Social Glasses - Designing Gaze Behaviors for Visually Impaired People

Shi Qiu

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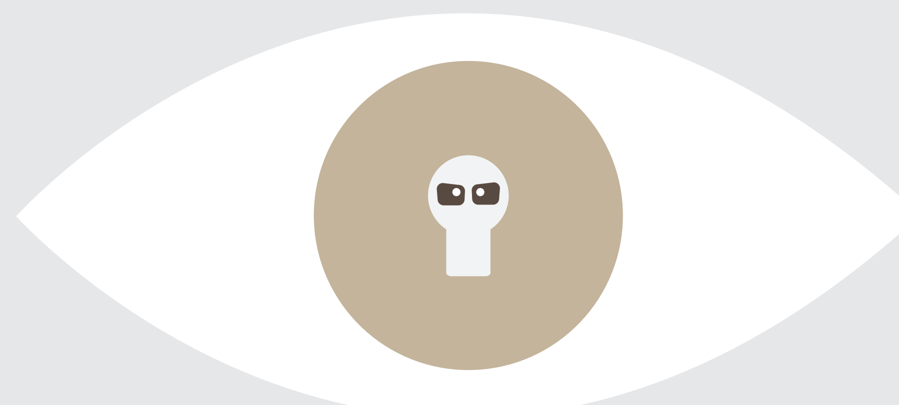

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PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven,
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Shi Qiu

geboren te Jiangsu, China

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To my parents,

Min Zheng and Ming Qiu,

for a lifetime of love and support.

Abstract

Gaze has important social meanings in face-to-face communication. A sighted person often uses various eye gestures to convey nonverbal information that a blind conversation partner cannot access and respond. In many examples, the eyes of blind people seem unattractive, and often with deformities, which make the eye appearances less appealing to sighted people. These factors influence the smooth communication between blind and sighted people.

Our research is to simulate the gaze for blind people, aiming at improving the quality of face-to-face communication between blind and sighted people. In this dissertation, the purpose of simulating the gaze includes two aspects: to assist blind people to perceive the gaze from the sighted and to simulate the appropriate gaze for blind people as a visual reaction. The research consists of four major studies:

Study I: Exploring Nonverbal Signals in Face-to-Face Communication

To investigate how blind people perceive and understand nonverbal signals in face-to-face communication, we interviewed 20 blind participants and collected qualitative data for analysis. The findings implied that the participants felt difficult to perceive positive feelings in conversations. The possibility is they received less positive signals in a conversation due to a lack of perceiving facial expressions and subtle gestures from their sighted conversation partners (e.g., eye contact, smile, nod and thumbs up). Thus, we should help blind people perceive visual signals that convey positive meanings (e.g., smile and eye contacts) from sighted people in blind-sighted conversations.

Study II: Providing Access to Gaze Signals from the Sighted with Tactile Feedback

A conceptual design was presented, aiming at establishing eye-to-eye communication between blind and sighted people. We interviewed 20 blind participants to envision the use of this conceptual design. Four features were explained to the participants using persona and scenarios. The participants discussed the features of the usefulness, efficiency, and interest. Based on the results of the user study, we clarified our design direction: selecting the gaze detection feature for the further design as the first step. We then developed this feature to a prototype, called Tactile Band.

The Tactile Band aims to test the hypothesis that whether the tactile feedback can enable a blind person to feel the attention (gaze signals) from the sighted, to enhance the level of engagement in face-to-face communication. We examined this hypothesis with 30 participants using a face-to-face dyadic conversation scenario, in which a blindfolded and a sighted participant talked about a daily topic. Although quantitative findings did not support a significant effect of the tactile feedback on the participants' engagement in conversations, some participants praised this idea and confirmed that the tactile feedback could make them feel more concentrated on the conversation partners.

Study III: Simulating Gaze Behaviors as Visual Reaction from a Blind Person

A working system, called E-Gaze glasses, was implemented based on an eye-tracking platform. It attempts to establish the "eye contact" between blind and sighted people, to enhance the communication quality in blind-sighted conversations. An interactive gaze displayed on the E-Gaze glasses was also implemented based on the eye-contact mechanism and a turn-taking strategy. To evaluate the impact of the interactive gaze, we performed dyadic-conversation tests under four experimental conditions (No Gaze, Constant Gaze, Random Gaze, and Interactive Gaze) for 40 participants. Quantitative results showed that the Interactive gaze had a positive impact on improving the communication quality between blind and sighted people, which were consistent with a qualitative analysis of the participants' comments.

Study IV: Simulating Gaze Behaviors and Providing Tactile Feedback in Conversations

In the improved system, a blind person wore a glasses device (E-Gaze) and a tactile wristband. Whenever the sighted is looking at the glasses, it reacts to the sighted with the simulated gaze. Meanwhile, the blind person receives the corresponding tactile feedback from the wristband. The tactile feedback enables the blind person to realize that the sighted is looking at the glasses. The user experiments demonstrated that the visual gaze and tactile feedback increased the communication quality significantly, and the system could indeed positively affect the participants' performance in face-to-face communication.

Overall, in this research, we integrated theoretical analysis, design practice, and experimental studies, attempting to use the eye-tracking technology to simulate the gaze for enhancing the communication quality between blind and sighted people. The findings can be used to guide the development of gaze simulation systems in the related areas of accessible computing for social interactions.

Contents

1

Introduction[1]

[1] This chapter is based on:

Qiu, S. (2017). Designing Gaze Simulation for People with Visual Disability. In *Proceedings of the Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 685-688). ACM.

Nonverbal signals are crucial in interpersonal communication. Nearly 65% of all human interpersonal communication occurs through nonverbal signals (Knapp et al., 2014). Most nonverbal signals are tacit, unconscious, and sometimes off-the-record, but they can still influence people's behaviors directly (Hall et al., 2005). Nakatsu et al. (2006) explained that nonverbal signals throughout the interaction, allowing to "exchange moods, emotions and share an instant both in a conscious and unconscious manner" (p.306). For instance, a speaker consciously and unconsciously uses the gaze to convey information to the listener. The speaker can sense the interest, engagement, happiness through the eyes of that listener. Other behaviors from the speaker such as hand and body gestures are naturally used to enhance the effect of the speaking. Meanwhile, the listener smiles or frowns, nods or shakes the head to deliver the information such as interest, doubt, agreement, and disagreement.

Most nonverbal signals rely on visual information such as eye contacts, facial expressions, as well as hand and body gestures. Such visual information is inaccessible for the blind and hardly accessible for the low-vision people. It leads to the physical and social isolation more or less for blind and low vision people because they could not see and make eye contacts with sighted people (Chapter 1.2).

1.1 Visual Impairment

According to the information from the World Health Organization (WHO) in 2017, it is estimated that 253 million people are visually impaired, in which 36 million are blind, and 217 have low vision (WHO, 2017). The term "visual impairment" includes a large span of situations ranging from mild to severe visual impairments. Arditi and Rosenthal (1998) described "visual impairment" as "a significant limitation of visual capability resulting from disease, trauma, or congenital condition that cannot be fully ameliorated by standard refractive correction, medication, or surgery" (p.3). Visual acuity and visual field are used to measure the extent of visual impairment.

The visual acuity is defined as "a measure of the ability of the eye to see details" (Keeffe, 1995, p.2). More specifically, visual acuity is calculated as the quotient of the distance B from which a visually impaired person sees an object and the distance N which the same object is seen by a person with normal vision. For example, 20/20 vision is a term used to express the normal visual acuity measured at a distance of 20 feet. If a person has 20/20 vision, she can see clearly at 20 feet, the same as a person with a normal vision. If a person has 20/100 vision, it means that person must be at 20 feet to see what a person with normal vision can see at 100 feet (American Optometric Association, 2018). Visual acuity values (B/N) can be represented in both decimal and fraction (in centimeters, feet or meters). The fraction can be converted to decimal values by using Table 1.1.

The visual field means "the whole area that is seen when looking straight ahead when the eyes, head, and body are still. The peripheral visual field is the outer edges of the field" (Keeffe, 1995, p.2). The visual field is used to define the extent of the visual impairment in the standards in mainland China and Hong Kong (Table 1.2 and Table 1.3).

In this dissertation, "blind people" and "blind participants" refer to people or participants with either low vision or blindness. In our studies, blind participants were recruited from two places: mainland China and Hong Kong, where two standards are used regarding visual impairment (Table 1.2 and Table 1.3). WHO (2008) categorizes the visual impairment based on the visual acuity (Table 1.4). Based on the visual acuity, we converted the categories of visual impairment in mainland China and Hong Kong to the WHO standard (Table 1.5). We also recorded the information regarding whether blind participants could perceive light and color.

Table 1.1 Visual acuity values: decimal values and Snellen fractions, adapted from (Hyvärinen and Jacob, 2011, Table 3b.1.).

Decimal	**Snellen fractions**					
	6m	**5m**	**4m**	**3m**	**20ft**	**10ft**
0.010	6/600	5/500	4/400	3/300	20/2000	10/1000
0.012	6/480	5/400	4/320	3/240	20/1600	10/800
0.016	6/380	5/320	4/250	3/190	20/1250	10/625
0.020	6/300	5/250	4/200	3/150	20/1000	10/500
0.025	6/240	5/200	4/160	3/120	20/800	10/400
0.03	6/190	5/160	4/125	3/95	20/630	10/315
0.04	6/150	5/125	4/100	3/75	20/500	10/250
0.05	6/126	5/100	4/80	3/63	20/400	10/200
0.06	6/95	5/80	4/63	3/47	20/320	10/160
0.08	6/75	5/63	4/50	3/37	20/250	10/125
0.10	6/60	5/50	4/40	3/30	20/200	10/100
0.12	6/48	5/40	4/32	3/24	20/160	10/80
0.16	6/38	5/32	4/25	3/19	20/125	10/63
0.20	6/30	5/25	4/20	3/15	20/100	10/50
0.25	6/24	5/20	4/16	3/12	20/80	10/40
0.32	6/19	5/16	4/12.5	3/9	20/63	10/32
0.40	6/15	5/12.5	4/10	3/7	20/50	10/25
0.50	6/12	5/10	4/8.0	3/6	20/40	10/20
0.63	6/9.5	5/8.0	4/6.3	3/5	20/32	10/16
0.80	6/7.5	5/6.3	4/5.0	3/4	20/25	10/12.5
1.00	6/6.0	5/5.0	4/4.0	3/3	20/20	10/10
1.25	6/4.8	5/4.0	4/3.2	3/2.4	20/16	10/8.0
1.63	6/3.8	5/3.2	4/2.5	3/1.9	20/12.5	10/6.3
2.00	6/3.0	5/2.5	4/2.0	3/1.5	20/10	10/5.0
2.50	6/2.4	5/2.0	4/1.6	3/1.2	20/8.0	10/4.0

Table 1.2 Categories of visual impairment based on visual acuity and visual field in mainland China, adapted from (CDPF, 2013).

	Category	**Visual acuity worse than**	**Visual acuity equal or better than**	**(or) Visual field worse than**
Blindness	Blindness 1	0.02	-	5°
	Blindness 2	0.05	0.02	10°
Low vision	Blindness 3	0.1	0.05	-
	Blindness 4	0.3	0.1	-

Table 1.3 Categories of visual impairment based on visual acuity and visual field in Hong Kong, adapted from (CUHK-WCC, 2017).

	Category	**Visual acuity worse than**	**Visual acuity equal or better than**	**(or) Visual field worse than**
Blindness	Total blindness	No light perception		
Low vision	Severe low vision	6/120	-	20°
	Moderate low vision	6/60	6/120	-
	Mild low vision	6/18	6/60	-

Table 1.4 Categories of visual impairment based on visual acuity, adapted from (World Health Organization, 2008, Table 1, p.4).

No.	**Category**	**Visual acuity worse than**	**Visual acuity equal or better than**
0	Mild or no visual impairment	-	6/18, 3/10, 20/70
1	Moderate visual impairment	6/18, 3/10, 20/70	6/60,1/10,20/200
2	Severe visual impairment	6/60,1/10,20/200	3/60,1/20,20/400
3	Blindness	3/60,1/20,20/400	1/60,1/50,5/300
4	Blindness	1/60,1/50,5/300	Light perception
5	Blindness	No light perception	
9	-	Undetermined or unspecified	

Table 1.5 Conversion table for three standards of visual impairment.

Three Standards of the Visual Impairment			**Visual acuity worse than**	**Visual acuity equal or better than**
World Health Organization	**Chinese Mainland**	**Hong Kong**		
Blindness 5	Blindness 1	Total blindness	No light perception	
Blindness 4	Blindness 1	Severe low vision	0.02	No light perception
Blindness 3	Blindness 2	Severe low vision	0.05	0.02
Severe visual impairment	Blindness 3	Moderate low vision	0.1	0.05
Moderate visual impairment	Blindness 4	Mild low vision	0.3	0.1
Mild or no visual impairment	-	-	-	0.3

1.2 Problems in Face-to-Face Communication

In social psychology, many investigations suggest that high eye contacts link with sincerity and friendliness, and low eye contacts often with insincerity and nervousness (Kleck and Nuessle, 1968; Cook and Smith, 1975; Arndt and Janney, 2011). People who look at others 15% of the time is considered as cold and lacking confidence (Kleck and Nuessle, 1968; Cook and Smith, 1975; Mutlu, 2009). However, blind people cannot see and make any eye contact in blind-sighted conversations. Due to a lack of the eye contact, blind people often experience communication breakdown in conversation scenarios, which leads to feelings of social isolation and low self-confidence (Hersen et al., 1995; Kleck et al., 1966; Naraine and Lindsay, 2011). According to Kemp and Rutter (1986), blind and sighted people behaved differently in face-to-face conversations. Blind people were less confident than sighted people to share their feelings in conversations. Due to a loss of vision, they became introverted, submissive and with low confidence in communication and activity.

In many examples, blind people's eyes seem unattractive, and often with deformities, which make the eye appearances less appealing to the sighted (Van Hasselt, 1983). The impatience, discomfort, or intolerance from the sighted was an important reason that influenced the involvement in communication or activities between blind and sighted people (Van Hasselt, 1983). Besides, a lack of eye contact might cause the sighted feel that the blind person was not fully engaged in communication (Van Hasselt, 1983). In our pilot investigation, twenty blind participants were interviewed about how to perceive nonverbal signals from the sighted in face-to-face communication (Qiu et al., 2015). The participants reported that they could not see and establish eye contacts with the sighted. Most of them often felt isolated in communication.

In response to this problem, social skills training was developed by researchers to improve the quality of face-to-face communication for blind people, especially improving their eye contacts. Such effort has been well performed based on social psychology, which documented the significance of the gaze in communication (Argyle and Dean, 1965; Argyle and Cook, 1976). For example, a blind person was asked to simply "look" in the direction of a sighted person who was talking to her. However, the gaze behavior from the sighted is far more than a simple "look." Appropriate gaze gestures link many psychological processes, regarded as a remarkably useful source of information during face-to-face communication (Gobel, Kim, and Richardson, 2015).

1.3 Research Questions

This research is to investigate and simulate nonverbal signals, especially the gaze and eye contact for blind people, to increase the quality of face-to-face communication between blind and sighted people. The function of the gaze simulation consists of two major aspects: the first is to assist blind people to feel the gaze from the sighted, and the second is to simulate the natural gaze for blind people as a visual reaction.

The overall research question (RQ) in this dissertation is to which extent and in which ways to improve face-to-face communication between blind and sighted people by exploring and simulating nonverbal signals and in particular, gaze signals?

Specific research questions are defined in the following:

RQ1: How do blind people perceive nonverbal signals in face-to-face communication and which problems do they have due to a lack of visual information?

RQ2: To which extent does the tactile feedback help a blind person feel the gaze (attention) from the sighted in face-to-face communication?

RQ3: To which extent does the "eye contact" simulation help a sighted person feel the visual reaction from the blind conversation partner in face-to-face communication?

RQ4: To which extent does the "eye contact" simulation integrating visual and tactile feedback improve the quality of face-to-face communication between sighted and blind people in dyadic conversations?

1.4 Research Approach

This dissertation is based on a multidisciplinary approach, which includes human-computer interaction (HCI), interaction design, industrial design, electronic engineering, social psychology, cognitive science, and behavioral science.

To begin with, we performed a comprehensive literature review regarding HCI designs for blind people. We identified the insufficiency from recent design solutions and positioned our research direction. Personas and scenario-based techniques were used in the initial user study to obtain target users' needs. These user research methods are powerful for enhancing engagement and reality (Grudin and Pruitt, 2002). Several conceptual design concepts regarding the E-Gaze glasses were then proposed based on design implications from the user study. The technological solution of the E-Gaze was inspired by the AgencyGlass (Osawa, 2014b). This prototype was originally designed for the sighted to decrease the emotional load, and it used a connected keyboard to control displaying the basic eye gestures. We introduced AgencyGlass into the E-Gaze system to provide means for the blind person to react to the sighted by simulating the appropriate gaze. We reprogrammed the E-Gaze glasses and connected it with an eye tracking system. The E-Gaze system was further improved through an iterative process of testing and improvements based on the user feedback. The E-Gaze system consists of three features for the blind person to: (1) feel the gaze, (2) send the gaze, and (3) feel the eye contact (Figure 1.1).

- **Feel the gaze.** By converting the gaze signal (the visual cue) to the corresponding tactile signal, the blind person can perceive the gaze from the sighted person in face-to-face communication (Figure 1.1 (a)).

- **Send the gaze.** A wearable glasses device is designed to simulate the natural gaze of the blind person as a visual reaction to the sighted conversation partner (Figure 1.1 (b)).

- **Feel the eye contact.** By simulating the natural gaze for the blind person and detecting the gaze from the sighted, the "eye contact" can be established between the blind and sighted people. The blind person can feel the corresponding tactile signal when the "eye contact" happens (Figure 1.1 (c)).

More specifically, we present four studies in this dissertation.

1.4.1 Study I

Study I investigated how blind people perceived nonverbal signals in face-to-face communication and identified the problems they might have due to the lack of visual information. Twenty blind participants were interviewed online. Qualitative data were collected for further analysis. In the interviews, a design concept of the E-Gaze glasses was introduced to the participants. In the concept, E-Gaze glasses attempt to create eye-to-eye communication between blind and sighted people in their conversations. Personas and use scenarios were utilized in introducing this concept to the blind interviewees. Four features of the E-Gaze were explained to participants in details and they were asked to discuss these features from three dimensions: usefulness, efficiency and interest. The initial user study helped identify our design direction: selecting the gaze detection feature for the further design as the first step.

1.4.2 Study II

Study II utilized a prototype called Tactile Band and attempted to test the hypothesis that tactile feedback could enable a blind person to feel the attention (gaze signals) from the sighted so as to enhance the quality of face-to-face communication. This hypothesis was tested with a dyadic conversation scenario, in which a blindfolded participant and a sighted participant discussed a daily topic. In this study, a Wizard-of-Oz method was used to map the gaze to the corresponding vibration signal.

1.4.3 Study III

In Study III, the E-Gaze (glasses) was implemented based on an eye-tracking system. E-Gaze simulated the gaze of the blind person, to establish the "eye contact" between blind and sighted people. An experiment was conducted to test the E-Gaze and hypothesized that Interactive Gaze of the E-Gaze could enhance the communication quality between blind and sighted people in dyadic conversations. In this user experiment, the E-Gaze had four test conditions: (a) No Gaze, (b) Constant Gaze, (c) Random Gaze, and (d) Interactive Gaze. The quality of face-to-face communication was measured by the questionnaires.

1.4.4 Study IV

The E-Gaze system was further developed to simulate the gaze and provide the tactile feedback. It allows the blind person not only to feel the "eye contact" from the sighted but also to simulate the gaze in a dyadic conversation. Dyadic conversations were tested under four experimental conditions (Table 6.1): (a) non-active Tactile Feedback and non-active Interactive Gaze, (b) non-active Tactile Feedback and active Interactive Gaze, (c) active Tactile Feedback and non-active Interactive Gaze, and (d) active Tactile Feedback and active Interactive Gaze.

1.4.5 Participants Consideration

It is challenging to recruit participants with disabilities for the research studies. Sears and Hanson (2012) pointed out several problems to recruit these participants. In some cases, it is not easy to bring the participants with disabilities into a specific location for the laboratory experiment. They also mentioned that traditional statistic techniques might be difficult to apply if there is a small number of participants. Therefore, sometimes the alternative participants can be accepted for the preliminary studies. In HCI, many studies have used blindfolded sighted users in place of real blind individuals when studying technical solutions intended for blind users (Moll, Huang, and Sallnäs, 2010; Nikolakis et al., 2005; Yusoh et al., 2008). In our research, we used comprehensive methods to study the participants.

In Study I, we tested remote participants. We conducted online interviews to investigate blind participants in mainland China and Hong Kong.

In Study II, we investigated perceptions and reactions of blindfolded participants to our initial prototype. Although they are non-presentative, they are acceptable for preliminary evaluations. We could still gain some insights into the system improvements.

The user experiments in Study III and Study IV include two kinds of user groups: the blind-sighted group and the blindfolded-sighted group. The first group includes our intended users, the real blind participants from Special Education School. The second group includes blindfolded participants. They are university students, which were considered as the standard HCI study participants (Sears and Hanson, 2012). One of the major reasons for using two groups was "Combining the data from the different groups to produce a larger N so traditional statistical analyses can be applied" (Sears and Hanson, 2012, p.7:4). Due to a limited number of blind participants, we also used a repeated measures design in the user experiments.

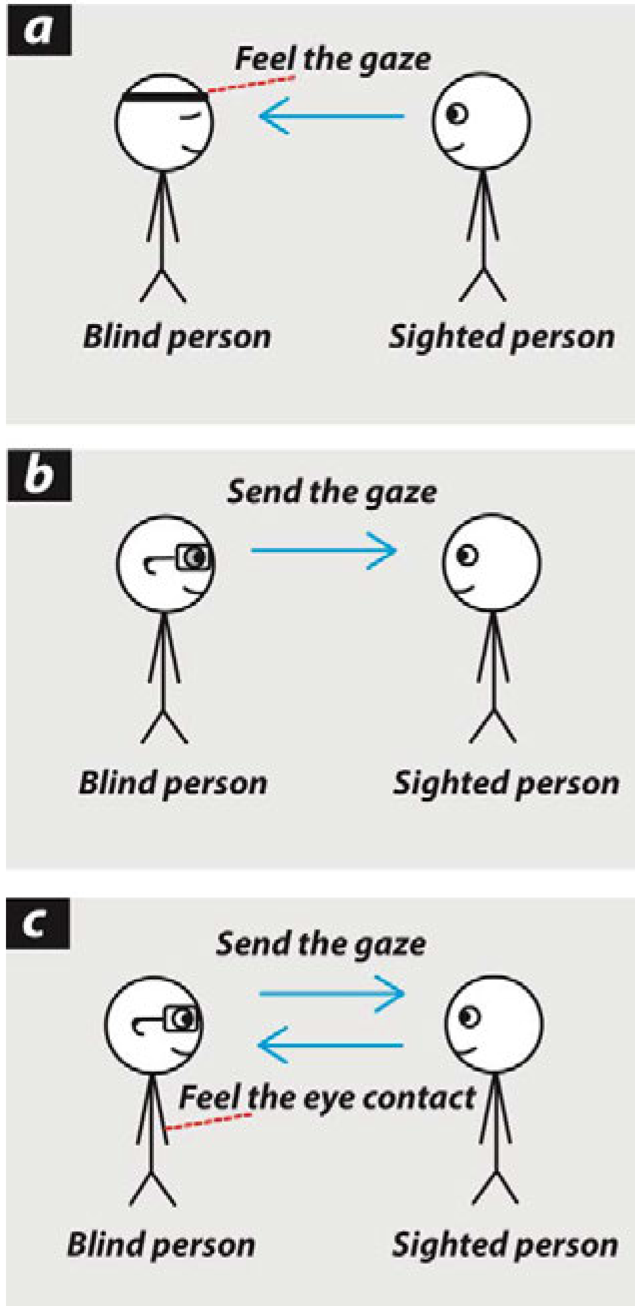


Figure 1.1 Three features for simulating the gaze for the blind person to (a) feel the gaze, (b) send the gaze, and (c) feel the eye contact.

1.5 Outline of the Thesis

This dissertation includes seven chapters (Figure 1.2), and the outline is as below:

Chapter 2 provides a review of the related work that to position my research.

Chapter 3 introduces a user study regarding how blind people perceive nonverbal signals in face-to-face communication and which problems they may have due to a lack of visual cues. Design implications are derived based on the analysis of qualitative data.

Chapter 4 presents a conceptual design of the E-Gaze glasses. It aims to create eye-to-eye communication between blind and sighted people in conversations. Twenty blind participants were interviewed, and they were asked to envision the use of the E-Gaze. The participants evaluated four features of the E-Gaze on the usefulness, efficiency, and interest. Based on the data and analysis, the feature of *gaze detection* was developed into a prototype. The purpose was to test whether the tactile feedback could enable a blind person to feel the attention (gaze signals) from the sighted in face-to-face communication. An experiment with 30 participants was conducted to test the prototype based on a Wizard-of-Oz setup. The experimental results provided useful insights for the further studies.

Chapter 5 presents a working prototype, called E-Gaze (glasses), aiming at establishing the “eye contact” between blind and sighted people in face-to-face communication. Interactive Gaze displayed on the E-Gaze glasses was simulated based on the eye-contact mechanism and the turn-taking strategy. A user experiment further investigated how sighted people perceived four gaze conditions of the E-Gaze (i.e., No Gaze, Constant Gaze, Random Gaze, and Interactive Gaze). The results demonstrated that Interactive Gaze could positively affect the quality of face-to-face communication in blind-sighted and blindfolded-sighted conversations.

Chapter 6 reports the final study that further investigated the communication quality of the improved E-Gaze system, which added a tactile wristband. The results indicated that providing the appropriate gaze and the tactile feedback could have a significant impact on the communication quality in blind-sighted and blindfolded-sighted conversations.

Chapter 7 presents the conclusions, limitations, and gives an outlook to the future work.

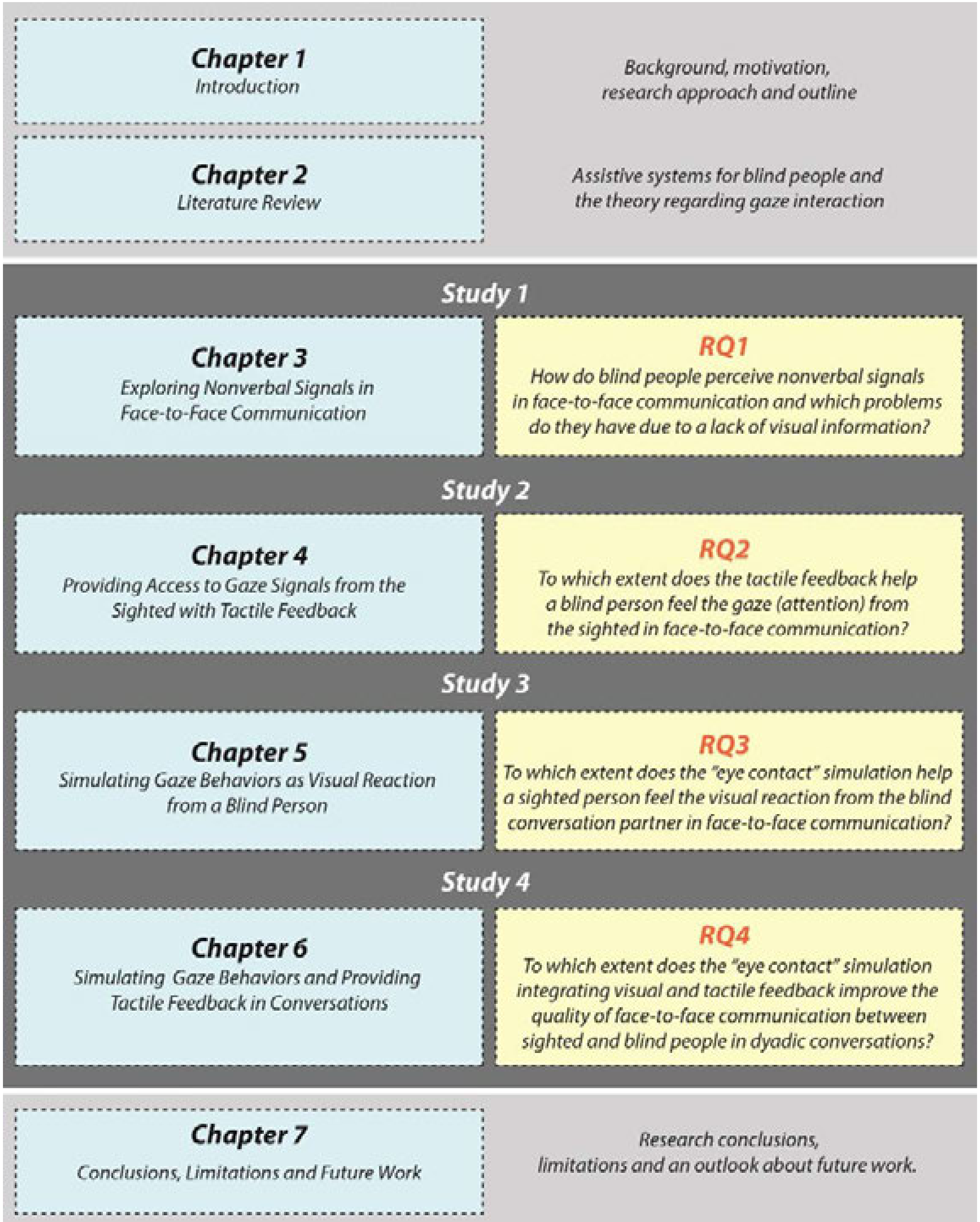


Figure 1.2 Overview of the structure of this dissertation.

2

Literature Review[2]

[2] This chapter is partly based on:

Qiu, S., Han, T., Osawa, H., Rauterberg, M., & Hu, J. (2018). HCI design for people with visual disability in social interaction. In *International Conference on Distributed, Ambient, and Pervasive Interactions* (pp. 124-134). Springer International Publishing.

In Chapter 1, we discussed our research goal and outline. In this Chapter, we first introduce assistive technologies and systems for blind people to access nonverbal signals (e.g., facial expressions) in face-to-face communication. Since one of our objectives is to simulate the gaze for blind people, we focus on the gaze and eye contact. Two relevant research areas are further investigated: (1) gaze interaction between humans, and (2) gaze interaction between humans and virtual agents. The former provides a solid basis of the psychological theories for simulating the gaze, and the latter provides input for modelling the gaze.

2.1 Introduction

This chapter includes five primary parts that form the theoretical framework presented in this dissertation:

1. Assistive technologies
2. Assistive systems in social interactions
3. Bionic eyes
4. Gaze interaction between humans
5. Gaze interaction between humans and virtual agents

Generally speaking, accessibility refers to the ability to reach, understand, or approach something or someone (WHO, 2011). The term accessibility in the context of HCI means all people should be able to access computer systems, regardless of different kinds of disabilities (Soegaard and Dam, 2012). A lack of accessibility influences the lives of many people with disabilities. For example, blind people are not able to use an interactive system which only provides graphics output. Overall, the aim of accessibility in HCI is to make the interaction experience of people with functional limitations as near as possible to people without such limitations (Soegaard and Dam, 2012).

With the development of smart technologies, a growing number of assistive systems in the accessibility field have been designed and developed for blind people. Assistive systems in social interactions are getting increased attention. For example, some studies presented systems for blind people which can identify conversation partners and their facial expressions (Krishna et al., 2005; Kramer et al., 2010; Neto et al., 2017). Besides, “bionic eye” is one of the emerging trends of the assistive technologies in social interactions. The “bionic eye” receives image information from the outside world, and delivers the information to the natural visual system, enabling a blind person to perceive a meaningful image (Maghami et al., 2014).

To obtain a deep understanding of gaze behaviors in face-to-face communication, we also conduct literature research regarding gaze interaction between humans. Since we cannot directly find the related work of simulating the gaze for blind people, we try to borrow the practical approaches to designing and modeling the gaze between humans and the virtual agents (avatars). An overview of related work is presented.

2.2 Assistive Technologies

Vision is considered as an important sensory modality in humans. Loss of vision influences the performance of almost all activities in daily lives. It also indicates loss of independence, lack of communication and human contact, which lead to a growing number of limitations in mobility and communication. In HCI, it has been a long traditional concern for accessibility and assistive technologies. Oppenheim and Selby (1999) investigated blind people met many problems with computer screens such as the text difficult to read and too many graphics. Such features are attractive to sighted people, but they may cause the website inaccessible to blind people. With the development of the assistive technologies (e.g., screen reader software and voice synthesis), some barriers that prevent blind people from access to computer systems are gradually removed (Iglesias et al., 2004).

According to WHO (2016), assistive technology refers to the technology designed for individuals with some types of the impairment (or older adults), to maintain or improve an individual's functioning and independence to enhance the overall well-being. Assistive technologies aim to help blind people overcome many physical, social, and accessibility difficulties in society. Recent developments in multisensory research, computer vision, wearable technology have introduced various assistive technologies for blind people. There are many different usage scenarios of such assistive technologies, ranging from navigation (Ivanchenko et al., 2008; Dunai et al., 2010), social networking (Wentz et al., 2011; Brady et al., 2013), graphic access (Yusoh et al., 2008), Braille displays (Prescher, et al., 2010) and photography (Jayant et al., 2011), to health care (Rector et al., 2013). According to the user interface, the most common assistive systems for blind people are auditory assistive systems (Stefik et al., 2011) and tactile assistive systems (Jayant et al., 2010).

