Social Gaze

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Gaze tracking methods are among very famous research fields in the past years. It adds significance in various applications especially studying usability in human computer interaction as eye gaze has a potential of accurate computer interface as an input. There is a lot of research going on head movement detection along with gaze detection and tracking. Several different types of methods have been proposed for implementation of gaze algorithms.

If we look back, we will see that there is hardly any work done to use these gaze detection and tracking methods in social websites. Implementing eye gaze tracking methods in social website will lead to some interesting things, e.g. what if the opponent's gaze point will be visible when playing a game (say, chess)? Or what if teacher could see the student's gaze point when he/she is solving a task? Or what if one can see, how their friends on social networking sites observe the images shared with them? This thesis work presents the results of an experiment that was conducted to understand the effectiveness of implementation of eye gaze tracking in different social networks. Post questionnaire shows a positive feedback from the participants when it comes to sharing their gaze in social networking sites.

Key words and terms: Human-computer interaction, gaze interaction, fixations, gaze tracking

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List of Abbreviations

HCI	Human-Computer Interaction
EOG	Electro Oculography
VOG	Video Oculography
POR	Point of Regard
TFT	Thin Film Transistor
SMI	Senso Motoric Instruments
SN	Social Networks
SNSs	Social Networking Sites
ETU	Eye Tracking Universal

1. Introduction

Computing and communication technologies have changed significantly during recent years. The affordance of personal computing devices let to a common case when a household owns several of them, including desktop PCs, laptops, tablets and smartphones. Started in the most developed countries, this trend now expands to the rest of the world.

Interaction with computers a whole day long has become a part of our life. We use them at work, while studying, and during leisure activities. Most of interaction with traditional computers involves operating a keyboard and a mouse. Excessive typing or mouse usage normally causes hands or fingers stress, sometimes resulting in a carpal tunnel syndrome. Partly to this and partly to other reasons, a lot of studies have been performed on experimenting with other interaction modalities that would make it more efficient and easier.

1.1 Human-Computer Interaction

Human-computer interaction as a research field studies how people interacts with computers and how this interaction could be improved to make it easy and quick [1]. It deals with designing, evaluating and implementing the interactive systems for humans.

One direction of such a research focuses on the interaction that is based on a combination of different types of command-production ways (*input channels*, or *modalities*). These interfaces are called *multimodal interfaces* [2]. Besides traditional devices like mouse, keyboards, printers and scanners, other modalities like speech, body gestures and eye-gaze play a significant role in these interfaces. The latter one, eye-gaze, was mainly used for accessibility purposes to support people with special needs. However, after eye tracking technologies matured and pushed the prices down during the last few years, the eye-gaze modality certainly deserves a close look to how it can be utilized in mass-market products and be beneficial to use by ordinal users.

Eyes are very vital source of information for humans. Observing eyes, we can get information related to person's attention, and in come case even to his/her intensions. Studying eye movements is very common in psychological studies that focuses on human behaviour [3] and has at least 50 years of a history record. However, the eye tracking technologies remained long time as a very niche product, partly due to a relatively high cost and partly to the absence of convenient methods to track the eyes: the visual methods based on capturing eyes by camera required special devices that processed video stream (and thus making eye tracking systems very expensive), and all other non-visual methods were not convenient to use. This has changes after fast video processing became available

on PCs, and later on mobile. The need for specialized camera have also gone, and nowadays even ordinal webcams may be sufficient to track gaze accurately enough (for example, for text typing) [4][5].

1.2 Eye-Gaze as Input

Traditionally, interfaces based solely on eye-gaze input have been used for disabled people who can't move (almost) anything but their eyes.

1.2.1   Advantages of Eye Gaze as input

Next, some advantages that an eye gaze interface can provide are listed:

Easy to use. The biggest advantage of using eye gaze as an input instead of hand is the avoidance of stress of hand muscles. The eye-based interaction does not put any extra pressure of eye muscles.

Free of Maintenance. Mouse and keyboard require regular cleaning when they are in use. This is not the case for eye tracking devices as there is no contact required. However, the device (camera) must be placed to a damage-proof position.

Wireless/Remote control. One advantage of using eye tracking is that it can be used from some distance as well. High resolution cameras and equipped with zoom lenses make possible eye tracking from a few meters' distance.

Quick Interaction. Eyes are much faster than hands and fingers. While the superiority in speed is very notable in pointing (as compared to mouse pointing), it has no such an effect on the *selection* operation, the other most important operation in HCI. This is especially evident when traditional and eye-based typing methods are compared: with ten fingers, each much slower than an eye, people type texts much faster than even with the fastest gaze-based method. However, a combination of hand and gaze inputs could lead to establishing new interaction techniques that supposedly will be faster than the interfaces based on a single modality.

Appropriate Attention. During eye-based interaction gaze is always directed to the location the interaction takes place. This may prevent mistakes that occur using other interaction modalities due to insufficient attention to the interaction process. For example, it often happens that buttons on a smart phone virtual keyboard are pressed accidently (also when the phone lays in a pocket) and this is left unnoticed before the text is inspected.

Healthy Interface. Nowadays we observe that diseases spread via contact of devices located in public spaces. Devices equipped with eye trackers are safer in this sense.

User activities information. Eye tracking can provide useful information about user's attention, which can be utilized in systems with context awareness. Physical or emotional user state may also be partly revealed analysing same video stream that is used for gaze direction estimation.

1.2.2 Problems of Eye Gaze as input

Along with the number of benefits of gaze used for interaction mentioned above there are some problems as well:

Conflicts between vision and input. The natural function of an eye is to enable our vision. Using eyes as an input for computer can result in some conflicts. The Midas touch [6] problem is the most important and well-known, i.e., it is not easy to recognize in eye-based interfaces when gaze dwells on some object with the purpose to conduct an action, and when it dwells without such an intention. The misinterpretation can cause actions that are not desired.

Controlling ability. As mentioned above, there are certain unconscious movements that eyes may perform, and they certainly can disturb the interaction in gaze-based system. To restrain from these unconscious movements, person should be able to consciously control the movement of his/her eye all the time while interacting.

1.3 Structure of thesis

This thesis consists of eight chapters. The first chapter represents the introduction. It starts from introducing the human-computer interaction, then it introduces advantages and problems of using gaze as an input. Eye-gaze interaction modality is presented in detail in the second chapter. It also presents types of gaze interaction and the role of feedback. Third chapter discusses gaze tracking devices, data gathering and visualization with the stress on heat-maps. Next chapter introduces social networks along with their historical background and explains gaze tracking usage in social networks. The chapter #5 explains the study conducted for this thesis and the details of the experiment. Results of both pilot testing and the main experiment along with feedback from the participants are presented in the sixth chapter. The discussion about the results is presented in seventh chapter, while the last chapter summarizes the work done in the study and mention future research opportunities in the field of eye gaze interaction in social websites.

2. Eye Gaze Interaction

2.1 Anatomy of Human Eye

Eyes play a vital role in communication providing different sorts of information about our attention point and mental state. In everyday life, eye contact is considered as socially significant in one-to-one communication . For example; when we talk to somebody and ask "What is there?" we often use direction of our gaze to reference the object we are talking about. Bolt was one of the pioneers in research of gaze interaction, explained same thing in the following way [7]:

'*Best example can be given of asking the question. "What is your favourite dish?" was asked in the presence of many people, but by looking at Henry, not by looking at Martin or Paul. Then the same question was asked again but now by looking at Paul. Although not a single word is changed, but the pair of eyes had addressed the intended person.*'

The main visible parts of human eye includes iris, pupil, sclera and cornea (Figure 2.1).
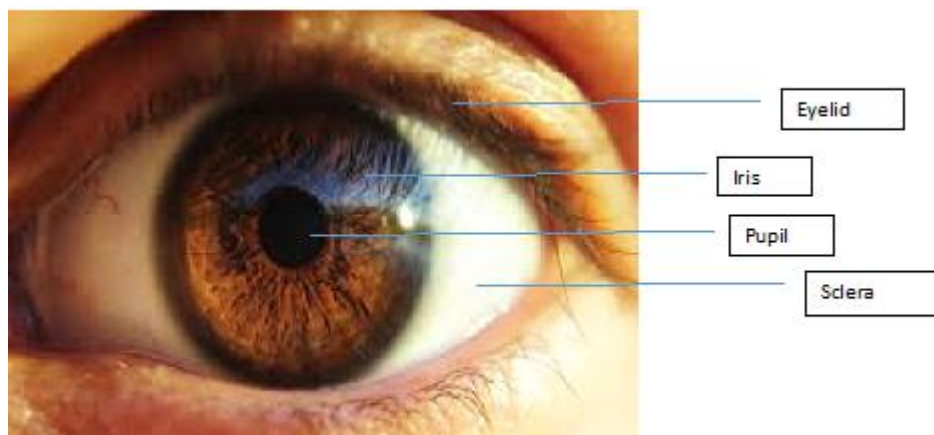
Figure 2.1 Human Eye

Cornea. Cornea is transparent and covers pupil, iris and front chamber. It comprises of cells and proteins. There are no blood vessels inside cornea. The main function of cornea is to refract light. It is also responsible for focusing light entering into the eyes [8].

Iris. Iris is the ring shaped muscular tissue behind the cornea that is responsible for controlling the amount of light that gets into the eye [8]. This structure defines what colour eyes have. Iris tends to shrink the pupil whenever too much light enters in one's eye and similarly it tends to widen if not much light is entering into the eye [9].

Sclera. The white part of an eye is known as sclera. It serves as a strong cover of an eye protecting it from injuries and providing an attachment for six small muscles known as extraocular muscles that control the movement of eye. Optic nerve is also connected to the sclera. Much thinner and luminous sclera is observed in young people as compare to yellow sclera among older people. [10]

Pupil. Pupil is a hole that is located in middle of the iris allowing for light to pass into the eyeball. It contains the lens that focuses light onto retina. Pupil is black, as much of the light that is entering is absorbed by the light-sensitive tissues present inside the eye. The size of the pupil depends upon how much the iris expands or contracts. [8]

2.2 History of Eye Tracking

History of Eye Tracking goes back to 18th century where direct observations were used for studying movement of eye. In 1792 eye movements were described for the first time [11]. In 1879, Louis Emile Javal observed that while reading, people do not move eyes smoothly across the text as it was used to be assumed earlier, but they stop on a word and move quickly the next one. To discover this phenomena further, Edmund Huey made a device for tracking eye movements of a person while reading [12]. In 1898, Delabarre cocainied an eye by using Plaster of Paris with moulded cap. Horizontal movements of the eye were drawn on kymograph cylinder using wire from cap to lever (Figure 2.2) [12].
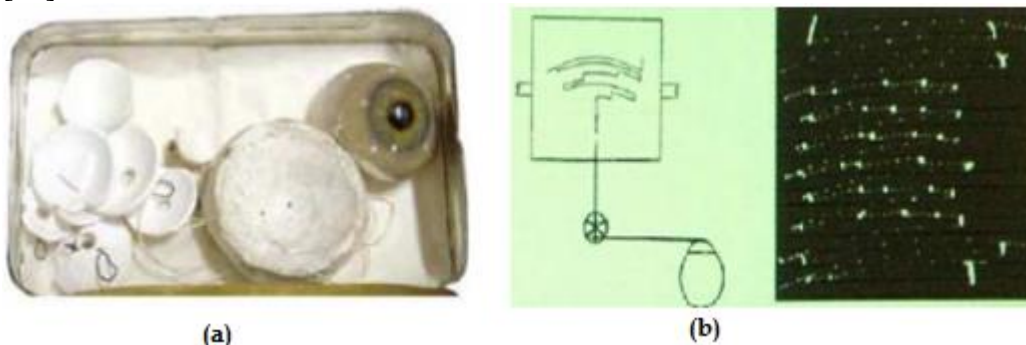
Figure 2.2 *(a) Cap with a drilled hole; (b) Rotating drum*

Later Charles H. Judd developed camera that helped for in-depth study of eye movement by recording eye movement on film. This method helped in recording eye motion in two dimensions [13]. Guy Thomas Buswell studied differences in eye motions in reading between various ages and levels of education. His good work earned him a place in the "Reading Hall of Fame". In 1930s, Miles Tinker use photographic techniques for studying eye motions in reading [14]. By varying the print size and page layout he studied the effects on people speed of reading and their eye movement patterns. Later in 1937, Dodge's photochronograph technique was improved by Guy Thomas Buswell by constructing a head tracker, as shown in Figure 2.3 [15].
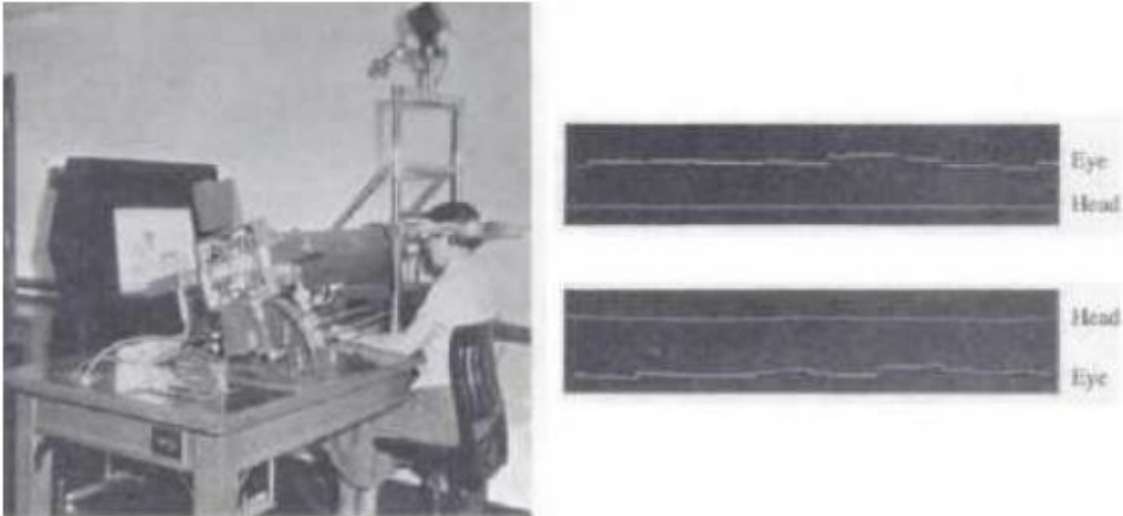
Figure 2.3 *Eye and Head Tracking by Guy Thomas Buswell*

Figure 2.4 *Electrodes using Electro-oculography by Jung*

In 1939, Jung invented electrooculography (EOG). This eye tracking method uses electrodes placed on skin close to eye, and at this time allowed more advanced eye measurements [16]. In 1948, Thompson and Hartridge invented the first head-mounted eye tracker. Later in 1962, Thomas improved the head-movement eye tracking system, making it less conspicuous and less restrictive in the participant head movement. [14]

Great advancements in eye tracking technology helped for prosperous eye tracking research in 1970s. Most of the technical improvements refer to the increased precision and accuracy in measurements. Just and Carpenter came up with the *Strong eye-mind hypothesis* in 1980s. There idea was that when a person is looking at some object or word, s/he is thinking about it at the same time. Video-based eye trackers were modernized in 1980s after the digital computing devices became common, and played further a vital role in opening doors for real-time eye tracking [15]. Nowadays, research in eye tracking

technologies is continuing to move forward rapidly, bringing up more and more accurate eye-gaze data.

