User Expectations of Everyday Gaze Interaction on Smartglasses

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ABSTRACT

Gaze tracking technology is increasingly seen as a viable and practical input modality in a variety of everyday contexts, such as interacting with computers, mobile devices, public displays and wearables (e.g. smartglasses). We conducted an exploratory study consisting of six focus group sessions to understand people's expectations towards everyday gaze interaction on smartglasses. Our results provide novel insights into the role of use-context and social conventions regarding gaze behavior in acceptance of gaze interaction, various social and personal issues that need to be considered while designing gaze-based applications and user preferences of various gaze-based interaction techniques. Our results have many practical design implications and serve towards human-centric design and development of everyday gaze interaction technologies.

Author Keywords

Everyday gaze interaction; gaze tracking; head-mounted displays; interactive eyewear;

ACM Classification Keywords

I.3.6 Methodology and Techniques: Interaction techniques.

INTRODUCTION

Gaze-based human-computer interaction has been available for decades. However, until recently its use has been limited to a desktop-based assistive technology catering for motor-disabled user groups. Recent advancements in both software and hardware technology have made gaze-tracking cheaper, more accurate and ergonomic to use. The technology is increasingly seen as a viable and practical input modality for able-bodied users in a variety of everyday contexts such as interacting with distant displays [30,33], mobile phones [16] and wearables such as smartwatches [2] and smartglasses [18].

Previous studies on gaze interaction targeting able-bodied users have mainly focused on the development of enabling technologies (e.g. developing gaze tracking sensors and algorithms to be used in various devices) [14,15] and experimental evaluations of specific interaction techniques and applications [9,16,30,33]. E.g., Vidal et al. [33] studied spontaneous smooth-pursuit gaze interaction on public displays and report the usability of the technique based on success of the interaction and other time-based measures. Similarly, Stellmach and Dachselt [30] studied the combination of gaze and touch to interact with computers and report both qualitative and quantitative findings. One should note that, all these insights are specific to the interaction technique in question and the context in which the study was conducted.

While very important for technology and research development, such studies provide limited insights into people's holistic perceptions and expectation of the future technology [25]. They do not answer questions like *"What are the users' impressions about an environment where gaze interaction is ubiquitous?", "In what contexts would users prefer to use gaze interaction if the technology was perfect?", "In what contexts would such a technology not be acceptable?"* and *"What are the social and personal implications of everyday use of this technology?"*. The ideal research method to answer these questions would be to conduct observational studies of how people use gaze tracking technologies in everyday scenarios. However, such studies are difficult to conduct now because gaze tracking technology still requires further research and development to work seamlessly in all the contexts and environments [5].

Another promising approach to get insights regarding a future technology, is to enquire about user's expectations of using the technology [25]. Olsson [25] notes that knowing people's technology expectations helps us to understand how a technology should function in varying contexts, providing both general and specific insights to channel its design and development. In this paper, we present a study that aims to

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understand the expectations, needs and concerns of future users of gaze-tracking technology.

While there are many potential form-factors that a future gaze-tracking capable device could take (e.g. displays with gaze-tracking sensors, smart contact lenses, smartglasses), we chose smartglasses as the platform for investigation. Within the scope of this study, we define smartglasses as eyewear computers with gaze-tracking capability and a binocular see-through display that enables augmenting virtual content on the real-world. Smartglasses are gaining popularity with the advent of commercial devices like Google Glass and Microsoft HoloLens. Gaze tracking is an input technology with large potential in such devices [5]. Unlike other form factors, smartglasses enable a use case in which gaze is tracked continuously and used in varied contexts, where people use gaze to interact with different objects in the environment, instead of confining the interaction to a display. Selecting smartglasses as the platform in our study allowed us to focus on a single form-factor, while broadening the investigation to a variety of use-context, providing richer understanding about suitability and acceptability of gaze interaction.

We conducted six focus group sessions with heterogeneous participant groups, using scenarios of gaze-tracking smartglasses as probing materials to enquire users' expectations. Our focus was to understand if the context of use (individual/social, public/private, indoor/outdoor) has an influence on the acceptability of the technology and to elicit specific needs and concerns of the users regarding the use of gaze interaction on smartglasses.

The rest of this paper is structured as follows. We begin by reviewing relevant related work. Then, we describe our study and the five scenarios for gaze interaction on smartglasses used as the introductory material in the focus group. Next, we report the results of our focus group study followed by discussion and conclusions.