2.3 Assistive Systems in Social Interactions

As social beings, humans have a fundamental need to communicate, to form, maintain and enhance social relationships (Bărboiu et al., 2000). According to Abraham Maslow's hierarchy (Maslow, 1954), human needs have several levels that include basic needs, psychological needs, and self-fulfilment. Once the basic needs are met, a person will strive to satisfy the need for love and belongings in social interactions. Recent developments in multisensory research, computer vision, and wearable technology introduce many assistive technologies for blind people. The majority of the assistive systems still aim at solving basic needs of blind people, such as navigation (Ivanchenko et al., 2008; Dunai et al., 2010), graphics access (Yusoh et al., 2008b) and Braille displays (Prescher et al., 2010). However, as Shinohara and Wobbrock (2011) suggested, "Research involving assistive technologies generally focuses on functionality and usability, yet technology use does not happen in a social vacuum."

Many studies describe assistive systems for blind people, which can identify their conversation partners. Krishna et al. (2005) presented a wearable device named iCare Interaction Assistant, to help blind users during social interactions. Based on the face recognition technology, it aims at identifying sighted conversation partners. Kramer et al. (2010) described a face recognition tool to help blind users identify people during group meetings. It is worn by a blind user and will identify the faces of co-works and colleagues from a database. Once a face is identified, the blind user can hear that person's name via a wireless earpiece. Neto et al. (2017) used a Microsoft Kinect sensor as a wearable device to solve blind people's difficulties of people recognition and localization. The results showed the system performed a significantly higher accuracy rate than traditional face recognition methods publicly available.

Beyond face recognition, some studies have presented assistive systems which can help blind people to identify their conversation partners' facial expressions. Krishna and Panchanathan (2010) implemented a prototype for accessing facial expressions of the conversation partners. The prototype is a vibrotactile glove worn by a blind person. It uses different vibration patterns to convey facial expressions of a sighted conversation partner (i.e., happy, sad, surprise, neutral, angry, fear and disgust) (Figure 2.1). Although it is feasible to change from one sensory modality to the stimuli of the other sensory modality (i.e., sensory substitution), it is not natural to map facial expressions to vibration patterns. Identifying seven vibration patterns may increase the cognitive load of blind people, which affects their engagement in conversations. Buimer et al. (2016) presented a similar design solution for accessing facial expressions. A blind person wears a haptic belt with six vibration actuators around the waist. Each of them is assigned to a given emotion. According to Ekman (1992), six universal facial expressions are joy, disgust, anger, sadness, fear and surprise. The facial expressions are recognized by the software, converting from visual to vibration signals that the blind person can perceive (Figure 2.2).

In summary, facial expression recognition systems presented here transfer visual signals to vibration signals. Although many assistive systems help improve the quality of blind people's lives by transferring visual signals into auditory signals (M. I. Tanveer et al., 2013; Hamilton-Fletcher et al., 2016), the auditory feedback is not suitable in a conversation scenario. It increases the hearing load of blind people and disturbs their conversations. Compared with the auditory feedback, the tactile feedback is tacit, which may be a good option that used in conversations.

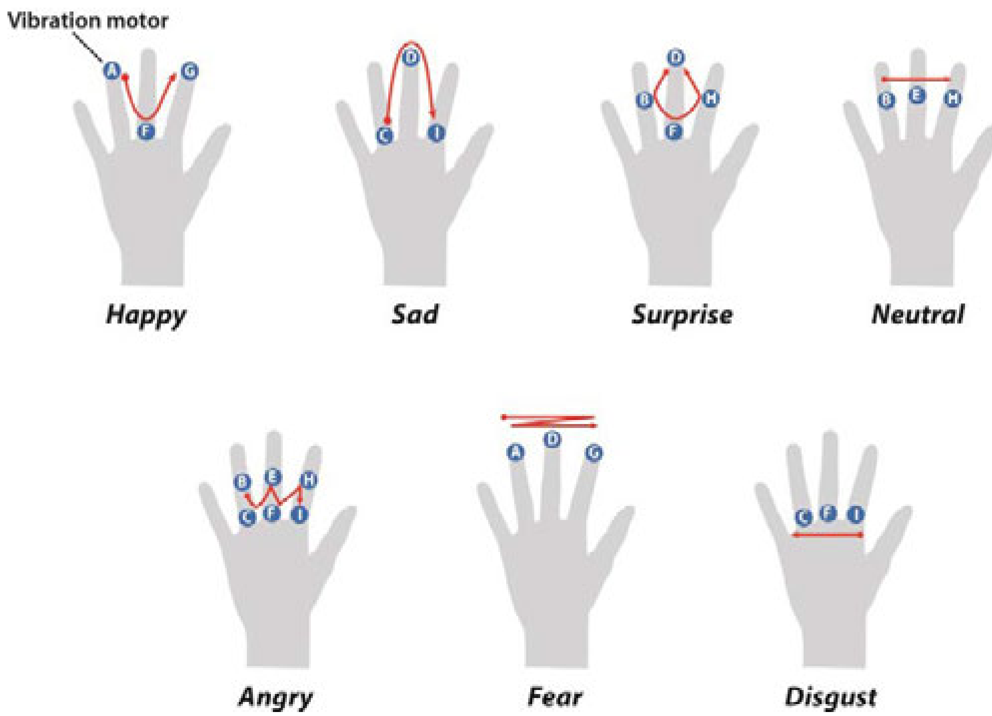


Figure 2.1 Vibration patterns of the Haptic Glove for conveying facial expressions, adapted from (Krishna and Panchanathan, 2010, Figure 14, p.1283).

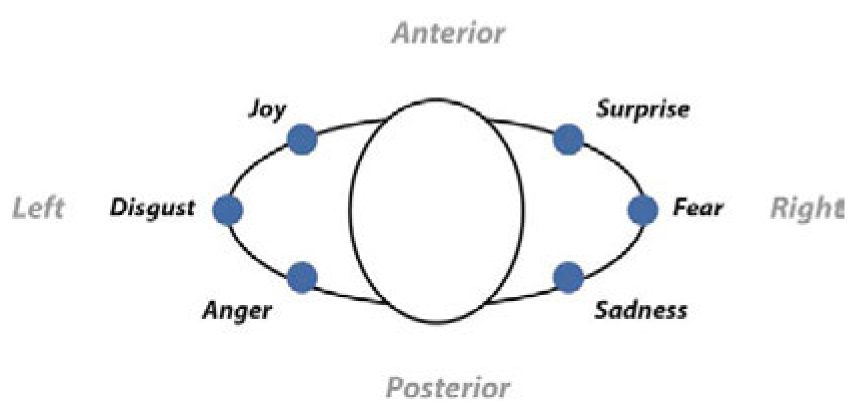


Figure 2.2 Locations of the vibration actuators and the emotions assigned to it across the waist, adapted from (Buimer et al., 2016, Figure 1, p.158).

In addition to the assistive systems for face and facial expressions recognition, some studies also investigated behavioral expressions such as head movements (Anam et al., 2014), and other nonverbal signals in social interactions (number of people present, their age and gender distributions (M. Tanveer, 2014). Although gaze signals are very important in social interactions, few studies explored how to transfer the crucial gaze to blind people in face-to-face conversations and how to help blind people react to their sighted conversation partners by simulating gaze behaviors.

2.4 Bionic Eyes

“Bionic eyes” is one of the emerging trends of the assistive technologies for blind people. Bhowmick and Hazarika (2017) suggested that the development of “bionic eyes” is a ground-breaking strategy for returning some functional vision to visually impaired people. It aims at improving their independence and quality of lives. “Bionic eyes” often refers to the visual prosthesis, to provide a complete and fundamental solution for blind people. The original idea of “bionic eyes” is not new and has been explored for many years in laboratories. In this research area, the most common technique is “to electronically stimulate the visual pathway with a visual prosthesis or bionic eyes” (Lewis et al., 2016, p.654). In addition to academia, the Second Sight Company has devoted much effort in the technologies of developing the “bionic eyes.” It attempts to test whether an array of electrodes placed on the surface of the brain can restore limited vision to people with partially or even completely blindness (Mullin, 2017).

Although the “bionic eyes” technology is promising, it still has some limitations. Firstly, it needs much time to verify the feasibility and safety by many rounds of clinical trials in humans. The “bionic eyes” and other kinds of visual prosthesis are implantable, invasive, and high cost. They are not feasible to become popular at the current stage. Secondly, it enables blind people with a certain form of blindness to restore the perception of the simple light patterns, but how to make such patterns meaningful to blind people and bring them the real benefits to know about this world? Finally, but most importantly, it lacks the visual reaction. It cannot provide the appropriate visual gaze for blind people in social interactions.

2.5 Gaze Interaction between Humans

Studies summarized in this section focus on gaze definitions, functions of gaze behaviors, and gaze behaviors in conversations.

2.5.1 Definitions and Functions of Gaze Behaviors

Some definitions of gaze behaviors were provided by Kleinke (1986), which were originally outlined by von Cranach (1971) and Harper et al. (1978). Kleinke (1986) explained typical gaze behaviors in more detail in the following:

Mutual gaze refers to two people looking at each other's faces.
Eye contact defines two people looking into each other's eyes.
Looking/gazing refers more generally to a gaze in the direction of another's face.
Gaze avoidance refers to intentional avoidance of eye contact (p.78).

There is a small difference between "mutual gaze" and "eye contact": the former is a behavior relevant to "eye-to-face" and the latter is about "eye-to-eye." Kleinke (1986) claims "these definitions require more accuracy than is present in most research studies because it is relatively difficult for people to discriminate between face-gaze and eye contact"(p.79). In response to this, "mutual gaze" and "eye contact" imply that "two people are simultaneously looking at each other's face and (possibly) eyes" (Kleinke, 1986). Therefore, these two terms are considered the same meaning in this dissertation.

The functions of eyes and the gaze in human relations have been long discussed by many researchers in psychology and relevant research fields. Patterson (1982) presented five categories to group the functions of exchanging nonverbal signals. Kleinke (1986) used the same five categories to classify functions of the gaze behaviors and organize relevant studies. These five categories (p.80-84) are: (a) *providing information* (e.g., liking and attraction, attentiveness, credibility), (b) *regulating interaction* (e.g., synchronization and regulation), (c) *expressing intimacy* (e.g., attraction, warmth and liking), (d) *social control* (e.g., persuasion and deception, threat and dominance, escape and avoidance), and (e) *service task* (e.g., information seeking, learning, cooperation and bargaining). Such categories are helpful to analyze gaze behaviors between humans, and they provide the theoretical support to simulate the gaze for blind people in face-to-face communication. Here we discuss gaze behaviors in a face-to-face conversation scenario, which has been used in our further studies.

2.5.2 Gaze Behaviors in Conversations

Many studies in psychology and relevant research fields have investigated gaze behaviors of sighted people in conversations. In our research, we aim at obtaining specific design strategies of how to simulate gaze behaviors. So the focus lays on studies of gaze amount and gaze direction in conversations.

2.5.2.1 Gaze Amount

Argyle and Cook (1976) presented a theoretical overview of many investigations in gaze behaviors, including gaze measurement. Most studies in this book relied on human observers for coding gaze. One of the examples was the research conducted by Argyle and Ingham (1972). They measured gaze amount in a dyadic (two-person) conversation, which was the simplest social interaction. Thirty-four participants (17 pairs) participated in lab-based user experiments. In the experiments, the participant pairs had conversations at a normal interaction distance of 1.5-1.8m. The results in Table 2.1 indicated the total amount of time for looking was 61%. The participants spent about 75% of the time looking at the speaker when they were listening. Argyle and Cook (1976) further mentioned that "glances are used by listeners to indicate continued attention and willingness to listen. The aversion of gaze means lack of interest or disapproval" (p.121). Listeners spend a lot of time to look at speakers in face-to-face communication, to study their facial expressions, and their direction of gaze (Argyle and Cook, 1976). In Table 2.1, we also observed that the participants looked less of the time at the listener (41%) when they were talking. During conversations, eye-contact (mutual gaze) happened around 31% of the time.

Argyle et al. (1974) examined how the participants perceived conversation partners' gaze behaviors. Conversation partners were trained with five gaze patterns: (1) zero, (2) looking while talking, (3) looking while listening, (4) normal, and (5) continuous, which were based on an increasing rate of the eye contact from zero (0%) to continuous (100%). The experimental results demonstrated that the normal gaze was the most liked by the participants and the zero gaze was the lowest on effectiveness. Although the continuous gaze was rated highest in effectiveness, it indicated for the dominance.

Table 2.1 Amount of gaze in the dyadic conversations, adapted from (Argyle and Cook, 1976, Table 5.1, p.99).

Gaze measures	**Sex Combinations [a]**				**All**
	MM	**FF**	**MF(M)**	**MF(F)**	
Total individual gaze (%)	56	66	66	54	61
Looking while listening (%)	74	78	76	69	75
Looking while talking (%)	31	48	52	36.5	41
Mutual gaze (%)	23	38	31.5	31.5	31
Length of individual glances (sec)	2.45	3.12	3.61	2.98	2.95
Length of mutual glances (sec)	0.86	1.42	1.25	1.25	1.18

[a] Abbreviations:
MM = male-to-male conversations, FF = female-to-female conversations, MF(M) = male in male-to-female conversations, MF(F) = female in male-to-female conversations.

2.5.2.2 Gaze Direction

Many studies investigated gaze direction in face-to-face communication. Kendon (1967) investigated the relationship between gaze direction and the occurrence of utterances in dyadic conversations. He claimed that gaze has an important role in regulating the flow of the conversation, and communicating emotions and relationships. In conversations, a speaker often ends the turn with a prolonged gaze at a listener. The listener then starts to accept the turn by looking away before speaking. This prolonged gaze is for signaling the end of the turn and for helping get the feedback if the conversation partner is going to speak.

Cassell et al. (1999) explored the relationship among gaze, turn-taking, and information structure. The linguistic structure of "theme-rheme" was introduced to explain turn exchanges in conversations. "Theme" means what the topic is about and what links it to the previous topic. "Rheme" means the contribution to the pool of knowledge in the conversation, and specifies what is new and interesting about the theme. Based on an empirical analysis of dyadic conversations, they found that the beginning of the thematic part of an utterance was often followed by the gaze that looked away from the listener, while the start of the rhematic part was always followed by the gaze that looked towards the listener. They concluded that there was a link between the gaze and the information structure, which helped predict gaze behaviors in conversations.

Vertegaal et al. (2001) extended a dyadic-conversation scenario to a multiparty-conversation scenario. They used an eye tracker to measure participant's gaze at conversation partners' faces in four-person conversations. The results showed that on average, the participants looked around seven times more at the conversation partner that they listened to (62%) than others (9%). They looked around three times more at the conversation partner that they spoke to (40%) than others (12%). They concluded that gaze was an excellent predictor of conversational attention in multiparty conversations.

In this section, we have discussed gaze behaviors in human-to-human and face-to-face conversations. Next, we present studies of gaze behaviors in mediated conversations between a human and a virtual agent.

2.6 Gaze Interaction between Human and the Virtual Agent

Since we cannot directly find the related work regarding designing the gaze for blind people, we attempt to borrow research approaches on how to model the gaze behaviors between humans and virtual agents (avatars). Many studies investigated gaze interaction between a human and a virtual agent (or an avatar) and provided the evidence that appropriate gaze behaviors of the virtual agent could elicit natural responses in humans. Gaze behaviors are very important for designing the virtual agent, which have a crucial impact on the quality of human-agent dialogues. We summarizes three ways of simulating gaze behaviors for virtual agents: (1) turn taking, (2) gaze model, and (3) reactive gaze.

2.6.1 Turn Taking

Gaze behaviors associate with the turn-taking phenomenon in conversations. Hirvenkari et al. (2013) suggested, eye contact often occurs around turn exchange in conversations. Turn-taking strategy has been widely used to design gaze behaviors for the virtual agent. Through an empirical analysis for dyadic conversations, Cassell et al. (1999) examined the relationship between gaze behavior and the information structure (e.g., turn-taking). Based on empirical findings, they presented an algorithm of designing conversation agents' gaze behaviors.

Garau et al. (2001) investigated the impact of the gaze between humans and humanoid avatars. They compared participants' responses in four conditions: (1) video, (2) audio-only, (3) random-gaze avatar and (4) inferred-gaze avatar. In the inferred-gaze avatar condition, the avatar's head and eye animations were related to turn-taking during the conversation. Experimental results showed that the inferred-gaze avatar perceived significantly better communication quality than the random-gaze avatar and audio-only. However, the inferred-gaze avatar was not significantly different from the video. The inferred-gaze avatar only used gaze behaviors, whereas the video presented participants' full and accurate nonverbal behaviors of the face.

Heylen et al. (2005) investigated the effects of different gaze behaviors of a cartoon-like talking face (Karin) on the quality of human-agent dialogues. They tested three versions of Karin: (1) optimal version, (2) suboptimal version, and (3) random eye-movement version. The optimal version designed Karin's eye-movements and information-structure based on the rules of Cassell et al. (1999). In the suboptimal version, Karin's eye-movements were limited, and there were no cues given by the eyes concerning the turn-taking structure. The results showed that the optimal version based on a turn-taking model positively influenced the dialogue quality.

Kang et al. (2015) examined users' reactions to a virtual human based on four conditions: (1) animation based on a statistical model while listening, (2) animation with a constant mutual gaze, (3) static image, and (4) no image. Their findings demonstrated that users engaged more by talking for a longer amount of time when they interact with a virtual human based on the turn-taking model than the other three conditions.

In summary, studies mentioned above-designed gaze behaviors of virtual agents based on the turn-taking model in conversations. Based on the experimental results, gaze behaviors linking with the turn-taking model efficiently improved the communication quality between humans and virtual agents.

2.6.2 Gaze Model

Lee et al. (2002) implemented a statistical eye movement model based on eye-tracking data. The statistical model consisted of three components: *Attention Monitor*, *Parameter Generator*, and *Saccade Synthesizer*. *Attention Monitor* detected the system state and other necessary information (e.g., in talking or listening mode, the change of the head orientation). *Parameter Generator* determined different parameters of the saccade (e.g., magnitude, direction and duration). *Saccade Synthesizer* calculated the sequence of coordinates of eye centers, based on the synthesis parameters mentioned above. They tested three face animations with (1) static gaze, (2) random gaze, and (3) gaze using the statistical model by measuring the naturalness and effectiveness in communication. The results showed that the gaze based on the statistical model outperformed the random gaze and the static gaze.

Fukayama et al. (2002) presented a gaze movement model, allowing the eyes-only agent to convey different impressions to people. The gaze model consisted of three gaze parameters: the *amount of gaze*, *mean duration of gaze* and *gaze point while averting*. In the experiment, participants described impressions they could feel from an eyes-only agent moving its eyes. Each impression of the agent was generated by the parametric control. The results demonstrated that such gaze parameters reliably induced the given impression and validated the gaze model.

Lance et al. (2007) presented an approach for a virtual agent to express emotions through gaze behaviors. They used an emotional model to describe specific states of the gaze behaviors. The model included three dimensions: pleasure, arousal, and dominance. In this work, they used arousal and dominance to describe the virtual agent's behavior. In the subsequent evaluation, they demonstrated that the encoded expressions could be successfully recognized.

In summary, studies presented above use multiple parameters to model gaze behaviors of the virtual agents, which are primarily based on statistical models of eye-tracking data. However, such gaze models do not track users' gaze behaviors in conversations. Users' gaze behaviors cannot trigger gaze behaviors of the virtual agents. It is a “one-way” behavior rather than a “two-way” interaction.

2.6.3 Reactive Gaze

Most virtual agent systems display gaze behaviors based on the turn-taking strategy or relevant gaze models rather than being reactive. In the reactive systems, a user’s gaze behaviors trigger a momentary response from a virtual agent, which in turn influences the user and results in a feedback loop (Kipp and Gebhard, 2008). For example, the reactive gaze behavior can instantaneously adapt to a user’s position.

Kipp et al. (2008) used head tracking to implement a semi-immersive system. The system aimed to explore reactive gaze behaviors between humans and virtual agents. A a virtual agent was implemented with three gaze strategies: (1) “Mona Lisa” strategy (continuous gaze following), (2) dominant strategy and (3) submissive strategy. The “Mona Lisa” strategy followed a user’s position with eyes all the time. In the dominant strategy, the virtual agent maintained the eye contact while speaking and randomly looked away while listening. In the submissive strategy, the virtual agent established the eye contact when starting to talk but looked away immediately after the eye contact. They tested how participants perceived three gaze strategies. The results showed that the dominant and submissive strategies conveyed intended impressions, and the “Mona Lisa” strategy was positively received by the participants.

Bee et al. (2010) presented an interactive gaze model for the embodied conversation agents to improve the user experiences in Interactive Storytelling. In the interactive gaze model, an eye tracker was connected to enable the interactive gaze of a conversation agent to respond to a user’s gaze (Figure 2.3). In the non-interactive gaze, the conversation agent randomly looked at the user or looked away. They tested participants’ responses to the interactive and non-interactive gaze models. A post-questionnaire was used to measure the participants’ sense of social presence, level of rapport, engagement, social attraction and the subjective perception of the story. The results showed that the interactive gaze model significantly outperformed the non-interactive gaze and provided the participants with the good user experiences.

In summary, the reactive gaze can be based on a head or eye tracking system. A user’s head orientation or gaze can trigger an instant response from the virtual agent. Therefore, “two-way” interaction is created between a user and a virtual agent.

Figure 2.3 The setup for the interaction with the conversation agent (Bee et al., 2010, Figure 2).

2.7 Conclusion

This chapter presented the theoretical background, which helps design assistive systems for improving the communication quality between blind and sighted people. By exploring such existing theories and relevant design solutions, we gained further insights into the following:

1. Based on a general understanding of current assistive technologies for blind people, we found such technologies have been widely used in many fields, ranging from mobility, wayfinding, information access, entertainment, and education to medical interventions (e.g., "bionic eyes"). Auditory and tactile systems are the mainstream assistive systems, consistent with the mechanism of the sensory substitution: after the vision loss, auditory and tactile perceptions become particularly helpful for blind people to perceive and adjust to the environment.

2. Assistive systems in social interactions are getting increased attention. Some studies presented systems for blind people which can identify conversation partners and detect their facial expressions. However, such assistive systems lack an exploration of gaze signals. Since one of our objectives is to simulate the gaze for blind people, we focus on the gaze and eye contact. The technology of "bionic eyes" aims to restore some functional vision to blind people. Despite some limitations at the current stage, it is still promising for the future trend of the assistive technologies.

3. To better understand how to simulate the gaze, we investigated gaze theories in psychology and relevant research fields. In addition to a general understanding of

gaze functions, we focused on gaze behaviors in face-to-face conversations. Gaze amount and gaze direction are described in more detail, providing us with a solid basis on how to simulate gaze behaviors in a dyadic-conversation scenario. Besides, the insights from the studies on gaze behaviors in turn taking, gaze models, and reactive gaze systems provide us with practical approaches on how to model the gaze.

Research findings presented in this chapter will be used as a reference to lay the foundation for the design and evaluation of our target system, for improving the communication quality between blind and sighted people. In the next chapter, we present the early stage of requirements elicitation for blind people in face-to-face communication.

3

Study I: Exploring Nonverbal Signals in Face-to-Face Communication[3]

[3] This chapter is based on:

Qiu, S., Hu, J., & Rauterberg, M. (2015). Nonverbal signals for face-to-face communication between the blind and the sighted. In *Proceedings of International Conference on Enabling Access for Persons with Visual Impairment* (pp. 157-165).

In the preceding chapter, we provided a theoretical background relevant to this dissertation. Assistive systems of nonverbal signals perception in social interactions are getting increased attention. However, we still lack an overall understanding of blind people's capabilities and limitations of the nonverbal signal perception. Such knowledge is important for informing the relevant design. In this chapter, we investigated how blind people experience their capabilities and limitations of perceiving nonverbal signals in face-to-face communication. We studied 20 blind participants regarding their lived experiences through in-depth interviews and systematic qualitative analysis. Furthermore, we presented design opportunities to inform the design of future HCI systems to support the nonverbal signal perception of blind people.

3.1 Introduction

Face-to-face communication includes both nonverbal and verbal communicative behaviors. According to Knapp et al. (2014), approximately 65% of all human interpersonal communication takes place through nonverbal signals. They suggested that looking into a person's eye and face area can signal an open channel for communication. In everyday life, we consciously and unconsciously communicate information in nonverbal ways (e.g., combine a frown and unblinking eyes to express disagreement). Such nonverbal signals are regarded as honest signals to sighted people since they are more spontaneous and not easy to fake than other ones (Knapp et al., 2014). Pentland and Heibeck (2010) reported several nonverbal signals that found in conversations by measuring the time, energy, and variability of the interaction. One example was: "the reflexive copying of one person by another during a conversation, resulting in an unconscious back-and-forth trading of smiles, interjections, and head nodding during a conversation" (p.4).

Nonverbal signals are important in face-to-face communication. However, most of them rely on visual cues (e.g., eye contact, head nods, facial expressions, and body gestures). Such visual cues are inaccessible for the blind and hardly accessible for low vision people. In this chapter, we conducted a user study and interviewed 20 blind and low vision participants over the Internet. The main objective of this study is: to gain a better understanding of nonverbal signals that blind people can perceive and to find out their problems in face-to-face communication due to a lack of visual cues.

3.2 User Study

3.2.1 Participants

Twenty blind participants participated in interviews. Ten were from Yang Zhou Special Education School in mainland China, and the other ten were from Hong Kong Blind Union. Their ages ranged from 16 to 29 (M = 20.30, SD = 2.79) and most of them were high school, college, and university students. There were eight female and twelve male participants. The participants were suggested to provide their vision conditions based on the diagnoses from doctors. All participants in Hong Kong knew their vision conditions based on official medical records. Some participants in mainland China were uncertain about vision conditions, so a teacher in Yang Zhou Special Education School provided vision conditions based on the participants' disability certifications from China Disabled Persons' Federation (CDPF). According to Table 1.5, we converted the participants' vision conditions in mainland China and Hong Kong to the WHO standard. The participants' demographic information and vision conditions are shown in Table 3.1.

Table 3.1 Vision conditions of twenty blind participants in our user study.

ID	**Sex**	**Age**	**Vision Condition (WHO Standard) [a]**	**Congenital Blindness (Y/N)**	**Light Perception (Y/N)**	**Color Perception (Y/N)**	**Causes of Blindness**
P1	F	19	Severe visual impairment	Y	Y	Y	Unknown
P2	F	21	Blindness 3	Y	Y	Y	Sickness
P3	F	20	Blindness 3	Y	Y	Y	Hereditary
P4	M	18	Blindness 3	Y	Y	Y	Hereditary
P5	M	23	Blindness 3	Y	Y	Y	Sickness
P6	F	23	Blindness 3	Y	Y	Y	Congenital amblyopia
P7	F	22	Blindness 3	Y	Y	Y	Sickness
P8	M	21	Blindness 5	Y	Y	Y	Sickness
P9	F	19	Blindness 4	Y	Y	Y	Hereditary
P10	F	21	Blindness 4	Y	Y	Y	Cataracts and glaucoma
P11	M	16	Blindness 4	Y	Y	Y	Optic nerve hypoplasia
P12	M	19	Blindness 5	N	N	N	Premature birth
P13	M	21	Blindness 5	N	N	N	Sickness
P14	M	18	Blindness 5	Y	N	N	Glaucoma
P15	F	22	Blindness 5	Y	N	N	Unknown
P16	M	19	Blindness 5	Y	N	N	Unknown
P17	M	19	Blindness 5	Y	N	N	Optic atrophy
P18	M	17	Blindness 5	Y	N	N	Premature birth
P19	M	29	Blindness 5	Y	N	N	Premature birth
P20	M	19	Blindness 5	N	N	N	Malpractice

[a] Vision impairments are sorted from low to high.

3.2.2 Setup

The interviews were conducted over the Internet due to the inconvenience for the participants to attend face-to-face interviews. Tencent QQ and Skype were preinstalled on the computers in Yang Zhou Special Education School and Hong Kong Blind Union respectively. Both the online audio and video channels were offered to the participants. All participants only chose the audio connection.

3.2.3 Questionnaire

A questionnaire was used in the semi-structured interview, and it included three parts:

1. **Background.** We began by asking the participants about their vision conditions and other demographic information.

2. **Nonverbal signals in face-to-face communication.** We first explained the meaning of nonverbal signals to the participants and then asked about specific topics, such as what types of nonverbal signals they could perceive in face-to-face communication and which problems they might encounter due to a lack of visual cues. Since eyes play an important role in face-to-face communication, some questions relevant to the eye perception were asked in the interviews:

    - What do you think of the importance of the eyes in face-to-face communication?
    - What is your perception of the appearance (shape and color) of the eyes?
    - What about your understandings of the eye gestures?

3. **Design concepts and evaluations.** Parallel design concepts were presented by using persona and use scenarios to the participants, and the results are presented in the next chapter. Here we focus on the user study regarding nonverbal signals and report our findings.

3.2.4 Procedure

Each interview started with a warm greeting that created a friendly atmosphere, making the participants feel comfortable to open up and talk about their experiences and opinions. The participants were reassured that the data collected from the interviews would be treated with confidentiality. We also got permission from all participants to record the interview. The researcher spoke and explained all the questions to the participants, and each interview took around one and a half hours.

Headland et al. (1990) suggested that interpretive validity emphasizes how the participants could understand the phenomenon in their own words. The participants in mainland China and the researcher were native Mandarin Chinese speakers. Besides, all participants from Hong Kong were proficient in Mandarin Chinese. Therefore, Mandarin Chinese was chosen to be the interview language to avoid possible misunderstandings.

3.2.5 Analysis

Twenty interviews were transcribed verbatim. To gain insights from this study, we conducted data analysis based on a standard method named *Qualitative Content Analysis* (Hsieh and Shannon, 2005), aiming at interpreting meaning from the context of text data based on a naturalistic paradigm. It consists of three approaches: (1) *conventional content analysis*, (2) *directed content analysis* and (3) *summative content analysis*. Hsieh and Shannon (2005) further explained how to analyze qualitative data by using *conventional content analysis*. The qualitative data are collected primarily through interviews with open questions. To analyze qualitative data, several steps were summarized by Hsieh, and Shannon (2005): (1) read all data repeatedly to obtain a general idea of the whole data set; (2) highlight the exact words from the text to capture the key thoughts or concepts, and derive the initial codes; (3) approach the text by making notes of the first impressions, thoughts, and initial analysis; (4) sort the codes into categories based on how different codes are related and linked; (5) use categories to organize and group codes into meaningful clusters.

In this study, we followed the approach of the *conventional content analysis* and the coding categories were derived directly from the text data. According to our coding scheme, each selected quote from the transcripts of interviews should describe how the participant perceives a certain nonverbal signal, or how the participant lacks a nonverbal signal in face-to-face communication. If multiple quotes are representing the same described situation, only one of them will be selected. This scheme guarantees that the selected quotes well reflect relevant information concerning our research aims and they are mutually exclusive without semantically repeating each other. QSR Nvivo[4] software was used to manage qualitative data of each open question in the questionnaire. We labelled the quotes based on their contents and obtained an initial overview of the classification of the quotes. The coder (the author of this dissertation) created categorizations for the set of quotes, and gradually organize categorizations into meaningful clusters.

[4] http://www.qsrinternational.com/

3.3 Findings

The major categories identified helped gain the knowledge and understanding of the participants' capabilities and limitations of perceiving nonverbal signals in face-to-face communication. More specifically, we were interested in the participants' perceptions of the eyes, which plays an important role in face-to-face communication. To gain such knowledge, we selected total 138 quotes from the qualitative data, including the participants' capabilities and limitations of perceiving nonverbal signals (76 quotes), communication problems due to a lack of visual signals (9 quotes), and their perceptions of eyes and eye behaviors (53 quotes). An overview of the categorization of the participants' nonverbal signal perception is shown in Figure 3.1.

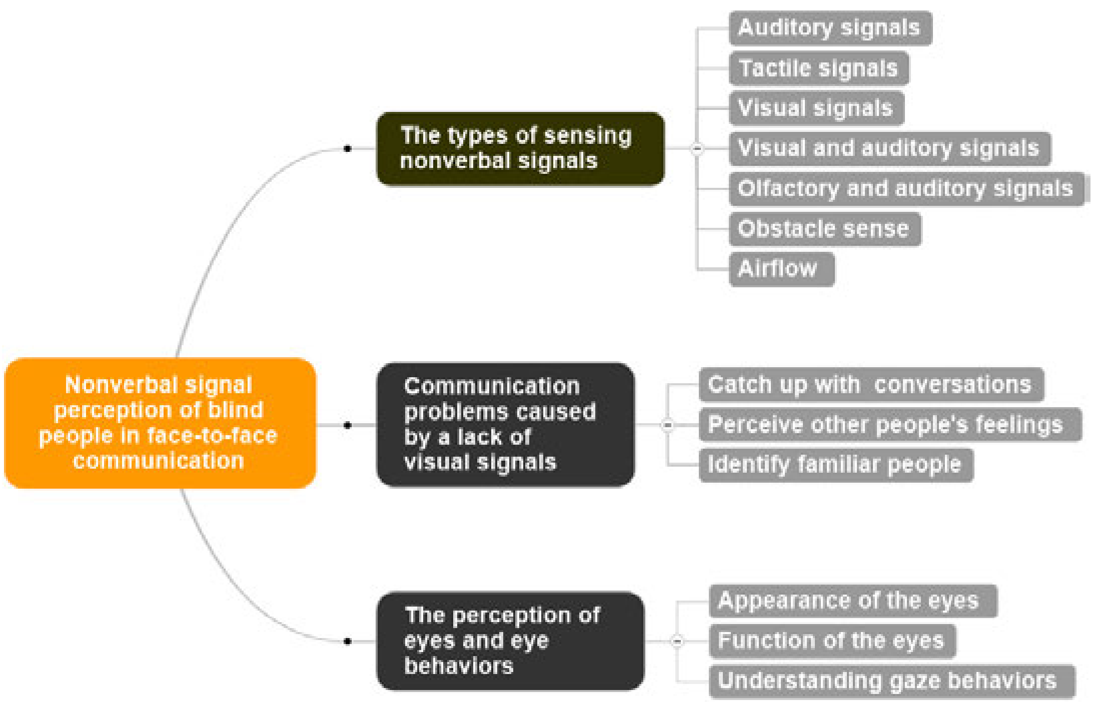


Figure 3.1 An overview of the categorization of the participants' nonverbal signal perception in face-to-face communication.