2.3 Eye-gaze Tracking Techniques

Eye tracking systems consist of hardware and software that is used to sense eye movement or its location and then compute the direction of a user gaze. Some eye tracking systems may have extra modules, like head trackers. Remote eye tracking systems usually compute the point on a screen where the gaze vector intersects it. Head-mounted eye trackers usually compute the gaze point relative to the video captured by a "screen camera", although some systems like the one shown in Figure 2.6 compute gaze points relative to a screen. Eye movement data consists of a sequence of such points. Some eye trackers may also estimate the pupil size and may notify users about eye-related events, such as blinking [17].

Figure 2.6 *Eye tracking in earlier stages*

Gaze tracking techniques approximate eye movements relative to either head position or to the point of regard (POR). POR is defined as the point where the eye visual axis and the object that is being observed intersects each other [20]. There are number of different eye tracking techniques among which the most important three are mentioned below.

Scleral Contact Lens. In this technique, a contact lens is worn and a mechanical object is connected to it to monitor the eye movement. The technique is very precise but also invasive and uncomfortable for users (Figure 2.7). Nowadays, it is not used in HCI but can be found in medical and physiological research where fast and accurate measurement is required.
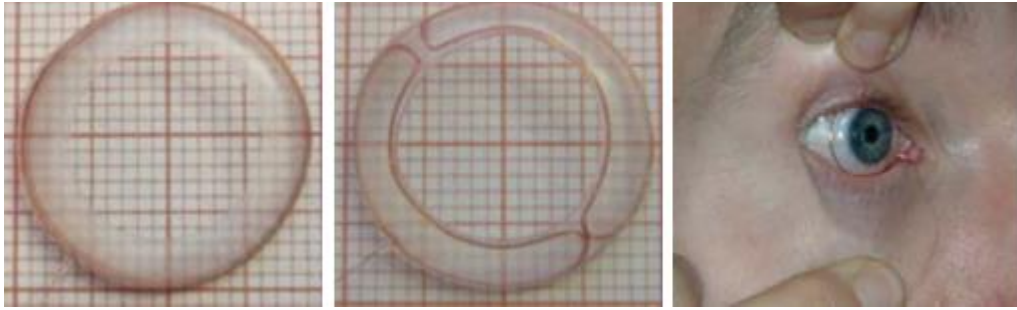
Figure 2.7 Scleral coils by Chronos Vision

Electroculography (EOG). This technique is based on the fact that a uniform potential difference of 0.4 - 1.0 mV, which is commonly known as corneo-retinal potential or as corneo-fundal potential, lies between the front (cornea) and back (retina) of the eye. This potential is measured by placing multiple electrodes at different locations close to the eye. The eye movement can be determined accurately by measuring the potential differences between electrode pairs. [21] Head tracking combined with EOG allows estimating POR. EOG has clinical applications and has a reported accuracy of two degrees. The major drawback of this technique is the requirement to place electrodes directly on a user skin. Another disadvantage of this technique is related to the corneo-retinal potential drifts. Thus, often recalibrations may be required for such a system. In order to compensate for the EOG signal drift, ambient lighting and the physical sensors integration into wearable EOG goggles (Figure 2.8) has been proposed in [22].
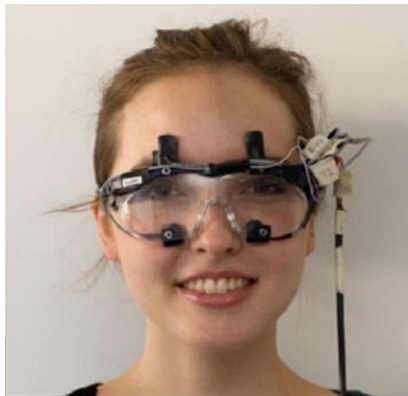
Figure 2.8 Wearable EOG goggles

Video-oculography (VOG). This technique is the most known technique used in gaze tracking. It processes video captures by a camera(s) to estimate pupil location. This technique requires a light source (usually infrared, IR) directed towards the eye. The trivial purpose of the light source is the eye illumination. The reflection of its light from cornea or pupil helps in computing the direction of gaze, mostly for head movement compensation. A variation of VOG deals with reflections from four different eye layers, that are called "Purkinje images" [20]. Cornea's outer surface is the place usually where first image appears and is usually strong which appears as a sparkle in the camera image.

The sparkle/glint remains stationary irrespective of the movement of eye due to the peculiar structure of cornea.

When the light source is light source is placed on the video camera's optical axis [23], the reflection from the retina becomes visible making the pupil look bright. In this case pupil detection could be more robust due to the higher contrast between iris and bright pupil. However, in bright outdoor conditions detection of the glint and pupil are often difficult regardless the IR illumination type. The techniques are called passive light approaches [23][3] helps in diminishing negative effects of external light sources in the outdoor usage conditions.

Video-based gaze tracker can be remote or head worn depending upon its physical setup. For mobile gaze tracking (Figure 2.9), head worn tracker can be more suitable as it provides some level of mobility. In remote gaze tracking devices both camera and infrared lighting are placed near to a screen (Figure 2.10). In this setup the gaze data quality degrades if a user moves out of the tracking box which is usually not large (approximately, 30x30x30cm).

Figure 2.9 VOG see-through goggles

Figure 2.10 Tobii Pro X2-60 eye tracker

Nowadays, large number of eye tracking companies and their VOG-based devices can be seen in the market. EyeTech Digital Systems designs, The Eye Tribe, LC Technologies, SMI (Senso Motoric Instruments) and Tobii are some of them to list.

2.4 Gaze data

Tracking of an eye-gaze refers to estimation of the approximate direction of user's gaze. Gaze direction itself is usually not of interest: rather, an object-of-interest, or area-of-interest (AOI), is required to be identified [24], as this knowledge give insight into cognitive processes that are closely related to objects we are looking at. If object/AOI is located on a computer screen, then a simple point-in-area computation is usually applied to detect whether this particular object/AOI is in focus. If gaze mapping involves objects located in a real world, then mapping could be rather complex, mainly due to the need to interpret the scene image captured by "scene camera". However, in a virtual world gaze-to-object mapping does not require video processing from a separate camera and may apply direct gaze vector intersection with the surrounding virtual objects to recognize which one should be marked as focused.

If pupil size is provided along gaze vector coordinates then it becomes possible to estimate user's emotional responses to shown stimuli. Strong emotion cause pupil widening and narrowing. However, stable light conditions are necessary to run this kind of studies, as pupil is also regulating the amount of light entering into an eye.

More rarely, eye tracking systems also provide data on eye rotation, eyeball shape, etc. [19]. These data are rarely used outside of a specific medical or behavioural research.

2.5 Use of Gaze Tracking

Nowadays, there are lots of application domains where eye trackers are being used. Some of them are mentioned below:

Vision Research. Gaze tracking devices are very important in psychology, cognition and vision research. Studies of reading process were among first studies conducted by psychologists with the help of eye trackers after they became available.

Assistant system in cars. Eye trackers can be used to construct in-car systems that alarm the driver as soon as s/he falls asleep during driving (Figure 2.11). The alarm should help in avoiding accidents.

Figure 2.11 *Assistant System in cars*

Medical research. Eye tracking is involved in certain medical diagnostics. It can provide valuable data when studying people with injuries effecting their vision.

Usability Research. Gaze trackers are widely used in usability testing. For example, usability tests of aircraft cockpit involving gaze trackers helped to determine best positions for various controls located there.

Accessibility. People with poor or no control over their muscles caused by injuries or different types of diseases may use eye tracking systems to interact with the rest of world, for example, controlling their wheelchairs or TV-sets using eyes only. Eye typing applications allow such people to communicate with other people, send them email or instant messages, write documents, etc. Applications like EyeDraw allow them to draw pictures; gaze-controlled games also play an important role in making the life of people with disabilities as comfortable as possible.

Research in Market. Advertisement campaign may strongly benefit from using eye tracker at the preparation step: knowledge obtained from a study of eye movements when a product is shown to potential clients (Figure 2.12) may provide a valuable insight into whether the advertisement was designed optimally or not. With the help of portable eye trackers it is also possible to find out which products people notice first in superstores.

Figure 2.12 *Eye Gaze utility in market*

2.6 Types of Gaze-Based Interaction

Eye-gaze is usually connected with the person's visual attention. It is known that this assumption is not the absolute, and sometimes it happens that the foveal gaze direction of a person can dissociate his/her attention and the person do not mentally attend the object even when looking at it. However, most of the eye tracking studies follows a solid considerations that the visual attention of person is associated with the foveal gaze direction [25]. This assumption will always be made when talking next about using eye-gaze as an input modality in human-computer interaction.

Eye movements consist of rapid jumps (saccades), relatively stable periods during which people can perceive information (fixations) and slow motion, usually when following a moving target (smooth pursuit). In gaze-based interaction with a computer, all three eye movements can be used to perform certain tasks. Fixations are used commonly in human-computer interaction, but some interaction methods require users to make saccades (eye-gestures) or even follow a moving target to complete a task. In this section we limit our attention on the usage of fixations and saccades for gaze-based interaction.

The main problem in gaze-based interaction that must be solved relates to providing a robust differentiation between natural eye movements and those that trigger intentional commands. Unintentional (passive) eye movements can cause undesired responses from a system. In gaze based interaction this is known as "Midas touch problem" [23]. This problem is usually solved applying two most common methods: gaze gestures and dwelling.

2.6.1   Gaze Gestures

Gesture-based interaction is known to be used also in daily human-to-human interaction. In this case, body gestures have a key role in complementing the speech. Gestures-based

interaction using different body parts also attracts a lot of attention in the HCI field of research.

Gaze gestures consist of a sequence of saccades called *strokes* [23]. The definition of "gaze gesture" according to [26] is:

> "*A definable pattern of eye movements performed within a limited time period, which may or may not be constrained to a particular range or area, which can be identified in real-time, and used to signify a particular command or intent.*"

Same gaze gesture may have a relative large variability, and therefore has weak dependence on the accuracy of gaze tracking. This gives and advantage for gestures-based interaction over dwell based interaction that requires relative good tracking accuracy. However, gaze gestures should consist of adequate number of strokes, otherwise it will take too much time to trigger a command.

Notably, gaze gestures may not require a screen, or a screen can be rather small. For examples, Isokoski proposed the use of off-screen targets for gaze-based text typing [27]. The user had to fixate for a short time at physical targets placed around the screen whiling making a gesture. Twenty seven letters corresponded to an English alphabet and a space. A generic gaze gesture recognizer was developed by Drewes and Schmidt [28]. The work was motivated by a plug-in for the Firefox web browser that allowed triggering some commands by producing mouse gestures. This recognizer dealt with eight strokes that form each gaze gesture (Figure 2.13).
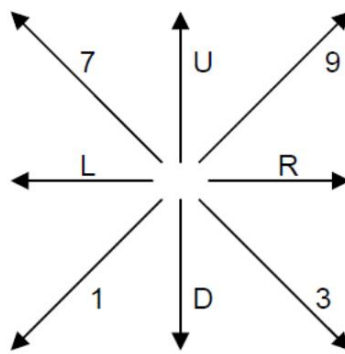
Figure 2.13 *Basing strokes used in gaze gestures*

The results of the study reveal that it is difficult to perform complex gaze gesture in the absence of visual aids to assist the gestures. Visual cues would certainly facilitate the users for directing their gaze to a specified location helping them to produce a desired gesture. This finding should be considered when planning off-screen gaze gesture based interactions. A proper feedback to confirm that the gesture was recognized is another important aspect of gaze-based interaction.

