. Results

All eight users could undertake the trial and completed the task. The button selection time was measured as the difference in time between two button selections or the time difference between selection of a combo box and next button press. The time involves pointing to the target and selecting it. The button selection time was significantly less for eye-gaze tracking based system than mouse (figure 3 showing average and standard deviation and figure 4 showing median and quartiles) in a Wilcoxon Signed-Rank Test ($Z = -2.84$, $p < 0.01$, $r = -0.33$).

In the present experimental set up, we have defined error or wrong selection as follows:

- Users selecting same item twice consecutively
- Users selecting ‘Remove last item’ button
- Users selecting ‘Clear All’ button

We found users committed 4 wrong selections among 93 selections for eye-gaze tracking system and 1 wrong selection among 79 selections using mouse. The error rate is below 5% in both cases.

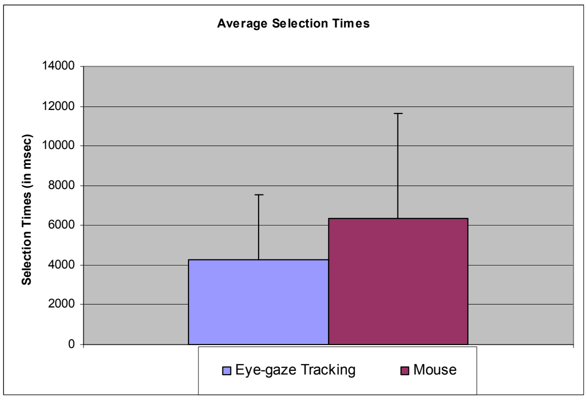


Figure 3. Average button selection times using eye-gaze tracker and mouse

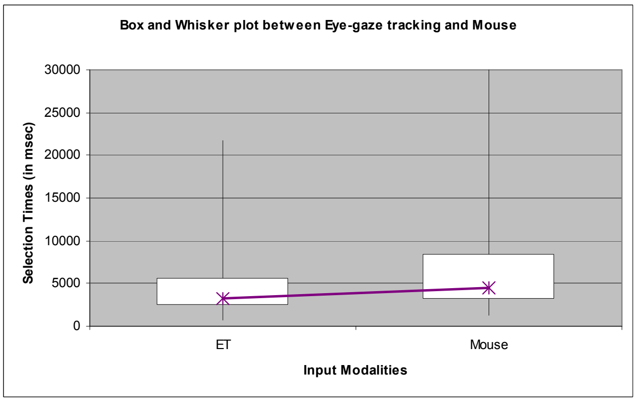


Figure 4. Box and whisker plot for button selection times using eye-gaze tracker and mouse

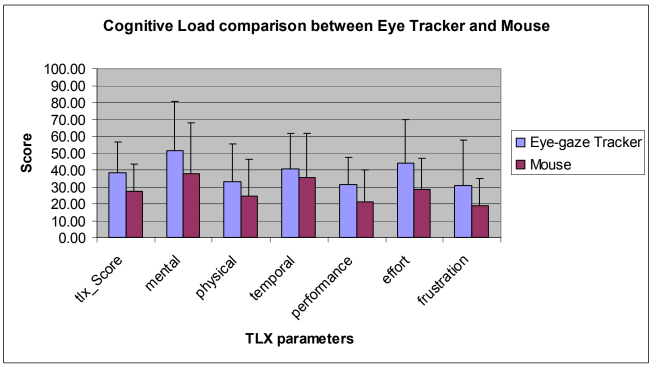


Figure 5. NASA TLX score comparison between Eye-gaze tracker and Mouse

Figure 5 shows the cognitive load in terms of NASA TLX scores. The columns correspond to average score while the Y error bars signify standard deviation. Users scored higher TLX scores for eye-gaze tracker (mean 38.48, stdev 17.85) than mouse (mean 27.66, stdev 15.67) though the difference was not significant in a paired two-tailed t-test.

4.1.5. Discussion

This study demonstrates that for an easy-to-use interface, novice users can complete tasks quicker using eye-gaze tracker than mouse, though the eye-gaze tracker tends to produce more cognitive load than mouse. It may be noted none of these users used eye-gaze tracker before though 6 of them used mouse before. We recorded only 4 occasions where users took more than 10 secs to select a button among 93 correct selections. The average button selection time was 4.3 secs. The next trial tried to reduce this selection time further through training users for a few days.

The result can also be attributed our target prediction algorithm [2], but we intend to evaluate the performance of the intelligent eye gaze tracking algorithm as a whole and so we did not separate out the target prediction technology from eye gaze tracking.