3.3.1 The Types of Sensing Nonverbal Signals

Seventy-six quotes report the participants' capabilities of perceiving nonverbal signals in face-to-face communication. We categorized these quotes based on four senses: vision, hearing, smell, and touch. Major types of nonverbal signals were the auditory (27 quotes), tactile signals (18 quotes), and visual signals (14 quotes). Other types of nonverbal signals that the participants could perceive were: visual and auditory signals (8 quotes), obstacle signal (5 quotes), olfactory and auditory signals (2 quotes), and the airflow signal (2 quotes). Table 3.2 provides an overview of all types of nonverbal signals that the participants could perceive.

Table 3.2 Perceiving nonverbal signals in face-to-face communication.

Perceiving nonverbal signals	**Number of quotes**	**Percentage**
Auditory signal	27	35.52%
Tactile signal	18	23.68%
Visual signal	14	18.42%
Visual and auditory signals	8	10.52%
Obstacle signal	5	6.57%
Olfactory and auditory signals	2	2.63%
Airflow signal	2	2.63%

3.3.1.1 Auditory Signal

Twenty-seven quotes describe that the participants could perceive conversation partners' auditory nonverbal signals during conversations.

Twelve quotes from ten participants mention that they could sense conversation partners' facial orientation by auditory signals. P14 stated that he could perceive a conversation partner's facial orientation when the partner was talking. However, it was difficult for him to discern the partner's facial orientation if the environment was noisy. Another participant mentioned his response to the conversation partner's facial orientation:

> "When I distinguished the direction of the conversation partner's facial orientation, I would intentionally turn my head to follow that direction. My head would stay in the direction of the biggest sound (when the conversation partner was talking)." — P11

Nine quotes from seven participants mention that they could sense conversation partners' body gestures such as leaning forward and backward by the auditory perception. One of the example responses is:

> "I could feel my conversation partner moving his head up and down when we were talking." — P15

Six quotes from five participants describe they perceived conversation partners' facial expressions by hearing their crying or laughing. The participants tended to distinguish and guess a conversation partner' emotions from the manners of speaking: if the voice was soft and gentle, the participant tended to believe she was pleasant; if the conversation partner spoke rudely and loudly, the participant probably thought she was angry.

Although the participants could not directly and exactly perceive facial expressions of conversation partners, they could guess conversation partners' emotions by auditory signals such as laugh, cry, voice, and tone.

3.3.1.2 Tactile Signal

Eighteen quotes mention the participants' experiences of perceiving tactile nonverbal signals in face-to-face communication. The participants (3 out of 18) expressed positive, neutral (13 of 18) and negative (2 out of 18) views towards tactile nonverbal signals, respectively (Table 3.3).

Table 3.3 Attitude and understanding towards tactile nonverbal signals.

Types	**Attitudes**	**Understandings**
Touch the shoulder	Positive	Friendly signal and feel being encouraged by friends
Touch the head slightly	Positive	Feel being supported and encouraged
Hold the hand	Neutral	Guide someone to a certain place
Touch the hand	Neutral	Let me know the other one is talking to me or let me do not speak in a public place
Touch the body	Negative	An invasion of privacy

3.3.1.3 Visual Signal

Fourteen quotes from six low-vision participants describe that they could perceive visual signals in face-to-face communication such as body gestures and facial orientations. P9 stated: "if you still have a certain vision, you will rather rely on it." All participants mentioned that they could see a large range motion of some hand gestures and body gestures (e.g., waving or pointing to one place by using an arm). Four of them reported that they could see facial orientations of the nearby conversation partner, whereas none of them could see any subtle finger gestures.

3.3.1.4 Visual and Auditory Signals

Eight quotes from five participants mention that they could sense body gestures and facial orientations by visual and auditory perceptions. An example is quoted as below:

> "I could feel a person's body gesture when she was talking, because her voice was shaking along with the body gestures. Sometimes, I could see the conversation partner's body gestures, but not very clear. " — P3

3.3.1.5 Obstacle Signal

Five quotes report that four totally-blind participants could perceive some obstacles. Nonvisual obstacle perception has been investigated by some experimental psychologists. Ashmead et al. (1989) suggested that congenitally blind people can perceive objects accurately, probably depending on the auditory information. An example of the obstacle perception was reported as below:

> "When I was walking before hitting an object, I felt something blocked me. I could not clearly explain that sense, and it might be called the obstacle sense." — P12

3.3.1.6 Olfactory and Auditory Signals

Two quotes mention the participants' experiences of identifying people by the auditory and olfactory perception. P3 mentioned that he was able to distinguish the subtle olfactory differences of some close friends, but no for all people around. He also stressed that he could not recognize a long-time-no-see friend, because the unique smell for a certain friend could change or be forgotten with the time. Sometimes he also made the judgement relying on patterns of footsteps and some special context. He further explained the context: "Smelling one person at school and sensing the similar smell of the person at home were regarded as two different people, because they appeared in two independent contexts." P11 also stated that he could identify a person by the olfactory and auditory signals. The quote is given below:

> "I lost my vision by birth. Therefore, I distinguished all people with different genders by the footsteps and smells. The first choice was the smell, but sometimes it was misleading. So I used footsteps to help: some people walked slowly, and some of them had heavy footsteps. I could distinguish people by their unique patterns of footsteps." — P11

3.3.1.7 Airflow Signal

Two quotes mention the participants could perceive some hand gestures by the airflow. One participant mentioned as below:

> "I could not see the hand gesture, but I know if someone is going to hit me. I could sense the subtle airflow caused by hand gestures of the conversation partner." — P11

3.3.1 Communication Problems Due to a Lack of Visual Signals

Twenty-nine quotes from 19 participants mention that they could perceive conversation partners' feelings by the voice tone (15 quotes) and gestures (14 quotes). Among 14 quotes of gestures, only five quotes mention the participants could perceive positive feelings from conversation partners' gestures, whereas the other nine only felt negative feelings. The participants shared their unhappy experiences due to a lack of visual signals in face-to-face communication. The example is:

> "One person had very funny facial expressions in our conversation, but I could not sense them and naturally did not know why other people laughed."— P8

3.3.1.1 Catch Up with the Conversation

Five quotes mention that the participants could not catch up with the discussion speed with sighted people due to a lack of visual signals (e.g., hand gestures, nods, eye contacts, and facial expressions). P4 complained about an unhappy personal experience when attending a discussion with several sighted people. During that discussion, sighted people exchanged the information fully through visual signals such as nodding expressed the agreement and headshaking indicated the disagreement. He even did not realize that the discussion was finished and still waiting for speaking. Such experience made him lost in discussions and feel frustrated.

3.3.1.2 Perceive People's Feelings

Three quotes mention that the participants encountered difficulties in observing feelings of conversation partners, because they could not sense any facial expressions. P4 said sometimes he became depressed when he could not exactly perceive people's feelings. For instance, his classmate said "yes" and agreed with him, but actually, that classmate was unpleased and disagreed with him. He did not observe his classmate's unhappiness from the tone, which was the same as usual. He stressed that he encountered a persistent difficulty in perceiving conversation partners' positive feelings:

> "When a person felt happy she would smile. But I could not see the smile. Besides, I could not sense nods and facial expressions, and I was only able to judge positive feelings by the conversation partner's voice tone or languages." — P4

3.3.1.3 Identify Familiar People

One participant stated he could not identify an intimate friend if this friend's nonverbal signals were changed.

> "I could not identify the person even we were very familiar with each other. If the feature of his nonverbal signals in my memory changed significantly, I could not identify him. For example: if he liked shaking legs during a conversation and one day he did not shake, I felt he changed. If changes were big, I could not identify him." — P11

3.3.2 The Perception of Eyes and Eye behaviors

We asked the participants four questions to gain a further understanding of their perception regarding eyes and eye behaviors. The first question "Whether the eyes were important or not in face-to-face communication" required the participants not only to answer "yes" or "no," but also to provide reasons. Eleven participants held the view of "eyes were important" for two major reasons: (1) the eye contact in communication can be used to understand conversation partner's emotions and intentions, (2) looking at the talking conversation partner indicates a kind of the response. Most participants seldom obtained such information from their personal experience. For example, one participant said she understood the importance of eye contact from the romance novels by highlighting descriptions of the eye contacts between lovers. Nine participants (six blind and three low-vision) expressed the opposite idea that eyes were not important in communication (Table 3.4). The major reason was they could not receive any information when they "looked" at others in face-to-face communication. One participant stressed that eyes were very important from sighted people's view, but they were not necessary for blind people. Blind people were very sensitive, and they did not need to see. As for her, she could be aware of a teacher's feelings, while sighted classmates might not, and even the teacher himself did not realize.

Table 3.4 The number of participants held different views of eyes.

Responses	**# Participants (%)**	**Vision conditions**	
		# Totally blind (%)	**# Low vision (%)**
Important	11 (55%)	5 (25%)	6 (30%)
Not important	9 (45%)	6 (30%)	3 (15%)

Eight participants said that they never obtained any explanations regarding eyes. Twelve participants stated they got explanations about the eyes from their teachers, parents, books, etc. One example quote was:

> "Eyes are the windows of the soul, to reflect the basic information of a person. When looking at the person, you could understand whether he/she was kind-hearted or not. You could also use the eyes to observe this beautiful world and the surroundings." — P14

Furthermore, the participants were asked with two open questions: "what do you think of the appearance and functions of the eyes" and "can you explain 'looking at' based on your understandings" to gain the extended information regarding the perceptions of the eyes. Several responses from participants are classified in Table 3.5 and Table 3.6. The participants reported more quotes regarding the eye shape (16 quotes) than the eye color (5 quotes). Nine quotes mention that the "looking at" behavior refers to "looking at someone's eyes," while six quotes refer to "looking at someone's face."

Table 3.5 Appearances and functions of the eyes.

Responses	**# Quotes (%) N=36**	**Keywords**
Shape	16 (44%)	Round, like a ball, oval, olive-shaped
Color	5 (14%)	Black center, white background, transparent
Function	15 (42%)	Establish eye contact, express feelings, be respected, get information, enhance facial expressions

Table 3.6 Understandings of "looking at."

Responses	**# Quotes (%) N=17**	**Keywords**
Looking at someone's eyes	9 (53%)	Eye contacts, focus, watch
Looking at someone's face	6 (35%)	Turn one's face, head orientation, face to face
The purpose of "looking at"	2 (12%)	Friendly, love, unfriendly

3.4 Discussion

The research described in this chapter aims at acquiring knowledge of the participants' capabilities and limitations of perceiving nonverbal signals in face-to-face communication. We are also interested in the participants' perceptions of eyes and eye behaviors. Now we discuss the research findings and relevant design implications for this study.

3.4.1 Use of Auditory, Tactile and Visual Signals

Three majorities of nonverbal signals that the participants could perceive are auditory signals (35.52%), tactile signals (23.68%), and visual signals (18.42%). A vast number of experimental studies support the notion that blind people have enhanced abilities in their remaining auditory and tactile modalities (Voss et al., 2010). In the neurophysiological mechanism, "loss of visual input could enhance the performance in the remaining sensory modalities through compensatory brain re-organization and attention shifts" (Théoret et al., 2004, p.222). Such findings are in line with mainstream assistive systems discussed in HCI: auditory assistive systems (Massof, 2003) and tactile assistive systems (Visell, 2008). Interestingly, we found that the participants still relied on the sight to perceive nonverbal signals in face-to-face communication. P9 stated: "if you still have a certain vision, you will rather rely on it."

We also learned that some participants used olfactory signals to identify people. Some participants had a better olfactory ability than sighted people, which might be due to a mechanism of the sensory substitution. Nevertheless, they could not identify people only depending on olfactory signals. They needed the assistance of auditory signals (e.g., the sound of footsteps). Several reasons could explain such a phenomenon:

- Olfactory signals are very complex for identifying people. A blind person may have several friends, and it is difficult to remember different smells from different friends.
- Some olfactory signals are very similar and sometimes easy to be mixed up.
- The olfactory signal of a person may change over time.

3.4.2 Subtle Information and Positive Signals

In this study, the participants mentioned communication problems coming from a lack of visual signals. Such signals can be categorized into two types of functions: conveying useful information (e.g., nodding or shaking the head means agreement or disagreement in discussions), and expressing different feelings (e.g., smiling or frowning). Some participants felt difficult to perceive positive feelings. One possible reason is that they are not able to see facial expressions and subtle finger gestures, which are used by sighted people to express positive emotions. For example, thumbs-up and smiling convey positive feelings and make the speaker feel more confident in conversations. On the other side, it is easier for the participants to perceive negative feelings through big and sharp hand/body gestures of conversation partners, or, even close the door loudly. For instance, P19 could feel the conversation partner was very emotional and angry since that person's body was moving dramatically.

3.4.3 A Fuzzy Understanding of the Eyes and Eye Gestures

All participants have an indirect and fuzzy understanding of eyes and eye gestures. In the interviews, most participants reported that they obtained the understanding of the eyes primarily from three ways. (1) Sighted people around them (e.g., parents, teachers) explained the basic meaning of the eyes and eye gestures. (2) Some romance novels and literary works described the eye contact between lovers in vivid details. (3) They gained information from their personal life experiences, most coming from the problems they met due to a lack of visual information in daily livings.

The participants tended to exaggerate the functions of the eyes, partly because the novels and some literary works often use metaphors and analogies to describe the gaze and eye contact with an exceeding literary flavor. For instance, one participant claimed looking at someone could distinguish whether that person was kind-hearted or not. It is impossible to determine a person's inner character at first sight, even for a sighted person with extensive life experiences. In the interviews, the participants had a more explicit concept towards the shape than the color of the eyes. The possibility is they can touch the eyeballs to know the eye shapes. However, all participants felt difficult to know the color of the eyes, even for the low-vision participants who could perceive the light and color. Most of them imagine the eye color based on indirect experiences, such as from descriptions in a book or by other people telling them.

The participants shared their different opinions of "looking at." We collected 17 quotes to answer this question: nine quotes mention "looking at" is a behavior triggered by the eyes (example keywords: eye contacts, focus, and watch), and six quotes mention "looking at" is a behavior relevant to the face and head (keywords: turn one's face, head orientation, and face-to-face). For example, one participant explained that he sensed the conversation partner looking at him by the facial orientation. From sighted people's view, "looking at" is defined as the gaze behavior rather than the head pose. We infer that the participants do not have an explicit concept of "looking at."

3.4.4 Design Opportunities

Based on the findings from the user study, we identified design opportunities for future work.

3.4.4.1 Design Opportunity 1: Sense Positive Visual Signals

Visual signals conveying positive meanings should be perceived by blind people in face-to-face communication. From the interviews, we found that participants received less positive signals in conversations due to a lack of sensing subtle gestures and facial expressions from sighted people. All participants could not perceive the subtle positive signals, such as gaze, smile, nod, and thumbs up, leading to less confidence in talking with sighted people. In response to this, our envisioned assistive system aims at helping blind people perceive subtle visual signals in conversations (e.g., gaze, gentle smiles, and finger gestures).

3.4.4.2 Design Opportunity 2: Sense the Facial Orientation

For blind people, sensing the facial orientations can sometimes take the place of sensing the gaze in the assistive systems. Some of them thought "looking at" was equal to "facing to." In the design scheme, we may provide the information about the facial orientation of sighted conversation partners rather than their gaze direction. In the interviews, the participants seldom perceived subtle gestures, and they did not have an explicit concept of gaze behaviors (e.g., looking at). Nevertheless, some of them, especially the low-vision participants, could perceive conversation partners' facial orientation based on auditory or weak visual signals. They have a more explicit concept of the "face" rather than the "eyes."

3.4.4.3 Design Opportunity 3: Design for Simulating the Gaze

Miller (2004) suggested that in face-to-face communication, there are three different strategies (i.e., passive, active, interactive strategies) when gathering information about strangers. According to Miller, the passive strategy refers to observation of the other in communication. Goharrizi (2010) pointed out that blind people often use the passive strategy to observe the way that a person interacted in a conversation. They were more passive than sighted people in communication. Therefore, our research objective is not just let blind people passively perceive visual signals (e.g., gaze) from sighted people in face-to-face communication. We wish to let them actively react to sighted people by using the simulated "gaze." In our future design, we will not only let blind people perceive visual signals from sighted people but also let them send the visual reaction to sighted people by using the appropriate "gaze."

3.4.5 Limitations

This study has some limitations that need to be taken into consideration. The participants' age ranges from 16 to 29, and it has a limitation in representing the whole population of blind people. The participants are too young to experience a gradual loss of the vision with the growth of the age. Since all participants share the same cultural background, we did not explore cultural differences of perceiving nonverbal signals. The communicative activity involves both blind and sighted people. It would be interesting to investigate the experiences of sighted people while communicating with a blind person. Sighted people would be teachers in Special Education School, parents, and friends, who have plenty of opportunities to communicate with blind people. We may identify more design opportunities from user experiences of sighted people in face-to-face communication.

3.5 Conclusion

To investigate blind people's experiences of nonverbal signal perception in face-to-face communication, we conducted online interviews with 20 blind participants. The findings revealed that due to the visual impairment, the participants perceived nonverbal signals through their compensatory modalities (e.g., hearing, touch, smell and the obstacle sense). Different from expected, the sight was still reported by many participants to perceive certain nonverbal signals (e.g., rough postures and gestures). Besides, the participants perceived less positive signals from conversation partners in face-to-face communication. They had an indirect understanding and a fuzzy imagination of eyes and eye gestures. Finally, we identify design opportunities to support the nonverbal signal perception of blind people such as simulating the gaze.

4

Study II: Providing Access to Gaze Signals from the Sighted with Tactile Feedback[5]

[5] This chapter is based on:

Qiu, S., Osawa, H., Hu, J., & Rauterberg, M. (2015). E-Gaze: Create Gaze Communication for People with Visual Disability. In *Proceedings of the 3rd International Conference on Human-Agent Interaction* (pp. 199-202). ACM.

Qiu, S., Rauterberg, M., & Hu, J. (2016a). Tactile Band: Accessing Gaze Signals from the Sighted in Face-to-Face Communication. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 556-562). ACM.

Qiu, S., Rauterberg, M., & Hu, J. (2016b). Designing and Evaluating a Wearable Device for Accessing Gaze Signals from the Sighted. In *Proceedings of the 18th International Conference on Human-Computer Interaction* (pp. 454-464). Springer International Publishing.

4.1 Introduction

Based on findings and design implications described in the preceding chapter, we aspired to design an assistive device, aiming at helping blind people access the subtle visual cues (e.g., gaze) from sighted conversation partners in face-to-face communication. The second part of the user study is reported in this chapter. In the interviews, we described four conceptual design features of the envisioned assistive device using persona and use scenarios (Buskermolen and Terken, 2012). Most participants demonstrated a great interest in the gaze detection feature. Based on this interest, Tactile Band, a wearable device, was developed to help a blind person feel attention (gaze signals) from a sighted conversation partner in face-to-face communication. The Tactile Band maps the gaze from the sighted to tactile signals and let the blind person feel such signals in real-time. Thirty participants (including 15 blindfolded participants) were invited to evaluate the prototype in the user experiment.

The main objective of this chapter is to contribute an understanding of how the tactile feedback can help a blind person feel attention (gaze signals) from the sighted conversation partner; how to improve the system and experimental settings according to the users' comments.

4.2 Evaluation of Design Concepts

The initial design of E-Gaze is inspired by the AgencyGlass (Osawa, 2014a), a prototype application that can be attached on a user's face and display the eye gestures. Their purpose is to decrease the emotional workload from sighted people by simulating the gaze. In our research project, we aim at motivating face-to-face communication between blind and sighted people. Based on this interest, we utilize AgencyGlass to our concept E-Gaze. E-Gaze is supposed to have two major functions: to help a blind person access gaze signals and to react to the sighted conversation partner by displaying the eye gestures. Based on these two functions, four features of the E-Gaze (Figure 4.1) were presented in the conceptual design: (C1) *gaze detection*, slight vibrations from the E-Gaze indicate the gaze from the sighted conversation partner; (C2) *eye contact simulation*, when the sighted looks at the E-Gaze, E-Gaze also looks back to establish the "eye contact"; (C3) *avoiding state*, if the sighted gazes long enough, E-Gaze switches to avoid the long gaze; (C4) *attention state*, the simulated eyes on the E-Gaze open bigger when the heart rate of the blind person increased, indicating an "attention state".

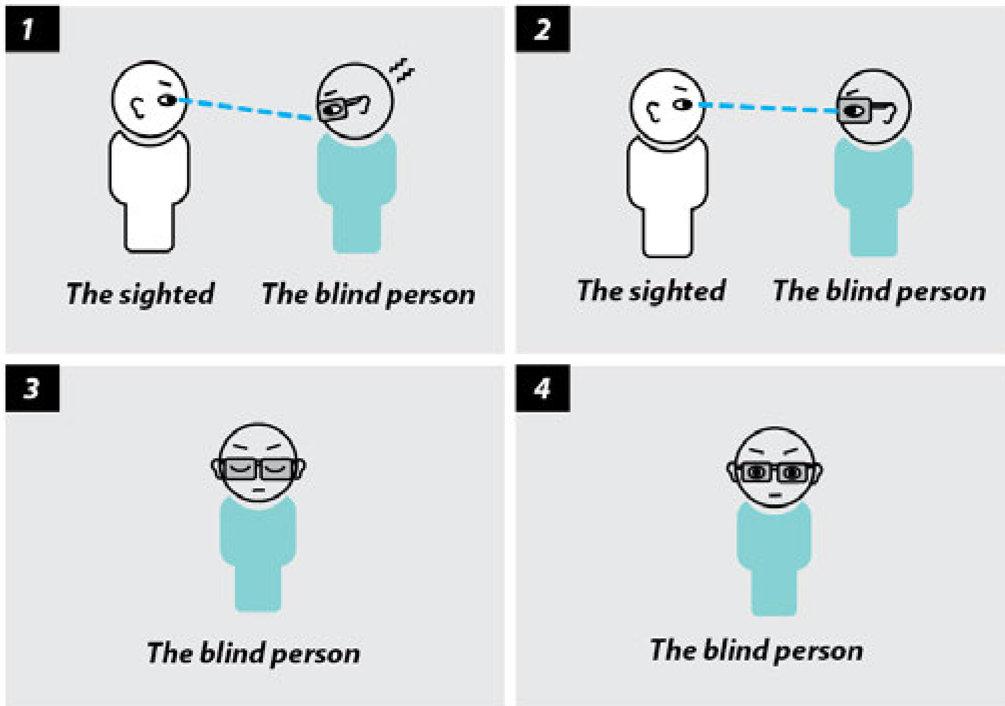


Figure 4.1 E-Gaze has four conceptual features: (1) gaze detection, (2) eye contact simulation, (3) avoiding state, and (4) attention state.

The E-Gaze concept was evaluated in the same user study described in Chapter 3. We explained four conceptual features of the E-Gaze to the participants with persona and use scenarios, aiming at eliciting the participants' experience and memories to help them envision the use (Buskermolen and Terken, 2012):

> Xiao Ming is sixteen. He studies in a high school. He is visually impaired. His uncle gave him E-Gaze glasses as a Christmas gift last year. Xiao Ming wears the E-Gaze and starts a new experience.

Scenario 1

> Xiao Ming feels a slight vibration at the right side of his forehead from the E-Gaze. His head turns right, and he wants to know who is looking at him. The artificial eyes of the E-Gaze start searching. After a short while, his sighted classmate Wang Wang comes, saying that: "I see you see me, and it reminds me to ask you a question." In this scenario, two features of the E-Gaze concept are presented: (C1) A slight vibration of the E-Gaze indicates the gaze from Wang Wang. (C2) When Wang Wang looks at the E-Gaze, the E-Gaze also looks back to establish the "eye contact."

Scenario 2

> Wang Wang looks at Xiao Ming all the time and seems very talkative about his study plan. Xiao Ming looks at him to show the politeness. After a short while, he feels bored for this endless talk. Wang Wang realizes and asks: "Are you still interested in my plan? I see you are sleepy now. Let's change to your favourite topic. I find a beautiful girl in Class 3 […]" Xiao Ming's eyes open bigger to indicate attention. In this scenario, the E-Gaze has two features: (C3) If the sighted gazes long enough, the E-Gaze closes the eyes to avoid the long gaze. (C4) The simulated eyes on the E-Gaze open bigger when Xiao Ming's heart rate increases, indicating an "attention state."

After explaining the use scenario of each of the four features, we asked participants: "What do you think of the idea? Imagine that you are Xiao Ming in this scenario." Then participants used the five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to evaluate each feature from three dimensions: usefulness, efficiency, and interest. Such dimensions have been used to evaluate concept designs in design research (Wang et al., 2014).

4.2.1 Results

4.2.1.1 Quantitative Results

Four features of E-Gaze were evaluated for the usefulness, efficiency, and interest by the repeated measures ANOVA. In the data analysis, we divided samples from the participants without and with the light perception into the totally blind and non-totally blind groups, respectively. An independent t-test was used to compare the perceived usefulness, efficiency and interest between the totally blind and non-totally blind groups.

Usefulness, Efficiency, and Interest. There was a significant main effect of usefulness in four concepts of E-Gaze as determined by the repeated measures ANOVA [$F(3, 57) = 4.804$, $p = .005$, $r = .449$]. We adopted the Bonferroni test in the post hoc analysis. For the usefulness (Figure 4.2 (a)), post hoc Bonferroni test revealed that the mean score of *gaze detection* (M = 4.15, SD = .81) was significantly higher than *attention state* (M = 3.15, SD = 1.18). Repeated measures ANOVA also revealed a significant main effect of efficiency [$F(3, 57) = 4.457$, $p = .007$, $r = .436$]. For the efficiency (Figure 4.2 (b)), Bonferroni test indicated that the mean score of *gaze detection* (M = 4.20, SD = .894) was significantly higher than *avoiding state* (M = 3.25, SD = 1.12). However, there was no significant effect of the interest as determined by the repeated measures ANOVA [$F(3, 57) = .487$, $p = .693$, $r = .158$].

Totally Blind and Non-Totally Blind Groups. Usefulness, efficiency, and interest of E-Gaze were compared between the totally blind and non-totally blind groups by using independent t-test. On average, participants expressed greater interest to the E-Gaze concept in the totally blind group (M = 4.20, SD = .97) than in the non-totally group (M = 3.73, SD = 1.09), [$t(78) = 2.067$, $p = .042$, $r = .228$] (Figure 4.3). There was no significant difference on the usefulness between the totally blind group (M = 3.90, SD = 1.06) and the non-totally group (M = 3.65, SD = .90), [$t(78) = 1.142$, $p = .257$, $r = .128$]. Besides, there was no significant difference on the efficiency between the totally blind group (M = 3.83, SD = 1.11) and the non-totally group (M = 3.58, SD = 1.01), [$t(78) = 1.055$, $p = .295$, $r = .119$].

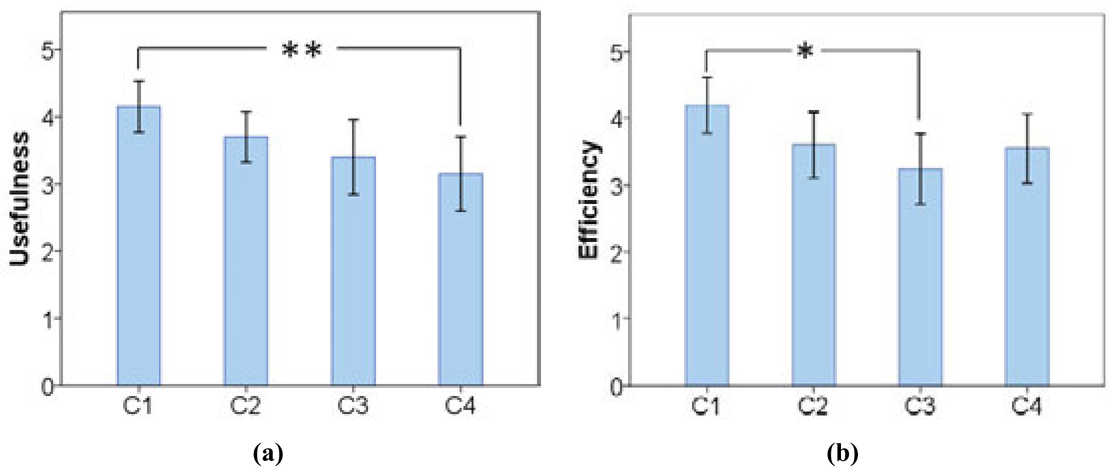


Figure 4.2 Mean and error bar of the usefulness and efficiency of the four features of the E-Gaze ((C1) gaze detection, (C2) eye contact simulation, (C3) avoiding state, and (C4) attention state). Significant group difference: $^{*}p < .05$, $^{**}p < .01$

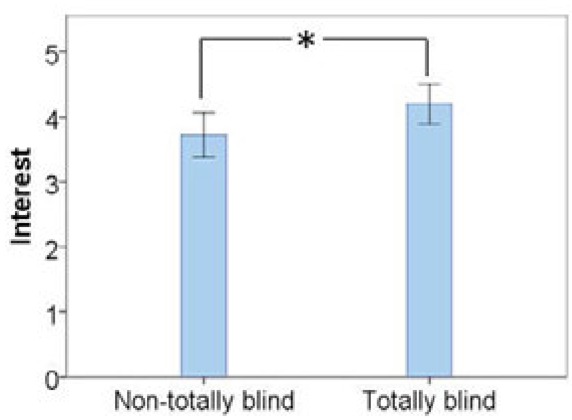


Figure 4.3 Mean and error bar of the interest between the non-totally blind group and the totally blind group. Significant group difference: $^{*}p < .05$, $^{**}p < .01$.

4.2.1.2 Qualitative Results

We collected in total 104 quotes of comments and suggestions about the E-Gaze design, which included 45 positive responses, 35 negative responses, and 24 responses for the design improvements. We gathered positive and negative comments from the answers to the question: “What do you think of the idea? Please tell the positive and negative feelings towards the E-Gaze.” We also collected suggestions for the design improvements. In the qualitative data analysis, the participants were anonymous with the numbers from P1 to P20. Example comments and suggestions are presented next.

Gaze Detection. In general, the majority of the participants felt the gaze detection was useful for them (Table 4.1). P20 said: “This idea is good because we could easily know some people will greet us or catch us.” However, three participants had negative comments on gaze detection. P18 argued, “It is not necessary for knowing being looked. The sighted could come to call my name directly.” Some questions and suggestions were provided by the participants. Two participants (P2,12) questioned the scenario: “If being looked at by many people, what will be the vibration feedback of the E-Gaze?” P1 also emphasized that blind people should control the eye gestures of the E-Gaze autonomously rather than only perceive the gaze from the sighed.

Table 4.1 Attitudes towards the concept of gaze detection.

Attitude	Number of quotes	Example keywords
Positive	18	Confident, warm, respected
Negative	3	Not necessary, useless

Eye Contact Simulation. We collected fourteen positive and six negative responses towards the attention state (Table 4.2). Example positive responses were, “It is useful at the start of the conversation, to show the respect to your conversation partner” (P1). “The sighted could feel me being polite if the E-Gaze has the eye contact with them” (P16). The negative responses were, “E-Gaze can establish the eye contact with the sighted, but I cannot feel the response of the eye contact” (P11). “The E-Gaze takes control over me and dominates my feelings. It replaces me to show the eye gestures (feelings) to the sighted, which is out of my control” (P14). For the suggestions, P8 and P14 wished to perceive the feedback of the eye contact. P14 fantasized the E-Gaze to detect the feelings and thoughts from his brainwaves and use the appropriate gaze to react to the sighted.

Table 4.2 Attitudes towards the concept of eye contact simulation.

Attitude	Number of quotes	Example keywords
Positive	14	Polite, comfortable, interesting
Negative	6	Horrible, unnatural, useless

Avoiding State. Table 4.3 shows participants' attitudes towards the avoiding state, including seven positive responses and thirteen negative responses. An example of the positive response was, "This idea is very helpful. Nobody liked being gazed at for a long time. It could be a feasible way to stop being gazed" (P13). An example negative response was, "The avoiding state creates the misunderstandings. The sighted may think you are not willing to communicate with them. If you can not stay patient with the conversation, you could tell the sighted or change to other topics" (P18). P2 stated, "If I am interested in a conversation, I want to continue talking rather than automatically change to the avoiding state even being gazed for a while." He further fantasized it was more natural to use brainwaves to control the opening and closing the E-Gaze. P14 also said, "If I am indeed impatient about talking, E-Gaze should have some subtle changes such as looking around or looking away. These responses are friendly to the sighted."

Table 4.3 Attitudes towards the concept of the avoiding state.