One of the well-known example of the application that is operated by gaze gesture is called Dasher [5]. Dasher was made by David J.C. MacKay [4]. It is an application that allows text entry using various input modalities; actually, any modality that can ensure a continuous control of the application pointer can be used to produce text. Initially, all the alphabet characters are present on one side of the application. Once the user moves the cursor towards any character, it starts to enlarge and moves towards the screen centre. The character is selected once it crosses the central vertical line (Figure 2.14). The selected character is added to the text on top of the application. Dasher uses a language model to predicts the next character, that appears closest to the pointer [5]. If the pointer moves to the left part of the application, the entered characters are removed from the end of the text in the same order they were added. It was observed that after practicing an hour, users can type 20 words (100 letters and spaces) in a minute, while the error rate was much lower (5%) when comparing with the on-screen keyboards operated by dwell (20%).
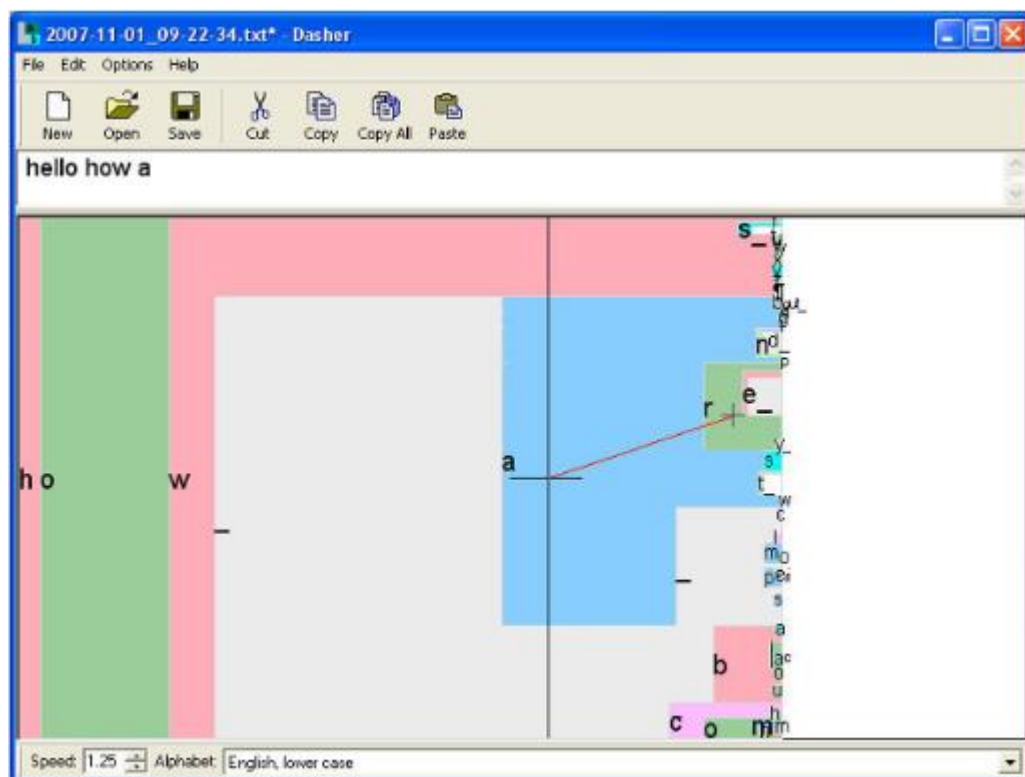
Figure 2.14 *Dasher application. Characters moved to on left side are considered as selected and appear in text box above*

2.6.2   Dwell-Time

This type of interaction requires for gaze to stay still for a certain amount of time while focusing on a specific target associated with a command. Usually, the target is a button that is selected (clicked) after the dwell is finished. The length of dwell time is crucial for comfortable and efficient interaction. If a long dwell time is set, then the performance

will suffer and users will get bored waiting for the command to be executed. On the other hand, if too short dwell time is set, then many unintended commands will be executed frustrating the user. Majaranta and Bulling [23] noticed that the ability for users to adjust the dwell time improves considerably the performance in different eye typing applications. Normally, novice users require dwell time much longer than the experienced use. However, the dwell time can be considerably decreased as users learn to interact by gaze and learn the system.

Dwell based interaction requires precise and accurate gaze tracking. If the interaction objects are not large, then even small offset may lead to triggering an undesired action.

2.7 Feedback in gaze-based HCI

Proper feedback is a very important component of interaction between two humans or between human and computer. Feedback plays a very vital role in human-computer interaction. It refers to communication from the system to the user as result of the user's actions. It provides the user with the closure evidences and helps in keeping the user informed about the operations that are being going on and which are completed.

Feedback in HCI is defined as:

"The Communication of the state of the system, either as a response to a user action, to inform the user about the conversation state of the system as a conversational partner, or as a result of some noteworthy event of which the user needs to be apprised". [29]

In typical human-to-human communication each participant expects that a partner will provide a certain feedback to his/her speech and actions that would regulate the discussion flow. The feedback may consist of positive (e.g. head nodding) or negative (e.g. raising the eyebrows) expressions. Same sort of feedback is expected to be found in HCI.

In gaze-based interfaces, feedback provides user status system by: informing that tracker is following the gaze accurately or not, and also by informing that the system has recognized the target the user is looking for or not and by letting know that the system has selected the intended object or not. Proper feedback reduces errors and increase the interaction speed in gazed based systems. For example, a simple animated feedback of progression of the dwell time helped novices to maintain their gaze on the target for the required time to select the items, thus this significantly reduce errors that are caused by early exits. Proper feedback also help users in feeling confident as they don't need to swap their gaze between input field and keyboard [23].

Pérez-Quiñones and Sibert [31] presented a community-oriented model for feedback. In their paper, they grouped all feedback types into five groups: processing, reporting, busy,

occupied-no-reaction, and occupied-deferred-reaction [32]. However, in HCI the feedback is modelled in a much simple way: it informs users that a) the system is ready (or not yet) for user actions, b) the system is currently acquiring the user's input (tracks his/her actions) and processes it, and c) the system has recognized the action and executes it, or 4) the action was not recognized or an error has occurred. Feedback also helps users to plan their future actions.

3. Gathering and Visualizing Gaze Data

Nowadays, large number of eye tracking companies and their devices can be seen in the market: Eye Tech Digital Systems Designs, The Eye Tribe, LC Technologies, SMI (Senso Motoric Instruments), Tobii to name a few. Most of the commercial eye trackers that are available today include infrared cameras and infrared lights, and use pupil centre estimation method for measuring the point of regard. Since the project work was done using Tobii EyeX eye tracker, I will present it and data is provides in details and continue then with the gaze data visualization methods.

3.1 Eye tracker by Tobii Technologies

Tobii is one of the leading companies that is working in making eye tracking devices. It was established in 2001 by John Elvesjo, Mårten Skogo and Henrik Eskilsson in Sweden, and revolutionized the commercial use of eye tracking devices, both from the technology and usability sides.

All Tobii eye trackers are based on processing video stream from cameras capturing both eyes illuminated by multiple IR light that generate reflection patterns on the cornea. Next, I list the most known tracker manufactured by this company.

Tobii EyeX. Tobii EyeX is a remote eye tracker that is mounted on desktop or a laptop PS below screen. It tolerates some head and body movements. The device is shipped with the software that supports out-of-the-box gaze-based interaction with MS Windows OS: it emulates mouse click, can zooming in or out the view, and allow document scrolling. A keyboard key is used for switching to another application. For scrolling, a user has to press and hold certain key. For zooming, both scroll wheel and a keyboard key can be used. Tobii EyeX uses near-infrared light for tracking the eye movements and gaze points of a user. Near-infrared light is used for creating reflection patterns on the pupil and cornea of the eye of the person while image sensors are used to capture images of the reflection patterns and the eyes. Image processing algorithms helps to estimate the position of the eye and gaze points accurately.

Tobii T60. Tobii T60 is integrated in a TFT monitor. It has similar characteristics as Tobii EyeX, but the sampling frequency is higher and occurs at more stable time intervals. This tracker is positioned as the capable to provide data accurately and timely that allows using it for academic and usability studies [33].

3.2 Tracker Calibration

An eye tracker should be calibrated before it can be used (Figure 3.1). During the calibration process, characteristics of the user's eyes are measured by an eye tracker, and

then used to build a physiological 3D model of an eye. The models takes into account light reflections and refraction properties of different parts of an eye [34]. For calibration, a user is asked to look at specific points located on the screen. While a user is looking at these points, a number of eye features are memorized. After the calibration ends, these data is used to create the model. The model is capable to interpolate gaze vector rather precisely given a set of eye features collected when a user looks at an arbitrary screen location.
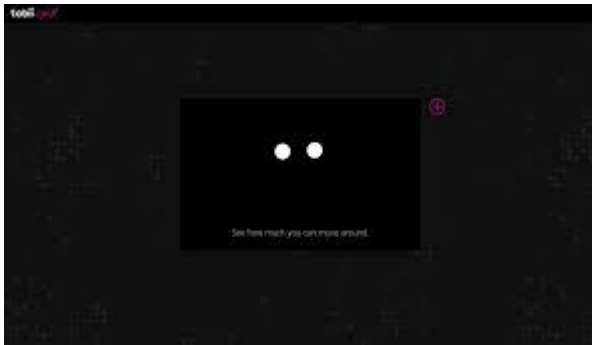
Figure 3.1 *Pair of eyes while calibration*

3.3 Positioning Tobii EyeX

Mounting Tobii EyeX in the right position is very important in order to have accurate calibration and precise gaze data. There are few mounting brackets provided with the Tobii EyeX package. Most often, the tracker is placed at the bottom of the screen [35], (see Figures 3.2 and 3.3))although it can be places on its top upside-down.

Figure 3.2 *Positioning Tobii EyeX on LCD*
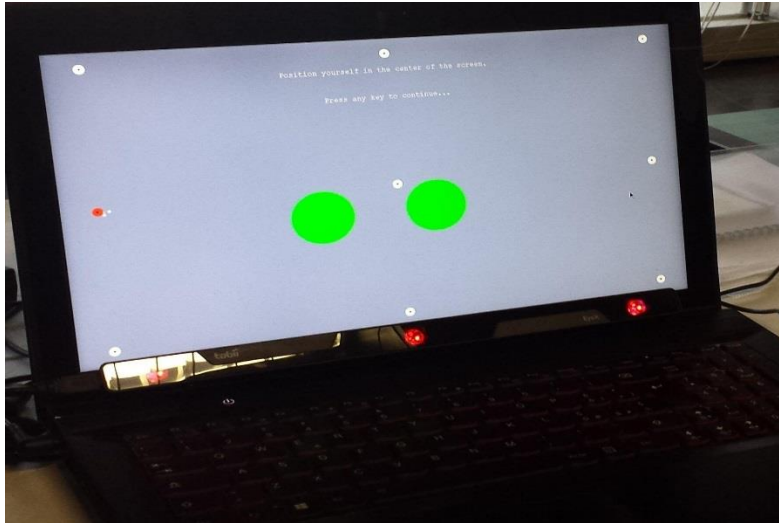
Figure 3.3 *Positioning of Tobii EyeX in Laptop*

In order to have the best performance, the distance between user's eyes and the tracker should be between 23" and 26", otherwise gaze tracking may not be reliable or available at all [36]. The tracker should be placed in a way to ensure that the angle between gaze and eye-to-camera vectors (α) is not exceeding 36 degrees, as shown in Figure 3.4.
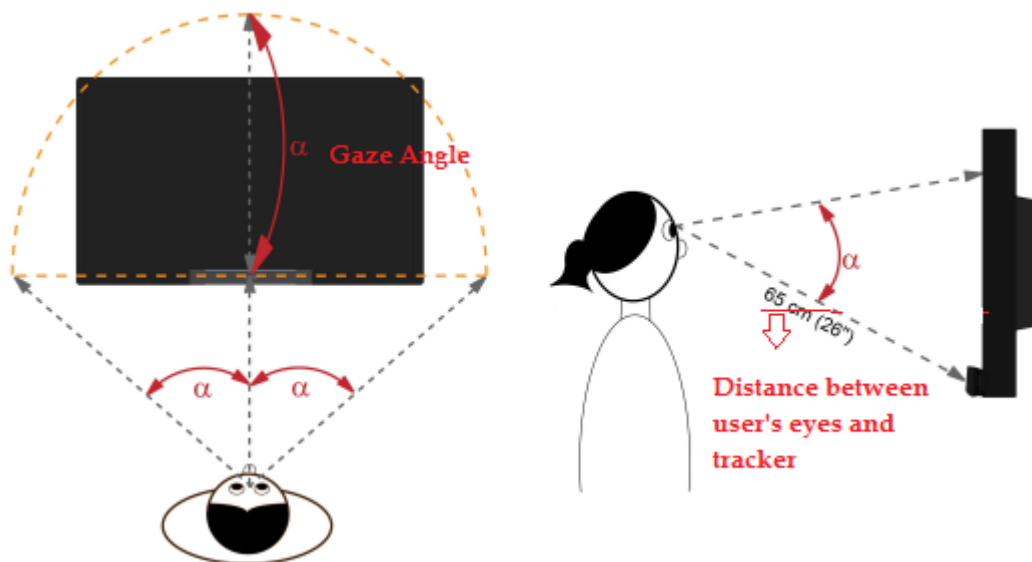
Figure 3.4 *Tobii EyeX positioning scheme*

There are two cameras in the optical sensor of the Tobii eye gaze trackers that capture an image of the eyes at 60 Hz frequency. These two cameras produce two images and reflections from cornea and pupil provides eye tracker with two information sources regarding the position of an eye. [37]

3.4 ETU-Driver

ETU-Driver stands for *Eye-Tracking Universal Driver* that was developed as a middleware to be used between end-user application and actual driver of eye tracker; so that device-independent control and data access can be provided. The ETU-Driver contains COM objects and uses device-dependent modules that convert native tracker API into a common API. This common API serves end-user applications to work with a variety of eye tracking systems transparently. In addition, there are three simulators that can be used for debugging:

- Mouse i.e. cursor location for emulating gaze points.
- Gaze data can be streamed from a file already recorded by ETU-Driver.
- It can also use a random scan-path generator.