RELATED WORK

Gaze-based Interaction techniques

There are multiple ways of using gaze in human-computer interaction. Gaze can be used as implicit input, where the system identifies user's interests based on the gaze pattern and modifies the system behavior accordingly. Alternately, gaze can also be used to provide explicit commands. There are three common ways of explicitly using gaze: dwell-time based interaction, gaze gestures and smooth-pursuit based interactions. Dwell-time based interaction requires the user to stare at items on a screen or in the real-world for a pre-defined time to select them. Gaze gestures are predefined eye movements that map to some specific user command [8]. Smooth pursuit-based interaction relies on correlation between trajectory of eye movement and on-screen object [33]. Gaze gestures and smooth-pursuit based interactions are known to be less sensitive to tracking inaccuracies and suitable for mobile gaze interaction.

Gaze Interaction on Smartglasses

Lee et al. [18] developed an augmented reality annotation system, by integrating an optical see-through head-mounted display device with a gaze tracker. The user could receive augmented information of real-world objects on their display, by selecting the object using gaze. They used a two-stage selection process using dwell and half-blink to avoid accidental invocation of actions. Baldauf et al. [3] studied the use of gaze-input and audio output for retrieving annotated digital information from the surroundings. In our study, we use smartglasses as the platform to further investigate users' expectation towards gaze interaction.

Challenges to Gaze Interaction in the Wild

The Midas-Touch problem (distinguishing eye movement for interaction from normal eye movement) and reduced gaze data quality are two of the classic problems in gaze-based interaction [21]. Bulling and Gellersen [5] note that for wearable trackers, the tracking accuracy is further reduced due to calibration drift during operation induced by mobility. Many different approaches are proposed to improve tracking quality using re-calibration procedures hidden from the user based on task characteristics [1] or visual saliency [31]. Another challenge in mobile video-based gaze tracking is the battery consumption. Most wearable trackers only work for a limited duration of 2-4 hours [5]. This has led research in the direction of light-weight eye movement measurement techniques based on electrooculography (EOG).

Many technical and interaction-level challenges still exist in the vision of ubiquitous gaze-based interaction. Our study complements the previous work in this area and aims to look at everyday gaze interaction, not from a technological perspective, but by enquiring the expectations and needs of potential users of this promising technology.

User Expectation and User Experience

Hassenzahl and Tractinsky [10] define user experience as *"consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system and the context within which the interaction occurs."* This definition emphasizes the role of temporality and context on experience. Michalco et al. [23] notes that people form expectations of an interactive product even before using it and these expectations influence their attitude towards the product. McCarthy and Wright [22] note that only when experience meets or exceeds the expectation, users identify positively with the experience. Expectation disconfirmation is a strong factor in the user's experience with the product.

There is wealth of literature that confirms the role of user expectation in shaping user experience. Gaze interaction is a promising future technology for the consumer market. In our study, we aim to understand and reflect the expectations of the potential users of this technology to further channel the research, design and development. In the following section, we explain the focus group study we conducted.

FOCUS GROUP STUDY

We conducted six exploratory focus group sessions with heterogeneous groups of participants. Focus groups were selected as the data collection method because it is suitable for early exploratory studies providing concentrated amounts of data on the specific topic of interest efficiently. Focus group sessions followed a scenario-driven approach. We created five scenarios presenting an "ideal-world" narration of a future with gaze-tracking smartglasses, which was used as probing material in the focus groups. The scenarios provided the participants a common ground to reflect upon their needs, preferences and expectations, without giving too much detail about the technology or the interactions. Each focus group session had 3-4 participants and lasted approximately 2 hours.

Five Scenarios

There were many potential ways of designing the scenarios, e.g. deriving it from mobile phone usage trends or surveying studies on applications of smartglasses. Our scenarios were mostly inspired from previous work on mobile gaze-based interaction, covered a variety of contexts of use and were all potential smartglasses applications. The scenarios were developed with the following considerations:

- Mix of indoor/outdoor, individual/social, private/public contexts.
- Mix of different gaze interaction techniques implicit/explicit, gaze gestures/dwell-time based.
- Plausible future real-world use case based on current trends and research.
- Each scenario highlighted a specific advantage of using gaze.

Handsfree interaction

It is the month of December and it has been a harsh winter so far. James is walking to the University of Tampere to attend the morning lecture. He is wearing his smartglasses with gaze-tracking capability. While on his way, James realizes that he had agreed to call Susan. Without taking his hands out of his pockets, James makes a 'Z' gesture with his eyes to launch the contact list. He uses his eyes to browse through the contacts one by one on his glasses and proceeds to call Susan. They decide to meet in the evening for coffee.

This scenario focuses on outdoor usage of the device in an individual context. The scenario further introduces the concept of using gaze gestures for mobile interaction [7]. The scenario was inspired by previous work by Kangas et al. [16].