Attitude	Number of quotes	Example keywords
Positive	7	Natural, avoid embarrassed
Negative	13	Impede communication, impolite, impatient, lack of respect

Attention State. We collected six positive and thirteen negative responses towards the attention state (Table 4.4). P20 expressed the positive opinion, "It is interesting to let the sighted talking to you know that you are interested in the topic." However, some participants thought this feature was not necessary. For example, "The attention state is too exaggerated and looks like the cartoon figures' expression. I prefer natural expressions" (P9). "I feel uncomfortable if the E-Gaze exposes my attention state, because it is my privacy" (P2). Seven responses mentioned the design suggestions. The examples were, "I wish the E-Gaze could express my mood. It can change to the attention state when I feel excited; it can also change to the normal when I calm down" (P12). P6 mentioned, "E-Gaze is expected to be controlled by the dopamine in my body, indicating the level of the happiness and excitement. If the dopamine is high, the E-Gaze will naturally switch to the attention state" (P6).

Table 4.4 Attitudes towards the concept of the attention state.

Attitude	Number of quotes	Example keywords
Positive	6	Indicate the interests
Negative	13	No privacy, not feasible, useless, strange, uncomfortable

4.2.2 Insights

Based on both quantitative and qualitative results from the evaluation, we now reflect on findings and discuss the design implications of E-Gaze.

4.2.2.1 Design for Personalized Needs

Vision conditions of the participants are likely to influence their opinions on the design concepts and have an impact on their needs. Design should, therefore, consider the difference between the totally blind and non-totally blind groups. The quantitative result revealed that the totally blind participants expressed greater interest in the E-Gaze than the non-totally blind participants. Qualitative findings also demonstrated the participants had different needs according to a variety of the visual impairments. For example, some totally blind participants appreciated the idea of wearing the E-Gaze glasses that could help improve their eye appearance. One of the participants mentioned that she had an illness of nystagmus (i.e., involuntary movements of eyeballs), which always caused misunderstandings in face-to-face communication. E-Gaze could replace her eye gestures when she was talking with the sighted. For the participants who could still perceive the light and color, wearing the E-Gaze seemed inconvenient, and it influenced their residual visual acuity.

4.2.2.2 Gaze Detection

Gaze detection is an interesting direction for further development. Several scenarios proposed by the participants demonstrated that gaze detection could be useful: (1) Before the conversation, it can help blind people find the sighted who is looking at them, and they can initiate a conversation rather than passively wait. (2) During the conversation, if know being looked at, blind people will be more confident in talking.

Besides, the feature of gaze detection may be useful for blind people to protect privacy. If the sighted wants to peek at a blind person's laptop screen in public, the blind person can feel the gaze (vibration) from the sighted immediately. This feature also has the limitation: the vibration feedback may not be a perfect solution to map the gaze if being looked at by several people from different sides.

4.2.2.3 Autonomous Control over the Eye Gestures

E-Gaze also attempts to assist the blind person to show eye gestures to sighted people. Some eye gestures of E-Gaze may cause misunderstandings in communication and even lead to a misinterpretation of the user's real intention. Some participants mentioned that the avoiding state feature misinterpreted their real intention. If they were interested in a conversation, it would not be appropriate for the E-Gaze to switch to the avoiding state. If they were not interested, the E-Gaze could look away or look around as a euphemistic reminder rather than directly change to the avoiding state. Blind participants wanted to acquire subtle control over eye gestures of the E-Gaze.

4.2.2.4 Privacy

In the design scheme, we also need to consider the privacy of the participants. Nowadays an increasing number of smart technologies can enable the system to detect a variety of physiological signals from the participants (e.g., heart rate, gaze), which may bring privacy problems. Many studies have reported that heart rate increases with the attention and emotional responses (Billings and Shepard, 1910; Appelhans and Luecken, 2006). In our concept, a wearable sensor is added to detect a blind person's heart rate. If the blind person's heart rate increases, the simulated eyes on the E-Gaze will open bigger to show attention. However, the majority of the participants expressed negative opinions about this concept. One participant stressed that he did not wish the E-Gaze to change to an "attention state" automatically. He did not want other people to know he was engaged in something, which belonged to his privacy.

Based on the findings, we identified our design direction: selecting the gaze detection feature for the further design as the first step. We then developed the gaze detection feature to a prototype, named Tactile Band.

4.3 Experiment

4.3.1 Tactile Band Design

The Tactile Band was designed to examine the hypothesis that by enabling a blind person to feel attention (gaze) from a sighted person, the tactile feedback can enhance the level of engagement in face-to-face communication. In our concept, an SMI eye tracker [6] is used to detect the gaze of the sighted on a blind person' face. Gaze signals are mapped to the vibration signals of an actuator embedded in the Tactile Band, worn by a blind person on the forehead. The blind person perceives a slight vibration from the Tactile Band when the sighted looks at the face of the blind person (Figure 4.4). Two vibration patterns are used to map the basic gaze behaviors of glance and fixation. In the glance pattern, the sighted has a glance at the blind person's face to trigger a slight vibration of the Tactile Band. If the sighted shortly looks away, the vibration stops. In the fixation pattern, the sighted gazes at the blind person's face for a while and looks away. In this process, the first fixation to the blind person's face triggers a slight vibration of the Tactile Band. If the sighted keeps looking at the blind person's face, the blind person can feel a

[6] http://www.smivision.com/

continuous slight vibration until the sighted looks away. In a conversation scenario, the vibration feedback is much better than the auditory feedback, which can decrease the hearing load in communication. In our design, a blind person wears the Tactile Band on the head. Vibration feedback on the forehead can make the blind person immediately realize that someone is looking at her face. Although the vibration may be a little bit annoying on the head, we still think it is a suitable location for receiving gaze (vibration) signals.

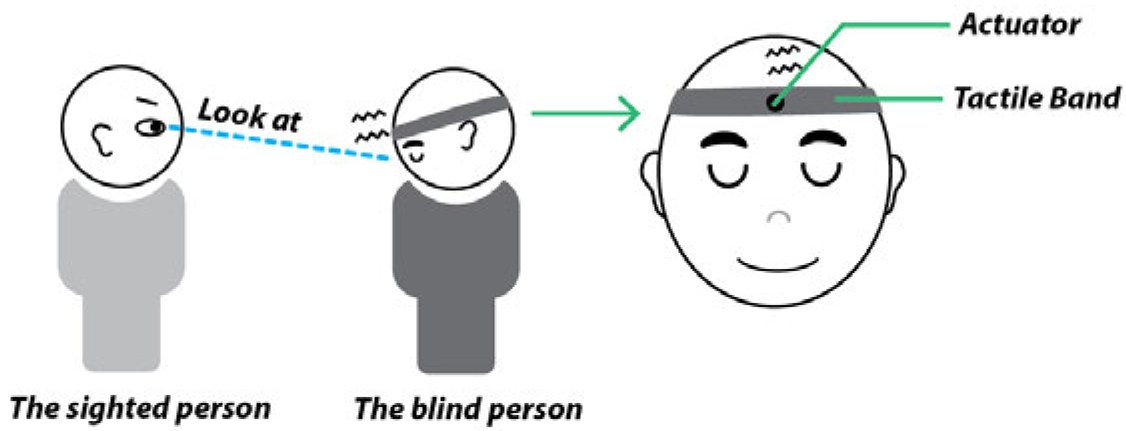


Figure 4.4 The design concept of the Tactile Band.

The experiment was conducted with a within-subject design. It included one independent variable with three levels (no Tactile Band, Tactile Band without vibrations, and Tactile Band with vibrations) and one dependent variable (the engagement in a conversation). Sears and Hanson (2012) suggested that due to a limited number of participants with certain disabilities, it is common to conduct research with participants that may be not representative of the intended users, especially in pilot studies. For example, in accessibility studies, many researchers use blindfolded sighted users in place of individuals who cannot see when studying solutions intended for real blind users. Therefore, blindfolded but sighted (hereafter blindfolded) participants were invited to our experiment as an alternative for the target blind users. The level of engagement in a conversation was measured using questionnaires with two subjective measures (i.e., relationship quality and partner closeness). Besides the questionnaires, gaze data was collected through the SMI eye tracker to help measure the engagement of the sighted participants in conversations. A qualitative analysis of the results from a post-experimental questionnaire was used to investigate subjective opinions of the participants towards the Tactile Band and to collect suggestions for further improvements.

4.3.2 Wizard-of-Oz Setup

The Tactile Band system used Wizard-of-Oz to simulate the behavior of the final system as closely as possible: a human "Wizard" simulated the response of the system in real-time, to interact with the users the same as the envisioned system (Dahlbäck et al., 1993). In the Wizard-of-Oz setup (Figure 4.5), two participants (A1: the blindfolded; A2: the sighted) had a conversation in Room 1, while a wizard was situated in Room 2. A2 wore the SMI eye tracker (C1). A1 wore the Tactile Band on her forehead. The wizard observed the real-time eye tracking video from C1 and controlled the vibration actuator of the Tactile Band accordingly. The video with the gaze information (recorded by the eye tracker C1) was used for the attention analysis after the experiment. Camera C2 captured the entire scene.

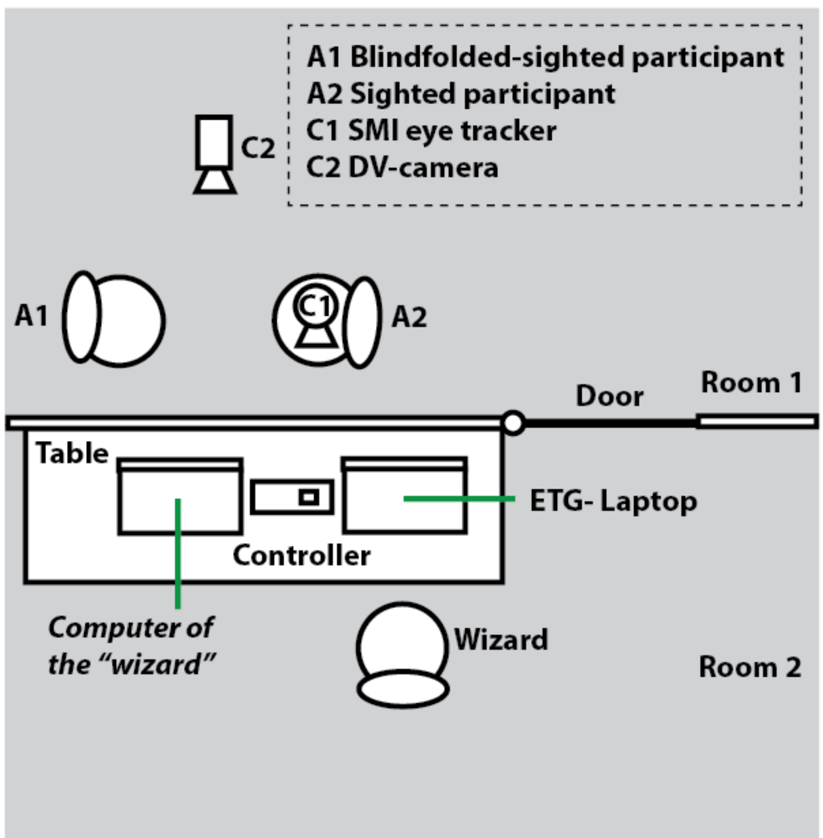


Figure 4.5 Wizard-of-Oz environment.

In the Tactile Band system, the SMI eye tracker (C1) connected to an ETG-Laptop and detected the gaze from the sighted participant in real-time. Gaze tracking accuracy of SMI eye tracker is 0.5° over all distances. The wizard observed the real-time gaze video from iView ETG 2.0 (i.e., eye tracking software[7]) installed on an ETG-Laptop. If the gaze hit the facial region of the blindfolded participant, a slight vibration was triggered by the wizard. If the gaze was still in the facial region, a continuous slight vibration was triggered by the wizard. The vibration stopped when the gaze was out of the facial region. Figure 4.6 shows an overview of the Tactile Band system.

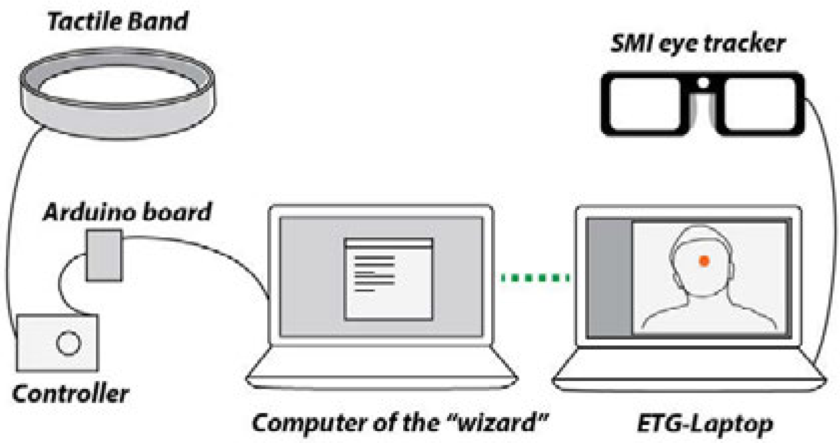


Figure 4.6 Overview of the Tactile Band system.

4.3.3 Participants

The participants were 30 student volunteers from Eindhoven University of Technology (11 females, M_{age} = 29.73, SD = 5.69; 19 males, M_{age} = 28.16, SD = 2.17) with age ranging from 21 to 42. They were divided into pairs to have dyadic conversations, and one of each pair was blindfolded. All participants had a normal or corrected-to-normal vision and were allowed to wear their contact lens, but not allowed to wear the glasses due to the inconvenience to wear the eye tracker and the blindfold. The participants were paired randomly: seventeen participants never met before; nine participants knew each other but had rarely or never had conversations; only four participants knew each other and sometimes had conversations.

4.3.4 Procedure

The procedure of the user experiment is shown in Figure 4.7. Two paired participants read and signed informed consents in the lab. In the informed consent, we told the blindfolded participants, "You are wearing a band that vibrates when your conversation partner looks at your face in the experiment." After completing informed consents, one participant was blindfolded and led to sit in a chair in Room 1, where we played some

[7] http://www.smivision.com/

soft music for relaxing. In Room 2, we helped the sighted participant wear the eye tracker and did the three-point calibration to catch his or her eye movements accurately. After the calibration, the sighted participant went to sit in the other chair in Room 1, facing the blindfolded participant (Figure 4.8).

After ensuring the blindfolded participant's comfort to blindness, we turned off the music. Then we randomly picked one topic in fourteen daily topics from IELTS oral exams ("IELTS Speaking Module - Part 2 - Sample Topics," 2012). These topics were all about daily lives and easy for the participants to start a conversation. One of the topics was for example "Describe a job you have done." Both participants were asked to share ideas about the topic. After that, the door was closed between Room 1, and Room 2 and the conversation started. After the average ten-minute conversation, the sighted participant completed a post-experimental questionnaire in Room 1, and the blindfolded participant was taken to Room 2 to finish with the blindfold off. Due to the pictorial measurements used in this process, the blindfolded participant was asked to take off the blindfold to complete the questionnaire. When both participants completed the questionnaires, we blindfolded the participant again and took her back to Room 1. Three conversations were taken place under the following experimental conditions for the blindfolded with a counterbalanced measure design: (I) no Tactile Band; (J) Tactile Band without vibrations; (K) Tactile Band with vibrations. Each conversation lasted around ten minutes, and after each conversation, participants were asked to answer a post-experimental questionnaire. After three conversations and post-experimental questionnaires, we did a short interview to collect the blindfolded participant's opinions towards the Tactile Band. Each conversation was videotaped, and the short interview was audio-tapped. The overall procedure of the experiment for each participant pair lasted approximately 90-120 minutes.

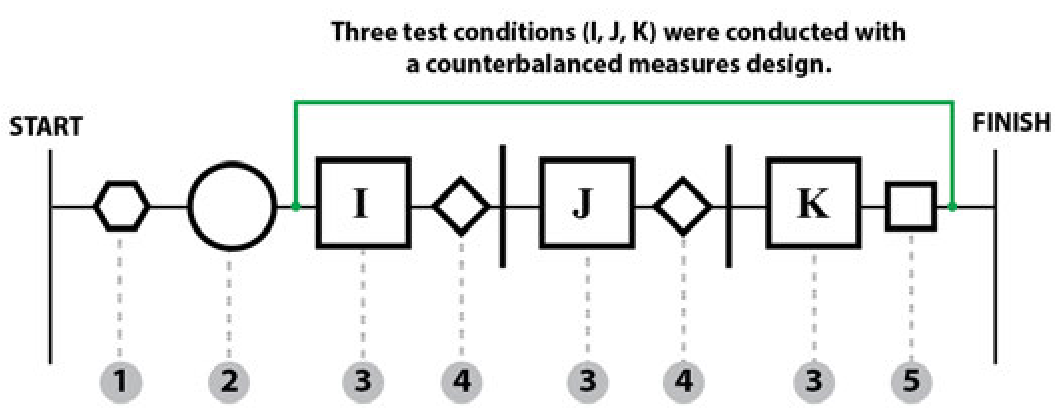


Figure 4.7 The procedure of the user experiment: (1) read and sign informed consents; (2) experience being blindfolded; (3) the test; (4) the post-experimental questionnaire; (5) the open questionnaire and the interview (only for the blindfolded participants).

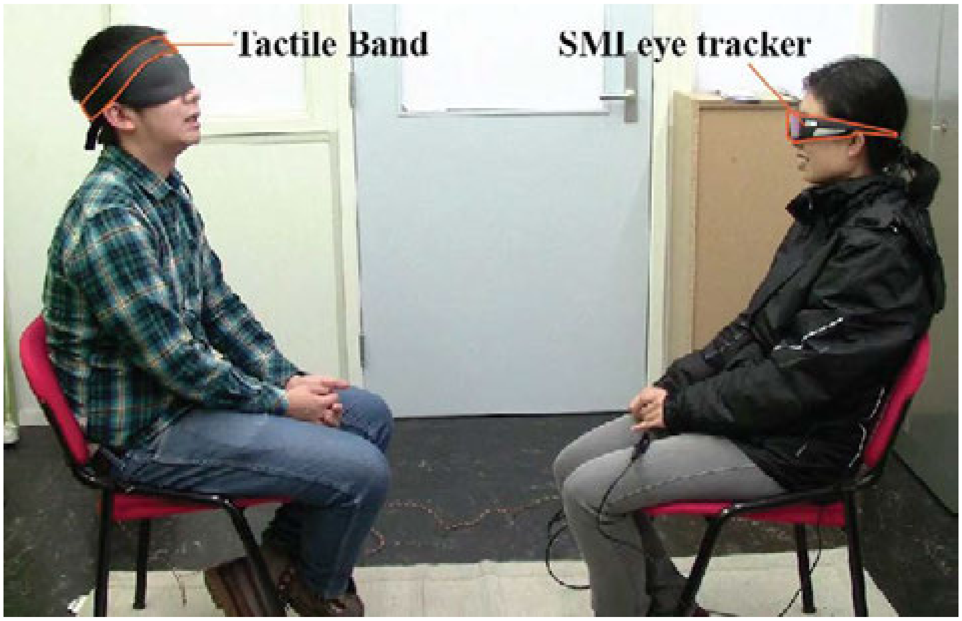


Figure 4.8 A blindfolded participant and a sighted participant in a conversation.

4.3.5 Measurements

We measured the level of engagement with two subjective measures: relationship quality (IMI: Intrinsic Motivation Inventory questionnaire) (McAuley et al., 1989) and partner closeness (IOS: The Inclusion of Other in the Self Scale) (Aron et al., 1992). IMI included 45 items, assigned to seven subscales. We were particularly interested in participants' mutual relationship in conversations. Therefore, the relatedness subscale of IMI was used. It has eight items, such as "It is likely that this person and I could become friends if we interacted a lot." IOS was used to measure the closeness. It includes seven increasingly overlapping circle pairs (Figure 4.9). One circle stands for a person, and the other circle stands for a conversation partner. A growing overlap of two circles illustrates an increasing closeness between two people.

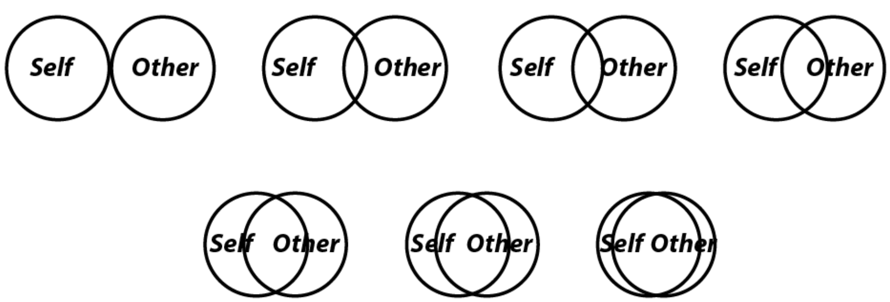


Figure 4.9 Seven increasingly overlapping circle pairs in IOS, adapted from (Aron et al., 1992, Figure 1, p.597).

We collected qualitative feedback with open questionnaires and interviews. After three tests, we left the blindfolded participant alone to complete the open questionnaire with five questions included the item: "Do you have some suggestions for improving the Tactile Band?" After finishing these questions, we did a short interview (average around five minutes) to confirm the answers.

Gaze tracking data from sighted participants in the tests were recorded and analyzed using the software BeGaze version 3.5, installed on the ETG-Laptop. The facial region of the blindfolded participant was chosen as the area of interest (AOI) for measuring the fixation duration. This metric was selected based on the relevant literature on the attention analysis with the eye movements (Mojzisch et al., 2006; Vertegaal et al., 2001).

4.3.6 Results

4.3.6.1 Quantitative Results

We used SPSS for the data analysis. Blindfolded participants in three pairs out of 15 could not consciously sense vibration signals during the experiment, but they were possibly influenced by the vibration signals unconsciously. Therefore, data from these blindfolded participants were not removed from the datasheet. The conversation quality was analyzed using a repeated measures ANOVA with the relationship quality and partner closeness as the within-subjects factors and the role (the blindfolded vs. the sighted) as a between-subjects factor. Table 4.5 presents the mean and standard deviation of the relatedness and partner closeness across three conditions. Before running the repeated measures ANOVA, we checked the data for violations of parametric analysis: the sphericity assumption was tested using Mauchly's test. There were no significant effects of relatedness [$F(2, 56) = .64$, $p = .53$], and partner closeness [$F(2, 56) = .20$, $p = .82$] in three conditions.

Since blindfolded participants wore the Tactile Band, we analyzed them in three conditions separately. The datasheet was split into two groups: the blindfolded and the sighted. There were no significant effects for blindfolded participants in relatedness [$F(2, 28) = .13$, $p = .88$], and partner closeness [$F(2, 28) = .04$, $p = .96$] in all conditions. There were also no significant results for the sighted participants of relatedness and partner closeness in three conditions ($p > .05$).

Table 4.5 Mean and standard deviation of relatedness and partner closeness across three experimental conditions: (I) no Tactile Band; (J) Tactile Band with no vibration; (K) Tactile Band with vibration.

	I (N=30)		**J (N=30)**		**K (N=30)**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Relatedness	5.58	0.86	5.71	0.71	5.59	0.87
Partner closeness	3.07	1.14	3.17	1.15	3.17	0.87

4.3.6.2 Qualitative Results

We adopted the conventional content analysis method that coding categories are derived directly from transcripts (Hsieh and Shannon, 2005) to analyze the comments from the blindfolded participants answering five open questions. In total 70 quotes were collected and they were merged into three categories: the vibration feedback (20 quotes), the prototype (31 quotes) and design suggestions (19 quotes).

We gathered the positive and negative comments regarding the vibration feedback from the result of the question "What do you think about the vibration feedback when your conversation partner looks at your face?" Two participants (P3 and P11) mentioned that they could not immediately relate the vibration to the gaze in conversations. The other participant (P10) explained, in the beginning, the vibration feedback helped her concentrate on the conversation partner, but after a while, it became just a subtle clue that she often neglected. The keywords in the findings are presented in Table 4.6.

Table 4.6 Positive and negative comments towards the vibration feedback of the Tactile Band.

Positive (frequency)	**Negative (frequency)**
Good (2), help to concentrate (1), take the conversation seriously (1), accurate (1), not obtrusive (1)	Difficult to relate the gaze to the tactile signal (3), neglect (3), unexpected (2), nothing special (2), strange (1), irritating (1), inconsistent (1), not necessary (1)

We asked participants the question, "Which aspects make you like/dislike the Tactile Band?" Six participants liked certain aspects of the Tactile Band. The example comments were: "The Tactile Band did not feel interfering too much. It was easy to wear, and it had a subtle cue" (P10). "It used the soft material, which was comfortable to the skin" (P14). Some participants also explained why they disliked the Tactile Band. The primary reason was wearing the Tactile Band on the head. The example comment was "The head feels like an unsuitable location for such direct vibrations. It might also be obtrusive for the conversation partner" (P14). The keywords in the findings are presented in Table 4.7.

Table 4.7 Like and dislike the Tactile Band.

Like (frequency)	Dislike (frequency)
Comfortable (5), subtle (3), not interfering (3), easy (1), relax (1), interesting (1), private (1), realize being looked at (1), soft material (1)	Uncomfortable (4), strange (2), unexpected (1), dislike (1), weak (1), not attractive (1), scary (1), obtrusive (1), not good (1), awkward (1)

We received design suggestions for improving the Tactile Band in two aspects: try other modalities to map the gaze and improve the wearability of the Tactile Band. As for the other modalities, two participants stated a change of the temperature could map to the gaze. For example, the soft warmth on the eyes indicated a kind of close feeling (P15). Other participants mentioned the cue tone, soft touch and different intensity of the vibration. For the wearability of the Tactile Band, participants proposed several design suggestions and the top three were: at hand, around the arm and using a mobile phone. If wearing the Tactile Band on these places, it was unobtrusive and did not draw attention during the conversation. The keywords in the findings are presented in Table 4.8.

Table 4.8 Design suggestions regarding the modality and the wearing position of the Tactile Band.

Modality (frequency)	Position (frequency)
Temperature (2), cue tone (2), soft touch (2), vibration with different intensity (1)	At hand (4), in the arm (2), mobile (2), body (1), the shoulder (1), waist (1), around the ear (1)

4.3.6.3 Gaze Data

In this subsection, we analyzed gaze data when the participants had conversations. To analyze the recorded gaze data from the video, we used BeGaze software to analyze the last five minutes of each conversation. We cropped the facial region of the blindfolded participant as the area of interest (AOI), shown in Figure 4.10.

Figure 4.10 Dynamic area of interest (AOI) of the blindfolded participant was defined in BeGaze software.

The AOI can synchronously match the dynamic facial region by setting keyframes. When the sighted participant's gaze hit the dynamic AOI, gaze data was registered for the attention analysis. Due to the frequent and strong head movements in the tests, the dynamic AOI was not able to accurately catch the facial regions of some blindfolded participants in the video. So ten sighed participants' eye-movement videos were used in the attention analysis, and five were excluded. The corresponding eye metrics inside the AOI area were calculated using BeGaze software and exported to SPSS for the analysis. We analyzed the effect of the Tactile Band by using fixation duration within the AOI area. It refers to how long the average fixation lasts, which is often associated with attention. Mean, and standard deviation of fixation duration was calculated for three experimental conditions (I, J and K) (Table 4.9). The repeated measures ANOVA analysis revealed that the main effect of fixation duration was not significant in all conditions, $F(1.41, 39.40) = 2.15$, $p = .14$.

Table 4.9 Mean and standard deviation of fixation duration (in milliseconds) across three conditions: (I) no Tactile Band; (J) Tactile Band with no vibration; (K) Tactile Band with vibration.

Test Conditions	**Facial Region**	
	M	**SD**
I (N=10)	280.88	28.14
J (N=10)	268.35	32.37
K (N=10)	256.92	26.32

4.4 Discussion

Although the quantitative results did not demonstrate the significant effect of the tactile feedback on the engagement between blindfolded and sighted participants in face-to-face communication, we still gained valuable insights while running the studies. We realized our experiment has certain limitations and we also get some useful implications for the further improvements in both the design and the experiment.

From observations, we found that (1) The vibration signals were too subtle for three participants to sense them; and (2) other participants could sense vibration signals, however, with the engagement in verbal communication, they started ignoring these signals. Simply increasing the intensity of the vibration may not be a good solution since it may become annoying in conversations. We expect to improve our design and experiment by improving the wearability, redesigning the scenario used in the experiment and providing more time to the participants to get used to the mapping between the gaze and the tactile signal.

According to the observations and user comments, we need to improve the wearability of the Tactile Band. For example, it could be worn on the wrist, which is less visible than on the forehead. The intensity of the tactile feedback could be fine-tuned. Other types of tactile feedback can also be explored besides vibration, such as a sense of pressure by changing the shape of the material. Since the auditory and tactile signals were two primary nonverbal signals for blind people to sense in face-to-face communication (Qiu et al., 2015b), we also consider using auditory signals to map the gaze. The scenario of a dyadic conversation is mainly verbal communication, which is easy to cause conflicts with other auditory signals. Mapping the gaze with the auditory signal is far from a perfect solution in our case, but it may be feasible under a certain condition. For example, one participant proposed to wear the earphone in conversations, mapping the gaze signal with the different cue tones from the earphone. It can avoid auditory interference to the conversation partner.

Besides the improvements of the prototype, redesigning the scenario used in the experiment is also needed. In the interviews, some blindfolded participants expressed several alternative contexts in which they would find them to be useful. For example, a slight vibration (gaze) signal from the conversation partner predicts the start of the conversation to help them be concentrated. In the turn-taking, the gaze plays an important role as it indicates where the speaker's focus of attention is directed (Jokinen et al., 2013). An alternative scenario can be that one sighted speaker discusses with two blindfolded participants in triadic (three-person) conversations. The sighted stops talking and gives her turn to one of two blindfolded listeners by the gaze.

Spending more time in learning the mapping between the gaze and the tactile signal may be helpful. The blindfolded participants knew the importance of the gaze, and they had the direct and clear understanding regarding the gaze behaviors. Nevertheless, the gaze is a visual cue. It will take some time, even long-term training for them to map the gaze to the tactile signal, which is so far unnatural for them. As for blind people, they tended to have the indirect and fuzzy understanding regarding the eyes and eye gestures (Qiu et al., 2015b). Mapping the gaze with the tactile signal is a new knowledge for them, which is likely to need more time for practicing and to get used to.

4.5 Conclusion

In this chapter, 20 blind and low-vision participants evaluated the features of the E-Gaze concept for usefulness, efficiency, and interest. Based on the evaluation, the concept is further developed into a working prototype, named Tactile Band. Also, we presented an experiment with the Tactile Band, which enabled a blind person to feel attention (the gaze) from the sighted. We expected the Tactile Band could enhance the engagement in face-to-face communication. Although the experimental results did not significantly demonstrate the effect of the tactile feedback on the engagement between blindfolded and sighted participants in face-to-face communication, we get many useful insights and design implications (e.g., improving wearability of the Tactile Band). As next steps, we will improve the prototype and involve some target blind users in the evaluation. More specifically, in the next chapter, we present the E-Gaze glasses, a wearable device to simulate the visual gaze for blind people.

5

Study III: Simulating Gaze Behaviors as Visual Reaction from a Blind Person[8]

[8] This chapter is based on:

Qiu, S., Anas, S. A., Osawa, H., Rauterberg, M., & Hu, J. (2016a). E-Gaze Glasses: Simulating Natural Gazes for Blind People. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 563-569). ACM.

Qiu, S., Anas, S. A., Osawa, H., Rauterberg, M., & Hu, J. (2016b). Model-Driven Gaze Simulation for the Blind Person in Face-to-Face Communication. In *Proceedings of the Fourth International Conference on Human Agent Interaction* (pp. 59-62). ACM.

5.1 Introduction

In Chapter 4, we presented the Tactile Band, which aimed to enable a blind person to perceive the gaze from a sighted conversation partner. In this chapter, we present E-Gaze, a smart glasses system based on an eye-tracking platform. It aims to improve the communication experiences of sighted people when they interact with blind conversation partners. An interactive gaze model was also presented, to simulate the appropriate gaze behaviors for blind people. It attempts to establish the "eye contact" between blind and sighted people to enhance their engagement in face-to-face communication. In our design scheme, the gaze model combines the eye-contact mechanism and the turn-taking strategy in conversations.

To evaluate the interactive gaze, we conducted a controlled laboratory experiment with a dyadic-conversation scenario. We recruited 40 participants to make up 20 pairs, including 10 blind-sighted and 10 blindfolded-sighted. The data from both pairs can be combined to produce a larger N so that the parametric statistical analysis can be applied. We can also examine whether a difference can be found between blind-sighted conversations and blindfolded-sighted conversations. A difference may indicate that blind participants cannot be substituted with blindfolded participants in evaluations, which contributes to the methodologies in the accessible computing area.

Overall, this chapter has two objectives: (1) Examine whether the communication quality of blind-sighted conversations and blindfolded-sighted conversations differ; (2) Investigate how the interactive gaze affects the communication quality in dyadic conversations.

5.2 E-Gaze, Version 1

In Chapter 4.2, a design concept of the E-Gaze glasses was proposed, aiming at creating eye-to-eye communication between blind and sighted people in face-to-face conversations. Four features of the E-Gaze system were introduced: (1) gaze detection, (2) eye contact simulation, (3) the avoiding state, and (4) the attention state. In this chapter, we refine two design features of this system: eye contact simulation, and the avoiding state. The first version of the E-Gaze aims at implementing the eye-contact mechanism (i.e., the reactive gaze), which links the eye tracking system with the eye animations of the E-Gaze glasses. In this version, a sighted user can use gaze to control the simulated eye gestures displayed on the E-Gaze glasses. For instance, if the user is looking at the E-Gaze, E-Gaze will look back to establish the "eye contact."