ETU-Driver can access a number of eye trackers, some of which are mentioned below:

- ITU GazeTracker
- LC EyeGaze
- SR EyeLink I/II/1000
- myGaze n 1000
- Tobii T/X-series and EyeX.

3.5 Gaze data visualization

There has always been a strong bond between the eye movements and one's thinking. Visualization of eye movements helps in acquiring knowledge about observer's attention distributed in space and time [38]. Lots of different techniques are used for gaze visualization of data taken by an eye tracker.

One of the easiest techniques include drawing of eye movements in two dimension with stimulus image being used as a background. This visualization forms gaze plots where fixations are represented as circles while saccades are usually presented as lines that are connecting the circles. [39]. In gaze plots (Figure 3.5) the fixation duration is reflected in a circle size. Larger circles represent longer fixations. Different color coding can be used to represent gaze data of different users.

Gaze replay is another technique for visualization of eye movements. The most advanced gaze data visualization tools implement the replay with ability to control its speed, as a real-time replay is often too fast for detailed analysis of eye movements. [39]
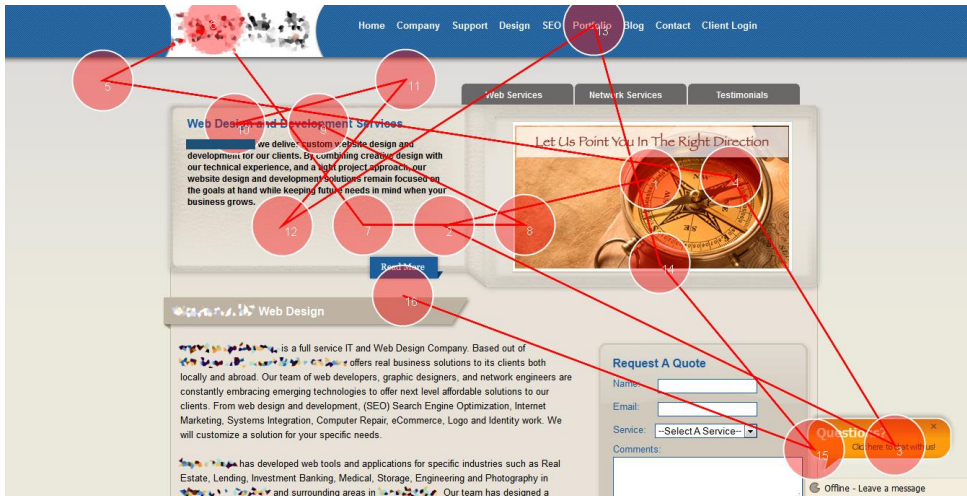
Figure 3.5 *Gaze Plots*

3.6 Heat map Visualization

Heat maps (Figure 3.6) is one of the static visualization methods of gaze data. The visualization helps in overviewing quickly the behaviour of one or more observers [40]. The origin of visualizing data via heat maps goes back to the 9th century as per description presented by Wilkinson. Generally, heat maps are suitable for visualizing large number of datasets with two or three dimensions.
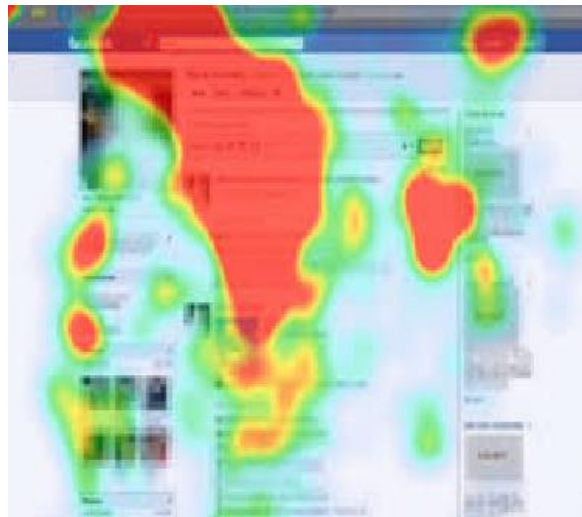
Figure 3.6 *Heat map*
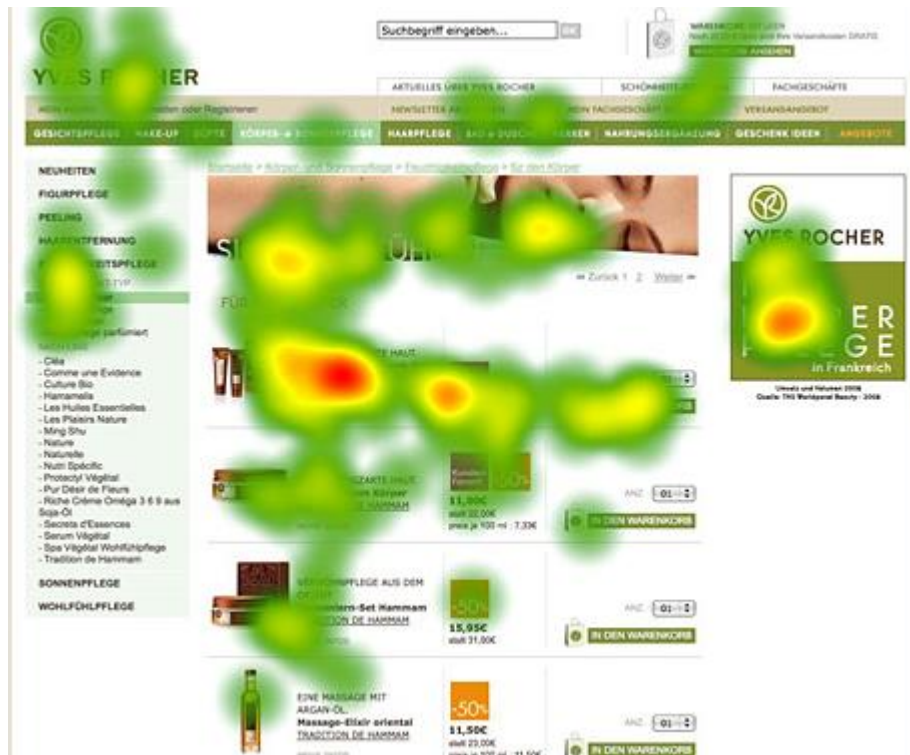
Figure 3.7 *Heat map visualization*

Heat map creation algorithm takes a sequence of fixations as an input and creates an overlay for the stimulus that is colorized according to attention received from user. Warm colours like red or yellow show areas that received more fixations or that were looked at by user for a longer period [38]. Similarly, green or blue colours represent areas that received fewer fixations or that were looked at by user for a shorter period.

4. Social Networks

Internet has turned this world into a global village, and has transformed all the aspects of communication in the world. Communication using internet is highly effective. It has outdone the conventional means of communication like print media, television and radio. People interaction with each other has been totally changed because of this major step in communication around the world. Nowadays, most of the young people use internet or mobile phone daily as a source of latest information, build, engage and increase social networks. Moreover, internet advertising has taken new forms in recent days which are highly advantageous in being more personal, precise, exciting and social. Different types of approaches of communication are developed in social networking sites like Twitter, Facebook, Bebo, LinkedIn, Xing and Orkut. [41] These sites have radically transformed young user's relationships with each other, with their families and with entire communities. There is a defined structure provided by all social-networking sites where anyone can form connections and friendships, can share all sorts of information, photos and major life happenings with each other [41]. Currently there are lots of different types of social networking sites (SNSs), all have one goal (i.e. social networking) but differ in their technological affordances.

4.1 Social Networking

Social networking involves the use of online platform that allows people to connect to one another. Users create their profiles on a site, set up an account to create a digital representation of them, select other people as contacts, communicate with them and recently use an interface to build applications. Social networking sites not only provide effective communication but also attracts the users to the popped up ads more than usual banners. Most sites help strangers to connect to other users based on shared interests, political views, or activities. Some sites try to diverse their audiences, while others attract people based on common language or shared racial, sexual, religious, or nationality-based identities [43]. Sites also vary in the number of tools that users can use, such as blogging, photo or video sharing.

4.2 Social Network Site

Social Network site can be defined as service based on web that allows the individuals to create a public or semi-public profile, enables them to see a list of other users to whom they want to connect, view and negotiate their networks [43].

Among various implemented technical features, the backbone of all the social networking sites (SNSs) is the public user profile that displays a list of friends who are also users of

the system. The profile usually includes answers to a list of basic questions that involve the description of age, interest and location etc. Most sites inspire the users for uploading their profile photo. Different sites have different rules and regulations when it comes to profile visibility, but in all the visibility depends upon the will of the user that to whom user wants his profile to be visible. While developing the profile, the user is urged to identify other users in the same networking site with which they are somehow related. Most SNSs needs consent and conformation from both sides for "friendship". The unidirectional ties are named as "friends", "followers" and "fans".

Displaying of connections in public is a very important part of SNSs. On most networking sites, anyone who has been allowed to see the profile can see the list of friends, but there are some exceptions as well. Most sites allow the users to write comments or share things on their friend's profiles both publically and privately. In addition to profile, friends and messages most SNSs also offer photo and video sharing or built-in blogging capabilities. Some SNSs are only mobile-specific (e.g. Dodgeball), i.e. some has client apps for mobile platforms only (Android, iOS) but most of others have client apps for both desktop and mobile platforms. Facebook and MySpace are well known examples of these type of social networking sites.

Major Social Networks

Some of the most commonly used social networking websites along with their logos are given below in the Table 4.1:

Table 4.1 Social Networking sites and Logos

Name	Logo	Photo sharing
Facebook		Possible both photo sharing and commenting
MySpace		Possible both photo sharing and commenting
Orkut		Possible both photo sharing and commenting
Bebo		Possible
Friendster		Possible both photo sharing and commenting
Google+		Possible both photo sharing and commenting

LinkedIn		Possible both photo sharing and commenting
Twitter		Possible
Instagram		Possible both photo sharing and commenting
Pinterest		Possible both photo sharing and commenting

4.3 History of Social Network Sites

The first recognizable social network site was launched in 1997. SixDegree.com beginning in 1998 allowed the users to construct profiles and their list of friends. Each of these features existed before in some major dating and community sites. SixDegrees.com promoted itself as a means to enable people to connect and send messages to each other attracted millions of users but failed to become a sustainable business and hence closed down in 2000. Thinking back, its author trusts that Six Degrees was essentially relatively revolutionary [44]. While individuals were at that point rushing to the internet, most did not have augmented systems of companions who were on the web.

From 1997 to 2001, many community tools (AsianAvenue, BlackPlanet, and MiGente) allowed users to create profiles and identify friends without seeking approval of those connections. The Korean virtual worlds site Cyworld was started in 1999 and added SNS features in 2001. Similarly, the Swedish web-company LunarStorm refashioned itself as SNS in 2001 with lists or friends, guest books and diary pages. The next wave of SNS began when Ryze.com was launched in 2001 to help users to leverage their business networks but it never gained mass popularity. The people behind Ryze.com, Tribe.net and LinkedIn were quite intervened personally and professionally. Only LinkedIn became a powerful business service. Friendster propelled in 2002 as a social supplement to Ryze. It was intended to contend with Match.com, a productive dating webpage. While most dating destinations concentrated on acquainting individuals with outsiders with comparable interests, Friendster was planned to help making companions-of-companions ties, in the light of suspicion that people in these ties would improve sentimental accomplices than outsiders would. Friendster gained a relative success mainly due to the support of 1) early bloggers, 2) participants of the burning man expressions celebration, and 3) gay men: 300,000 clients were registered in the system in May 2003. [44]

From 2003 onwards several SNSs were launched including professional sites like LinkedIn, Visible Path, and Xing (formerly "open BC") and passion centric sites (e.g. Dogster). Moreover, as the role of social media grew, the websites focused on media

sharing eventually found themselves as full-functional SNSs: eFlickr (photo sharing), Last.FM (music listening) and YouTube (video sharing). MySpace launched in 2003 was able to grow rapidly by alienating of Friendster's early adopters. Teenagers got attracted to MySpace in 2004. Rather than rejecting juvenile users, MySpace altered its user policy to allow minors. Later, safety issues plagued MySpace and were implicated in a number of sexual scandals between adults and minors prompting legal action. [44]

Facebook began in early 2004 as a Harvard-only SNS expanded include high school students, professionals inside corporate networks, and, eventually, everyone. Unlike other SNSs, Facebook users were not capable of making their full profiles public to all users [44]. It was the first SNS with the ability for outside developers to build "Applications" to place inside this SNS, which allow users to personalize their profiles and perform other tasks, such as compare music preferences and chart travel histories.

Instagram was launched in October 2010 as a free mobile app. The service rapidly gained popularity, with over 500 million active users till 2014. At present, there are no reliable data regarding to how many people use SNSs, although marketing research indicates that SNSs popularity is growing worldwide.

The number of people who has at least one account in SNSs is increasing yearly. For example; statistics for Facebook shows that the number of active users has been increased immensely from 2008 to 2016. Facebook had 1.71 billion active users monthly as of second quarter of 2016 (Statista 2016). Normally those users are considered as active users who have logged into Facebook during last 30 days. The number of the most recognizable SNSs has settled down as of 2016 (some examples are listed in Table 4.2), although new services with SNS features appear constantly.