Private interaction

Laura has decided to go watch the local ice hockey game with her friends. They gather at the city center and wait for others to join them. Laura suddenly notices a notification on her glass display. She quickly looks at the notification to open the message. It is Laura's boyfriend from Germany. The message says: 'It's a beautiful evening, wish you were here with me'. Her face glows and she cannot help but smile. She gazes at the 'Reply' option for a short while and selects a 'Kiss' symbol. She responds to the message with her eyes and then joins her friends in the conversation.

This scenario focuses on outdoor usage of the device in a social context. The scenario was inspired by earlier work on the use of smartglasses to receive and read mobile notifications [19,20] and using gaze to interact with notifications on smartwatches [2].

Implicit interaction

Martin loves to travel and has just arrived in Helsinki. The weather is nice, and the place is full of tourists. Martin likes to explore a new place on his own and decides to take a walking tour of the city. Wearing his smartglasses, Martin walks down the street along the park and sees a beautiful and royal-looking building to his right. Intrigued by the architecture, Martin starts looking at it more carefully. He wishes he knew more about the building. As if they could read his mind, the smartglasses recognize Martin's interest based on the long staring. They then display that the building is the Royal Museum built in 1887. When Martin finishes reading the information, it shows more information and a brief history of the building.

This scenario focuses on outdoor usage of gaze-tracking capable smartglasses in an individual context. This scenario was motivated by two previous studies. First, the work of Qvarfordt et al. [28] on the use of eye gaze to detect user interest and proactively adapt output information in a desktop-based tourist information system. Second, the work by Baldauf et al. [3] on the use of mobile gaze trackers to retrieve georeferenced information for urban exploration.

Unobtrusive interaction

Mark is a student at the University of Tampere. He is a fun-loving person and loves to keep himself engaged. Mark wants to travel Helsinki to meet a friend. He boards a bus and sits next to an elderly person who is sleeping. While looking around, Mark finds out that the bus offers onboard entertainment similar to that in airplanes. It includes entertainment eye glasses with gaze-tracking capability and a display on the glasses. Mark switches on the glass and wears it. Mark can see a menu with options like 'News', 'Music', 'Games' and 'Movies'. Mark realizes that the glass is responding to what he looks at. He swiftly scrolls to the 'Movies' section and selects one of the latest movies from the list with his eyes.

This scenario focuses on indoor usage in a (semi) public social context. The scenario is inspired by the previous work on gaze as attentive interfaces [4] and use of smartglasses for entertainment applications [26]. Unlike the other scenarios, the smartglasses are not a personal device but part of the bus's onboard entertainment system.

Social interaction

Anne is at a business conference. She knows a few of the other participants but not all. She realizes that it's a great networking opportunity. Anne looks at different people around her one by one. Her glass identifies them and displays their name and interests on the display. She slowly changes her gaze from one person to another and soon finds someone with similar business interests. She decides to go say hi and to discuss some ideas. Anne is ecstatic about making the most out of this networking opportunity.

This scenario focuses on the use of the device in an indoor, social context. The scenario is motivated by previous work on using gaze input on smartglasses for networking [29] and using smartglasses as a name-tag application by facially recognizing collocated individuals [32].

Technology Demonstration

We felt it was critical to give participants concrete examples of the potential of the technology before the start of the discussions. We prepared four demonstrations to convey the capabilities of smartglasses with binocular see-through display and gaze-based interaction.

Remote Gaze-Tracking

We used an EyeTribe gaze tracker connected to a Windows 7 tablet for the gaze interaction demonstrations. We developed a messaging application (see Figure 1a), which could be navigated horizontally or vertically by either dwelling at the corresponding red arrows for 750ms, or by using simple two-stroke gaze gestures. The first stroke of the

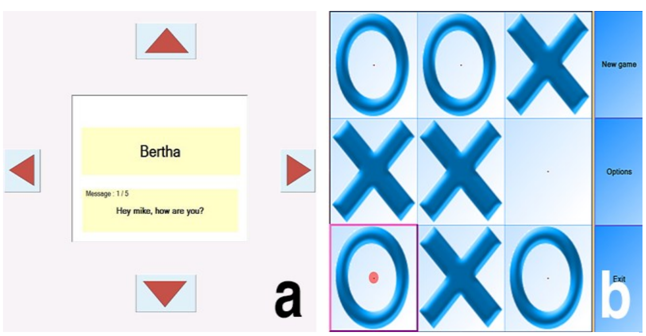

Figure 1. Technology demonstrations: a) messaging application that uses dwell and simple two stroke gaze gestures, and b) dwell-time based TicTacToe game.

gaze gesture started from the center of the box towards any of the four cardinal directions and the second stroke returned the gaze back to the box. The gaze gestures were the same as used by Kangas et al. [16]. We used a time-out of one second between strokes to differentiate between normal eye movements and an intentional gaze gesture. Secondly, we used a gaze controllable version of the TicTacToe board game. In the game, each cell could be selected by dwelling at it for 750ms (see Figure 1b).