5.2.1 Conceptual Design

Argyle et al. (1974) suggested that in face-to-face conversations, the interlocutors' typical gaze patterns are making eye contact or looking away. In this chapter, we start by simulating these two gaze patterns in the E-Gaze system. Specifically, we are interested in linking gaze behaviors with the conversation flow by the turn-taking strategy, since gaze behaviors, turn taking and information structure are correlated (Torres et al., 1997). A speaker often averts the listener's eyes when she starts to speak (to concentrate on what she is going to say). At the end of the turn, the speaker often directs to the listener again, signaling the end of the turn and indicating the listener to take the turn (van Es et al., 2002).

In our design, E-Gaze is a wearable glasses device worn by a blind person. E-Gaze displays two basic eye gestures (i.e., "look at" and "look away") to the sighted person based on whether the blind person is talking. When the blind person starts talking, the E-Gaze will "look away" from the sighted to concentrate on what the blind person is going to say; when the blind person ends talking, the E-Gaze will "look at" the sighted to help establish the "eye contact" between two people, signaling the turn for the sighted. If the sighted stares at the E-Gaze, it will "look away" to avoid the long gaze. There is an equilibrium level of the eye contact in a face-to-face conversation, so avoiding the long gaze may make the conversation feel comfortable. According to Argyle and Dean (1965), if the eye contact rises above a certain amount, it will arouse the anxiety.

The initial version of E-Gaze is based on AgencyGlass programmed in C++ in Visual Studio 2012 (Osawa, 2014b). AgencyGlass was designed for sighted people to decrease the emotional load and it used a connected keyboard to control displaying five basic eye gestures. We introduced the AgencyGlass design into our E-Gaze system to provide means for a blind person to react to the sighted by displaying the appropriate eye gestures in conversations. In our conceptual setup, an Eye Tribe Tracker [9] is placed in front of the sighted to detect the gaze coordinates. A blind person wearing the E-Gaze sits face-to-face with a sighted person (Figure 5.1).

[9] https://theeyetribe.com/

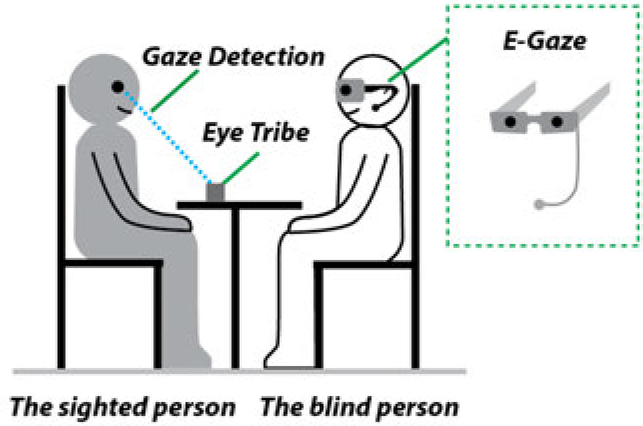


Figure 5.1 A dyadic-conversation scenario between the blind person and the sighted person.

5.2.2 Implementation

We connect the Eye Tribe tracking system with the corresponding eye gestures of the E-Gaze[10]. The speech detection model of this system is reported in Section 5.3.1. This study uses the Eye Tribe as a gaze input apparatus, which is an open source eye-tracking device. Compared to other existing eye-tracking devices, the Eye Tribe is low-cost and is freely programmable based on its open-source codebase. In the E-Gaze system, an Eye Tribe Tracker is used to calculate the location of the gaze point of the sighted by extracting information from the camera images of this sighted person's face and eyes. When the eye tracking system is calibrated, the supporting software can measure the sighted person's gaze coordinates with an average accuracy of around 0.5 to 1º of visual angle. It enables the client applications to interact with the underlying tracker server to obtain gaze data both in raw and smoothed forms based on an open Application Program Interface (API). A computer acting as a server extracts the data gathered by the Eye Tribe Tracker.

The E-Gaze system consists of an Eye Tribe Tracker[11], a laptop, an Arduino microcontroller, a Bluetooth module, two uOLED-160-G2 display modules with an embedded GOLDELOX graphics processor, and a physical glasses-shaped prototype fabricated by a 3D printer. The overview of the E-Gaze system is as shown in Figure 5.2. A graphical user interface (GUI) with 15 points of gaze is created to detect eye gestures from the sighted using the Eye Tribe. Central five points with the blue color can be activated in gaze detection. Whenever the sighted is focusing on an area that is close to the gaze point among the five, it highlights that point and triggers the corresponding eye animations on the OLED. The eye animations were taken from Agency Glasses (Osawa,

[10] E-Gaze is programmed in Java by Siti Aisyah binti Anas.
[11] http://theeyetribe.com/dev.theeyetribe.com/dev.theeyetribe.com/general/index.html

2014b). The online video[12] shows the detailed interactions between the E-Gaze glasses and the sighted.

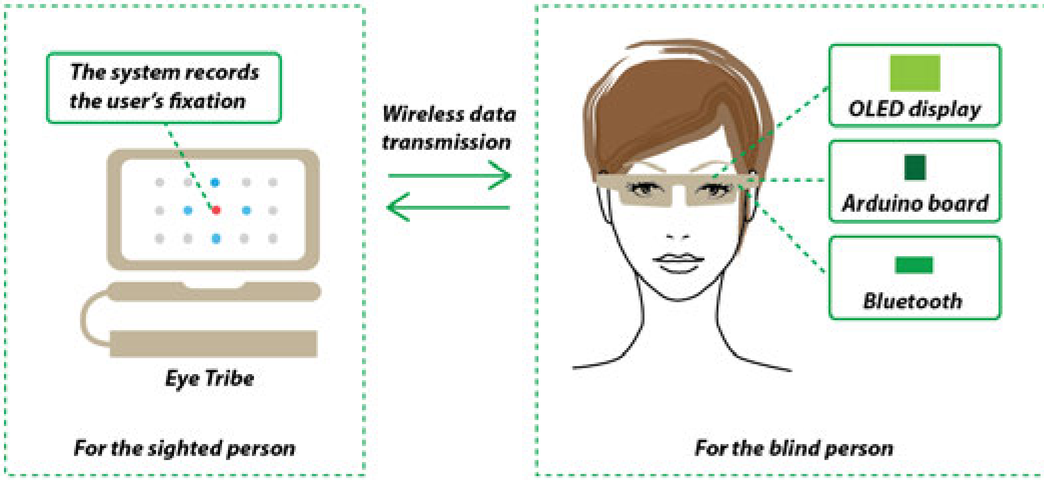


Figure 5.2 Overview of the E-Gaze system.

5.3 E-Gaze, Version 2

The E-Gaze was further iterated and improved. In the second round of iteration, we aim at implementing the interactive gaze model of the E-Gaze and making the working system available for user experiments with dyadic-conversation scenarios between a blind person and a sighted person.

5.3.1 Interactive Gaze Model

Since we did not find any literature of designing the gaze for blind people, we attempted to borrow the practical approaches on how to simulate the gaze between humans and the virtual agents (avatars) (Chapter 2.6). Simulating appropriate gaze for virtual agents can effectively evoke natural feelings in human users (Andrist et al., 2012). Most virtual agent systems simulate the gaze based on the turn-taking in conversations rather than being reactive. Kipp and Gebhard (2008) introduced a reactive gaze system. In this reactive system, the gaze of a user can trigger an instantaneous response on the agent side which in turn influences the user.

In this section, we proposed an interactive gaze model, combining the eye-contact mechanism (i.e., the reactive gaze) and the turn-taking strategy in conversations. When the turn-taking occurs, a sound detector can detect the change in the listening and speaking modes in the conversation flow. The detailed timing of the interactive gaze is based on the research of dyadic conversations between a human and a virtual agent

[12] https://vimeo.com/141387464

(Kendon, 1967; Bee et al., 2010). In the interactive gaze model, whenever the sighted is looking at the E-Gaze, it reacts to the sighted with a “look at” eye gesture, and holds it for about one second, trying to establish the “eye contact.” Then it looks away for about four seconds to avoid a dominance for gazing too long. One of the four eye gestures (i.e., look up, down, left, and right) are randomly chosen to display a “look away” eye gesture. The timing of the E-Gaze “look at” and “look away” is varied according to whether the blind person is talking or listening. This strategy is based on the experimental studies of Argyle and Cook (1976), in which they found that people looked more at the conversation partner while listening than speaking. In our system, the E-Gaze displays a “look at” eye gesture for two seconds and looks away for four seconds while the blind person is speaking. If the blind person is listening, E-Gaze displays a “look at” eye gaze for three seconds and then looks away. The interactive gaze model is presented in Figure 5.3.

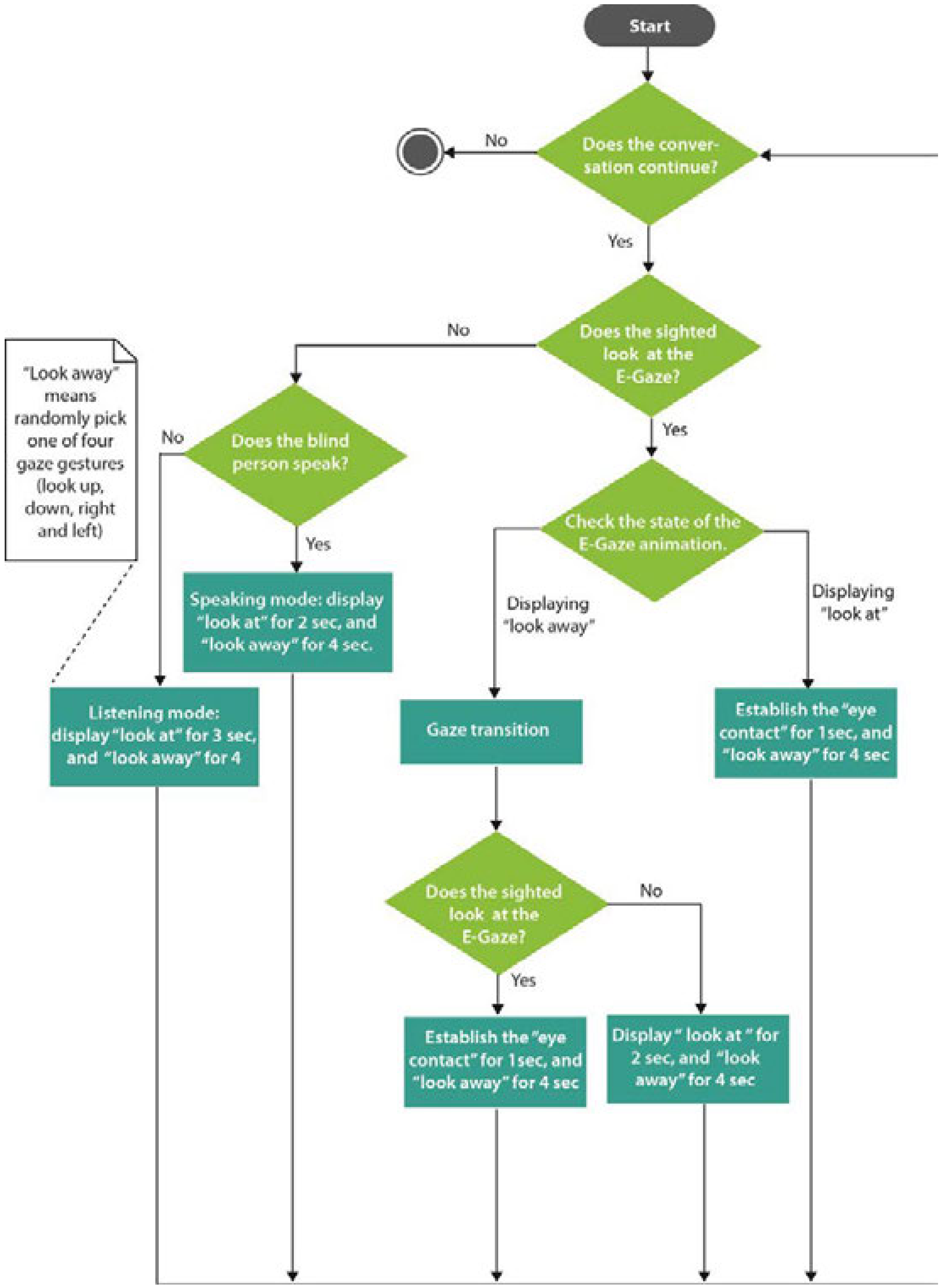


Figure 5.3 The flowchart of the interactive gaze model.

5.3.2 System Improvements

In this section, we introduce the implementation of the interactive gaze model for the E-Gaze system. The E-Gaze animations are driven by two sensors: an Eye Tribe Tracker and a sound detector. The Eye Tribe detected gaze signals from a sighted person, and the sound detector detected audio signals from a blind person. The Eye Tribe is used to implement the eye-contact mechanism, while the sound detector was added to the earlier design (Section 5.2.2) for implementing the turn-taking strategy (Figure 5.4). In a dyadic-conversation setting, to detect the blind person's speaking clearly, the sound detector is fixed on a flexible rod that can be adjusted to near the mouth of the blind person. The sensitivity of the sound detector is regulated and calibrated only to detect the speaking from the blind person.

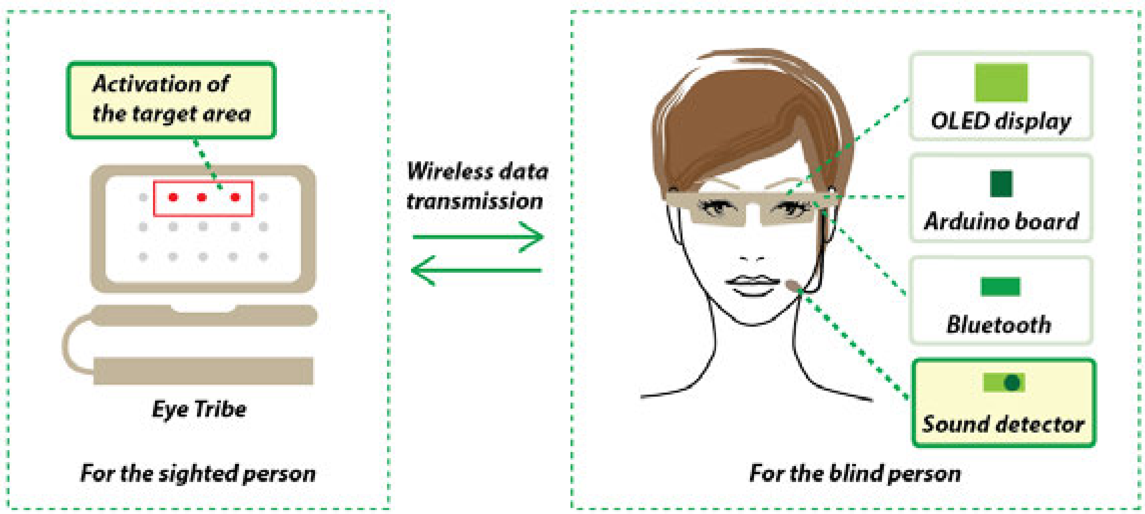


Figure 5.4 The modified E-Gaze system with a sound detector.

For the calibration of the gaze signal from the sighted, a laptop screen is placed in front of the sighted, displaying a graphical user interface (GUI) with 15 targeted areas to indicate the point of interest. When the sighted fixates on one of the target areas, the E-Gaze system activates the corresponding area to display the red points (Figure 5.5 (a)). The red dot in Figure 5.5 (a) indicates that the sighted is looking at the direction of the target area of the E-Gaze. The target area is defined as a rectangle area with 1000 pixels width and 500 pixels height. It is larger than the actual size of the E-Gaze, to ensure that the target area can cover the entire E-Gaze glasses. The laptop is removed after calibration (Figure (b)). When the sighted looks at the E-Gaze, the corresponding points of interests will be detected to signal the gaze. The same eye-tracking system and similar setup have been used in the study of (Anas et al., 2016).

When the sighted looks at the E-Gaze, the system sends the command to the Arduino through a wireless Bluetooth connection. To enable the E-Gaze to respond to the gaze of a sighted person, the position of the E-Gaze is predetermined and must be within the Eye Tribe Tracker's tracking area. The Eye Tribe Tracker detects the gaze from the sighted, and if her gaze is in the area of the E-Gaze, a command is sent out via Bluetooth adapter from the laptop to a Bluetooth module connected to the Arduino. E-Gaze then displays a "look at" eye gesture to establish the eye contact with the sighted. We used the same human's eye gestures videos (Osawa, 2014b) to display on the OLED display. The videos were saved into an SD card with a raw format which is readable by GOLDELOX graphics processors. Figure 5.6 shows the E-Gaze worn by a person.

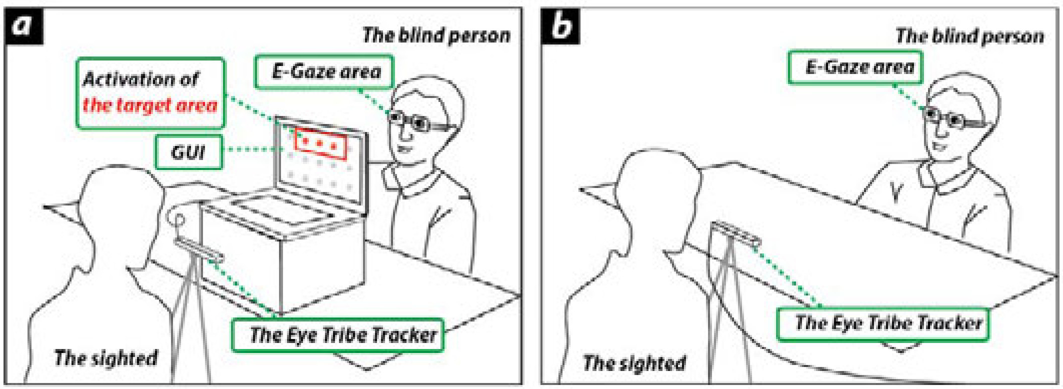


Figure 5.5 (a) Calibration, and (b) Remove the laptop after calibration.

Figure 5.6 The E-Gaze glasses worn by a person (with consent).

5.4 Experiment

We conducted a user experiment to test the perceptions and reactions of the participants to the E-Gaze and specifically examined whether the interactive gaze model could affect the communication quality. Besides the real blind participants, we recruited sighted people being blindfolded, namely blindfolded participants, to attend the lab-based experiment.

The experimental researches were designed and performed around the following three research questions regarding the face-to-face communication:

1. How is the communication quality of blind-sighted conversations different from blindfolded-sighted conversations?
2. How does the Interactive Gaze affect the communication quality?
3. How does the Interactive Gaze in blind-sighted conversations affect the communication quality?

To test the effectiveness of the Interactive Gaze, we compared the Interactive Gaze with other three conditions: No Gaze, Random Gaze, and Constant Gaze, which were based on an increasing rate of the eye contact from zero to continuous (Argyle et al., 1974). Thus, the corresponding $4 \times 2 \times 2$ mixed factorial experimental design was proposed, using four gaze conditions (No Gaze, Constant Gaze, Random Gaze, Interactive Gaze) as the within-subjects factor, the conversation groups (blind-sighted, blindfolded-sighted) as the between-subjects factor, and the participant roles (blind and blindfolded participants, sighted participants) as the between-subjects factor.

We recruited 40 participants to make up 20 pairs (10 blind-sighted pairs and 10 blindfolded-sighted pairs). These two kinds of pairs followed nearly the same procedure in the user experiment. In the blind-sighted pair, a blind participant wore the E-Gaze and discussed a given daily topic with a sighted participant. They had four conversations with each other, and each conversations lasted around 10 minutes. Four conversations took place under four gaze conditions of the E-Gaze (No Gaze, Constant Gaze, Random Gaze, and Interactive Gaze) with a counterbalanced measures order to avoid the carry-over effects.

5.4.1 Independent Variables

Three independent variables were introduced as below:

The first independent variable is the way how E-Gaze displays the gaze behaviors. This variable is treated as a within-subject factor. It has four conditions: No Gaze, Constant Gaze, Random Gaze, and Interactive Gaze.

1. No Gaze: E-Gaze only has two black OLED screens.
2. Constant Gaze: E-Gaze displays a “look at” eye gesture.
3. Random Gaze: E-Gaze randomly displays five eye gestures (look at, up, down, left, and right). The average duration of each state is two seconds.
4. Interactive Gaze: E-Gaze displays the eye gestures based on an interactive gaze model that has been introduced in Section 5.3 (E-Gaze, Version 2).

The second independent variable is the type of conversation groups. This variable is treated as a between-subject factor. It has two conditions: (1) the blind-sighted group, and (2) the blindfolded-sighted group.

The third independent variable is the role of the participants. This variable is treated as a between-subject factor. It has two conditions: (1) the blind and blindfolded participants, and (2) the sighted participants.

5.4.2 Hypotheses

We formulated three categories of the hypotheses based on the research questions.

H1 There is a significant difference of the communication quality between the blind-sighted group and the blindfolded-sighted group.

- **H1.1** There is a significant interaction effect between the type of the conversation groups and the role of the participants.
- **H1.2** There is a significant interaction effect between gaze conditions and the type of conversation groups.
- **H1.3** There is a significant interaction effect among gaze conditions, the type of conversation groups and the role of the participants.

H2 There is a significant difference of the communication quality among four gaze conditions.

- **H2.1** There is a significant interaction effect between gaze conditions and the role of the participants.

H3 There is a significant difference of the communication quality among four gaze conditions in the blind-sighted group.

- **H3.1** There is a significant interaction effect between gaze conditions and the role of the participants in the blind-sighted group.

5.4.3 Participants

User experiments were conducted in two locations, Shanghai and Yangzhou in China. For the experiments conducted in Shanghai, only the sighted participants were recruited from Shanghai Jiao Tong University (SJTU) by posting the recruitment information on the university website (tongqu.me) without any particular criterion. For the experiments conducted in Yangzhou, both blind and sighted participants were recruited. The blind participants were recruited from Yangzhou Special Education School (YZSES) under the help of the teachers based on two criteria: (1) blindness should be the only significant handicap, and (2) students should be registered blind in China Disabled Persons' Federation (CDPF, 2013). The sighted participants were recruited from Jiangsu College of Tourism (JCT) under the help of the teachers without any particular criterion.

Demographic Information. The participants were 40 student volunteers in China (M_{age} = 19.35, SD = 2.98, N = 20 females vs. 20 males) with ages ranging from 16-26. The participants were divided into two groups: (1) the blindfolded-sighted group from SJTU, and (2) the blind-sighted group from YZSES and JCT (Table 5.1). The experiment with the blindfolded-sighted group was conducted in SJTU, and the blind-sighted group was in YZSES.

Table 5.1 Two conversation groups.

Conversation Groups	**Number of Participants**	**Sight Capacity**	**University, College and School**	**Experiment location**
Blindfolded-sighted	10 10	Blindfolded Sighted	SJTU SJTU	SJTU SJTU
Blind-sighted	10 10	Blind Sighted	YZSES JCT	YZSES YZSES

The participants to be blindfolded were randomly selected in the blindfolded-sighted group. This group consisted of 10 pairs with one blindfolded and one sighted in each (M_{age} = 21.65, SD = 2.390, N = 8 females vs. 12 males). The blind-sighted group consisted of 10 pairs with one real blind and one sighted (M_{age} = 17.05, SD = 1.191, N = 12 females vs. 8 males). The participants in each pair were matched with the same gender to avoid the heterosexual effect in conversations. Two participants in each pair had a similar age, which might be easier for them to generate discussions. Each participant was compensated 100 CNY at the end of the experiment. The information regarding age, gender, and education of the participants is presented in Table 5.2, Table 5.3, and Table 5.4.

Table 5.2 Participants' age.

Conversation Group	N	Mean	Std. Deviation	Minimum	Maximum
Blindfolded-sighted	20	21.65	2.390	18	26
Blind-sighted	20	17.05	1.191	16	20
Total	40	19.35	2.983	16	26

Table 5.3 Participants' gender.

Conversation Group	Gender	N
Blindfolded-sighted	Male	8
	Female	12
Blind-sighted	Male	12
	Female	8
Total	Male	20
	Female	20
	Total	40

Table 5.4 Participants' education.

Conversation Group	Education	N
Blindfolded-sighted	Bachelor	11
	Master	9
	Total	20
Blind-sighted	The eighth grade	1
	The tenth grade	17
	The eleventh grade	2
	Total	20

Vision Conditions. Blind participants provided vision conditions based on their disability certificates from CDPF (2013). We converted vision conditions of the blind participants in mainland China to the WHO standard (Table 5.5).

Table 5.5 Vision conditions of the blind participants in the blind-sighted group.

Gender	Age	Vision Conditions (WHO Standard) [a]	Congenital Blindness (Y/N)	Color Perception (Y/N)	Light Perception (Y/N)
F	19	Moderate visual impairment	Y	Y	Y
M	20	Moderate visual impairment	Y	Y	Y
M	17	Moderate visual impairment	Y	Y	Y
M	16	Moderate visual impairment	Y	Y	Y
F	16	Severe visual impairment	N	Y	Y
M	18	Severe visual impairment	N	Y	Y
M	19	Severe visual impairment	Y	Y	Y
M	16	Blindness 3	N	Y	Y
F	18	Blindness 4	N	Y	Y
M	16	Blindness 5	Y	N	N

[a] Vision impairments are sorted from low to high.

Familiarity. In all participants, 34 participants never knew each other, and only six participants knew each other (Table 5.6). In the blindfolded-sighted group, 14 participants never knew each other, and six participants knew each other. In the blind-sighted group, none of the participants knew each other before.

Table 5.6 Familiarity among the participants in each group.

Conversation Groups	Initial Familiarity	N
Blindfolded-sighted	Never knew each other	14
	Knew each other	6
Blind-sighted	Never knew each other	20
Total	Never knew each other	34
	Knew each other	6
	Total	40

5.4.4 Setup

The participants were divided into pairs to take dyadic conversations. Schematic diagrams of the experimental setup are presented in Figure 5.7 and Figure 5.8. A blind or a blindfolded participant wore the E-Gaze glasses and sat in front of a sighted participant. The sighted participant was approximately 1.8m away from the blind or blindfolded conversation partner. It is a comfortable social distance for people sitting in chairs or gathered in a room (E. T. Hall, 1963). We aligned the Eye Tribe tracker and adjusted it towards the sighted participant's face for the maximum trackability. The tracker connected to a laptop was installed around 0.5m away from the sighted participant. To stabilize and track the gaze accurately, we used a comfortable pillow to support the neck of the sighted participant well. The observation camera captured the whole scene. In the experimental setup, we used a USB cable to connect the laptop and the E-Gaze rather than the wireless connection. Figure 5.9 shows a picture taken from the observation camera during the experiment.

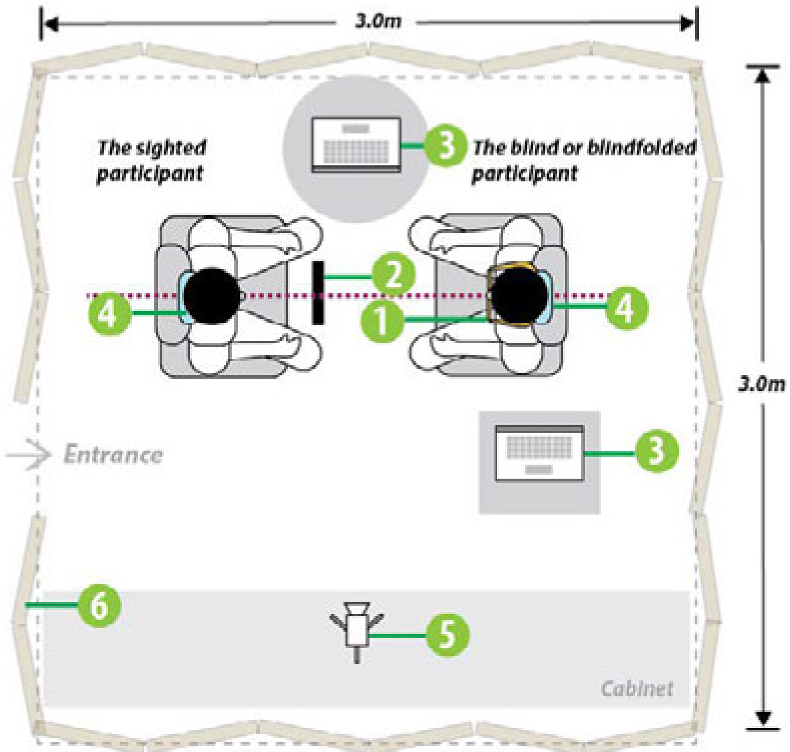


Figure 5.7 Overhead view of the experimental setup: (1) the E-Gaze glasses, (2) the Eye Tribe Tracker, (3) the laptop, (4) the pillow to support the neck of the participant, (5) the observation camera, and (6) folding screens.

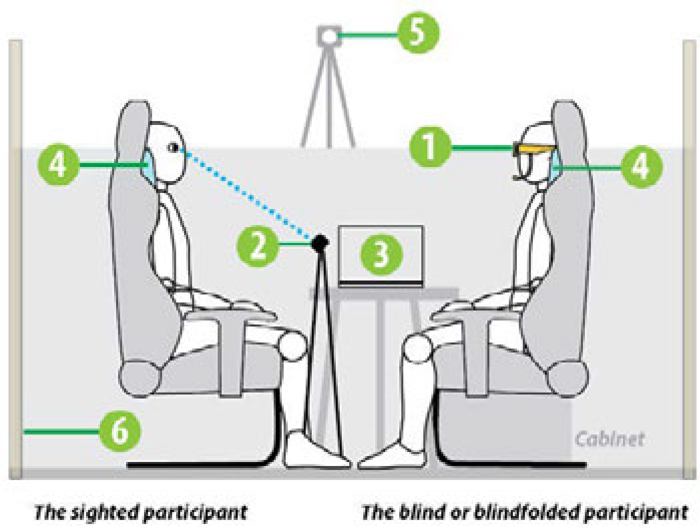


Figure 5.8 Front view of the experimental setup: (1) the E-Gaze glasses, (2) the Eye Tribe Tracker, (3) the laptop, (4) the pillow to support the neck of the participant, (5) the observation camera, and (6) folding screens.

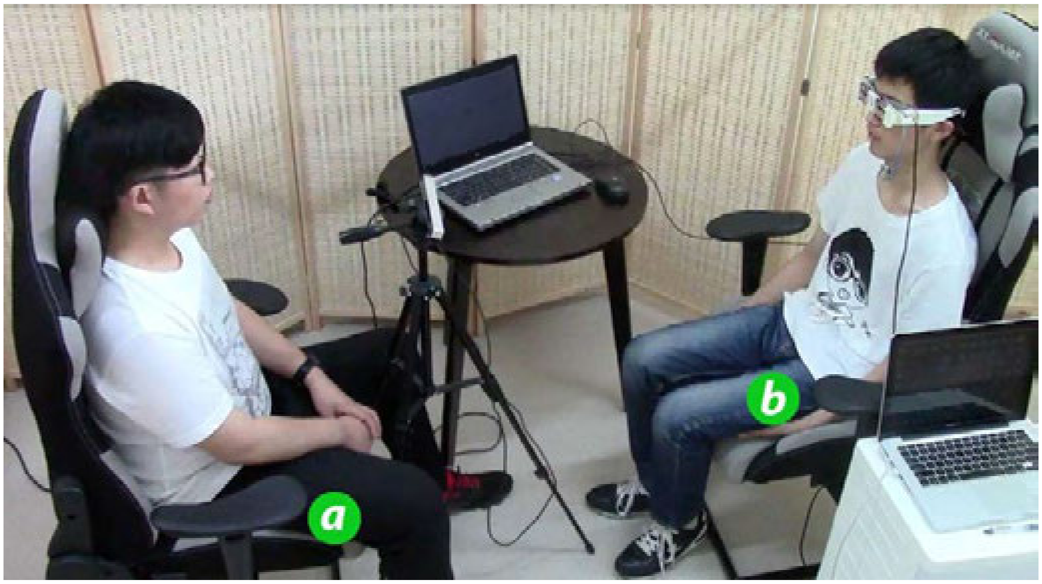


Figure 5.9 The picture was taken from the observation camera during the experiment: (a) the Eye Tribe detected the gaze from the sighted; (b) a blind participant wore the E-Gaze glasses.

5.4.5 Procedure

The procedure of the experiment is shown in Figure 5.10. All experimental sessions were executed completely in Chinese. In the experiment, the participants in the blindfolded-sighted pair signed consent forms and completed pre-experimental questionnaires by themselves. In the blind-sighted pair, the blind participant cannot read the consent form due to the blindness. Besides the researcher, a volunteer who did not belong to the research team was invited to observe the consent process. The volunteer orally presented the consent form and allowed the blind participant sufficient time for the questions to be asked and answered. With clear understanding, the blind participant had an oral statement: "I agree to participate in this research. My name is [...], and the date is [...]." The volunteer also orally presented his name and the date, then signed and dated the form for the blind participant. The whole consent procedure was audio recorded as part of the documentation of the consent forms.