Table 4.2 *Social Media Examples*

Multimedia	Entertainment	News	Communication
Photo-sharing: Flickr	Virtual Words: Second life	Social news: Digg, Reddit	Microblogs
Video-sharing: You Tube	Online Gaming: World of War craft	Reviews: Yelp, Eponions	Events: Evite
Audio-sharing: Imeem			Social Networks: Facebook, LinkedIn, MySpace

4.4 Benefits of Social Media

Social Networking sites had penetrated into our everyday life and become an important place for computer mediated interaction [43]. Facebook, Twitter, Instagram and MySpace are renowned examples. Different sorts of operational mode innovations in SNS has resulted in ever growing users.

There is a wide range of benefits associated with the use of SNSs such as media literacy, education, individual identity, self-expression, creativity, building and strengthening social relationships, civic and political participation, self-efficacy and wellbeing.

The use of SNSs can support the development of media literacy. The users can obtain certain technical skills while creating and sharing their content (as they learn to use code to create the profile in MySpace). There is high interest from schools and universities in the potential of SNSs to complement formal education activities. The teenagers value the social opportunities highly for information purposes. Moreover, access to online and virtual learning may appear as more beneficiary and easy than physical education. Evaluations of e-learning strategies have found SNS platforms allow for the extension of learning discussion outside the formal classroom setting, therefore promoting deeper and conceptual learning.

Creative content sharing exercises such as blogs, videos, animations etc. are an important part of young people's communicative exchange. It enables the youth to develop a sense of identity, personal achievement and self-worth in a community. SNS can present young people with a space to work out status, make sense of cultural cues and negotiate public life. [45]

Most evidently it enables the users to get connected and build social relationships. Having positive interpersonal relationships is an essential predictor of wellbeing and can buffer individuals from many of the important stressors that characterize the transition from childhood to adulthood. SNSs facilitate a sense of community, connectedness and belonging. Furthermore, organizations and services are increasingly viewing social networking practices as the next step in user participation in government and community decision making.

Some other common benefits of social networking services are:
- Technical Literacy, i.e., the use of computer and other similar devices
- Important content literacy
- Mobile media literacy
- Creativity
- Individual Identity
- Interpersonal relations

- Building Communities
- Civic Engagements
- Wellbeing of society

Finally, this discussion of the benefits of SNS elucidates the ways in which the online and offline worlds are mutually constituted. If it is to retain significance and be advantageous to the community, our understanding of cyber citizenship should be more holistic, to include and resonate across all of the settings in which we live our lives - be that home, school, work, our local communities or our communities of interest.

4.5 Sharing Gaze on shared images

Image sharing is one of the most important features of a SNS. Shared images can usually be rated and commented by other users. These forms of feedback can be treated as "traditional" in modern SNSs. However, the image owner stays unaware of what was the most attractive on image of the majority of observers, as well as for an individual observer. With graze-tracking devices affordable today and possibly embedded in many devices in the near future, the form of image observation feedback may change radically. An observer's gaze recoded while looking at an image and shared with the image owner could form a feedback as such, not requiring explicitly rating the image or writing a comment, or just supplementing them. The implementation of gaze sharing on images and collection of responses from image owners form the body of the work done in this thesis.

Before the implementation of this idea, a number of Facebook users were asked to share their thoughts on this and what sort of advantages/uses they can think when sharing gaze with people in general. Lots of people find it interesting and came up with number of interesting uses in different fields. Some of the common ideas that were shared by the people are listed next.

Multiplayer Games

It would be interesting to observe the opponent's gaze point while playing a game; especially strategic games or chess. There will be a chance to predict opponent's next move by looking at his gaze pointer.

Education

What if teacher could see the student's gaze point when he/she is solving a task? It could help teachers in understanding behaviour of different students.

Social Networks

It will be interesting to see how people are looking at someone's picture. For example: if Chris posted his picture on Facebook; then he then would be able to get the information on how much time his friend Anna was looking at this picture and what was the most interesting for her.

5. Heat-maps Creation Using Gaze on Shared Images

This subsequent chapter of the thesis describes the study that was conducted. Demographics of the participants, apparatus used, method of the experiment and pilot testing is mentioned in detail.

The analysis of eye gaze data assumes that there is a relation between what we see with our eyes and what we think about. However, a caution should be taken when applying this assumption in studies.

First, depending upon the objective and the context of the study, eye gaze fixations can be interpreted in certain number of different ways. While planning the test, objective of the study must be clear. For example, if the participant is asked just to browse freely a website, then it is possible that the area with higher number of fixations may indicate his interest in that area of the website or it can also mean that the participant have difficulties in comprehension or interpretation of the information found on that specific area. However, if the participant is asked to perform some specific task, larger number of fixations will indicate confusion in recognizing different elements to complete the task.

Secondly, sometimes fixations cannot necessarily be translated into a mindful cognitive process. For example, it is possible for the participant to fixate shortly and miss the presence of an object that is being searched, especially if this object has unfamiliar or unexpected size or shape. This issue can be solved by providing participants with clear instructions and post-test small interview for assessing the participant motivation.

And lastly, it may happen participants will be able to notice the searched objects in the peripheral area, despite its low acuity, but do not fixate them. Thus, it is important that the test should be accompanied by a questionnaire or interview to verify whether the object that was required to be noticed was actually noticed, even though there are no fixations made directly on it.

5.1 Design of the experiment

A simple experiment was conducted to study how people react to the feedback on sharing image expressed as summarized a gaze data collected from all other users who observed this image. Each participant in the study also observed images shared by other participants while being informed that his/her own gaze is recorded for the feedback purposes. Beside the reaction to observing someone else's gaze path, the participants were interviewed on their willingness to share their own gaze. They also were encouraged to suggest other scenarios of gaze sharing, either with friends or anonymous Internet user.

5.2 Participants

In order to run this experiment, we recruited 8 students from the university community. All the participants were familiar with gaze tracking and with each other as well. The demographics of the participants are shown in Table 5.1.

Table 5.1 *Demographics of participants*

Gender	Age group (years)	Image sharing in social media	Vision
Female	40-45	Never	Normal
Male	40-45	Never	Normal
Male	25-30	Weekly	Normal
Male	55-60	Monthly	Corrected normal
Female	45-50	Monthly	Corrected normal
Female	30-35	Monthly	Corrected normal
Male	50-55	Weekly	Normal
Male	35-40	Never	Corrected normal

5.3 Apparatus

Windows 7 PC was used running an application developed specifically for this study. One webpage was developed to run a JavaScript code that displayed stimuli and collected gaze data. Another webpage visualized the collected gaze data.

To stream gaze data from an eye tracker to the webpage, an ETU-Driver software was user. ETU-Driver consists of a COM object which exposes a common API for several eye trackers and has a modular structure. To make gaze data available from a new eye tracker model, a separate DLL module should be developed that translates requests from the ETU-Driver client into call of native tracker functions. This module later can be copied into the ETU-Driver installation folder, thus the rest of the software should be changed.

The ETU-Driver service tool shipped with the software package acts a WebSocket server. It sends gaze data delivered by ETU-Driver to connected clients in JSON format. Pupil size and eye position in the camera view are transmitted along the gaze point coordinated on the computer screen [34]. Tobii Eye-X eye tracker was used a source of gaze point and a 24" screen was used for displaying stimuli.

The stimuli presentation and gaze recording webpage presented a set of image one-by-one automatically. Users were instructed to press a spacebar to proceed to the next image. At the end of a session all data was recorded to a file.

Images with shared gaze displayed as a heat-map were also displayed one-by-one on another webpage. This page also contained a control panel that is shown in Figure 5.1. The buttons in the panel were used to change size, intensity and transparency of the heat maps. "Size" influences the area that is affected by each gaze points when adding "heat". Similarly, "Intensity" affects the "amount of heat" that each gaze points add. "Transparency" regulates the level of heat-map transparency, and therefore the visibility of the original image.
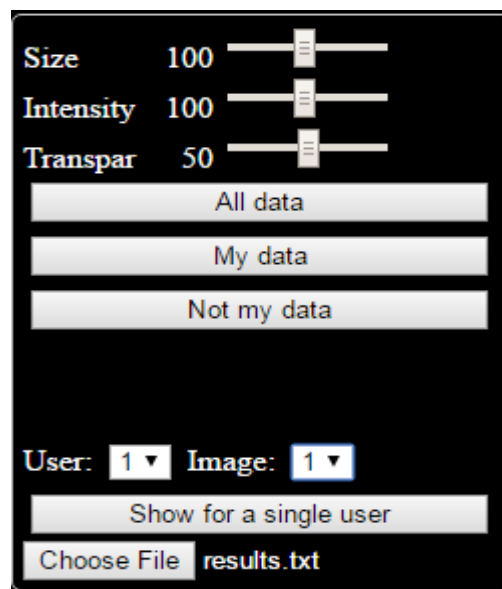
Figure 5.1 *Interface of the experiment*

5.4 Procedure

Few days prior to the experiment, all the participants were requested to share one picture that they already had or would like to share on the social networking site. Participants were asked to fill a small background questionnaire (appendix A) at beginning of the experiment.

The experiment was divided into two parts. In the first part, the participants visit to the lab started with the short description to the participants about the study. The participants were introduced to the experiment equipment and then guided through the eye tracker calibration routine. The participants were seated in front of the computer screen at a distance of about 50-70 cm. After the experimenter started the test, nine images were displayed sequentially (i.e. eight images from participants and one for calibration verification purpose). It was up to the participants to device how much time they need to

observe each image. The participants were instructed to press the space key to stop displaying the current image. The image was shown to them with the heat-map from the gaze data just recorded superimposed. Pressing spacebar once again displayed the next image. This continued until all the images were presented. On average, the experiment duration was about 1-2 minutes per participant.

The second part of the experiment was performed on the next day after data was collected from all participants. On this day, the participants were shown the images they shared before the experiment. First, each participant was shown their own gaze heat-map and then the cumulative heat-map of all other participants on the same image. Participants were asked to share their thoughts about the heat-map made from the data of all other participants, like whether their expectation matched what was shown. In the end, participants were requested to fill another questionnaire. (Appendix B)

5.5 Pilot testing

Prior to the actual experiment, the experiment software was tested several times in pilot tests in order to have more refine values of different design parameters. The most important parameter was accurate calibration because unless system is calibrated accurately, correct data can't be gathered. For this purpose, five users were asked to participate in this pilot test. They were not asked to share their own pictures and also they were not familiar with each other. All the participants were aware of gaze tracking and were using social media. In this pilot testing, each participant was asked to look at some specific point in first image while they were free to look at anywhere in rest of the images. The main results that came from pilot testing are given below in figures.

For example; participant #1 was asked to look at right side of the image for a while. The heat-map produced from this data contains a big red blob, as shown in the Figure 5.2. As the time increases, the size of the red blob increases.

Figure 5.2 *Big Red blob on the right side of the picture validating the fact that participant was gazing at that part of the picture for some time as instructed*

Another participant, unlike the first one, was asked to look at two different parts of the image. As seen in Figure 5.3, there are two red blobs, one is on the right and a much bigger than the other on the left side of the image. There are few very light and small green blob seen between these two red blobs, because the saccade from one corner to another was interrupted by a short fixation as it often happens when making long saccades.

Figure 5.3 Two big red blobs indicating long fixations and marginally visible light stop indicating a very short transition fixation on a long saccade from one corner to another

Heat-maps for rest of the images illustrating image observation patterns from a single participant are shown in Figure 5.4.
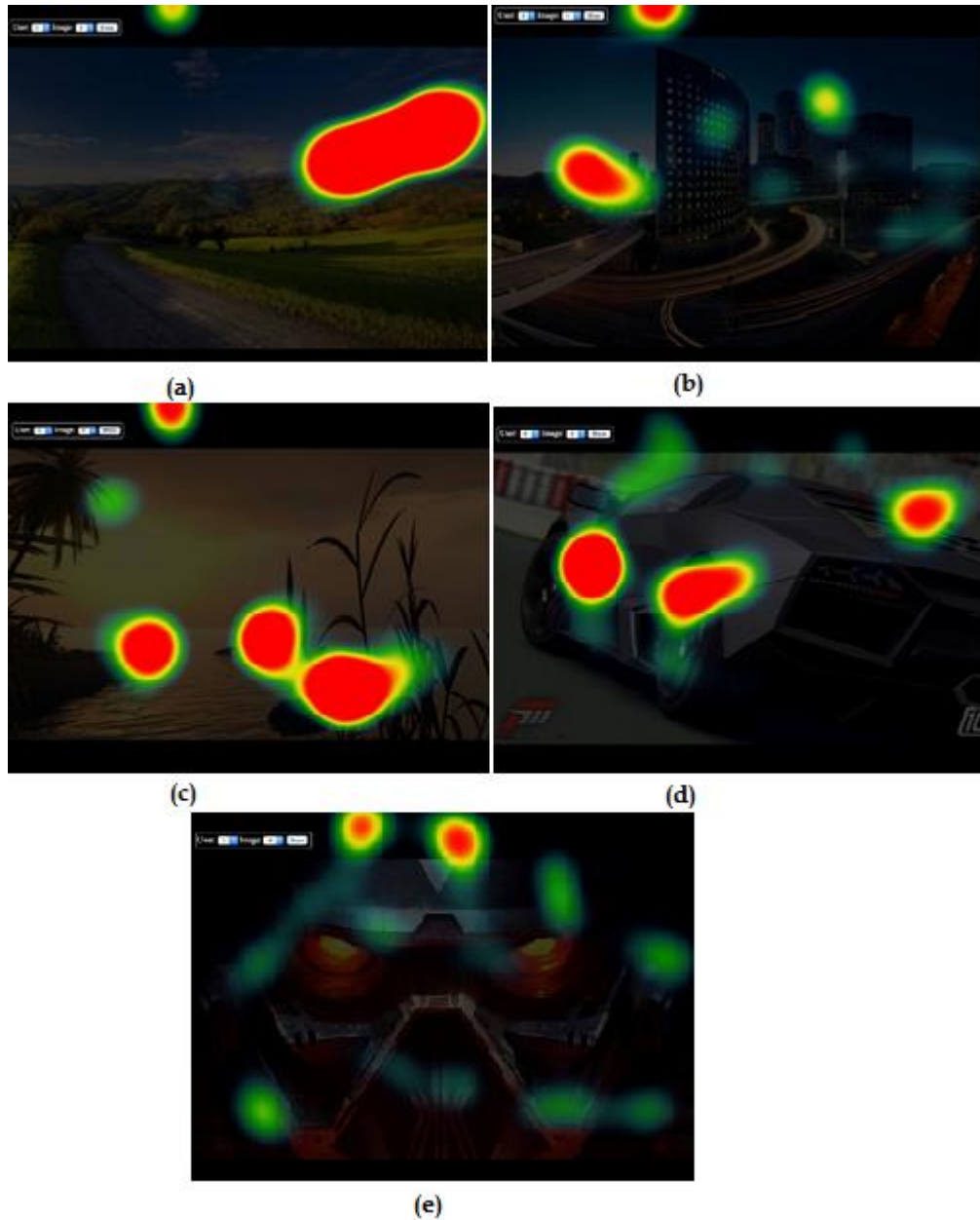
Figure 5.4 *Heat maps of all of the images for the single participant*