Smartglasses Demonstration

We used Epson Moverio BT-100 binocular see-through smartglasses for demonstration. The built-in gallery application showed various 2-D and 3-D images, which could be browsed using the handheld touchpad.

Mobile Gaze Interaction

Further, we developed an application using the Ergoneer Dikablis head-worn monocular gaze tracker. Several visual markers were placed in different parts of the room and the application could recognize when the person was looking at the visual markers and gave auditory feedback (i.e. a short beep) and visual feedback (i.e. color of a corresponding GUI object turned blue) when the user fixated upon the markers for longer than 300ms.

Video Demonstration

We selected a video developed by Nokia Research Center[1], depicting a concept of gaze-based interaction on smartglasses along with other smart technologies. The video was freely available on the internet.

Participants

A total of 23 participants from the local university were recruited using noticeboard advertisements and mailing lists. Participants varied in age (19-52 years, median 24), gender (10 male and 13 female) and study background (e.g. computer science, business, health-science, literature and education). Eight participants had prior experience in gaze interaction as part of previous experiments and two participants had earlier used head-mounted display devices. In the background questionnaire, on a scale of 1 to 7 (where 1 is strongly disagree and 7 is strongly agree), participants stated that personal devices were an important part of their lives (Mean=5.9, StDev=0.92) and that they are interested in trying new technological devices (Mean=5.4, StDev=1.07).

Figure 2. Seating arrangement of participants and moderator (rightmost) during the focus group session

[1] https://www.youtube.com/watch?v=A4pDf7m2UPE

Procedure

The study consisted of four main parts: introduction, technology demonstration, scenario discussion and debriefing.

Introduction

The moderator welcomed all the participants to the focus group discussion. The participants and the moderator were then seated on a couch in a semi-circle around a coffee table (see Figure 2) and then they were asked to introduce themselves. The moderator described the purpose of the study, and then participants signed an informed consent form and completed a short background questionnaire.

Technology Demonstration

Participants took turns trying the remote gaze-tracking demonstration, while the rest watched. Participants sat comfortably on a chair in front of the tablet connected to the EyeTribe gaze tracker that was set up on a table. After a brief 9-point calibration procedure, participants first played 3-5 rounds of the dwell-time based TicTacToe game, followed by the messaging application. The participants used the messaging application using both gaze gestures and dwell-time based input. Next, all participants tried the smartglasses demonstration. The participants were instructed to walk around the room wearing the glasses and asked to imagine wearing such a device while walking in an outdoor environment. This was required to give the participants perception of a real-world mobile scenario. Further, one participant per focus group session demonstrated the mobile gaze interaction system. Again, following a 4-point calibration routine, they were asked to gaze at the different visual markers placed nearby. The other focus group participants watched the demonstration. Finally, the participants viewed the video of gaze-based interaction on smartglasses. This part lasted for approximately 25 minutes.

Scenario Discussion

After a brief general discussion on the demonstrations and the technologies, the five scenario descriptions were handed out to the participants on paper. The moderator then instructed the participants to read a specific scenario. For each scenario, the participants were encouraged to imagine an idealistic world were the different technologies would work seamlessly. The participants discussed their general impression of using gaze in the specific context. This was followed by several open-ended questions relating to the use of gaze interaction on smartglasses. The scenarios were presented to all the focus groups in the same order. After approximately 1 hour, there was a 10-minute coffee break. The discussion for each scenario lasted approximately 15 minutes, for a total of 75 minutes.

Debriefing

Following the scenario discussion, the moderator asked a few closing questions, to elicit any concluding remarks. The moderator then thanked the participants for their participation. Participants were compensated with a movie ticket for their time. The focus-group sessions were video recorded for later analysis.

Analysis

The focus group sessions were first transcribed and later analyzed using affinity diagramming [11]. Four researchers involved in the study individually analyzed the transcripts of three different sessions each, creating 40-50 affinity notes per session. The affinity notes were then hierarchically organized and grouped into common themes, while relevant user quotes were preserved.

RESULTS

In the following sections, we describe our main results. Figure 3 gives an overview of the thematic structure of the focus group data.