4.2. Effect of Training for Eye-gaze Tracker

This study evaluates the effect of training on performance of users while undertaking task using eye-gaze tracker. Two users used the eye-gaze tracker for three consecutive days undertaking 6 sessions. We investigated how the pointing and selection times improved with training.

4.2.1. Participants

We collected data from two users – Participant 1 was 62 years old male, while Participant 2 was 26 years old female. None of them used eye-gaze tracker based system before but otherwise expert computer users and operated computers regularly. The study was conducted at Kolkata, India.

4.2.2. Material

We have used a Windows 7 HP computer with 54 cm × 33 cm monitor having 1920 x 1080 pixels resolution to record users' performance with the eShopping system. We used a Tobii TX2 eye-gaze tracker to record eye gaze.

4.2.3. Procedure

Participants were instructed to buy a few items and check out using the eShopping interface of figure 1a. They undertook the trial twice every day for three consecutive days. Each session lasted from five to ten minutes.

4.2.4. Results

We recorded 48 minutes 43 seconds of interaction from Participant 1 and 54 minutes and 18 seconds of interaction from Participant 2. We analyzed the change in button selection times across sessions for both participants and also investigated changes in selection times during each individual session. The median of selection times (figures 6 and 7) were 2.9 secs and 2.8 secs for participants 1 and 2 for the first session while it was reduced to less than 2 secs after 4th session for participant 1 and after 2nd session for participant 2. There was a slight increase in median selection time for participant 1 in last session.

The average selection times also showed a decreasing trend. We found a significant effect of session on selection times in one-way ANOVA ($F(5,679)=10.98$, $p<0.001$ for Participant 1 and $F(5,1059)=9.75$, $p<0.001$ for Participant 2). A *USER* × *SESSION* Factorial ANOVA found a significant effect of *SESSION* ($F(5, 270) = 10.41$, $p < 0.01$, $\eta^2 = 0.16$), but did not find a significant effect of *USER* at $p< 0.05$.

There was also a significant interaction effect between *USER* and *SESSION* ($F(4, 216.54) = 3.08$, $p < 0.05$, $\eta^2 = 0.05$, *The df is fractional due to applying Greenhouse-Geisser correction)*. A Multivariate test also confirmed significant effects of *SESSION* ($F (5, 50) = 9.1$, $p < 0.01$, $\eta^2 =0.48$) and interaction effect of USER and *SESSION* ($F(5, 50)= 3.46$, $p < 0.01$, $\eta^2 =0.26$). The pair-wise comparison among different sessions found

- A significant effect of Session 1 with sessions 3, 4, 5 and 6 at $p< 0.05$
- A significant effect of Session 2 with Session 5 at $p<0.5$

The pair-wise comparison did not find any other significant effect at $p < 0.05$

We also investigated the within subject contrasts and found a significant effect of linear $(F(1, 54) = 31.57, p < 0.01, \eta^2 = 0.37)$ and quadratic $(F(1, 54) = 6.38, p < 0.01, \eta^2 = 0.11)$ contrasts for *SESSION* .