For most of the participants the calibration quality was good and was just done once except one participant, which calibrated the device twice. Most of the images in Figure 5.4 were showing heat-maps as expected, except the heat-map on Figure 5.4e where it was very unusual not to have gaze on the eyes. Generally, it is very common to have gaze on eyes on images containing them.

6. Results

This section of the thesis contains the results of the study conducted in order to evaluate the effectiveness of gaze tracking to images on a social networking site. It consists of two parts: first provides the verification of code and the second provides the experimental results. All the participants were able to complete the experiment. There was some issue with one participant calibrating the eye tracker, but finally the experiment was completed quite smoothly.

6.1 Data verification

Validation of the experiment was performed with the help of first image which contains four black dots. User was asked to look at each black dot. In the visualizations the user's gaze on this image appears as big red circles in the corresponding locations. Except one participant, all heat maps were consistent. Figure 6.1(a-h) shows the validation process against each user.
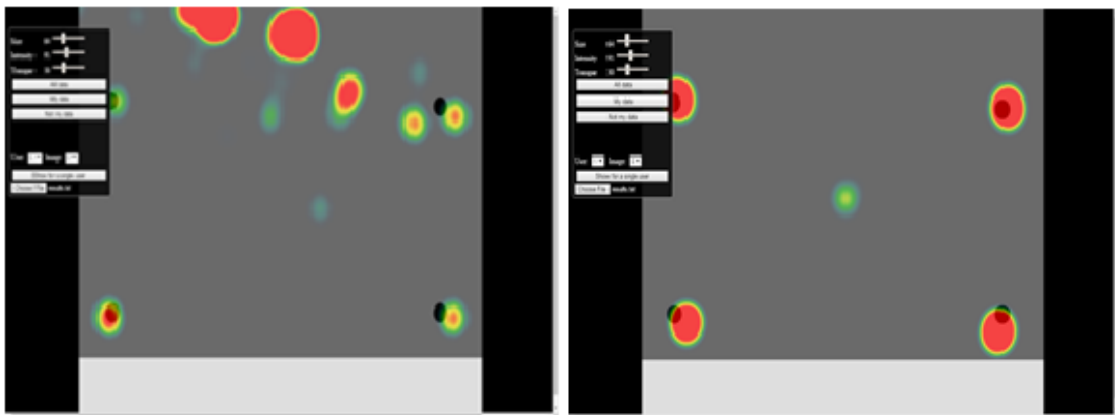
(a) Participant #1

(b) Participant #2
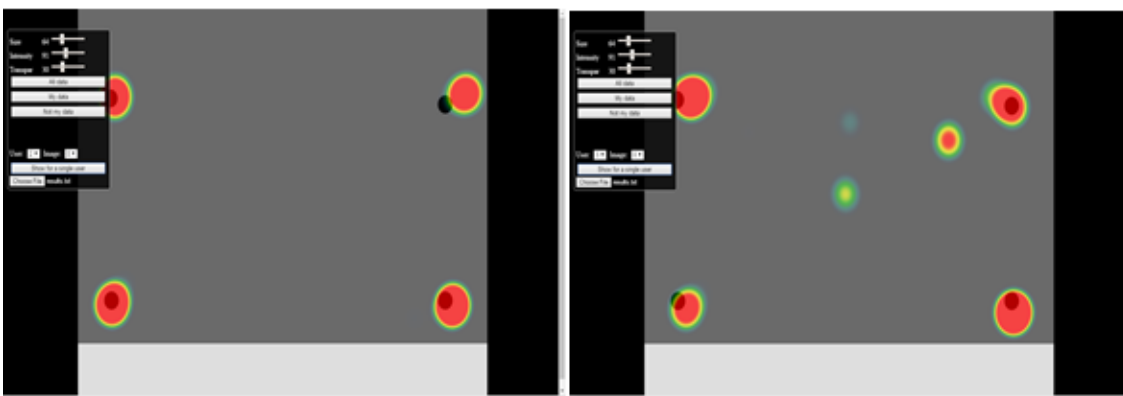
(c) Participant #3

(d) Participant #4

(e) Participant # 5

(f) Participant #6

(g) Participant #7
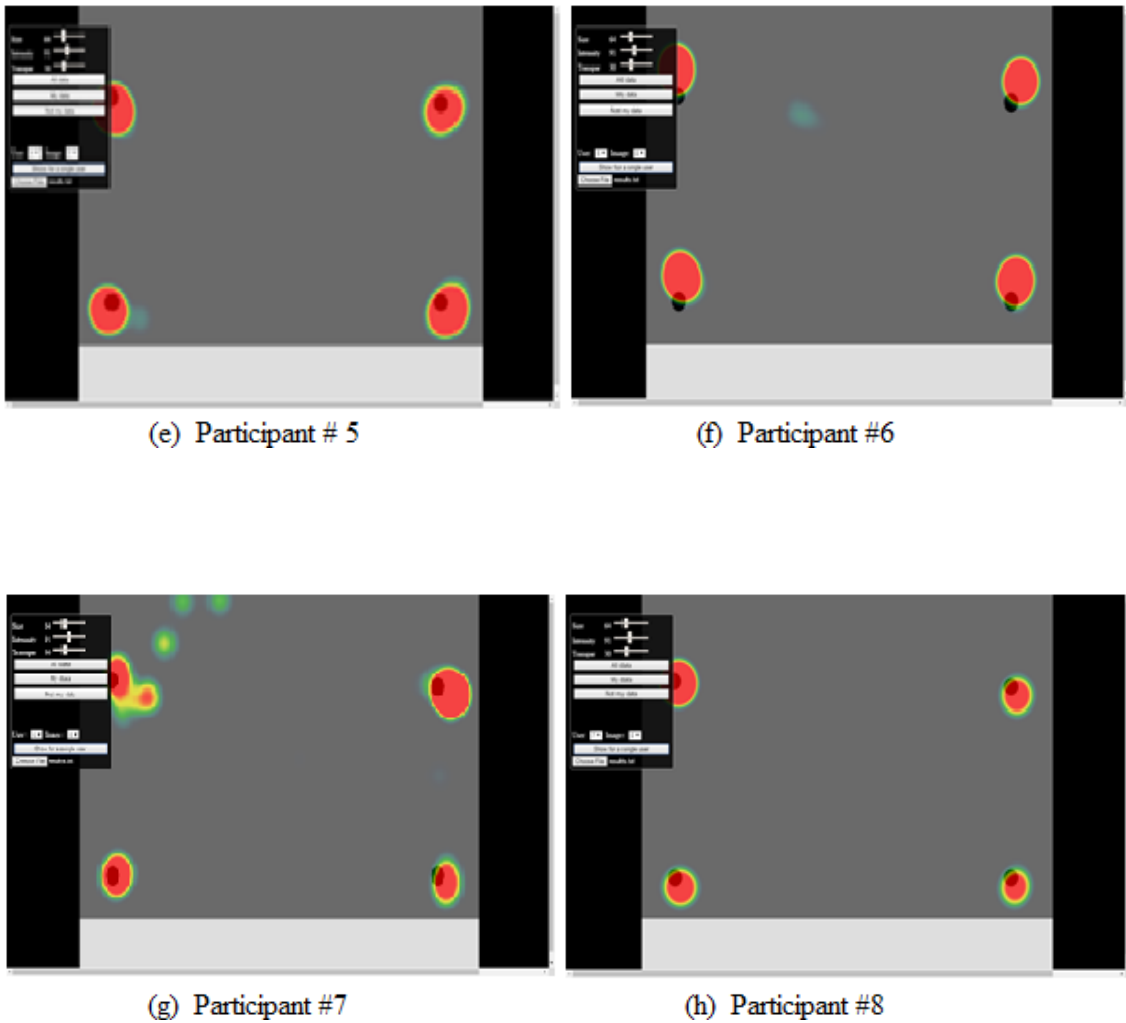
(h) Participant #8

Figure 6.1 *Gaze points of all the participants validating the experiment*

6.2 Experimental Results

After the verification, all the participants went through the standard experiment procedure as mentioned in the previous chapter. Most of the participants produced very different gaze-path patterns. Each participant was shown their own image with the heat map made from their own gaze data, and then with the heat map made from data of all other participants. Results of the participants are given below in Figures 6.2 – 6.9:
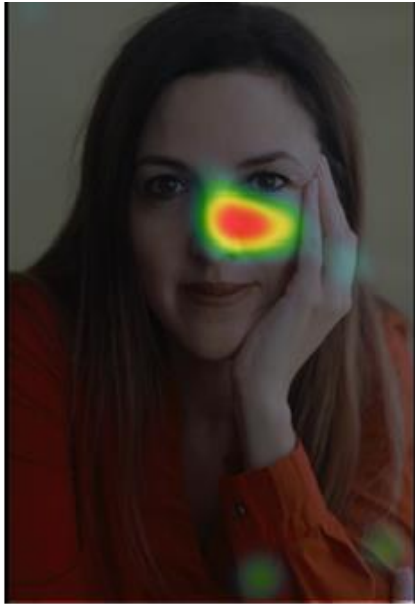
(a) Heat map of participant 1 against image 1   (b) Heat map of all other participants against image 1

Figure 6.2 *Heat maps of participants against image 1*
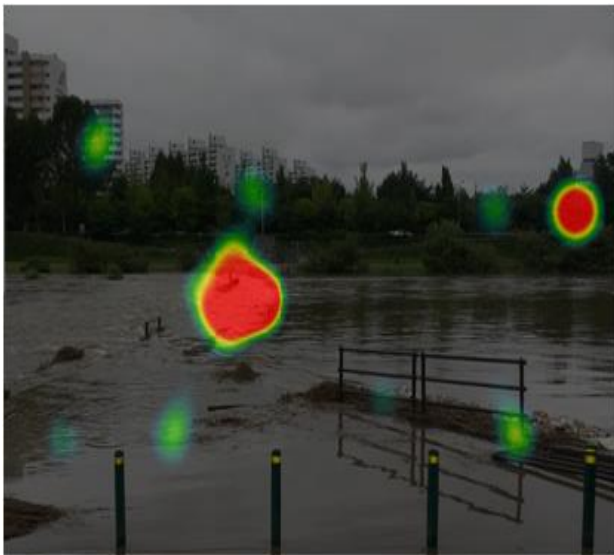
(a) Heat map of participant 2 against image 2   (b)   Heat map of all other participants against image 2
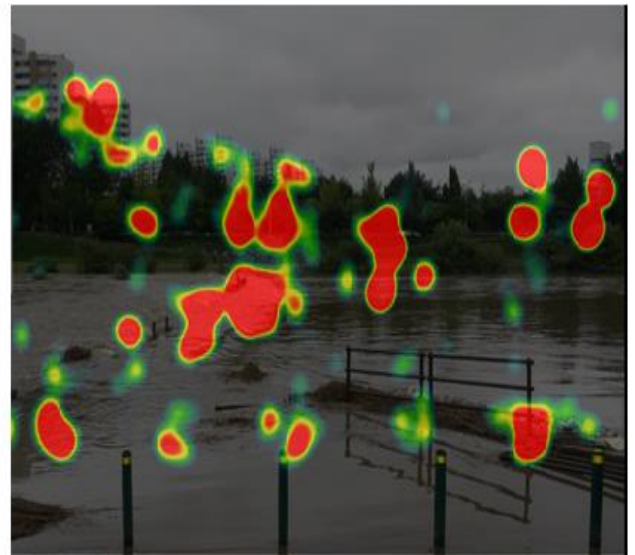
Figure 6.3 *Heat maps of participants against image 2*
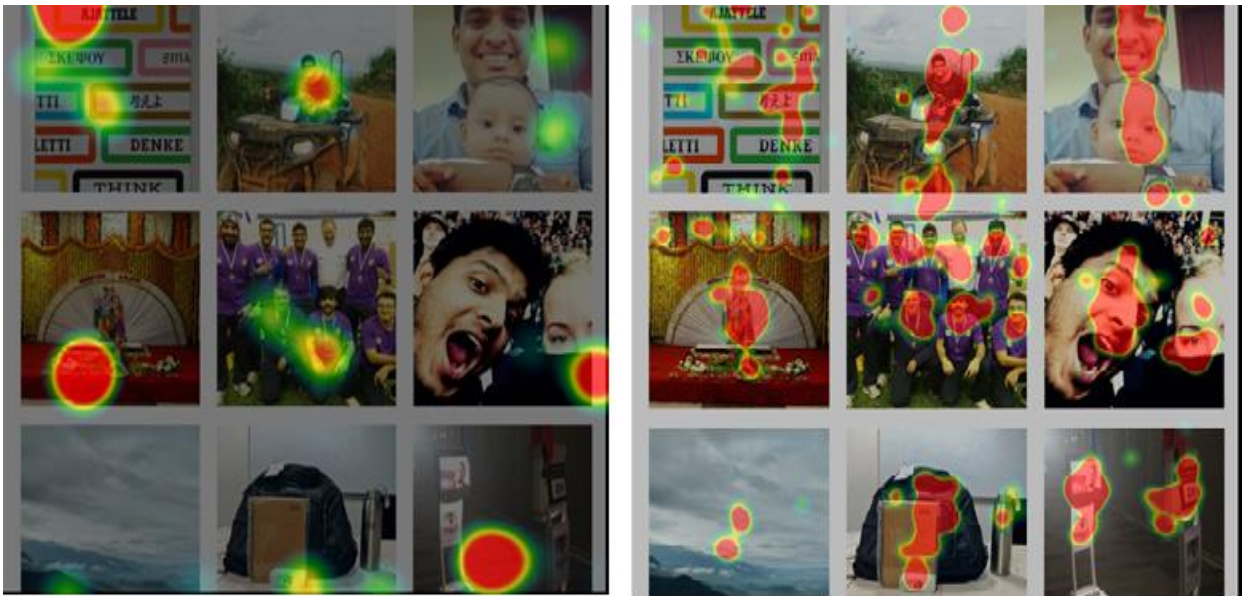
(a) Heat map of participant 3 against image 3