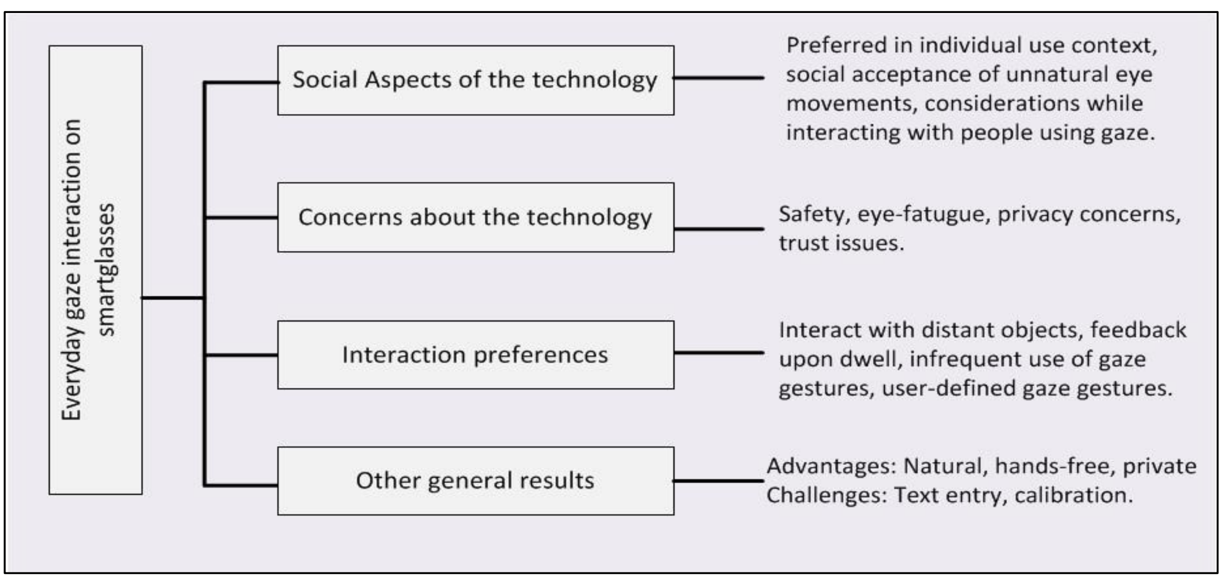

Figure 3. Thematic structure of focus group data

Social Aspects

Context of use had a strong influence on how participants perceived the technology. Participants generally felt positive about the use of gaze interaction on smartglasses in an individual context in both private and public environments, but not in social scenarios. "*I think that this technology is better used when you are alone, not when you are with other people*" (P3). Participants had three distinct concerns about use of such technology in social situations.

Gaze Interaction in the Presence of Onlookers

Participant expressed that watching a collocated person performing unnatural eye movements like gaze gestures in a public environment will be "*noticeable*", "*little weird*" and "*take some getting used to*". Many participants compared it to the *"talking to yourself"* feeling when Bluetooth headsets were launched. *"You might think they are looking at you or making some gestures to you. It is the same, sometimes I think someone is talking to me when they are talking to their headsets."* (P12). Interacting with the device may give the impression that the person is performing the eye movements looking at another person. For the same reason, few participants felt that it would be more comfortable for the user if the glasses are tinted, so that onlookers cannot see the users' eye movements. "*I would use it, if there is some shades or something. So that it is not clear glass" (P21). "It (*tinting*) could help so that people cannot see that you are [*makes sequence of eye movements*]. You are going to be comfortable doing that on the streets (P15)".*

Gaze Interaction on People

Participants also felt strongly about using gaze to interact with collocated people, i.e. dwelling at people to get more information about them (as in the *conference* scenario) or something worn by them (e.g. dwelling at the shirt or shoe to know its brand). Participants felt that even though it is natural to glance at people in an environment, it is disturbing to look at people for a longer duration. *"It is quite disturbing to stare at some people, especially strangers. I think it is invasive in general."* (P20). *"People are not products. I am not interested in using it on people"* (P3). Though some participants felt such interactions may be acceptable in a controlled environment, where the user already knows about the purpose of the technology and knows what the "*staring*" means.

Another interesting difference emerged about the visualization of information when they were related to a person and an object or product. In case of interacting with an object using gaze, the participants preferred the extra information be shown on display and visually linked to the object (e.g. by placing the information above the object). However, while interacting with people (or clothes and accessories worn by them), participants suggested that the user could glance at the person or the object worn and read more about them on glasses later without requiring to dwell at the person for long or appear to be staring in the person's vicinity while reading the information on the display.

Gaze Interaction in Social Situations

Participants recognized that eyes, and especially eye contact, are important elements in everyday social interactions and hence our participants felt such technology may be disruptive, distracting and not socially engaging. *"I would not like to use this in a social environment, because the way you initiate social contact is through eye contact. If you are interacting with something using the eyes, you may miss the other person's eye contact. It is not conducive to sociability in my opinion."* (P10)

A majority of the participants also felt that unlike using other modalities like touching the device or using voice commands to interact with smartglasses, gaze makes it easy to covertly interact with the device, or pretend to attend to a situation while acting on the glasses. Few participants felt strongly about wearing such gaze tracking capable smartglasses in social scenarios.