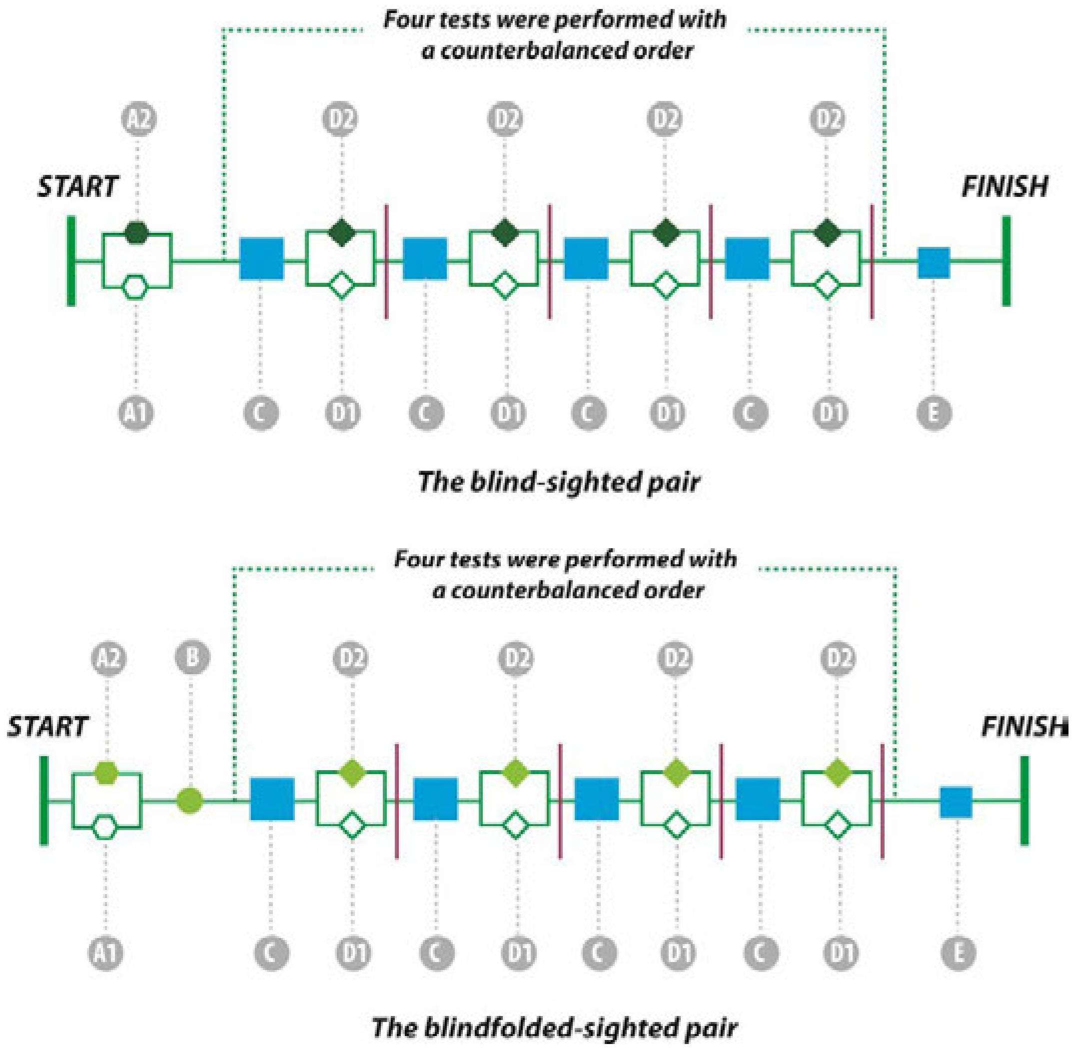


Figure 5.10 The procedure of the experiment: (A1) read and sign consent forms; (A2) a volunteer helped in the consent process (only for the blind participants); (B) experience being blindfolded (only for the blindfolded participants); (C) test; (D1) complete the post-experimental questionnaire; (D2) the researcher orally presented the questionnaire to the blind or blindfolded participants and completed the questionnaires based on their oral answers; (E) the interview for the open questions.

After completing the consent forms, the participants filled out the pre-experimental questionnaire regarding the demographic information. Next, the blind or blindfolded participants wore the E-Gaze. In the blindfolded-sighted pair, one participant was randomly selected to wear the blindfold. We ensured the participant's comfort to the blindness and this participant needed to wear the blindfold and the E-Gaze during the entire experiment, including answering the questionnaires.

We randomly picked one of the fourteen daily topics from the IELTS oral exam ("IELTS Speaking Module - Part 2 - Sample Topics," 2012). The topics regarding daily lives were easy for the participants to start a conversation. One of these topics was for example "Describe an important choice you have to make in your life." We asked two participants in the same pair to share ideas about the topic and gave them three minutes to prepare the topic. Next, we calibrated the eye tracker for the sighted participants, which took less than two minutes. The participants completed the post-experimental questionnaires after a ten-minute conversation. The sighted participant could complete the paper questionnaires. Meanwhile, the researcher orally presented the questionnaire to the blind or blindfolded participants, and completed questionnaires based on their oral answers. After each conversation, answering the questionnaire took around 20-25 minutes for a blind participant and 15-20 minutes for a blindfolded participant. The participants had a total four conversations in the experiment. Each conversation lasted around 10 minutes, and after each conversation, the participants were asked to answer the post-experimental questionnaires. After completing four conversations and post-experimental questionnaires, we conducted a short interview to collect the participants' comments towards the E-Gaze. The conversations were videotaped, and the interviews were audio-tapped. The overall experiment in the blind-sighted pairs lasted approximately 150-180 minutes, while in the blindfolded-sighted pairs lasted about 120-150 minutes.

5.4.6 Measurements

In social science, the communication quality has been used in the research fields of communication and personal relationships. Keeley and Hart (1994) explained, "Quality of a personal relationship is inexorably related to the quality of communication between the parties involved in that relationship." Montgomery (1988) suggested that high-quality communication is positive, intimate and controllable, which is often associated with positive relationship outcomes.

In HCI, Garau et al. (2001) measured the communication quality between humans and avatars in dyadic conversations. In their study, the communication quality consisted of four sub-dimensions: *face-to-face*, *involvement*, *co-presence*, and *partner evaluation*. *Face-to-face* described the extent that the conversation was experienced as the real face-to-face communication. *Involvement* described the extent that the participants involved in communication. *Co-presence* is the sense of being with and interacting with another person rather than computer interfaces. *Partner evaluation* included two aspects: (1) the extent that the participants positively evaluated their conversation partners, and (2) the extent that the conversation was enjoyed.

In our study, we measure the level of communication quality with two aspects: social presence and closeness.

5.4.6.1 Social presence

According to Biocca et al. (2003), a brief description of "social presence" is the "sense of being with another." "Another" refers to either a human or an artificial agent. In our experiment, we use an adapted version of the "Networked Minds Social Presence Inventory" (NMSPI) developed by Harms and Biocca (2004). NMSPI includes 36 items. It is composed of six sub-dimensions with a seven-point response scale ranging from one (strongly disagree) to seven (strongly agree) (Table 5.7).

Table 5.7 Six sub-dimensions in an adapted version of the Networked Minds Social Presence Inventory (Harms and Biocca, 2004).

No.	Sub-dimensions	Descriptions of each sub-dimension	Example item	[a] Cronbach's alpha
1	Co-presence	the level of awareness of the partner	I noticed (my partner).	.83
2	Attentional allocation	the amount of attention that a person provides to, and receives from the partner	I was easily distracted from (my partner) when other things were going on.	.81
3	Perceived message understanding	the ability that a person could understand the message from the partner	(My partner) found it easy to understand me.	.87
4	Perceived affective understanding	a person's ability to understand a partner's emotion and attitudes	I could describe (my partner's) feelings accurately.	.86
5	Perceived emotional interdependence	the extent that a person's emotional state affects, and is affected by the partner	(My partner) was sometimes influenced by my moods.	.85
6	Perceived behavioural interdependence	the extent that a person's behaviour affects and is affected by the partner	My behaviour was often in direct response to (my partner's) behaviour.	.82

[a] All scales described above showed good reliability.

5.4.6.2 Closeness

Pipp et al. (1985) found that closeness and amount of the circle overlap were strongly related to the degree of love and friendship. This idea of closeness as overlapping selves is consistent with some approaches to closeness in the social psychology literature (Reis and Shaver, 1988; McAdams, 1988). In our experiment, we used "Inclusion of Other in the Self" (IOS) Scale (Aron et al., 1992) to measure the closeness between two conversation partners. It includes seven increasingly overlapping circle pairs, indicating the distance of the relationship between themselves and their conversation partners. Because the blind and blindfolded participants could not see the circle pairs, we used the percentage (0%, 15%, 30%, 45%, 60%, 75%, 90%) to match the level of two circles' overlap (Figure 5.11). In the experiment, the researcher orally explained each option to the blind or blindfolded participants.

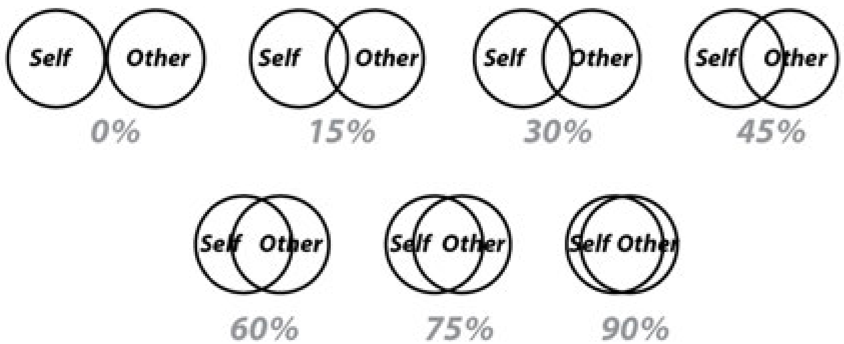


Figure 5.11 The modified version of the Inclusion of Other in the Self (IOS) scale (Aron et al., 1992) with the percentage numbers.

5.4.6.3 Open Questions

We collected the participants' comments from six open questions and the interview. Among six open questions, we asked the user experience of the blindfolded participants in conversations through the question: "How do you feel when you are blindfolded in conversations?" We gained insights from their user experiences, which helped validate the Hypothesis 1. We also asked the perceptions of the sighted participants towards four conditions of the E-Gaze through the question: "How do you feel the E-Gaze in the test?" Their comments for this questions helped validate the Hypothesis 2 and 3.

5.5 Results

5.5.1 Quantitative Results

The quantitative results consist of three parts: (1) analysis of group types, (2) analysis of gaze conditions in all groups, and (3) analysis of gaze conditions in the blind-sighted group. Table 5.8 presents abbreviations used in quantitative results.

Table 5.8 Abbreviations used in quantitative results.

Abbreviations	Conversation Groups	Participant Roles
BS-B	Blind-sighted	Blind
BS-S	Blind-sighted	Sighted
BFS-BF	Blindfolded-sighted	Blindfolded
BFS-S	Blindfolded-sighted	Sighted

5.5.1.1 Analysis of Group Types

A 4 × 2 × 2 mixed ANOVA was conducted, using four gaze conditions (No Gaze, Constant Gaze, Random Gaze, Interactive Gaze) as the within-subjects factor, conversation groups (blind-sighted, blindfolded-sighted) as the between-subjects factor, and participant roles (blind and blindfolded participants, sighted participants) as the between-subjects factor.

Co-presence. The predicted main effect of the conversation groups was not significant [$F(1, 36) = 3.062$, $p = .089$]. However, a significant interaction effect was observed between the conversation groups and the participant roles [$F(1, 36) = 7.384$, $p = .010$, $\eta_p^2 = .170$]. The contrast revealed that the blindfolded participants felt significantly higher co-present than the blind participants in conversations. A non-significant interaction effect was observed between the gaze conditions and the conversation groups [$F(3, 108) = 2.638$, $p = .053$]. The calculated interaction among gaze conditions, conversation groups, and participant roles was significant [$F(3, 108) = 4.346$, $p = .006$, $\eta_p^2 = .108$]. The contrast revealed that the blindfolded participants felt significantly higher co-present than the blind participants in the No Gaze condition, the Constant Gaze condition, and the Random Gaze condition. The contrast also revealed that sighted participants felt significantly higher co-present in the blind-sighted group than the blindfolded-sighted group in the No Gaze condition. The results of the participants' co-presence are presented in Table 5.9 and Table 5.10.

Attention Allocation. The predicted main effect of the conversation groups was not significant [$F(1, 36) = 1.797$, $p = .188$]. However, a significant interaction effect was observed between the conversation groups and the participant roles [$F(1, 36) = 4.036$, $p = .052$, $\eta_p^2 = .101$]. The contrast indicated that the sighted participants in the blind-sighted group perceived significantly higher attention allocation than in the blindfolded-sighted group. A non-significant interaction effect was observed between the gaze conditions and the conversation groups [$F(3, 108) = .245$, $p = .865$]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [$F(3, 108) = .481$, $p = .696$]. The results are presented in Table 5.11 and Table 5.12.

Perceived Message Understanding (PMU). The predicted main effect of the conversation groups was not significant [$F(1, 36) = 1.085$, $p = .305$]. However, a significant interaction effect was observed between the conversation groups and the participant roles [$F(1, 36) = 16.262$, $p < .001$, $\eta_p^2 = .311$]. The contrast revealed that the sighted participants in the blind-sighted group perceived significantly higher PMU than in the blindfolded-sighted group. A non-significant interaction effect was observed between gaze conditions and conversation groups [F(3, 108) = 1.080, p = .361]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [F(3, 108) = .619, p = .604]. The results are presented in Table 5.13 and Table 5.14.

Perceived Affective Understanding (PAU). The predicted main effect of the conversation groups was not significant [F(1, 36) = 1.952, p = .171]. However, a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 8.268, p = .007, η_p^2 = .187]. The contrast revealed that the sighted participants in the blind-sighted group perceived significantly higher PAU than in the blindfolded-sighted group. A non-significant interaction effect was observed between gaze conditions and the conversation groups [F(3, 108) = 1.526, p = .212]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [F(3, 108) = .179, p = .910]. The results are presented in Table 5.15 and Table 5.16.

Perceived Emotional Interdependence (PEI). The predicted main effect of the conversation groups was not significant [F(1, 36) = .774, p = .385]. A non-significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = .704, p = .407]. There was also a non-significant interaction effect between gaze conditions and conversation groups [F(3, 108) = .164, p = .921]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [F(3, 108) = 1.848, p = .143]. The results are presented in Table 5.17 and Table 5.18.

Perceived Behavioral Interdependence (PBI). The predicted main effect of the conversation groups was not significant [F(1, 36) = 1.482, p = .231]. A non-significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 3.759, p = .060]. There was also a non-significant (*ns*) interaction effect between gaze conditions and conversation groups [F(3, 108) = 1.726, p = .166]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [F(3, 108) = .331, p = .803]. The results are presented in Table 5.19 and Table 5.20.

Closeness. The predicted main effect of the conversation groups was not significant [F(1, 36) = 3.673, p = .063]. A non-significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 1.415, p = .242]. A non-significant interaction effect was also observed between gaze conditions and conversation groups [F(3, 108) = .809, p = .492]. The predicted interaction among gaze conditions, conversation groups, and participant roles was not significant [F(3, 108) = .149, p = .930]. The results are presented in Table 5.21 and Table 5.22.

Table 5.9 Means and standard deviations of the participants' co-presence in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Co-presence Mean	Std. Deviation
No Gaze	Blind-sighted	Blind	10	5.02	.89
		Sighted	10	5.20	.87
		Total	20	5.11	.86
	Blindfolded-sighted	Blindfolded	10	5.98	.57
		Sighted	10	4.17	.92
		Total	20	5.08	1.19
	Total	Blind and blindfolded	20	5.50	.88
		Sighted	20	4.68	1.02
		Total	40	5.09	1.03
Constant Gaze	Blind-sighted	Blind	10	4.97	.94
		Sighted	10	5.32	.74
		Total	20	5.14	.84
	Blindfolded-sighted	Blindfolded	10	6.02	.34
		Sighted	10	5.15	.83
		Total	20	5.58	.76
	Total	Blind and blindfolded	20	5.49	.88
		Sighted	20	5.23	.77
		Total	40	5.36	.82
Random Gaze	Blind-sighted	Blind	10	5.02	1.10
		Sighted	10	5.24	.55
		Total	20	5.13	.86
	Blindfolded-sighted	Blindfolded	10	5.95	.57
		Sighted	10	5.43	.63
		Total	20	5.69	.64
	Total	Blind and blindfolded	20	5.48	.98
		Sighted	20	5.33	.58
		Total	40	5.41	.80
Interactive Gaze	Blind-sighted	Blind	10	5.08	1.00
		Sighted	10	5.57	.82
		Total	20	5.33	.92
	Blindfolded-sighted	Blindfolded	10	5.75	.53
		Sighted	10	5.78	.76
		Total	20	5.77	.64
	Total	Blind and blindfolded	20	5.42	.85
		Sighted	20	5.67	.78
		Total	40	5.55	.81

Note. The mean score ranges from 1-7.

Table 5.10 Mixed ANOVA results summary of main effects and interaction effects on co-presence for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	1.253	1	1.253	3.062	.089
Participant Role * Conversation Group	3.022	1	3.022	7.384	**.010***
Error	14.735	36	.409		
Gaze Condition * Conversation Group	2.088	3	.696	2.638	.053
Gaze Condition * Conversation Group *Participant Role	3.441	3	1.147	4.346	**.006****
Error(Gaze Condition)	28.501	108	.264		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.11 Means and standard deviations of the participants' attention allocation in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Attention Allocation	
				Mean	Std. Deviation
No Gaze	Blind-sighted	Blind	10	5.25	.78
		Sighted	10	4.70	.78
		Total	20	4.97	.81
	Blindfolded-sighted	Blindfolded	10	5.53	.76
		Sighted	10	3.88	.92
		Total	20	4.71	1.18
	Total	Blind and blindfolded	20	5.39	.76
		Sighted	20	4.29	.93
		Total	40	4.84	1.01
Constant Gaze	Blind-sighted	Blind	10	5.30	.86
		Sighted	10	5.18	.70
		Total	20	5.24	.76
	Blindfolded-sighted	Blindfolded	10	5.43	.88
		Sighted	10	4.40	.87
		Total	20	4.92	1.00
	Total	Blind and blindfolded	20	5.37	.85
		Sighted	20	4.79	.86
		Total	40	5.08	.89
Random Gaze	Blind-sighted	Blind	10	5.38	.61
		Sighted	10	4.63	1.16
		Total	20	5.01	.98
	Blindfolded-sighted	Blindfolded	10	5.45	.83
		Sighted	10	3.80	.92
		Total	20	4.63	1.20
	Total	Blind and blindfolded	20	5.42	.71
		Sighted	20	4.22	1.11
		Total	40	4.82	1.10
Interactive Gaze	Blind-sighted	Blind	10	5.38	.99
		Sighted	10	5.13	1.17
		Total	20	5.26	1.06
	Blindfolded-sighted	Blindfolded	10	5.45	.89
		Sighted	10	4.80	.83
		Total	20	5.13	.90
	Total	Blind and blindfolded	20	5.42	.92
		Sighted	20	4.97	1.00
		Total	40	5.19	.97

Note. The mean score ranges from 1-7.

Table 5.12 Mixed ANOVA results summary of main effects and interaction effects on attention allocation for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.764	1	.764	1.797	.188
Conversation Group* Participant Role	1.715	1	1.715	4.036	.052
Error	15.298	36	.425		
Gaze Condition * Conversation Group	.348	3	.116	.245	.865
Gaze Condition * Conversation Group * Participant Role	.683	3	.228	.481	.696
Error(Gaze Condition)	51.086	108	.473		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.13 Means and standard deviations of the participants' PMU in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Message Understanding	
				Mean	**Std. Deviation**
No Gaze	Blind-sighted	Blind	10	5.72	.69
		Sighted	10	5.10	.88
		Total	20	5.41	.83
	Blindfolded-sighted	Blindfolded	10	6.12	.82
		Sighted	10	3.82	1.16
		Total	20	4.97	1.53
	Total	Blind and blindfolded	20	5.92	.77
		Sighted	20	4.46	1.20
		Total	40	5.19	1.24
Constant Gaze	Blind-sighted	Blind	10	5.43	.71
		Sighted	10	5.37	.78
		Total	20	5.40	.73
	Blindfolded-sighted	Blindfolded	10	6.02	1.06
		Sighted	10	4.05	1.14
		Total	20	5.03	1.47
	Total	Blind and blindfolded	20	5.72	.93
		Sighted	20	4.71	1.17
		Total	40	5.22	1.16
Random Gaze	Blind-sighted	Blind	10	5.23	.86
		Sighted	10	5.18	.83
		Total	20	5.21	.82
	Blindfolded-sighted	Blindfolded	10	6.18	.87
		Sighted	10	3.93	1.05
		Total	20	5.06	1.49
	Total	Blind and blindfolded	20	5.71	.97
		Sighted	20	4.56	1.12
		Total	40	5.13	1.19
Interactive Gaze	Blind-sighted	Blind	10	5.37	.82
		Sighted	10	5.44	.98
		Total	20	5.40	.88
	Blindfolded-sighted	Blindfolded	10	6.12	.80
		Sighted	10	4.72	.68
		Total	20	5.42	1.02
	Total	Blind and blindfolded	20	5.74	.88
		Sighted	20	5.08	.90
		Total	40	5.41	.94

Note. The mean score ranges from 1-7.

Table 5.14 Mixed ANOVA results summary of main effects and interaction effects on PMU for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.548	1	.548	1.085	.305
Conversation Group * Participant Role	8.208	1	8.208	16.262	**.000****
Error	18.172	36	.505		
Gaze Condition * Conversation Group	1.287	3	.429	1.080	.361
Gaze Condition * Conversation Group * Participant Role	.737	3	.246	.619	.604
Error(Gaze Condition)	42.892	108	.397		

Significant group difference; * $p < .05$, ** $p < .01$.

Table 5.15 Means and standard deviations of the participants' PAU in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Affective Understanding	
				Mean	Std. Deviation
No Gaze	Blind-sighted	Blind	10	4.92	.85
		Sighted	10	4.85	1.05
		Total	20	4.88	.93
	Blindfolded-sighted	Blindfolded	10	5.29	.98
		Sighted	10	3.47	1.67
		Total	20	4.38	1.63
	Total	Blind and blindfolded	20	5.10	.91
		Sighted	20	4.16	1.53
		Total	40	4.63	1.33
Constant Gaze	Blind-sighted	Blind	10	5.00	.92
		Sighted	10	5.15	.93
		Total	20	5.08	.91
	Blindfolded-sighted	Blindfolded	10	5.22	1.24
		Sighted	10	3.55	1.41
		Total	20	4.38	1.55
	Total	Blind and blindfolded	20	5.11	1.07
		Sighted	20	4.35	1.43
		Total	40	4.73	1.30
Random Gaze	Blind-sighted	Blind	10	4.75	1.13
		Sighted	10	5.00	1.05
		Total	20	4.87	1.07
	Blindfolded-sighted	Blindfolded	10	5.25	1.12
		Sighted	10	3.73	.75
		Total	20	4.49	1.21
	Total	Blind and blindfolded	20	5.00	1.12
		Sighted	20	4.37	1.10
		Total	40	4.68	1.14
Interactive Gaze	Blind-sighted	Blind	10	4.85	1.04
		Sighted	10	5.10	1.25
		Total	20	4.97	1.12
	Blindfolded-sighted	Blindfolded	10	5.50	.91
		Sighted	10	4.33	.93
		Total	20	4.92	1.08
	Total	Blind and blindfolded	20	5.17	1.01
		Sighted	20	4.72	1.14
		Total	40	4.95	1.09

Note. The mean score ranges from 1-7.

Table 5.16 Mixed ANOVA results summary of main effects and interaction effects on PAU for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	1.680	1	1.680	1.952	.171
Conversation Group * Participant Role	7.117	1	7.117	8.268	**.007****
Error	30.988	36	.861		
Gaze Condition * Conversation Group	2.137	3	.712	1.526	.212
Gaze Condition * Conversation Group * Participant Role	.251	3	.084	.179	.910
Error(Gaze Condition)	50.413	108	.467		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.17 Means and standard deviations of the participants' PEI in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Emotional Interdependence	
				Mean	**Std. Deviation**
No Gaze	Blind-sighted	Blind	10	5.35	1.02
		Sighted	10	4.88	1.16
		Total	20	5.12	1.09
	Blindfolded-sighted	Blindfolded	10	5.55	.82
		Sighted	10	4.08	1.37
		Total	20	4.82	1.33
	Total	Blind and blindfolded	20	5.45	.91
		Sighted	20	4.48	1.30
		Total	40	4.97	1.21
Constant Gaze	Blind-sighted	Blind	10	5.37	1.16
		Sighted	10	5.03	1.15
		Total	20	5.20	1.13
	Blindfolded-sighted	Blindfolded	10	5.50	.98
		Sighted	10	4.35	1.06
		Total	20	4.93	1.16
	Total	Blind and blindfolded	20	5.43	1.04
		Sighted	20	4.69	1.13
		Total	40	5.06	1.14
Random Gaze	Blind-sighted	Blind	10	5.68	.99
		Sighted	10	4.83	1.11
		Total	20	5.26	1.11
	Blindfolded-sighted	Blindfolded	10	5.38	.86
		Sighted	10	4.47	1.05
		Total	20	4.92	1.05
	Total	Blind and blindfolded	20	5.53	.92
		Sighted	20	4.65	1.07
		Total	40	5.09	1.08
Interactive Gaze	Blind-sighted	Blind	10	5.60	.77
		Sighted	10	4.82	1.42
		Total	20	5.21	1.18
	Blindfolded-sighted	Blindfolded	10	5.52	1.00
		Sighted	10	4.55	1.11
		Total	20	5.03	1.14
	Total	Blind and blindfolded	20	5.56	.87
		Sighted	20	4.68	1.25
		Total	40	5.12	1.15

Note. The mean score ranges from 1-7.

Table 5.18 Mixed ANOVA results summary of main effects and interaction effects on PEI for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.733	1	.733	.774	.385
Conversation Group * Participant Role	.667	1	.667	.704	.407
Error	34.099	36	.947		
Gaze Condition * Conversation Group	.141	3	.047	.164	.921
Gaze Condition * Conversation Group * Participant Role	1.590	3	.530	1.848	.143
Error(Gaze Condition)	30.978	108	.287		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.19 Means and standard deviations of the participants' PBI in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Behavioral Interdependence	
				Mean	Std. Deviation
No Gaze	Blind-sighted	Blind	10	5.47	1.01
		Sighted	10	5.12	.99
		Total	20	5.29	.99
	Blindfolded-sighted	Blindfolded	10	5.63	.68
		Sighted	10	4.00	1.35
		Total	20	4.82	1.34
	Total	Blind and blindfolded	20	5.55	.84
		Sighted	20	4.56	1.29
		Total	40	5.05	1.19
Constant Gaze	Blind-sighted	Blind	10	5.32	1.22
		Sighted	10	5.28	1.06
		Total	20	5.30	1.11
	Blindfolded-sighted	Blindfolded	10	5.30	1.34
		Sighted	10	4.12	.99
		Total	20	4.71	1.30
	Total	Blind and blindfolded	20	5.31	1.25
		Sighted	20	4.70	1.16
		Total	40	5.00	1.23
Random Gaze	Blind-sighted	Blind	10	5.28	1.07
		Sighted	10	5.07	.89
		Total	20	5.17	.96
	Blindfolded-sighted	Blindfolded	10	5.57	.98
		Sighted	10	4.32	.72
		Total	20	4.94	1.06
	Total	Blind and blindfolded	20	5.43	1.01
		Sighted	20	4.69	.88
		Total	40	5.06	1.00
Interactive Gaze	Blind-sighted	Blind	10	5.42	.91
		Sighted	10	5.38	1.17
		Total	20	5.40	1.02
	Blindfolded-sighted	Blindfolded	10	5.77	.74
		Sighted	10	4.97	.69
		Total	20	5.37	.81
	Total	Blind and blindfolded	20	5.59	.83
		Sighted	20	5.17	.96
		Total	40	5.38	.91

Note. The mean score ranges from 1-7.

Table 5.20 Mixed ANOVA results summary of main effects and interaction effects on PBI for group types.

Source	***SS***	***df***	***MS***	***F***	***p***
Conversation Group	1.108	1	1.108	1.482	.231
Conversation Group * Participant Role	2.810	1	2.810	3.759	.060
Error	26.915	36	.748		
Gaze Condition * Conversation Group	1.874	3	.625	1.726	.166
Gaze Condition * Conversation Group * Participant Role	.359	3	.120	.331	.803
Error(Gaze Condition)	39.085	108	.362		

Significant group difference; $^{*} p < .05$, $^{**} p < .01$.

Table 5.21 Means and standard deviations of the participants' closeness in two conversation groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Closeness	
				Mean	Std. Deviation
No Gaze	Blind-sighted	Blind	10	5.40	1.84
		Sighted	10	5.30	1.57
		Total	20	5.35	1.66
	Blindfolded-sighted	Blindfolded	10	4.90	1.73
		Sighted	10	3.90	1.52
		Total	20	4.40	1.67
	Total	Blind and blindfolded	20	5.15	1.76
		Sighted	20	4.60	1.67
		Total	40	4.88	1.71
Constant Gaze	Blind-sighted	Blind	10	5.30	1.64
		Sighted	10	5.20	1.55
		Total	20	5.25	1.55
	Blindfolded-sighted	Blindfolded	10	4.80	1.93
		Sighted	10	3.70	1.64
		Total	20	4.25	1.83
	Total	Blind and blindfolded	20	5.05	1.76
		Sighted	20	4.45	1.73
		Total	40	4.75	1.75
Random Gaze	Blind-sighted	Blind	10	5.00	1.56
		Sighted	10	4.90	1.20
		Total	20	4.95	1.36
	Blindfolded-sighted	Blindfolded	10	4.90	1.60
		Sighted	10	3.60	1.26
		Total	20	4.25	1.55
	Total	Blind and blindfolded	20	4.95	1.54
		Sighted	20	4.25	1.37
		Total	40	4.60	1.48
Interactive Gaze	Blind-sighted	Blind	10	5.10	1.66
		Sighted	10	5.40	1.43
		Total	20	5.25	1.52
	Blindfolded-sighted	Blindfolded	10	5.10	1.60
		Sighted	10	4.90	1.52
		Total	20	5.00	1.52
	Total	Blind and blindfolded	20	5.10	1.59
		Sighted	20	5.15	1.46
		Total	40	5.13	1.51

Note. The mean score ranges from 1-7.

Table 5.22 Mixed ANOVA results summary of main effects and interaction effects on closeness for group types.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	5.256	1	5.256	3.673	.063
Conversation Group * Participant Role	2.025	1	2.025	1.415	.242
Error	51.513	36	1.431		
Gaze Condition * Conversation Group	3.525	3	1.175	.809	.492
Gaze Condition * Conversation Group * Participant Role	.650	3	.217	.149	.930
Error(Gaze Condition)	156.950	108	1.453		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Summary. A significant interaction effect was observed between the conversation groups and the participant roles. It revealed that the blindfolded participants felt significantly higher co-present than the blind participants (Table 5.12 (1)). The sighted participants in the blind-sighted group perceived significantly higher attention allocation, PMU, and PAU than in the blindfolded-sighted group (Table 5.12 (2)(3)(4)).

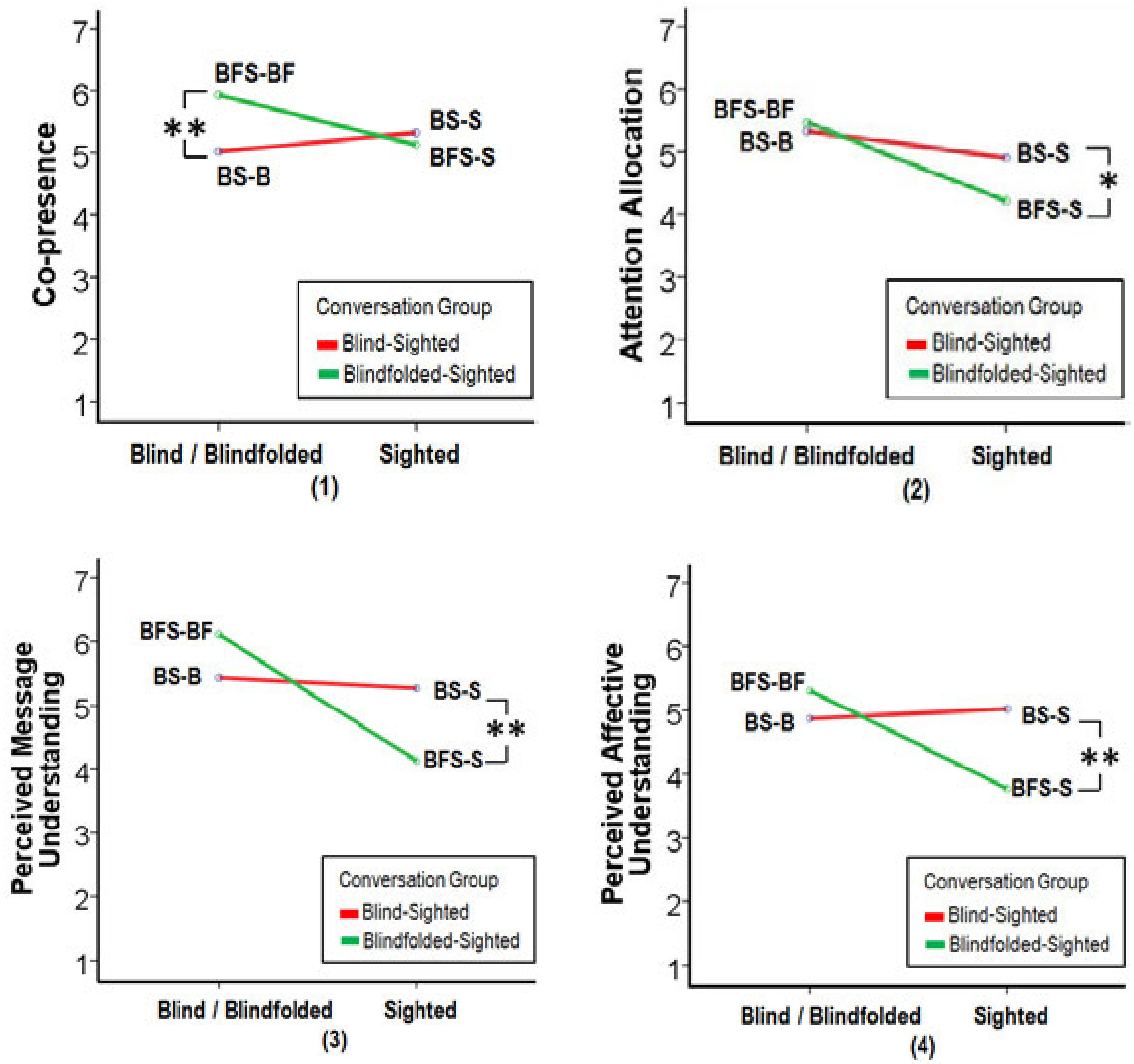


Figure 5.12 Interaction effects between conversation groups and participant roles on co-presence, attention allocation, PMU and PAU. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

A significant interaction effect was observed among gaze conditions, conversation groups and participant roles for the participants' co-presence (Table 5.13). It revealed that in the No Gaze condition the sighted participants felt significantly higher co-present when they communicated with the blind participant than with the blindfolded participant. Such difference disappeared when the gaze was added in other three conditions. It also revealed that the blindfolded participants felt significantly higher co-present than the blind participants in the No Gaze condition, the Constant Gaze condition and the Random Gaze condition.