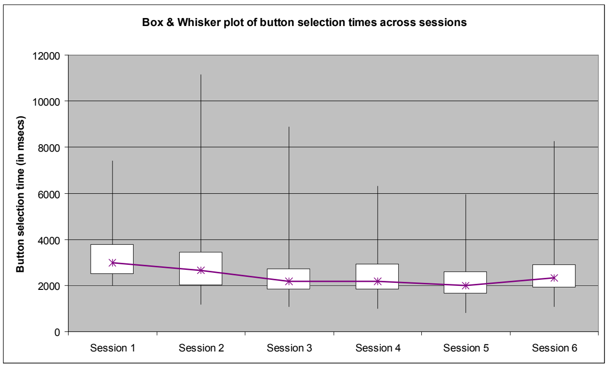


Figure 6. Box and Whisker plot for button selection times for Participant 1

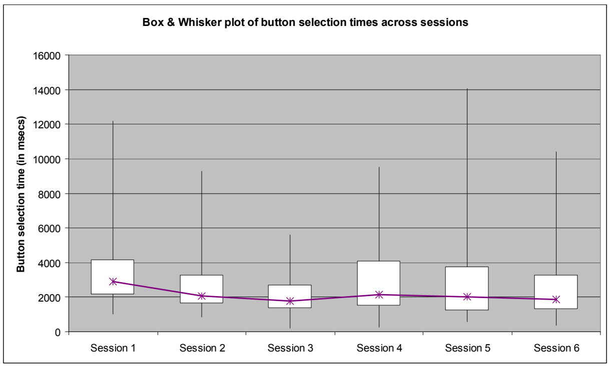


Figure 7. Box and Whisker plot for button selection times for Participant 2

We have analyzed the learning effects during each individual session (figures 8 and 9). During first session, both participants generated a U-shaped learning curve indicating their selection time initially decreases (after approximately 100 secs) and then increases again perhaps due to fatigue. For session 1, Participant 2's learning curve shows this effect more prominently than Participant 1. However the learning curves turns almost horizontal after third session for participant 1 and after first session for Participant 2. It indicates that participants were no longer going through a learning phase during the session. However Participant 1's last session generated an increase in selection time, perhaps due to fatigue or boredom.

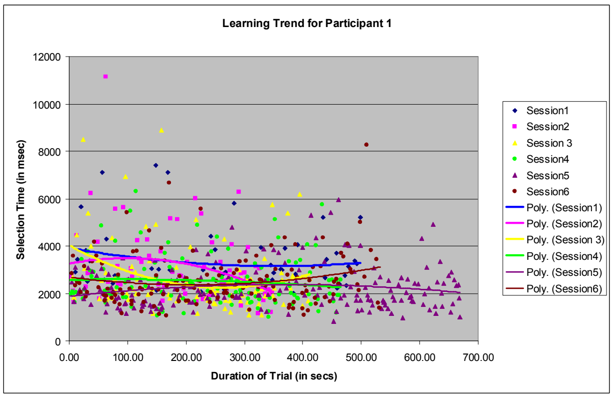


Figure 8. Learning trend in terms of button selection times for Participant 1

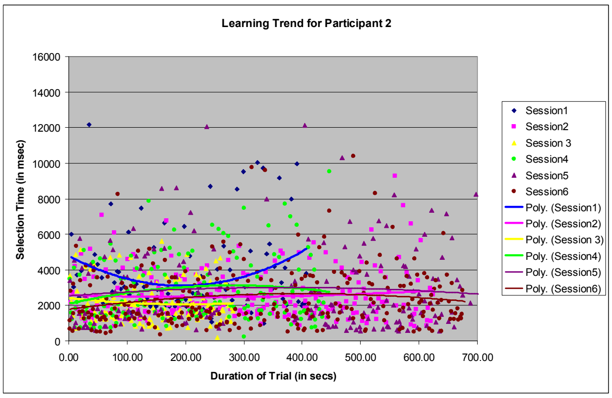


Figure 9. Learning trend in terms of button selection times for Participant 2

4.2.5. Discussion

This study demonstrates that with a simple and easy-to-use interface, users can point and select using eye-gaze tracker within 2 secs. Although Penkar and colleagues [11] reported a pointing and selection time of 1.02 secs but our task was different than them. Penkar's task [11] had targets only at the middle of the screen so they could achieve an average selection time of 1.02 secs even with 1 sec dwell time. In our task users needed to point across a wide area of the screen and for pressing 'Check Out' button, they needed to point at the edge of the screen. So the task was more realistic than Penkar's task.

Our study also demonstrated that even first time users can learn to use eye-gaze tracking after going through training. The significant effect of quadratic contrast also supports the existence of a learning pattern. The pair-wise comparison shows users attained optimum speed after approximately two sessions. The individual analysis shows that the training duration differs between two participants – the elder participant took 20 minutes (3 sessions) before having nearly uniform selection times while the younger participant could do it only after using the system for approximately 7 minutes (1 session). Tuisku and colleagues' [16] study on Dasher system [19] could not achieve a steady speed even after ten sessions. We demonstrated that with the target prediction system and simple interface, users can learn eye-gaze tracking based interaction within 20 minutes. This result can be used to develop training program for future eye-gaze tracking based interfaces. Our future study will consider more participants and more complex tasks.

5. CONCLUSION

This paper presents a case study of using eye-gaze tracking based interaction for common computing tasks. We chose to conduct this study in India as a lot of Indian middle aged and elderly users were not proficient with existing user interfaces but keen to use computers and other digital devices if it is easy to use and learn. We found that with a user friendly interface and intelligent eye-gaze tracking system, users can not only outperform the conventional computer mouse but also learn to use this system within 20 minutes. We hope results from these studies will be useful to develop algorithms and applications for future eye-gaze tracking systems.

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