(b) Heat map of other participant against image 3

Figure 6.4 *Heat maps of participants against image 3*
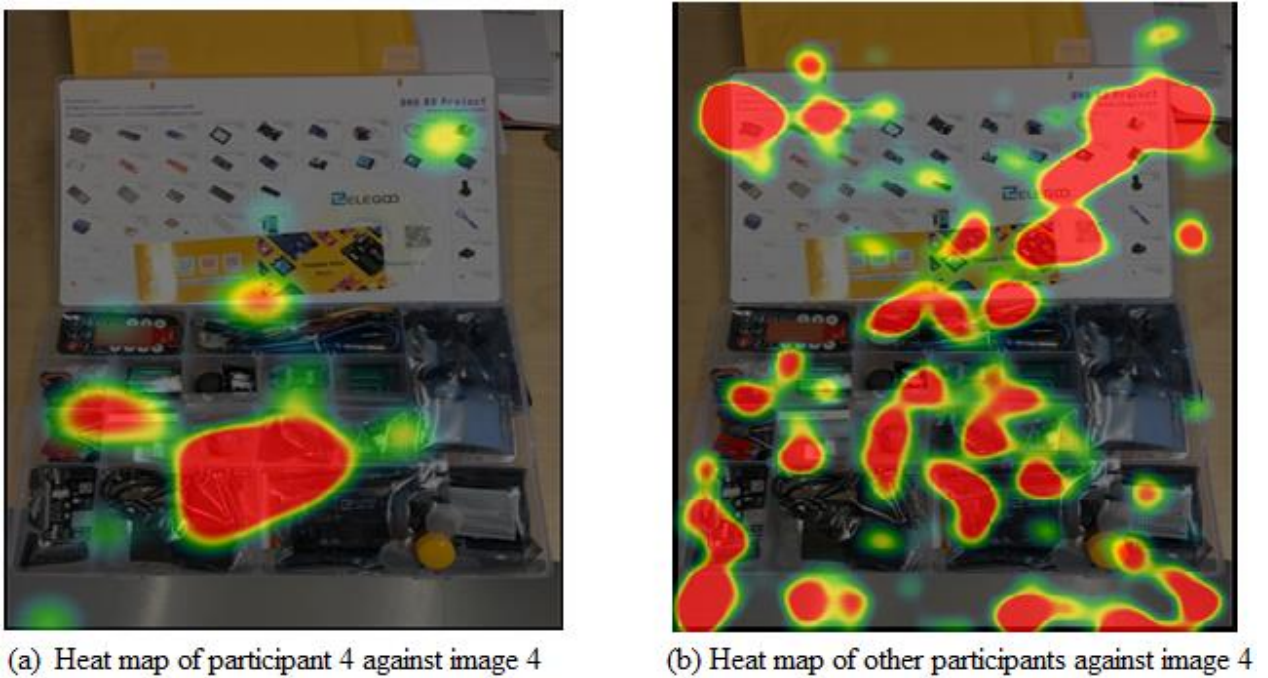
(a) Heat map of participant 4 against image 4

(b) Heat map of other participants against image 4

Figure 6.5 *Heat maps of participants against image 4*
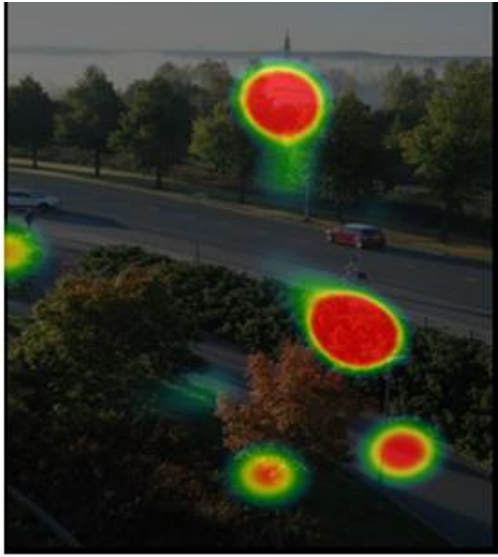
(a) Heat map of participant 5 against image 5
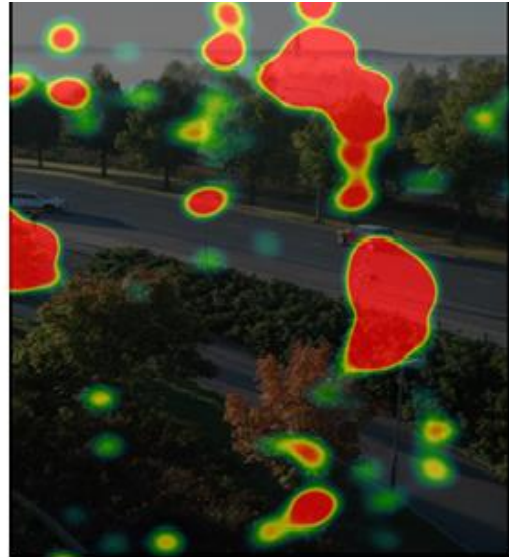
(b) Heat map of other participants against image 5

Figure 6.6 *Heat maps of participants against image 5*

(a) Heat map of participant 6 against image 6
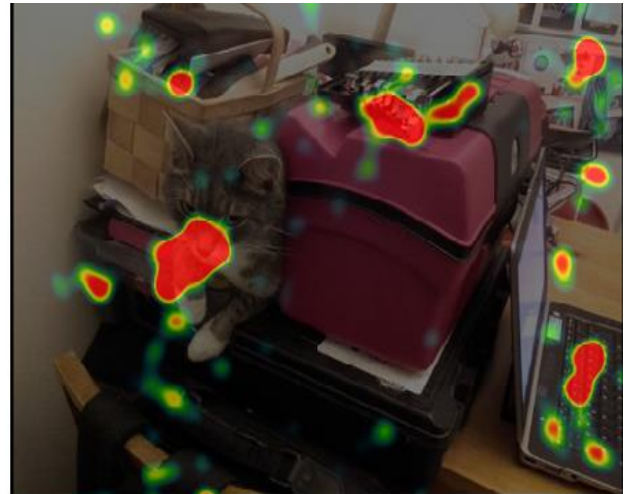
(b) Heat map of all other participants against image 6

Figure 6.7 *Heat maps of participants against image 6*
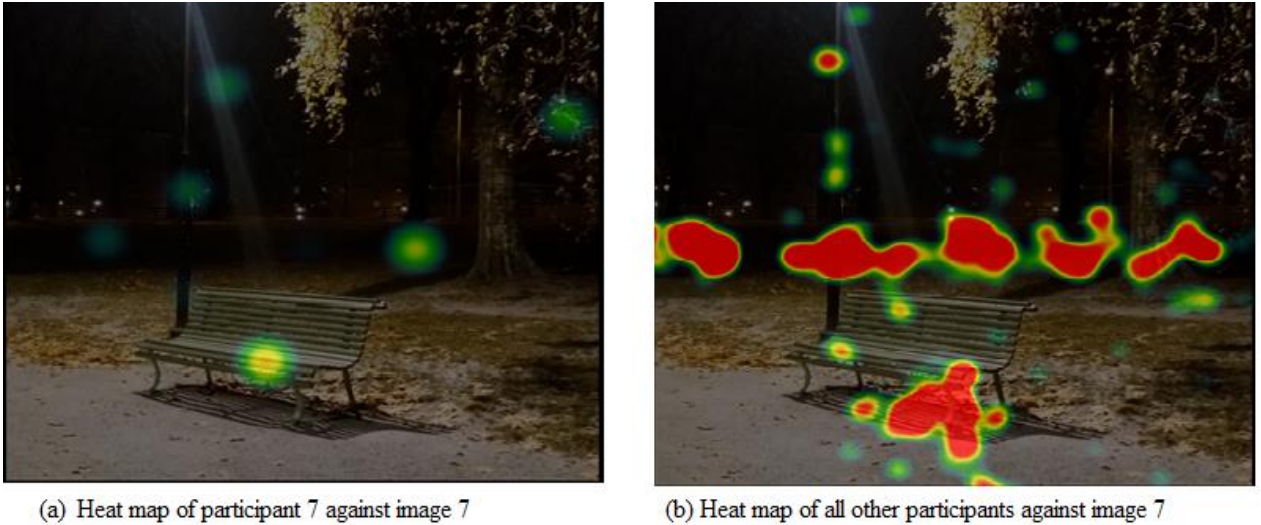
Figure 6.8 *Heat maps of participants against image 7*
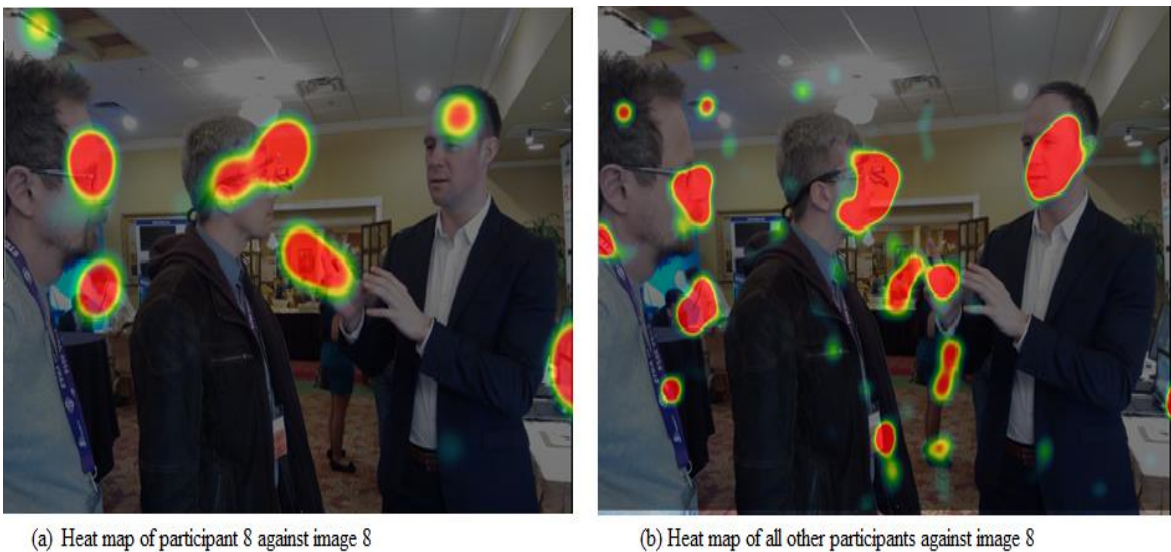
Figure 6.9 *Heat maps of participants against image 8*

6.3 Feedback from Participants

A post-experiment questionnaire was shared with the participants in which they were asked questions related to sharing gaze in social networking sites. These include:

Q1) I'd be interested in being aware of how my friends in SN are observing the images I share with them.

Q2) I'd be interested in being aware of how others/strangers are observing the images I publish.

Q3) I'd be interested in looking at gaze data visualization on my friends' images.

The answer scales consisted of 9 rates ranged from -4 ("Not at all") to +4 ("very much").

Statistical tests were used to determine the significance of differences in observed data between two or more groups or subjects or conditions. Such tests evaluate the probability p of the null hypothesis (the hypothesis that there is no difference in the observed data between the groups) being true. The t-test is a type of inferential statistical test used in cases where few samples of data distributed normally available from two groups. The probability threshold (significance level) is usually set to 0.05: if p value is higher than this threshold, then the difference in data means is considered as being not significant (null-hypothesis is true), otherwise the difference reliable.