[P6] *I personally hate it when I communicate with somebody and he uses mobile phone or is thinking something else. That is why I would not use it in social situations.*
[P8] *Maybe in black sunglasses. Then other person would not see your eyes.*
[P6] *It is the same. I will just feel that I am talking to a wall.*

Some participants were of the opinion that when gaze tracking becomes common in smartglasses, wearing a smartglasses in conversations could be perceived negatively. "*People usually appreciate if others listen to them. When you have the glasses on, and everybody also knows that you can be doing stuff there with your eyes, it can be unnerving" (P16).* While few others thought that people may get used to others wearing such glasses while in a conversation. If the glasses are tinted, they proposed that there could be some visual indicator of the activity, so that the conversation partner can know if the person is interacting with the glasses or listening to the conversation. "*If someone is talking to you, it might be a good thing that they know you are doing something on your smartglasses. It might be a good idea to have some light showing that (P13)*".

Safety, Health and Privacy Concerns

Personal Safety and Health

Many of the participants also raised personal safety and health-related concerns. Participants raised concerns about the safety aspect of long-term use of gaze-tracking technology. *"Is it (gaze tracking) safe to use for long durations?"* (P6). Earlier work has investigated health issues with desktop-based eye gaze interaction for disabled user groups [6,24]. Most current day commercial wearable gaze trackers use artificial infrared lighting close to the eyes for tracking the pupil. Long-term exposure of the eye to strong infrared (IR) lighting may have health implications [24]. Considering that people could wear smartglasses for long durations every day, and that the infra-red source is closer to the eyes than remote trackers, extensive research should go into the safety aspect of the system.

Participants felt that using eyes to control such glasses, especially using frequent gaze gestures, may be unhealthy or lead to eye fatigue. *"I can see eye strain happening really easily, trying to move your eyes that much."* (P18). Chitty [6] investigated eye fatigue using assistive eye gaze interaction on desktop computers. Novice users may feel eye fatigue due to unnatural eye movement. However, most experienced users do not normally report any fatigue in use of gaze interaction in desktop computers.

Privacy

Participants also raised privacy concerns of using gaze-tracking smartglasses in everyday life. The privacy issues associated with the video capability of such devices and its covert use in public places was discussed. However, another important concern raised was about the ease of collecting personal gaze data and the potential misuse of it. Information about what a person is looking at and for how long, or how carefully, can provide a wealth of sensitive information about the person's interests and preferences *"Somebody is probably going to collect that data of what you are looking at and start recognizing certain patterns. It is like a very effective data collection tool."* (P9).

Trust

Participants in general did not feel gaze tracking smartglasses, can be trusted to replace more mature technologies like mobile phones. "*I still do not think I can trust such a device (P6)*". "*I would probably lose my nerves if the glasses did not obey me automatically. I look there and nothing happens! Then, I am not going to use this ever again* (P12)". Unlike familiar devices like mobile phones, users expressed concern about potential ease of identifying when the device is not working properly, troubleshooting issues and recovering from errors. "*It would be very frustrating if it did not work. I will not know if it is my mistake or the system's mistake.* (P12)".

Interaction Preferences

Most of the participants felt that interacting with distant objects or retrieving information about objects in the environment as a key application for gaze tracking smartglasses. *"This is one application the glasses would be really good for. If glasses are on your eyes and (its display) overlaid on your vision and then you could see that there is a tag to a hotel, there is a tag to a museum and there is a tag to a subway station, you could then look at the tags and get more information."* (P16).

Dwell-time based Interaction

Dwell was considered the most natural method for selecting an item, using gaze on smartglasses. Participants felt that in scenarios of dwelling at a real-world object or glasses implicitly identifying user interest (as in the *tourist* scenario), the glasses should provide some gentle feedback when there is more information available about the real-world object that is glanced at and it should be under the user's request that more information be displayed. *"Glasses should be polite, it should ask if the user wants to know more information about the item."* (P18).

Gaze Gestures

Participants preferred dwell-time based interaction over gaze gestures for frequent interactions, as gestures require unnatural eye movements. Many of the participants felt that gaze gestures are better suited to short and infrequent interactions as they were clear and less likely to be misinterpreted by the system (e.g. simple distinct commands like 'Yes', 'No', 'Ok', shortcuts to different applications, unlock the device). Most earlier works on gaze gesture in desktop computing scenarios use the technique for frequent interactions, like scrolling text entry [12], or as discrete input in games [13]. Our results suggest that gaze gestures may be more suited for clear but infrequent interactions.