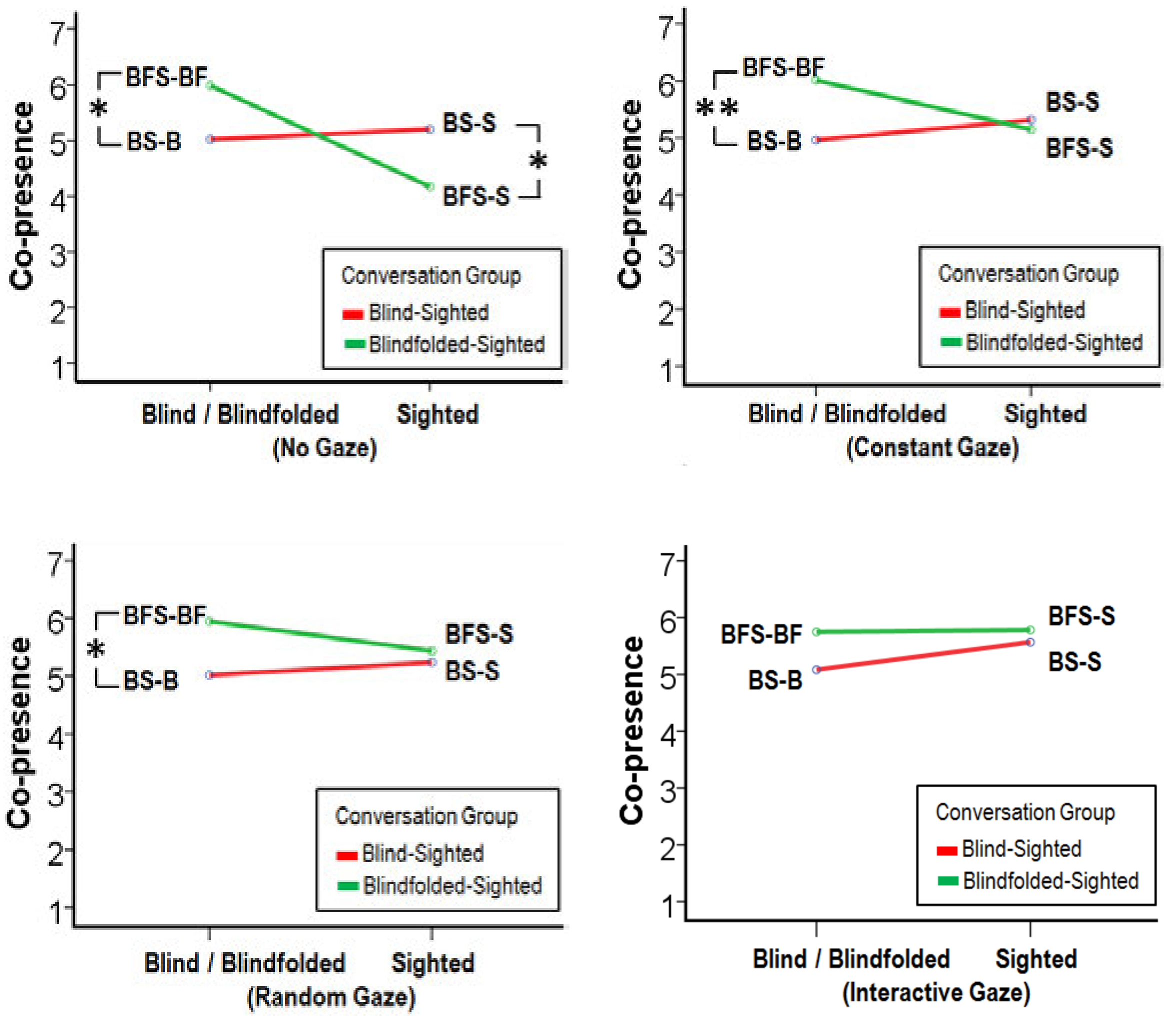


Figure 5.13 Three-way interaction effects on co-presence among four gaze conditions, conversation groups, and participant roles. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

5.5.1.2 Analysis of Gaze Conditions in All Groups

In this section, we reported the analyzed results of gaze conditions in all groups.

Co-presence. A significant main effect was observed among four gaze conditions [$F(3, 108) = 5.472$, $p = .002$, $\eta_p^2 = .132$]. The contrast revealed that the participants felt significantly higher co-present to use the E-Gaze with Interactive Gaze (M = 5.55, SE = .13) than without any gaze (M = 5.09, SE = .13). A significant interaction effect was also observed between gaze conditions and the participant roles [F(3, 108) = 7.461, $p < .001$, $\eta_p^2 = .172$]. It indicated that the participants' co-presence towards the four gaze conditions differed according to the participant roles. For the blind and blindfolded participants, their co-presence was generally the same towards the four gaze conditions. For the sighted participants, they felt significantly higher co-present to see the conversation partners with the Interactive Gaze (M = 5.68, SE = .18) and Random Gaze (M = 5.33, SE = .13) than without any gaze (M = 4.68 , SE = .20). The results are presented in Table 5.23.

Attention Allocation. A significant main effect was observed among four gaze conditions [F(3, 108) = 2.837, $p = .041$, $\eta_p^2 = .073$]. The contrast revealed that the participants perceived significantly higher attention allocation to use the E-Gaze with Interactive Gaze (M = 5.19, SE = .16) than Random Gaze (M = 4.82, SE = .14). A significant interaction effect was also observed between gaze conditions and the participant roles [F(3, 108) = 2.968, $p = .035$, $\eta_p^2 = .076$]. It indicated that the participants' attention allocation towards four gaze conditions differed according to the participant roles. For the blind and blindfolded participants, their co-presence was generally the same towards four gaze conditions. For the sighted participants, they perceived significantly higher attention allocation to see the conversation partners with the Interactive Gaze (M = 5.00, SE = .23) than Random Gaze (M = 4.22, SE = .23). The results are presented in Table 5.24.

Perceived Message Understanding (PMU). A non-significant main effect was observed among four gaze conditions [F(3, 108) = 1.451, $p = .232$]. However, a significant interaction effect was found between gaze conditions and the participant roles [F(3, 108) = 2.721, $p = .048$]. It indicated that the participants' PMU towards four gaze conditions differed according to the participant roles. For the blind and blindfolded participants, their co-presence was generally the same towards four gaze conditions. For the sighted participants, they perceived significantly higher PMU to see the conversation partners with the Interactive Gaze (M = 5.08, SE = .19) than Random Gaze (M = 4.56, SE = .21). The results are presented in Table 5.25.

Perceived Affective Understanding (PAU). A non-significant main effect was observed among four gaze conditions [F(3, 108) = 1.643, $p = .184$]. There was also a non-significant interaction effect between gaze conditions and the participant roles [F(3, 108) = .896, $p = .446$]. The results are presented in Table 5.26.

Perceived Emotional Interdependence (PEI). A non-significant main effect was observed among four gaze conditions [F(3, 108) = .622, $p = .602$]. There was also a non-significant interaction effect between gaze conditions and the participant roles [F(3, 108) = .305, p = .822]. The results are presented in Table 5.27.

Perceived Behavioral Interdependence (PBI). A significant main effect was observed among four gaze conditions [F(3, 108) = 3.354, p = .022, η_p^2 = .085]. The contrast revealed that the participants experienced significantly higher PBI to use the E-Gaze with Interactive Gaze (M = 5.38, SE = .14) than Constant Gaze (M = 5.00, SE = .18). However, a non-significant interaction effect was observed between gaze conditions and participant roles [F(3, 108) = 1.603, p = .193]. The results are presented in Table 5.28.

Closeness. A non-significant main effect was observed among four gaze conditions [F(3, 108) = 1.359, p = .259]. There was also a non-significant interaction effect between gaze conditions and the participant roles [F(3, 108) = .791, p = .501]. The results are presented in Table 5.29.

Table 5.23 Mixed ANOVA results summary of main effects and interaction effects on co-presence for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	4.332	3	1.444	5.472	**.002****
Gaze Condition* Participant Role	5.907	3	1.969	7.461	**.000****
Error(Gaze Condition)	28.501	108	.264		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.24 Mixed ANOVA results summary of main effects and interaction effects on attention allocation for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	4.026	3	1.342	2.837	**.041***
Gaze Condition * Participant Role	4.211	3	1.404	2.968	**.035***
Error(Gaze Condition)	51.086	108	.473		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.25 Mixed ANOVA results summary of main effects and interaction effects on PMU for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	1.729	3	.576	1.451	.232
Gaze Condition * Participant Role	3.241	3	1.080	2.721	**.048***
Error(Gaze Condition)	42.892	108	.397		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.26 Mixed ANOVA results summary of main effects and interaction effects on PAU for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	2.301	3	.767	1.643	.184
Gaze Condition * Participant Role	1.255	3	.418	.896	.446
Error(Gaze Condition)	50.413	108	.467		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 5.27 Mixed ANOVA results summary of main effects and interaction effects on PEI for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	.535	3	.178	.622	.602
Gaze Condition * Participant Role	.262	3	.087	.305	.822
Error(Gaze Condition)	30.978	108	.287		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 5.28 Mixed ANOVA results summary of main effects and interaction effects on PBI for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	3.641	3	1.214	3.354	**.022***
Gaze Condition * Participant Role	1.741	3	.580	1.603	.193
Error(Gaze Condition)	39.085	108	.362		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 5.29 Mixed ANOVA results summary of main effects and interaction effects on closeness for gaze conditions in all groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Gaze Condition	5.925	3	1.975	1.359	.259
Gaze Condition * Participant Role	3.450	3	1.150	.791	.501
Error(Gaze Condition)	156.950	108	1.453		

Significant group difference; * *p < .05,* ** *p < .01.*

Summary. The results demonstrated that Interactive Gaze was more effective than the other three gaze conditions to improve the participants' communication quality. Interactive Gaze positively affected the participants' co-presence, attention allocation and PBI in conversations (Figure 5.14 (1)(2)(3)).

A significant interaction effect was observed between gaze conditions and the participant roles. The sighted participants perceived significantly higher attention allocation and PMU in the Interactive Gaze condition than in the Random Gaze condition (Figure 5.15). They also perceived significantly higher co-presence in the Interactive Gaze and Random Gaze conditions than in the No Gaze condition (Figure 5.15 (1)).

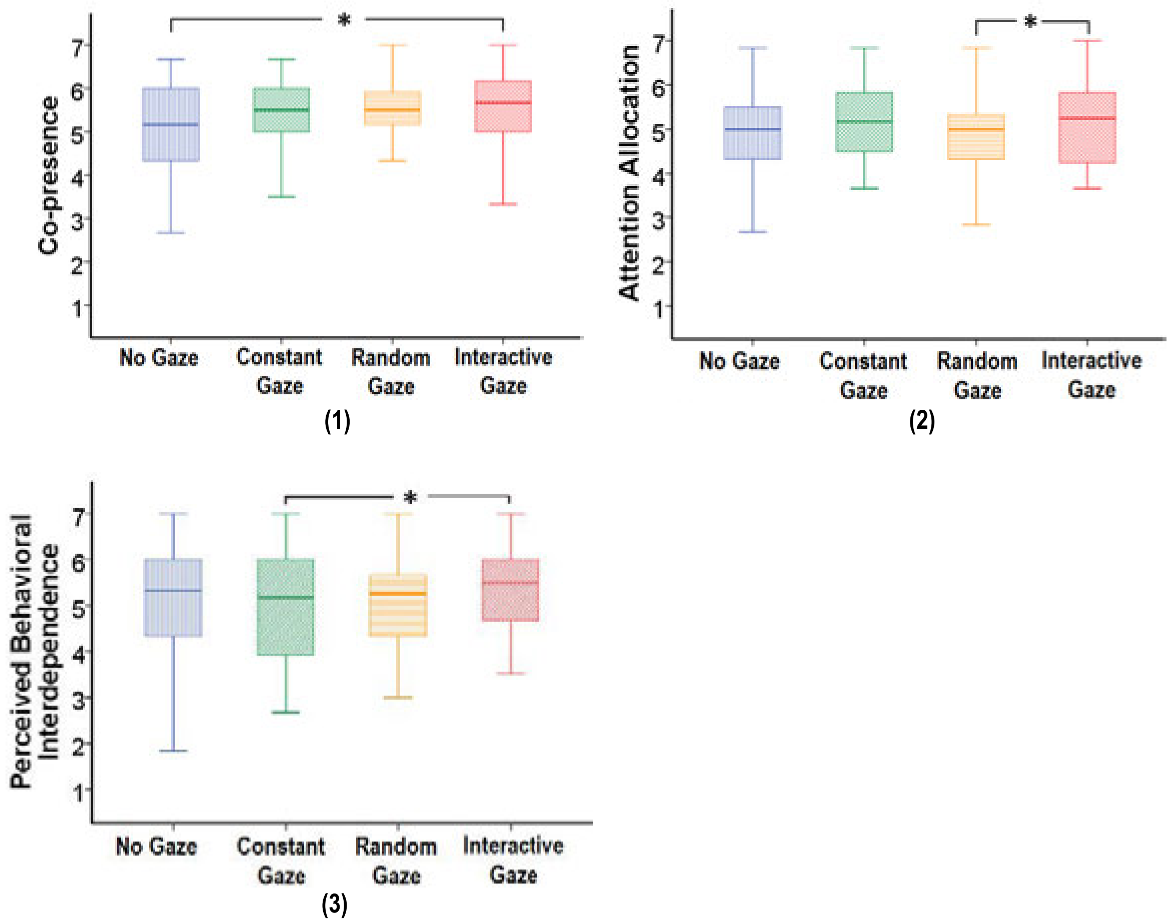
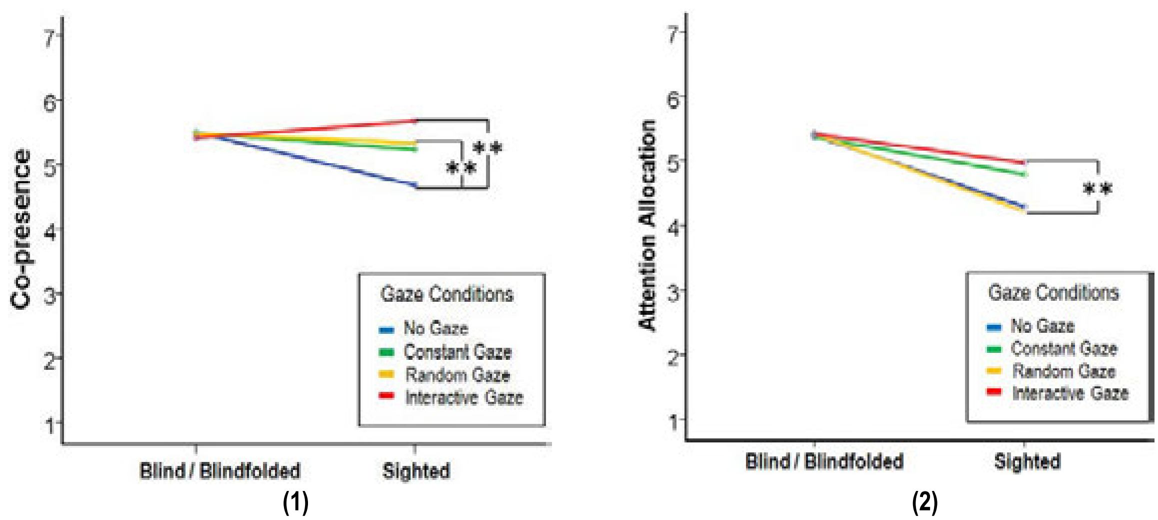


Figure 5.14 Boxplot of the main effect of four gaze conditions on co-presence, attention allocation, and perceived behavioural interdependence. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.



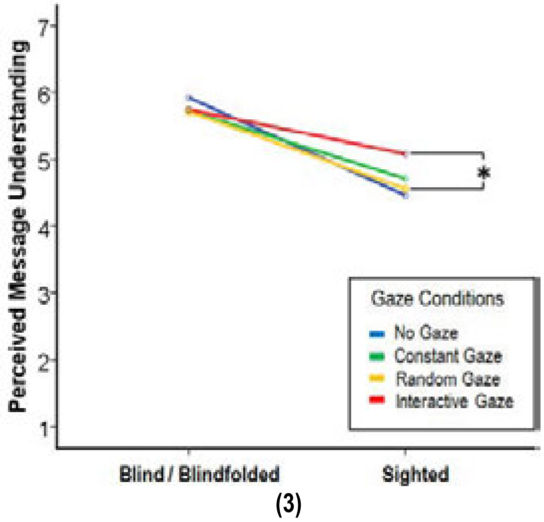


Figure 5.15 Interaction effects between four gaze conditions and participant roles on co-presence, attention allocation, and perceived message understanding. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

5.5.1.3 Analysis of Gaze Conditions in the Blind-Sighted Group

In this section, we analyzed the experimental data from the blind-sighted group. A 4 × 2 mixed ANOVA was conducted, using four gaze conditions (No Gaze, Constant Gaze, Random Gaze, Interactive Gaze) as the within-subjects factor, and participant roles (blind participants, sighted participants) as the between-subjects factor.

Co-presence. A non-significant main effect was observed among four gaze conditions [$F(3, 54) = 1.558$, $p = .210$]. Although not significant, the sighted participants felt higher co-present in the Interactive Gaze condition (M = 5.57, SD = .82) than the No Gaze condition (M = 5.20, SD = .87), the Constant Gaze condition (M = 5.32, SD = .74), and the Random Gaze condition (M = 5.24, SD = .55). The predicted interaction between gaze conditions and participant roles was not significant [$F(3, 54) = .721$, $p = .544$]. The results are presented in Table 5.30 and Table 5.31.

Attention Allocation. A non-significant main effect was observed among four gaze conditions [$F(3, 54) = 1.103$, $p = .356$]. Although not significant, the sighted participants perceived higher attention allocation in the Interactive Gaze condition (M = 5.13, SD = 1.17) than the No Gaze condition (M = 4.70, SD = .78), and the Random Gaze condition (M = 4.63, SD = 1.16). The predicted interaction between gaze conditions and participant roles was also not significant [$F(3, 54) = 1.009$, $p = .396$]. The results are presented in Table 5.32 and Table 5.33.

Perceived Message Understanding (PMU). A non-significant main effect was observed among four gaze conditions [$F(3, 54) = .590$, $p = .624$]. Although not significant, the sighted participants perceived higher PMU in the Interactive Gaze condition (M = 5.44, SD = .98) than in the No Gaze condition (M = 5.10, SD = .88), the Constant Gaze condition (M = 5.37, SD = .78), and the Random Gaze condition (M = 5.18, SD = .83). The predicted interaction between gaze conditions and participant roles was also not significant [F(3, 54) = 1.456, *p* = .237]. The results are presented in Table 5.34 and Table 5.35.

Perceived Affective Understanding (PAU). A non-significant main effect was observed among four gaze conditions [F(3, 54) = .641, *p* = .592]. Although not significant, the sighted participants perceived higher PAU in the Interactive Gaze condition (M = 5.10, SD = 1.25) than in the No Gaze condition (M = 4.85, SD = 1.05), and the Random Gaze condition (M = 5.00, SD = 1.05). The predicted interaction between gaze conditions and participant roles was also not significant [F(3, 54) = .417, *p* = .741]. The results are presented in Table 5.36 and Table 5.37.

Perceived Emotional Interdependence (PEI). A non-significant main effect was observed among four gaze conditions [F(3, 54) = .263, *p* = .852]. The predicted interaction between gaze conditions and participant roles was also not significant [F(3, 54) = 1.186, *p* = .324]. The results are presented in Table 5.38 and Table 5.39.

Perceived Behavioral Interdependence (PBI). A non-significant main effect was observed among four gaze conditions [F(3, 54) = 1.016, *p* = .393]. Although not significant, the sighted participants perceived higher PBI in the Interactive Gaze condition (M = 5.38, SD = 1.17) than in the No Gaze condition (M = 5.12, SD = .99), the Constant Gaze condition (M = 5.28, SD = 1.06), and the Random Gaze condition (M = 5.07, SD = .89). The predicted interaction between gaze conditions and participant roles was also not significant [F(3, 54) = .711, *p* = .549]. The results are presented in Table 5.40 and Table 5.41.

Closeness. A non-significant main effect was observed among four gaze conditions [F(3, 54) = .544, *p* = .655]. Although not significant, the sighted participants perceived higher closeness in the Interactive Gaze condition (M = 5.40, SD = 1.43) than the No Gaze condition (M = 5.30, SD = 1.57), the Constant Gaze condition (M = 5.20, SD = 1.55), and the Random Gaze condition (M = 4.90, SD = 1.20). The predicted interaction between gaze conditions and participant roles was also not significant [F(3, 54) = .181, *p* = .909]. The results are presented in Table 5.42 and Table 5.43.

Table 5.30 Means and standard deviations on the participants' co-presence in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Co-presence	
			Mean	**Std. Deviation**
No Gaze	Blind	10	5.02	.89
	Sighted	10	5.20	.87
	Total	20	5.11	.86
Constant Gaze	Blind	10	4.97	.94
	Sighted	10	5.32	.74
	Total	20	5.14	.84
Random Gaze	Blind	10	5.02	1.10
	Sighted	10	5.24	.55
	Total	20	5.13	.86
Interactive Gaze	Blind	10	5.08	1.00
	Sighted	10	5.57	.82
	Total	20	5.33	.92

Note. The mean score ranges from 1-7.

Table 5.31 Mixed ANOVA results summary of main effects and interaction effects on co-presence for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	.611	3	.204	1.558	.210
Gaze Conditions * Participant Role	.283	3	.094	.721	.544
Error(Gaze Conditions)	7.056	54	.131		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.32 Means and standard deviations on the participants' attention allocation in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Attention Allocation	
			Mean	**Std. Deviation**
No Gaze	Blind	10	5.25	.78
	Sighted	10	4.70	.78
	Total	20	4.97	.81
Constant Gaze	Blind	10	5.30	.86
	Sighted	10	5.18	.70
	Total	20	5.24	.76
Random Gaze	Blind	10	5.38	.61
	Sighted	10	4.63	1.16
	Total	20	5.01	.98
Interactive Gaze	Blind	10	5.38	.99
	Sighted	10	5.13	1.17
	Total	20	5.26	1.06

Note. The mean score ranges from 1-7.

Table 5.33 Mixed ANOVA results summary of main effects and interaction effects on attention allocation for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	1.348	3	.449	1.103	.356
Gaze Conditions * Participant Role	1.233	3	.411	1.009	.396
Error(Gaze Conditions)	21.997	54	.407		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.34 Means and standard deviations on the participants' PMU in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Message Understanding	
			Mean	Std. Deviation
No Gaze	Blind	10	5.72	.69
	Sighted	10	5.10	.88
	Total	20	5.41	.83
Constant Gaze	Blind	10	5.43	.71
	Sighted	10	5.37	.78
	Total	20	5.40	.73
Random Gaze	Blind	10	5.23	.86
	Sighted	10	5.18	.83
	Total	20	5.21	.82
Interactive Gaze	Blind	10	5.37	.82
	Sighted	10	5.44	.98
	Total	20	5.40	.88

Note. The mean score ranges from 1-7.

Table 5.35 Mixed ANOVA results summary of main effects and interaction effects on PMU for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	.570	3	.190	.590	.624
Gaze Conditions * Participant Role	1.408	3	.469	1.456	.237
Error(Gaze Conditions)	17.400	54	.322		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.36 Means and standard deviations on the participants' PAU in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Affective Understanding	
			Mean	Std. Deviation
No Gaze	Blind	10	4.92	.85
	Sighted	10	4.85	1.05
	Total	20	4.88	.93
Constant Gaze	Blind	10	5.00	.92
	Sighted	10	5.15	.93
	Total	20	5.08	.91
Random Gaze	Blind	10	4.75	1.13
	Sighted	10	5.00	1.05
	Total	20	4.87	1.07
Interactive Gaze	Blind	10	4.85	1.04
	Sighted	10	5.10	1.25
	Total	20	4.97	1.12

Note. The mean score ranges from 1-7.

Table 5.37 Mixed ANOVA results summary of main effects and interaction effects on PAU for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	.528	3	.176	.641	.592
Gaze Conditions * Participant Role	.344	3	.115	.417	.741
Error(Gaze Conditions)	14.818	54	.274		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.38 Means and standard deviations on the participants' PEI in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Emotional Interdependence	
			Mean	Std. Deviation
No Gaze	Blind	10	5.35	1.02
	Sighted	10	4.88	1.16
	Total	20	5.12	1.09
Constant Gaze	Blind	10	5.37	1.16
	Sighted	10	5.03	1.15
	Total	20	5.20	1.13
Random Gaze	Blind	10	5.68	.99
	Sighted	10	4.83	1.11
	Total	20	5.26	1.11
Interactive Gaze	Blind	10	5.60	.77
	Sighted	10	4.82	1.42
	Total	20	5.21	1.18

Note. The mean score ranges from 1-7.

Table 5.39 Mixed ANOVA results summary of main effects and interaction effects on PEI for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	.205	3	.068	.263	.852
Gaze Conditions * Participant Role	.925	3	.308	1.186	.324
Error(Gaze Conditions)	14.041	54	.260		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.40 Means and standard deviations on the participants' PBI in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Behavioral Interdependence	
			Mean	Std. Deviation
No Gaze	Blind	10	5.47	1.01
	Sighted	10	5.12	.99
	Total	20	5.29	.99
Constant Gaze	Blind	10	5.32	1.22
	Sighted	10	5.28	1.06
	Total	20	5.30	1.11
Random Gaze	Blind	10	5.28	1.07
	Sighted	10	5.07	.89
	Total	20	5.17	.96
Interactive Gaze	Blind	10	5.42	.91
	Sighted	10	5.38	1.17
	Total	20	5.40	1.02

Note. The mean score ranges from 1-7.

Table 5.41 Mixed ANOVA results summary of main effects and interaction effects on PBI for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	.511	3	.170	1.016	.393
Gaze Conditions * Participant Role	.357	3	.119	.711	.549
Error(Gaze Conditions)	9.044	54	.167		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 5.42 Means and standard deviations on the participants' closeness in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Closeness	
			Mean	Std. Deviation
No Gaze	Blind	10	5.40	1.84
	Sighted	10	5.30	1.57
	Total	20	5.35	1.66
Constant Gaze	Blind	10	5.30	1.64
	Sighted	10	5.20	1.55
	Total	20	5.25	1.55
Random Gaze	Blind	10	5.00	1.56
	Sighted	10	4.90	1.20
	Total	20	4.95	1.36
Interactive Gaze	Blind	10	5.10	1.66
	Sighted	10	5.40	1.43
	Total	20	5.25	1.52

Note. The mean score ranges from 1-7.

Table 5.43 Mixed ANOVA results summary of main effects and interaction effects on closeness for gaze conditions in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Gaze Conditions	1.800	3	.600	.544	.655
Gaze Conditions * Participant Role	.600	3	.200	.181	.909
Error(Gaze Conditions)	59.600	54	1.104		

Significant group difference; * $p < .05$, ** $p < .01$.

Summary. Overall, we did not find any statistically significant result among four gaze conditions in the blind-sighted group. Although not significant, we observed that the sighted participants perceived higher co-presence, attention allocation, PMU, PAU, PBI and closeness in the Interactive Gaze condition than the No Gaze and Random Gaze conditions. They also perceived higher co-presence, PMU, PBI and closeness in the Interactive Gaze condition than the Constant Gaze condition.

5.5.2 Qualitative Results

We collected the comments of the participants from an open-ended questionnaire with six questions (Table 5.44) about their (1) interests towards the E-Gaze, (2) perceptions towards the E-Gaze, (3) opinions about functions of the E-Gaze, (4-5) design suggestions, and (6) user experience of being blindfolded.

The interviews for six open questions were transcribed verbatim. To gain the insights from the transcripts, we conducted the data analysis based on the *qualitative content analysis* (Hsieh and Shannon, 2005). This method has been introduced in Section 3.2.5. We collected in total 257 quotes from the answers and identified six themes based on the transcripts. These themes are interests (41 quotes), perceptions towards four gaze conditions (80 quotes), functions of the E-Gaze (29 quotes), the preference in the future of the eye appearance (39 quotes), design suggestions (64 quotes), and the user experience of being blindfolded in conversations (24 quotes). Every participant was assigned with a unique ID to indicate the source of the quotes (Table 5.45). In this section, we report the qualitative data from the open question 2 and 6, which directly help answer the hypotheses. We leave results from other open questions for the later report in Appendix C.

Table 5.44 Open questions for the participants.

No.	**Questions**	**Answered by the blind and blindfolded participants**	**Answered by the sighted participants**
1	Do you have an interest in the E-Gaze system? If yes, why you are interested in this system?	√	√
2	E-Gaze has four gaze conditions in four tests: (i) No Gaze, (ii) Constant Gaze, (iii) Random Gaze, and (iv) Interactive Gaze. How do you feel the E-Gaze in each test?	-	√
3	What do you think the function of the E-Gaze with Interactive Gaze in the conversation?	√	√
4-1	If the E-Gaze can display two eye patterns: animated eyes, and realistic human's eyes, which pattern you are willing to express to your conversation partner and why?	√	-
4-2	If the E-Gaze can display two eye patterns: animated eyes, and realistic human's eyes, which pattern you are willing to interact with and why?	-	√
5	Do you have any other suggestions for improving this prototype (E-Gaze glasses)?	√	√
6	How do you feel when you are blindfolded in conversations? (Only for the blindfolded participants)	√	-

Table 5.45 ID of the participants.

Conversation Groups	Participant Roles	ID
Blind-sighted	Blind	BS-B1, BS-B3, BS-B5, BS-B7, BS-B9, BS-B11, BS-B13, BS-B15, BS-B17, BS-B19
	Sighted	BS-S2, BS-S4, BS-S6, BS-S8, BS-S10, BS-S12, BS-S14, BS-S16, BS-S18, BS-S20
Blindfolded-sighted	Blindfolded	BFS-BF1, BFS-BF3, BFS-BF5, BFS-BF7, BFS-BF 9, BFS-BF11, BFS-BF13, BFS-BF15, BFS-BF17, BFS-BF19
	Sighted	BFS-S2, BFS-S4, BFS-S6, BFS-S8, BFS-S10, BFS-S12, BFS-S14, BFS-S16, BFS-S18, BFS-S20

5.5.2.1 The Participants' Perceptions towards Four Gaze Conditions

The participants' positive and negative attitudes towards four gaze conditions of the E-Gaze are presented in Table 5.46. Eighty quotes from 20 sighted participants mention their perceptions of four gaze conditions.

No Gaze. Two quotes mention the positive attitudes of the participants towards the E-Gaze. BFS-S8 stated, "It seems to communicate with a person wearing the black glasses, which enables me to feel relaxed." Eighteen quotes mention the participants' negative attitudes towards the E-Gaze in the No Gaze condition. An example quote is, "I do not pay attention to the blind conversation partner, because I cannot see anything from the black screens of the glasses. It is difficult for me to know his mood" (BS-S4).

Constant Gaze. Eight quotes mention the positive factors of the Constant Gaze. BFS-S12 said, "I feel my conversation partner is very earnest to listen to me, which encourages me to continue talking." Twelve quotes mention the negative factors of the E-Gaze in the Constant Gaze condition. The participants reported that the constant gaze looked unnatural, horrible, and lifeless. They were more willing to look elsewhere than look at the E-Gaze in face-to-face communication. BFS-S8 said, "The eyes (displayed on the E-Gaze) seem very monotonous and sometimes even horrible. My conversation partner always stares at me, which makes me feel uneasy."

Random Gaze. Six quotes describe the positive factors of the Random Gaze. BFS-S10 said, "It seems the conversation partner is thinking about the topic, and she is trustworthy." Fourteen quotes show the opposite ideas. The participants reported that the

Random Gaze looked impolite and distracted their attention. They felt difficult to distinguish the real attention and feelings of the conversation partners. BFS-S20 said, "I cannot feel the conversation partner concerns me in face-to-face communication. I always doubt that I speak something wrong or offend her in some aspects."