In this study participants were divided into two groups. One group consisted of participants who share images on social networking sites daily, weekly or monthly. The other group was made of the participants who never share their images on social networking sites. T-test was applied to compare the differences in answers between these two groups.

Table 6.1(a). Questionnaire results (Q1-Q3)

Q1		Q2		Q3	
Sharing	**Non-sharing**	**Sharing**	**Non-sharing**	**Sharing**	**Non-sharing**
-1	1	-2	0	-1	3
3	3	1	2	2	1
1	4	0	4	2	2
3		3		2	
3		3		3	
Avg-value=1.8	Avg-value=2.6	Avg-value=1	Avg-value=2	Avg-value=1.6	Avg-value=2
P-value = 0.5127		**P- value = 0.535**		**P-value= 0.702**	

Table 6.1(b) shows the average values for rest of the questions (appendix B) for both groups.

Table 6.1(b). Questionnaire results (Q4-Q11)

Questions	Average Values	
	Sharing	Non-sharing
Q4	1	2
Q5	0.2	2.3
Q6	-0.2	1
Q7	1.8	1.3
Q8	1.6	2
Q9	1.4	1.6
Q10	2.8	3.6
Q11	-2.4	-1
	P-value = 0.275	

7. Discussion

Heat maps (figures 6.2-9) shows that there is a difference between heat maps of image owner and rest of the people i.e. heat maps of users owing the images are more centric while other heat maps are spread almost whole images. Secondly, we can see that there are much bigger red blobs which shows people had been concentrating more on some things in the images as compare to the owner himself.

Normally in any statistical test, the critical value of P that is used is 0.05. If P-value from the TTest is less than 0.05, normally the null hypothesis is rejected while if the value is greater than 0.05, the null hypothesis is accepted. We can see that in tables 6.1(a) (b), P values are larger than 0.05. This shows that there is no statistically difference between the two samples in both the tables.

In the current study, participants were asked to share their thoughts about the ability to inspect heat maps produced from gaze data of all people viewed the image their shared. The most interesting question was whether the participants found useful to inspect whether others noticed things in their images that were expected to notice. The answer was quite interesting which are stated below.

Most of the participants were interested in being aware of how their friends or strangers in social networking sites are observing the images they share. Some of them were also interested in looking at gaze data visualization on the image shared by their friends. Few concerns were expressed by some participants when they were asked about sharing of their gaze data with social networking site friends or strangers given it is anonymized.

A mixed response was observed when participants were asked about making the gaze data visualization on their images accessible to others. According to participants, sharing gaze can be very useful when looking at text and in games, while not many of the participants think that sharing gaze can be useful in videos.

Participants made the consensus that sharing their gaze with others can also help them in achieving better experience in using eye gaze controlled communication and computing. Almost all the participants were willing to pay 100 euros extra for a laptop with built in accurate and robust eye tracker.

Although most of the participants were not interested in sharing their gaze with advertisement companies, some very interesting notes were expressed. One participant wrote that advertising companies already know most of the things about him from the clicks. However, he can have control over those clicks and interactions. But it is very difficult to control movement of your eyes. Gaze data would give lots of information that

one would consider to be more accurate than clicks. Another participant wrote that anything that is shared by users on social networking sites is bound to be public at some point. So according to him, he would be very reluctant to share his gaze points on social networks.

The future prospects of implementing eye gaze tracking methods in social media can be very interesting. For example, while playing a game (e.g. chess), it may get very exciting for spectators if the eye gaze points of both the opponents are visible. Keeping an eye on these eye gaze points, one can make better prediction of his opponent's next move in the game. Secondly, besides social media; eye gaze tracking can also be used by teachers to keep an eye on the student while he/she is solving a task.

Further, our study has its limitation i.e. our study was conducted in indoor conditions that were quite stable. No outside interruptions which can cause attention shift were considered. There can be lots of interruptions in the real life which can shift the attention of the participants to any other object in surrounding while looking at an image. This can cause false results. This attention shift should be explored further so that trade-off effects during studying different users can be understand.

8. Conclusion and Future work

The focus of this thesis was to find out whether gaze tracking technology can be acceptable for people to become a part of social networking sites. The study was conducted where people were shown pictures from their colleagues and their eye gaze data was recorded. The results about the time spend on looking at different pictures showed variations depending upon each individual person. This shows that gaze behaviours highly depend upon different personalities. As the data was verified by a short verification procedure; these results can be considered as reliable.

The continuous improvement of eye-tracking methods and wide spread in certain areas has helped technology to become more affordable and less invasive. Now gaze tracking is not limited to be used by only few group of users or some special research laboratories, but rather it is actively being used in different types of disciplines. In future, if the gaze-based techniques will be implemented in social networking sites; privacy issues will become dominant: how much of user eye gaze data should be saved?

Recently there has been lot of work going on wearable computing. It is expectable that eventually gaze tracking devices will appear as tiny gadgets located on a head, thus making gaze tracking data available to share on social networking sites even easier and at any time, just like photography became available at any moment with the spread on smart phones. Moreover, with a large amount of users with gaze tracking enabled constantly an interaction with real object could also be used widely. Such interaction most likely will require other input modality in addition to gaze tracking.

In summary, the results that are presented here show that gaze tracking in social networking looks like a promising direction in the consumer technology development. To conclude, I am hopeful that this study will contribute to the research in gaze shared in virtual public places that is just beginning to settle down.

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Appendix A: Background information

Age:

Gender

☐ Female
☐ Male

My eyesight is

☐ Normal
☐ Corrected normal
☐ I have glasses or contact lenses, but I will not wear them during the test

I'm sharing image/photos in a social network

☐ Daily
☐ Weekly
☐ Monthly
☐ Not every month
☐ Never, as I use social networks for other tasks
☐ Never, as I'm not using social networks

Appendix B: Post Experiment Questionnaire

I'd be interested in being aware of how my friends in SN are observing the images I share with them

not at all   -4   -3   -2   -1   0   +1   +2   +3   +4   very much

I'd be interested in being aware of how others/strangers are observing the images I publish

not at all   -4   -3   -2   -1   0   +1   +2   +3   +4   very much

I'd be interested in looking at gaze data visualization on my friends' images

not at all   -4   -3   -2   -1   0   +1   +2   +3   +4   very much

I do not concern of sharing my gaze data with my SN friends given it is anonymized

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I do not concern of sharing my gaze data with anyone in the internet given it is anonymized

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I could make the gaze data visualization on images I shared accessible to others (if the permission is given)

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I think that the current gaze data visualization could be improved or replaced with some other that gives deeper insight in how people are viewing my images

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

_____

_____

_____

_____

_____

I can image how sharing my gaze with others (friends, colleagues) could also be useful when I am / my friends are looking at

text

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

videos

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

games

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I can image how sharing my gaze with others (friends, colleagues) can help me in completing the tasks I often do online, or archiving better experience in using certain apps I use

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

_____

_____

_____

_____

I'd pay 100 euros extra for a laptop with accurate and robust eye tracker built in if I see clear benefits having it for

       my work/education

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

       my entertainment

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I think that privacy issues would be very important when using eye-tracking devices daily

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

I could share my gaze with advertisement companies

disagree   -4   -3   -2   -1   0   +1   +2   +3   +4   agree

Other notes:

_____

_____

_____

_____

_____

_____

Appendix C: HTML and JAVA Script code

```html
<!DOCTYPE HTML>
<html>
<head>
<title>Gaze tracking with ETU-Driver over WebSocket: heatmaps</title>
<script type="text/javascript" src="libs/jquery-2.0.3.min.js"></script>
<script type="text/javascript" src="libs/html5slider.js"></script>
<script type="text/javascript" src="libs/webgl-heatmap.js"></script>
<script type="text/javascript" src="libs/etudriver.js"></script>
<script type="text/javascript" src="heatmap.js"></script>
<link rel="stylesheet" type="text/css" href="heatmap.css">
</head>
<body>
<div id="image1" class="image invisible"></div>
<div id="image2" class="image invisible"></div>
<canvas id="heatmap"></canvas>
<div class="controls">
<div id="imageStatus">Showing No Image</div>
<div id="heatmap-size">
<label>Size <span></span></label><input style="width:80px" type="range" min="1"
      max="300" value="200"></input>
</div>
<div id="heatmap-intensity">
<label>Intensity <span></span></label><input style="width:80px" type="range"
      min="1" max="200" value="30"></input>
</div>
<input id="showImageWithHeatMap" type="button" class="hidden" value="Show
      Image With Heat Map">
</div>
</body>
</html>
```

```javascript
var allowTracking = true;

$(function (){

  // Interface
  var images = [$('#image1'), $('#image2')];
  var canvas = $('#heatmap');
  var controls = $('#controls');
  var imgIdx = -1;
  var debug = false;
  var imgIndex = -1;
  var userId = 0;
  var heatMapData = [];


  var showImageWithHeatMap = $("#showImageWithHeatMap");
  var imageStatus = $("#imageStatus");



  heatMapData[userId] = [];

  // Show image with heat map button - click handler
  showImageWithHeatMap.click(function () {
    images[0].toggleClass('invisible');
  });

  var loadNewImage = function (elem) {
    if (imgIndex < maxImages) {
      imgIndex++;
    }
    else {
      console.log("User changed");
      userId++;
      imgIndex = 0;
      heatMapData[userId] = [];
    }

    heatMapData[userId][imgIndex] = {x:[],y:[],size:[],intensity:[]};

    console.log('Showing image '+imgIndex+" for user" + userId);
```

```
   elem.css({backgroundImage: 'url(img/' + imgIndex + '.jpg)'});
   imageStatus.html('Showing image '+ imgIndex +'<br/>');


};


try {
   var heatmap = createWebGLHeatmap({canvas: canvas[0]});
}
catch(error) {
   $('<div class="error"></div>').text(error).appendTo('body');
   return;
}


// Heatmap


var setupSlider = function(name, onChange){
   var input = $(name).find('input');
   var span = $(name).find('span');
   input.change(function(){
      var value = parseInt(input.val(), 10);
      span.text(value);
      onChange(value);
   });
   var startValue = parseInt(input.val(), 10);
   span.text(startValue);
   return startValue;
}


var count = 1;
var size = setupSlider('#heatmap-size', function (value) {size = value;});
var intensity = setupSlider('#heatmap-intensity', function (value) {intensity =
   value;});
var spread = 0;
var decay = 0;


if (debug) {
   var raf = (
      window.requestAnimationFrame ||
      window.mozRequestAnimationFrame ||
```

```
          window.webkitRequestAnimationFrame ||
          window.oRequestAnimationFrame
    );
    var update = function(){
       heatmap.update(); // adds the buffered points
       heatmap.display(); // draws the heatmap to the canvas
       raf(update);
    };
    raf(update);


    canvas.removeClass('hidden');
}


heatmap.adjustSize();
//loadNewImage(images[0]);


// Tracking
etudriver.init({
    panel: {
       show: true
    },
    pointer: {
       show: false
    }
}, {
    state: function (state) {
       if (state.isStopped) {
          if (!debug)  {
             canvas.removeClass('hidden');
             controls.removeClass('hidden');


             heatmap.adjustSize();
             heatmap.update();
             heatmap.display();
             //heatMapData[userId][imgIndex] = heatmap;


             console.log(heatMapData);
             images[0].addClass('invisible');
             showImageWithHeatMap.removeClass('hidden');
```

```
        if (imgIndex === maxImages) {
            var msg = 'Participant ' + (userId + 1) + ' finished. Thank you!';
            if ((userId + 1) === maxUsers) {
                localStorage.setItem("heatMapWidth",canvas.width());
                localStorage.setItem("heatMapHeight",canvas.height());
                localStorage.setItem("heatMapData",JSON.stringify(heatMapData));
                saveToFile( JSON.stringify(heatMapData) );
                msg += '\n\nAll participants finished';
            }

            alert(msg);
        }
    }
    //loadNewImage(images[1 - imgIdx])
} else if (state.isTracking) {
    heatmap.clear();
    // Save heatmap in local storage

    if (!debug)  {
        canvas.addClass('hidden');
        controls.addClass('hidden');
    }
    /*if (imgIdx < 0) {
        imgIdx = 0;
    } else {
        images[imgIdx].addClass('invisible');
        imgIdx = 1 - imgIdx;
    }*/
    loadNewImage(images[0]);
    images[0].removeClass('invisible');
    showImageWithHeatMap.addClass('hidden');
}
},

sample: function (ts, x, y, pupil, ec) {
    heatmap.addPoint(x, y, size, intensity/1000);
    heatMapData[userId][imgIndex]['x'].push(x);
    heatMapData[userId][imgIndex]['y'].push(y);
    heatMapData[userId][imgIndex]['size'].push(size);
```

```
      heatMapData[userId][imgIndex]['intensity'].push(intensity/1000);
    }
  });


  function saveToFile (data) {
    var blob = new Blob([data], {type: 'text/plain'});

    var downloadLink = document.createElement('a');
    downloadLink.download = 'results.txt';
    downloadLink.innerHTML = 'Download File';

    var URL = window.URL || window.webkitURL;
    downloadLink.href = URL.createObjectURL( blob );
    downloadLink.onclick = function(event) { // self-destrly
      document.body.removeChild(event.target);
    };
    downloadLink.style.display = 'none';
    document.body.appendChild( downloadLink );

    downloadLink.click();
  };
});
```