Participants thought that it is important to let users define the gestures that they find comfortable. *"If the user has the ability to custom define the gesture. A 'Z' gesture might not be easy for me but, might be easy for someone else. If I can make my gesture that will make it easier."* (P10). "*I might prefer an 'N' gesture (P21)*". While earlier work has investigated the usefulness of user-defined hand gestures for smartglasses [27], most work on gaze gestures has used predefined gestures for interaction. Our results suggest that allowing users to customize the gaze gestures to suit their preferences may be advantageous.

Participants felt that another drawback of gaze gestures is that the user may forget the gesture or may not be aware of it during first time use. It could hence be beneficial if the glasses reminded the users of some of the possible gestures. "*If I do not remember all the gestures, it could remind me some of the gestures*" (P1). Participants also felt that the system should provide adequate feedback to aid performing the gestures, this is in-line with work by Kangas et al [16].

Other General Results

Our participants also highlighted many positive aspects and challenges of using gaze interaction on smartglasses. Unlike in handheld devices that can be easily touched to interact, gaze was considered to be a natural method for interaction in smartglasses. Our participants felt the main advantage of gaze is that it is hands-free and the interactions are more private and unobtrusive. *"The most important thing is to free the hands. If we use other methods to interact, it defeats the purpose."* (P22).

Participants also identified few interaction challenges. Most participants considered entering text (e.g. to respond to a message or search for music) by eyes to be complex, strenuous and slow. *"Entering text using eyes will be very difficult and unnecessarily time-consuming, I would not want to use it"* (P9). This is in-line with previous work on dwell-time based text entry by Majaranta et al. [21]. Another challenge recognized by the participants was the need for calibration. Our participants had only knowledge of the conventional methods for calibrating the trackers using multiple on-screen or real-world fixation points from the technology demonstrations. They considered this technique not suitable for smartglasses as it is slow and expected more flexible calibration procedures, in-line with previous work on automatic recalibration of tracker by Sugano et al. [31].

In general, participants felt that combining smartglasses with mobile phones could be desirable. The glasses were not considered a device that the user would wear at all times. Also, mobile phones were considered to complement smartglasses in functionalities in which glasses are lacking (e.g. text entry). Participants also observed the need for different output modalities to support the interaction effectively. While mobile, voice was the preferred output modality over visually presenting information, in-line with previous work by Baldauf et al. [3] that combined gaze events with audio output in mobile scenarios.

DISCUSSION

Enquiring user expectation towards everyday gaze interaction on smartglasses is important, considering that gaze tracking is soon expected to be a mainstream technology and also the social acceptability issues that are known to be associated with smart glasses (e.g. Google Glass). Our study was designed to be exploratory in nature and provides practical user-expectation insights and design guidelines that could serve as the basis for designing future gaze interaction applications. In the following section, we discuss the design implications of our results.

Design Implications

Our results suggest that context of use has a strong influence on how people feel about gaze technologies. Wearers of gaze tracking glasses may not be always comfortable performing unnatural eye movements in public scenarios and such gestures may also have an influence on the onlookers. Designers and application developers should consider the usage context of the system and attention should be given to social norms concerning eye-contact and unnatural eye movement. Eye contact is critical in face-to-face communication. Applications for smartglasses to be used in social environments, or to facilitate collaboration between collocated users, should hence consider approaches to minimize the use of eyes for interaction and free them for their face-to-face conversational functions.

Human eyes naturally support visual exploration of an environment and participants felt that eyes are a powerful modality to find and interact with objects in the environment. However, designers should be careful while developing applications where eyes are used as a medium to "select or point at" other collocated individuals. Careful design should be employed to use natural glancing as the interaction mechanics and reduce staring at the individual or their vicinity while pointing at them or reading information about them on the display of the glasses.

Special attention should be taken while using gaze gestures for interaction on smartglasses. Gaze gestures have the advantage that they are clear and not invoked by accident. However, our results suggest that gestures are more suited for short and infrequent interactions. While using gestures, the system should support options to remind the users of the possible gestures and also allow users to define their own gestures for flexibility and comfort of use.

Participants raised concerns regarding eye-fatigue while using gaze interaction. Designers of everyday gaze interaction applications should strive to reduce the unnatural eye movements or design to provide adequate rest for people's eyes. These approaches are especially important for early stage users, as experienced users do not report eye fatigue [6]. Ensuring a positive user experience for novice users is critical for technology adoption. Gaze interaction application could keep track of the experience of the user and employ interactions that require complex unnatural eye movements only for more experienced users.

Further, technology manufacturers and designers should consider the perceived safety and privacy concerns of potential users of the technology. These concerns could also be dealt with at a design level. Considerations like relying on visible spectrum gaze-tracking when possible and automatically turning off the IR light source when no eye movement is detected, may greatly reduce the adverse effects of long-term use of gaze-tracking technology and the perceived safety issues with the device. Such approaches will also help reduce the power consumption, which is a major problem in such wearable devices.

Participants voiced privacy concerns regarding storing and sharing gaze data. The device should support options to disable gaze tracking in specific environments. Providing other flexible input methods like combining the smartglasses with mobile devices or voice-based input would mean that users can continue to use the device, even in scenarios where gaze tracking is disabled. Designers should also employ a transparent privacy policy. Allowing the users to control the data recorded and transmitted online will be critical to reduce the privacy concerns of the potential users.

Our participants felt that gaze-tracking technologies cannot be "trusted" to replace other established devices. Participants also raised the need for ways to easily identify and troubleshoot problems with the device. In order for everyday gaze interaction technologies to be widely adopted by consumers, it is important that the technology instills a feeling of reliability and confidence in the minds of the users. Some desktop-based gaze-tracking systems (e.g. Tobii EyeX) provide users a continuous indication of visibility of the eye and tracking robustness. This continuous feedback allows users to ascertain when the device may not function (e.g. because eyes are not visible) and take corrective measures. For wearable systems, dynamic situations like lighting, vibrations in the environment and movement of the device may affect robustness and accuracy of tracking. One should note that the accuracy required depends on the task (e.g. accurate tracking is required to precisely point with gaze a distant landmark from a high rise building but not necessarily to point at a large object near the user). Feedback options should also be employed in wearable gaze tracking systems, allowing users to easily ascertain the robustness of tracking and to assess if the device can be efficiently used in the specific context for the task at hand. There should be hence ways of not just automatically (re)-calibrating the tracker (e.g. [31]), but also keeping the users continuously aware of the tracking status and enabling them to take flexible and intuitive corrective measures when tracking quality is not enough for the current task.

Our results suggest that participants may not want to use gaze interaction in all use contexts. It would hence be important to support complimentary input modalities (e.g. mobile device, voice input *etc.*). Different output modalities should also be provided to enable flexible use cases (e.g. by allowing users to disable the display and use the device with voice output while outdoors, supporting haptics to convey subtle information without distracting the user *etc.*).

Limitations and Future Work

Our study has a few limitations. First, our participants were educated and technically-oriented. While we tried to have a heterogeneous mix of participants in terms of gender and study background, it should be noted that our participants were predominantly from Europe. It is likely that culture has an effect on people's attitudes and preference towards technology. Culture is also known to have an effect on the social gaze behavior [17]. Further research is required to understand the effect of participant selection on our results.

Second, our participants were unfamiliar with gaze tracking technology and smart glasses. The technology demonstration before the start of the discussion helped them get a fair understanding of the technology. However, it may have also influenced the participants' perception and opinion about the technology.

Third, we had to focus on one specific form factor for the smartglasses, i.e. smartglasses with binocular see-through displays, to reduce the scope of the study and not confuse the participants with different options. We think, however, that many of the results could also be extended to other everyday gaze interaction technologies (e.g. on a mobile phone). Future work could investigate if that is really the case.

Fourth, our study focused on understanding user expectation of gaze-based interaction on smartglasses. One could imagine that a combination of modalities (gaze, touch, voice, body gestures *etc.*) could be beneficial in many scenarios to interact with smartglasses. The focus of the work was not to compare the user preferences of using gaze interaction with other plausible combinations. Future work should look into how users would prefer to combine these modalities to interact with smartglasses. Also, while we tried to cover a wide range of gaze interaction techniques, our study did not focus on smooth-pursuit based interaction, a calibration-free gaze interaction technique that has been gaining popularity recently. Future work should investigate user expectations and preferences of using smooth pursuits for everyday interactions.

Inquiring about needs and expectations of users of a future technology is challenging, especially without tangible prototypes to test the interactions. The intention of this study was to inform the design of future gaze-based technologies and increase awareness of some of the social and personal issues that needs to be taken into account while designing such systems. The goal of this study is not to replace an actual field observation of people using gaze-tracking capable smartglasses, when ubiquitous gaze interaction becomes technically feasible. Rather, this research contributes as a significant step towards gaining understanding of users' expectations towards everyday gaze interaction.

CONCLUSION

Our study was designed to be broad and exploratory in nature. It presents many new insights regarding expectation of potential users (e.g. social aspects of gaze interaction, need for flexible and complementary supporting modalities, concerns of the potential user group, and expectations regarding gaze gestures). In future, we plan to continue this line of research and develop applications for gaze-tracking capable smartglasses using other user-centric methods, focusing on the various social and personal issues that was revealed in this study.

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