Interactive Gaze. Most quotes (17 out of 20) mention that the Interaction Gaze could increase the participants' communication quality in conversations. BS-S2 said, "I feel I am interacting with a sighted person in conversations […]" The other example is, "He carefully listens to me and think how to answer my questions" (BFS-S12). Only three quotes mention the participants' negative attitudes towards the Interactive Gaze. BFS-S10 said, "The eyes (displayed on E-Gaze) looks so rigid that I feel uncomfortable."

Table 5.46 The participants' perceptions towards four gaze conditions of the E-Gaze.

Test conditions	Attitudes	Example keywords and phrases	Number of quotes
No Gaze	Positive	Relaxed, feel at ease	2
	Negative	Easy to be distracted, difficult to know the conversation partner's mood, a little scared, awkward, confused	18
Constant Gaze	Positive	Magical, attractive, realistic, feel respected	8
	Negative	Unnatural, monotonous, horrible, boring, lifeless, uncomfortable, want to look elsewhere	12
Random Gaze	Positive	Amazing, trustable, attract the attention, feel very intimate	6
	Negative	Easy to be distracted, impolite, uncomfortable, do not pay attention to me, feel irritable	14
Interactive Gaze	Positive	Look like the sighted person, communicate without any difficulties, magical, high-tech, comfortable, natural, realistic	17
	Negative	Inflexible, cannot feel the sincerity	3
Total			80

5.5.2.2 User Experience of Blindfolded in Conversations

In total 24 quotes from 20 blindfolded participants reported their experiences of being blindfolded in conversations. Seven categories were generated from the analysis (Table

5.47): relying on listening (5 quotes), enthusiastic to speak in conversations (5 quotes), nonverbal behaviors (3 quotes), differences between familiar and unfamiliar people (3 quotes), visualize the conversation partner (3 quotes), time becomes fast (2 quotes), and others (3 quotes).

Table 5.47 User experience of being blindfolded in conversations.

Categories	**Example quotes**	**Number of quotes**
Relying on listening	"I feel I communicate with a loudspeaker. It does not matter whether the conversation partner is present or absent, and that person is female or male […] I only rely on listening in conversations, and almost lost the sensitivity towards other nonverbal cues. For example, I do not notice the conversation partner has the perfume scent" (BFS-BF9).	5
Enthusiastic to speak in conversations	"I try to explain everything only relying on verbal communication. If I am not blindfolded, I can express myself by using the gaze or the eye contact to emphasize my intention. Now I cannot see, and I become enthusiastic to speak in conversations" (BFS-BF17). "I listen to the conversation partner more attentively than usual, and I am fully engaged in conversations" (BFS-BF19).	5
Nonverbal behaviours	"If I can see in conversations, I will have some body languages. For example, when I agree with the conversation partner, I can imitate his behavior, and synchronize our behaviors" (BFS-BF5). "Although I cannot see anything, I still keep gaze behaviors (e.g., look down unconsciously)" (BFS-BF9).	3
Differences between familiar and unfamiliar people	"If the conversation partner is a stranger, I feel a little worried about my appearance of wearing the E-Gaze" (BFS-BF3). "I feel almost the same as usual in conversations. Because I am familiar with my conversation partner, and often communicate with her" (BFS-BF13).	3

Visualize the conversation partner	"As being familiar with her voice, I start to imagine she is sitting there, and visualize her appearance according to her voice. In my imagination, she has a wavy, brown and shoulder-length cut hair. Her face is a little bit bigger, which looks like a sporty girl. Her voice is similar to one of my classmates, so I can visualize her face by using my classmate's facial appearance" (BFS-BF7).	3
Time becomes fast	"I feel the time becomes faster. There are four conversations with the same duration in the tests. However, I do not feel each conversation has the same duration. I guess the duration based on the amount of information exchanged in conversations. If there is a large amount of information exchanged in conversations, I feel there is a long duration. Similarly, the duration becomes shorter if we have less information exchanged" (BFS-BF5).	2
Others	"We keep silent at the beginning of the conversation. If I can see the conversation partner is hesitant to speak, I will speak first without any hesitation" (BFS-BF15).	3
Total		24

5.6 Discussion and Conclusion

In this section, we discussed the findings based on three aspects: (1) We examined whether the participants' perceptions were different between the blind-sighted group and the blindfolded-sighted group; (2) We investigated how the participants perceive four gaze conditions in conversations; (3) We also presented how the E-Gaze affects the communication quality in the blind-sighted group.

5.6.1 Group Types

Due to limited access to blind participants, it is common to use blindfolded participants for the preliminary evaluations of the new technologies or interaction solutions (e.g., Moll et al., 2010). But, in our study, we found that there was a significant difference of the participants' perceptions between the blind-sighted group and the blindfolded-sighted group. It implies that in the user experiments, especially in dyadic-conversation scenarios, we may not substitute the blind participants with the blind participants since their behaviors and perceptions differ. More specifically, the quantitative findings from the study supported the formulated Hypothesis 1.1 and Hypothesis 1.3.

Hypothesis 1.1 A significant interaction effect was observed between the conversation groups and the participant roles. The blindfolded participants felt significantly higher co-present than the blind participants. The sighted participants in the blind-sighted group perceived significantly higher attention allocation, PMU and PAU than in the blindfolded-sighted group.

Hypothesis 1.3 A significant interaction effect was observed among gaze conditions, conversation groups and participant roles. The blindfolded participants felt significantly higher co-present than the blind participants in the No Gaze condition, the Constant Gaze condition, and the Random Gaze condition. Besides, the sighted participants felt significantly higher co-present in the blind-sighted group than the blindfolded-sighted group in the No Gaze condition.

In addition to the quantitative findings, we also gained insights from self-reports of the blindfolded participants' perceptions. In conversations, the blindfolded participants completely relied on listening, and lost almost sensitivities towards the nonverbal cues (e.g., ignore the perfume scent). They became enthusiastic to speak in conversations, and earnest to get the feedback through the conversation partners' utterance. Although they could not see, some of them still kept gaze behaviors as usual. Some participants even tried to visualize the conversation partners' face based on their voice. Such behaviors were quite different from blind people. In Section 3.3.1, we found that in face-to-face communication, some blind people were very sensitive to smell and even could distinguish subtle olfactory differences of their friends. Due to the loss of vision, the remaining sensory modalities of blind people were gradually enhanced. This mechanism could not occur to blindfolded participants in a short-duration test. In our study, the qualitative findings from the blindfolded participants provide us with the evidence that the perception and behaviors of the blind and blindfolded participants are different during face-to-face communication.

5.6.2 The Effect of Gaze Conditions in All Groups

The findings from the study supported Hypothesis 2 and Hypothesis 2.1.

Hypothesis 2 The quantitative results strengthened our confidence that Interactive Gaze was more effective than other three gaze conditions to improve the communication quality. Interactive Gaze positively affected the participants' co-presence, attention allocation and PBI in conversations.

Hypothesis 2.1 A significant interaction effect was observed between gaze conditions and participant roles. The sighted participants perceived significantly higher attention allocation and PMU in the Interactive Gaze condition than in the Random Gaze condition. The sighted participants also perceived significantly higher co-presence in the Interactive Gaze and Random Gaze conditions than in the No Gaze condition.

This hypothesis was also supported by the qualitative data. Most sighted participants (17 out of 20) liked the E-Gaze in the Interactive Gaze condition (Section 5.5.2.1). The sighted participants reported that Interactive Gaze looked more natural than the other three conditions. It could draw the conversation partner's attention in listening, increasing the overall communication quality in face-to-face conversations. This finding was consistent with one of the positive functions of gaze in face-to-face social interaction. Gaze often associates with conversation partners' attention and engagement, which has been well documented by many researchers (e.g., Argyle and Cook, 1976; Kendon, 1967; Kleinke, 1986; Rutter et al., 1984). Besides, we found that Constant Gaze was less favorable than Interactive Gaze. According to Argyle and Dean (1965), the relation between the gaze and how it is perceived is not linear. If someone likes a person more, she looks at that person more. But, if she looks for a greater proportion of the time than the norms for the situation permit, she makes the situation too intimate and may be seen as intrusive.

5.6.3 The Effect of Gaze Conditions in the Blind-Sighted Group

We analyzed the data from the participants in the blind-sighted group for the gaze conditions. We did not see any statistically significant difference in the blind-sighted group for Hypothesis 3 and Hypothesis 3.1. Although not significant, in the blind-sighted conversations, the sighted participants perceived higher co-presence, attention allocation, PMU, PAU, PBI and closeness in the Interactive Gaze condition than in other conditions (Section 5.5.1.3). It indicates that the Interactive Gaze still has a positive impact on the communication quality in the blind-sighted group, but this impact is smaller than in the blindfolded-sighted group. One of the possible reasons is the participants' verbal communication may influence communication quality. Based on the researcher's observation, some blind participants could not speak fluently and coherently. Their pronunciation was not very clear. Besides, the topics with unfamiliar location information seem difficult for blind participants (e.g., museums, galleries and even their hometowns). Due to a loss of vision, they are not easy to go out independently. Therefore, they lack the personal experiences of these places. Compared with the blindfolded participants, it took more time for some blind participants to think and respond in conversations. It caused the impatience from their sighted conversation partners.

5.6.4 Limitations

This study yielded rich quantitative data and qualitative information by evaluating the E-Gaze system. Nevertheless, there are several limitations to the research. Firstly, the age, education background, and the level of spoken language were not balanced in the between-group tests. In the blindfolded-sighted group, the participants' average age was 21.6, and they were all university students with a good spoken language. In the blind-sighted group, the average age was 17.05, and the participants were from college and high school. The spoken language of some blind participants was not very good, which might affect communication quality.

Secondly, we used the "Inclusion of Other in the Self " (IOS) Scale (Aron et al., 1992) to measure the closeness between two conversation partners. This questionnaire has been used in similar researches regarding social computing (e.g., Davis et al., 2017). We converted seven increasingly overlapping circle pairs on IOS scale to the corresponding percentage numbers and orally presented them to the blind and blindfolded participants in the experiments. In the quantitative findings, we did not find any statistically significant difference in closeness among four gaze conditions. Two possible reasons are presented: (1) 10-minute conversations are too short to develop interpersonal closeness between two people; (2) The participants may not well understand the IOS scale only based on the oral description. It also has a cognitive bias for the blind participants to imagine the image questionnaire. Using tactile pictures of the IOS scale may be helpful. However, the tactile perception of blind people may be different because of the complexity of their visual impairments (Heller, 1989; Heller et al., 2005). Overall, the IOS scale is not appropriate for the blind participants to measure their relationship with the conversation partners.

Finally, four gaze conditions required 24 order of treatments (4×3×2×1) in a within-subjects design, and the number of the participant pairs must be a multiple of 24. In this experiment, there was a very limited number of truly blind students that could meet all criteria (e.g., age, intelligence quotient and without any other disabilities). Therefore, 10 orders of treatments for the blind-sighted group was a compromise in our study.

In summary, this study yields the following contributions:

- An innovative wearable device was designed and developed which can help a blind person establish the "eye contact" with a sighted conversation partner.
- It demonstrates that there is a significant difference of the communication quality between the blind-sighted group and the blindfolded-sighted group.
- It shows the evidence that Interactive Gaze has a positive impact on the communication quality in a dyadic-conversation scenario.

In more detail, an interactive gaze model based on the E-Gaze was implemented for blind people. A lab-based user experiment was conducted to compare four gaze conditions. The results demonstrated that the participants perceived significantly better communication quality with the Interactive Gaze than other three gaze conditions.

In this chapter, the E-Gaze simulate the natural gaze for blind people. It helps establish eye-to-eye communication between blind and sighted people, enabling both sides to be more engaged in conversations. For blind people, E-Gaze provides mental comfort and makes them more confident in conversations. Although the E-Gaze system benefits blind people, it still has an inadequacy: blind people cannot receive the feedback of gaze signals from sighted people in conversations. In the next chapter, we will improve the E-Gaze system to let blind people also feel the “eye contact” in face-to-face communication. If the E-Gaze can give the prompt of the gaze from sighted people, it will help blind people participate in a more effective social interaction.

6

Study IV: Simulating Gaze Behaviors and Providing Tactile Feedback in Conversations

6.1 Introduction

In Chapter 5, the E-Gaze system simulated the "gaze" for blind people, to provide sighted people with the visual feedback. However, the system has an inadequacy that blind people cannot receive any signals of gaze behaviors from sighted people. The Tactile Band presented in Chapter 4 enables a blind person to feel gaze signals (vibrations) when a sighted person is looking at her face. Here we modify the system based on prior work introduced in Chapter 4 and 5. A tactile wristband is added to the E-Gaze system. It allows a blind person to perceive the corresponding tactile feedback when the "eye contact" is established between a blind and a sighted person.

We tested the improved E-Gaze system with a dyadic-conversation scenario. Total 80 participants were divided into four groups, and each group consisted of 20 participants. Among the four groups, the blind-sighted group and the blindfolded-sighted group were experimental groups; the blind-blind group and the sighted-sighted group were control groups.

Overall, we have three objectives in this chapter: (1) Investigate how the communication quality of four conversation groups is different; (2) Examine how the interactive E-Gaze system affects the communication quality; (3) How to design future smart glasses systems to support the nonverbal signals perception of blind people in face-to-face communication.

6.2 E-Gaze, Version 3

In the third round of iteration, we aim at implementing the interactive gaze model with the tactile feedback and making the working system available for user experiments in a dyadic-conversation scenario.

6.2.1 Design

In our design concept, the iterative system consists of the E-Gaze glasses and a tactile wristband. The E-Gaze glasses can help a blind person react to a sighted person with "eye gestures." Meanwhile, the tactile wristband can provide the blind person with the corresponding feedback when the sighted is looking at his E-Gaze glasses. Specifically, whenever the sighted is looking at the E-Gaze, it reacts to the sighted with a "look at" eye gesture, and holds it for about one second to establish the "eye contact." Meanwhile, the blind person receives the tactile feedback for one second from the wristband. The tactile feedback enables the blind person to realize that the sighted is looking at the E-Gaze. The interactive gaze model is presented in Figure 6.1.

According to Dim and Ren (2017), the wrist and finger are the most preferred positions for perceiving the vibration. In our design, the wrist is chosen to be the right position for blind people to perceive the tactile feedback. Ghent (1961) stated there is a difference of tactile sensitivity between human's dominant and non-dominant hands. The tactile perception of the dominant hand is viewed as more sensitive than the non-dominant hand. Therefore, in our design, blind people should wear the tactile wristband on the dominant hands.

6.2.2 Implementation

The E-Gaze Version 2 (Section 5.3) implemented the Interactive Gaze driven by gaze signals and audio signals. The Eye Tribe detected gaze signals, and the sound detector detected audio signals. In this chapter, the E-Gaze Version 3 was designed and developed by adding a vibration motor to the previous system (E-Gaze, Version 2). The vibration motor was fixed inside a soft wristband, providing the tactile feedback to a blind person. Whenever a sighted person is looking at the E-Gaze, the sensor module will track her gaze behaviors and send the data to the Arduino board. The Arduino board activates the vibration motor to send the corresponding tactile feedback for one second to the blind person. The system will record and save the gaze data.

The E-Gaze Version 3[13] consists of an Eye Tribe Tracker, a laptop, a vibration motor, an Arduino microcontroller, two 1.7" Intelligent OLED modules with an embedded graphics processor, a sound detector, and a physical glasses-shaped prototype. The digital model of the glasses-shaped shape prototype was built by the software Rhinoceros 5 for 3D printing (Figure 6.2). Figure 6.3 and Figure 6.4 show the system and the prototypes.

[13] E-Gaze, Version 3 is programmed in Java by Siti Aisyah binti Anas.

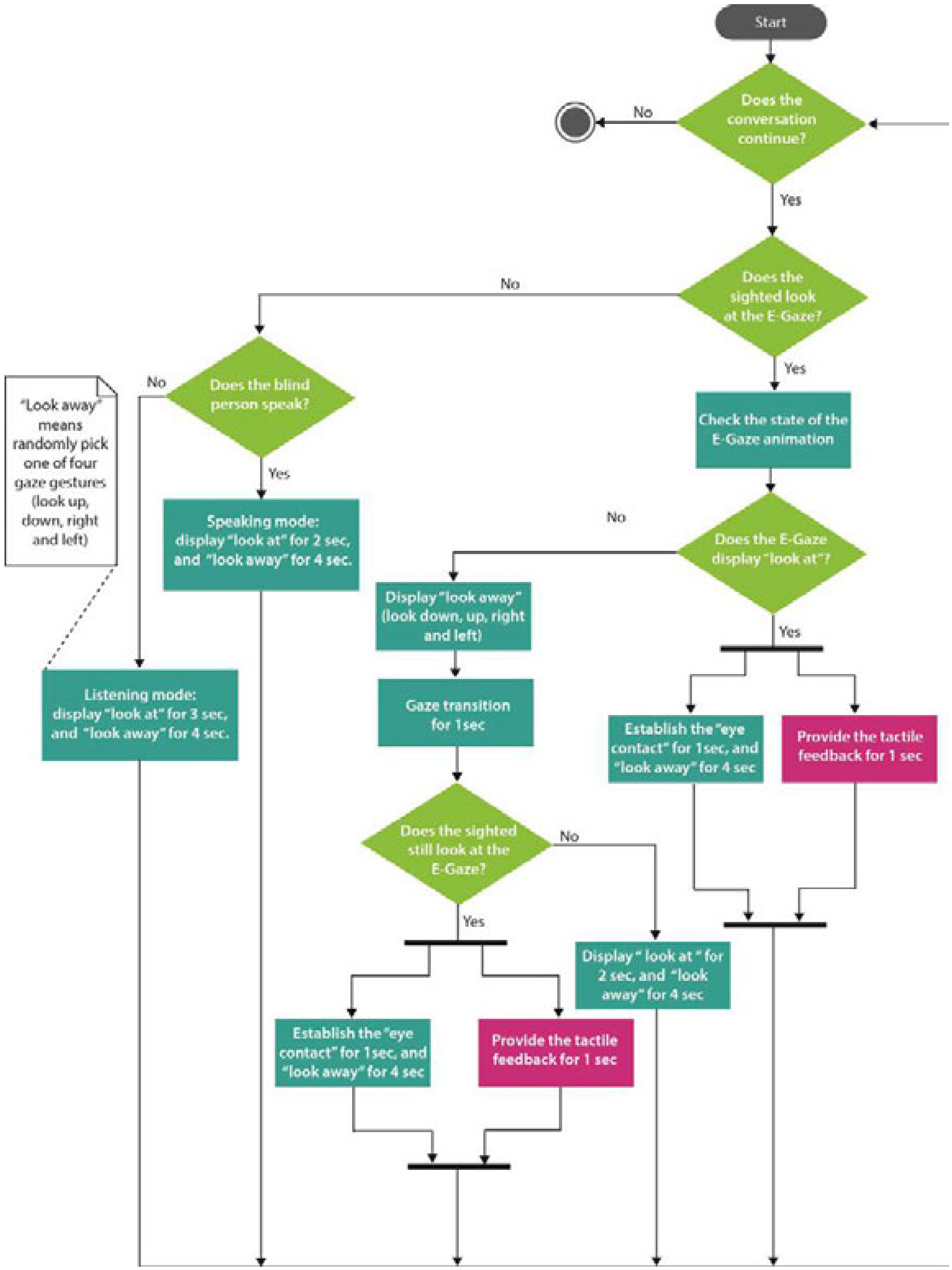


Figure 6.1 The flowchart of the modified gaze model: the Interactive Gaze and the corresponding tactile feedback.

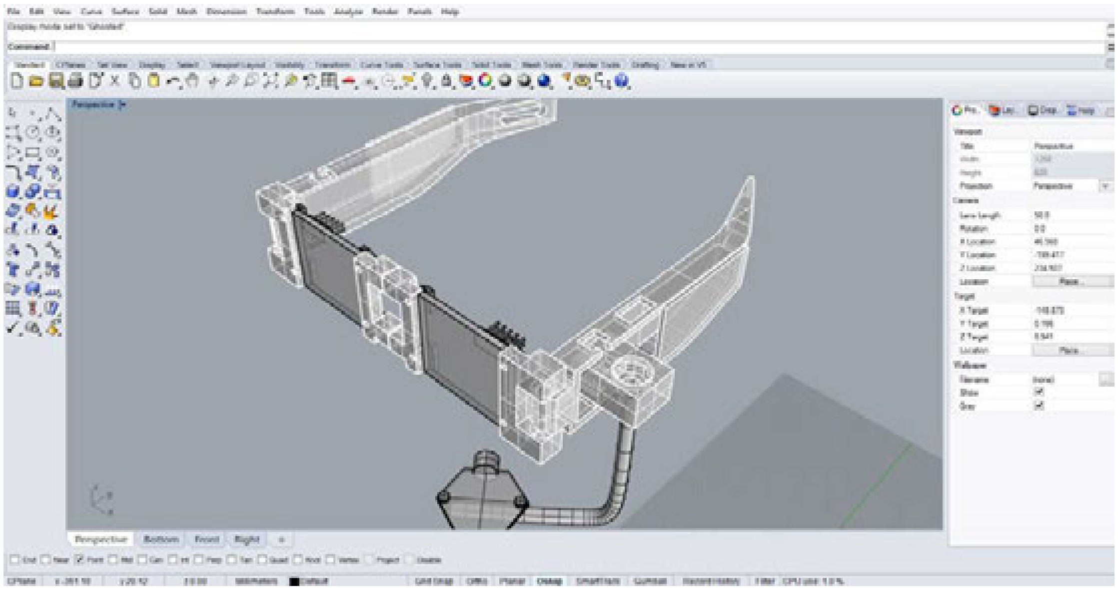


Figure 6.2 The 3D model of the glasses built by the software Rhinoceros 5.

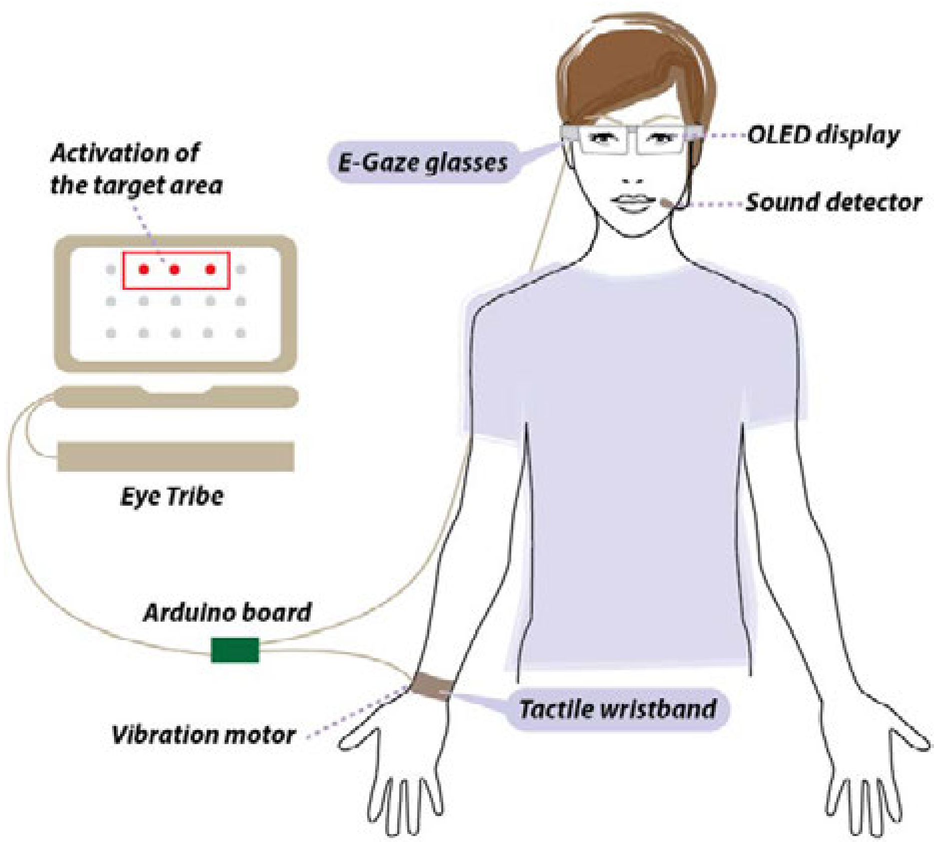


Figure 6.3 Overview of the E-Gaze, Version 3 system.

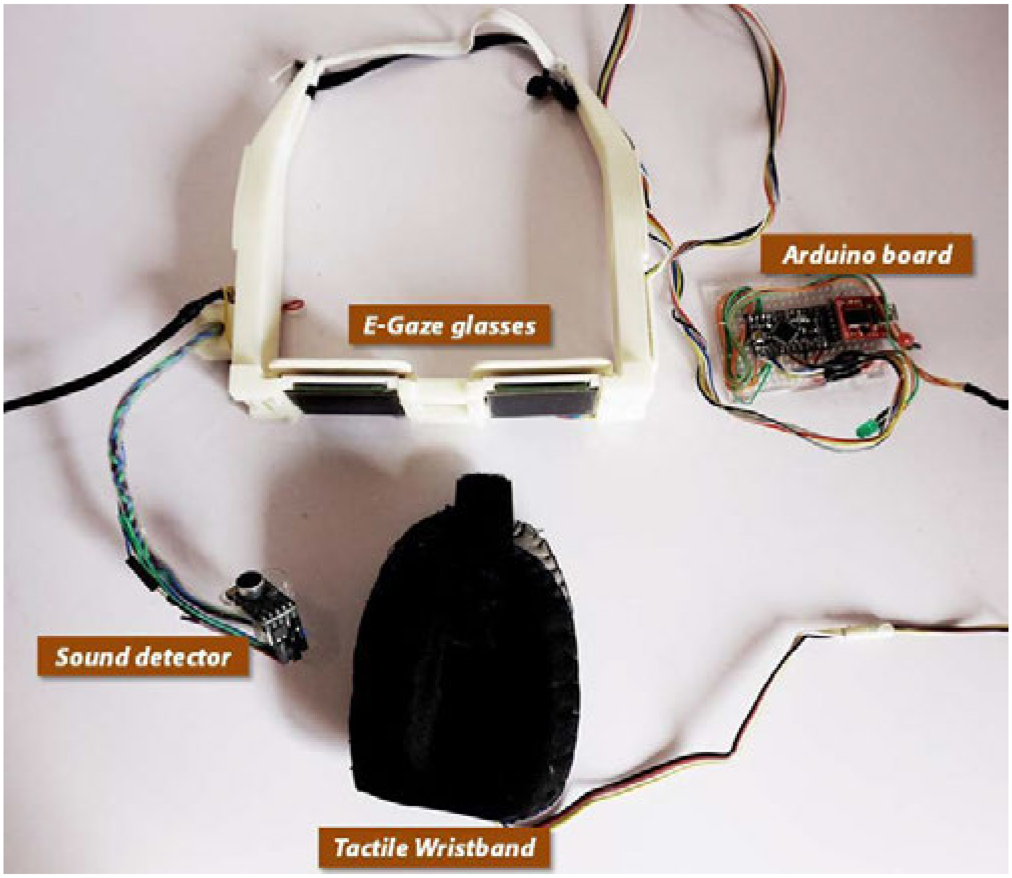


Figure 6.4 Prototypes of the E-Gaze glasses and the tactile wristband.

6.3 Experiment

We investigated the perceptions and reactions of the participants to the system. Specifically, we examined whether the tactile feedback and Interactive Gaze could affect the communication quality. The Interactive Gaze has been introduced in Section 5.3.1. Both blind and blindfolded participants were recruited for the experiment. The research questions regarding face-to-face communication were presented in the following:

1. How does the communication quality differ among four types of conversations (blind-sighted, blindfolded-sighted, blind-blind, sighted-sighted) without the intervention of the tactile feedback and Interactive Gaze?

2. How is the communication quality of blind-sighted conversations different from blindfolded-sighted conversations?

3. How does the tactile feedback in blind-sighted conversations and blindfolded-sighted conversations affect the communication quality?

4. How does Interactive Gaze in blind-sighted conversations and blindfolded-sighted conversations affect the communication quality?

5. How does the tactile feedback in blind-sighted conversations affect the communication quality?

6. How does the Interactive Gaze in blind-sighted conversations affect the communication quality?

In response to the research question 1, we presented the experimental design for four groups in a baseline condition of "Non-active Tactile Feedback and Non-active Interactive Gaze" (TNIN) (Table 6.1), using the conversation groups (blind-sighted, blindfolded-sighted, blind-blind, sighted-sighted) as the between-subjects factor.

In response to the research questions 2-4, we proposed a $2 \times 2 \times 2 \times 2$ mixed factorial experimental design, using the Tactile Feedback (active, non-active) and the Interactive Gaze (active, non-active) as the within-subjects factors, the conversation groups (blind-sighted, blindfolded-sighted) and the participant roles (blind and blindfolded participants, sighted participants) as the between-subjects factors.

In response to the research questions 5-6, we proposed a $2 \times 2 \times 2$ mixed factorial experimental design, using the Tactile Feedback (active, non-active) and the Interactive Gaze (active, non-active) as the within-subjects factors, and the participant roles (blind participants, sighted participants) as the between-subjects factors. An experimental example for blind-sighted conversations is introduced as below:

A blind participant wore both E-Gaze glasses and the tactile wristband in the experiment. She discussed a given daily topic with a sighted participant. They had four conversations with each other, and each conversation took around 10 minutes. Four conversations took place under four test conditions (Table 6.1) with a counterbalanced order to avoid the carry-over effects.

Table 6.1 Four test conditions of the E-Gaze system.

Test Conditions	**Active Tactile Feedback (Y/N)**	**Active Interactive Gaze (Y/N)**
TNIN	N	N
TNIY	N	Y
TYIN	Y	N
TYIY	Y	Y

6.3.1 Independent Variables

Four independent variables were identified as below:

The first independent variable is the state of the Tactile Feedback. This variable is treated as a within-subject factor. It has two conditions: (1) the active state, and (2) the non-active state.

The second independent variable is the state of the Interactive Gaze. This variable is treated as a within-subject factor. It has two conditions: (1) the active state, and (2) the non-active state (Figure 6.5).

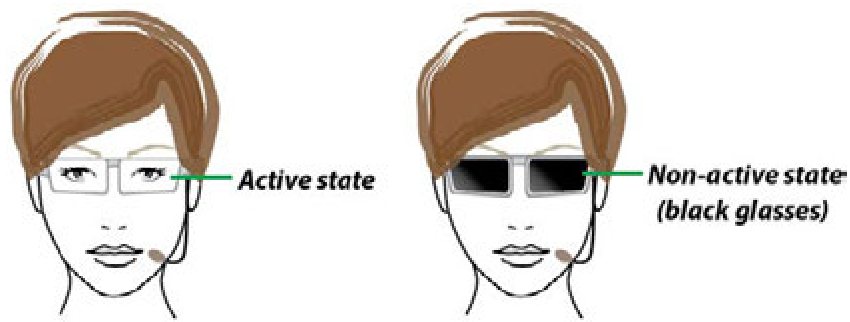


Figure 6.5 Two states of the Interactive Gaze displayed on the E-Gaze (glasses).

The third independent variable is the type of conversation groups. This variable is treated as a between-subject factor. It has four conditions: (1) the blind-sighted group, (2) the blindfolded-sighted group, (3) the blind-blind group, and (4) the sighted-sighted group.

The fourth independent variable is the role of the participants. This variable is treated as a between-subject factor. It has two conditions: (1) the blind and blindfolded participants, and (2) the sighted participants.

6.3.2 Hypotheses

Six categories of the hypotheses were presented based on the research questions.

H1 There is a significant difference of the communication quality among four conversation groups in a baseline condition.

H2 There is a significant difference of the communication quality between the blind-sighted group and the blindfolded-sighted group.

- **H2.1** There is a significant interaction effect between the type of the conversation groups and the role of the participants.
- **H2.2** There is a significant interaction effect between the state of the Tactile Feedback and the type of conversation groups.
- **H2.3** There is a significant interaction effect between the state of the Interactive Gaze and the type of conversation groups.

H3 There is a significant difference of the communication quality between the active and non-active Tactile Feedback.

- **H3.1** There is a significant interaction effect between the state of the Tactile Feedback and the role of the participants.

H4 There is a significant difference of the communication quality between the active and non-active Interactive Gaze.

- **H4.1** There is a significant interaction effect between the state of the Interactive Gaze and the role of the participants.

H5 There is a significant difference of the communication quality between the active and non-active Tactile Feedback in the blind-sighted group.

- **H5.1** There is a significant interaction effect between the state of the Tactile Feedback and the role of the participants in the blind-sighted group.

H6 There is a significant difference of the communication quality between the active and non-active Interactive Gaze in the blind-sighted group.

- **H6.1** There is a significant interaction effect between the state of the Interactive Gaze and the role of the participant in the blind-sighted group.

6.3.3 Participants

User experiments were conducted in two locations, Shanghai and Yangzhou in China. In this study, we recruited 80 participants including 30 blind participants. The recruitment principle of all participants is the same as we have mentioned in Section 5.4.3.

Demographic Information. The participants were 80 student volunteers in China (M_{age} = 19.73, SD = 3.61, N = 36 females vs. 44 males) with ages ranging from 15-30. They were divided into four conversation groups: sighted-sighted, blind-blind, blindfolded-sighted and blind-sighted (Table 6.2).

Table 6.2 Four conversation groups.

	Conversation Groups	Number of Participants	Sight Capacity	University, College and School [a]	Experiment Location
Experimental groups	Blind-sighted	10 10	Blind Sighted	YZSES JCT	YZSES YZSES
	Blindfolded-sighted	10 10	Blindfolded Sighted	SJTU SJTU	SJTU SJTU
Control groups	Sighted-sighted	10 10	Sighted Sighted	SJTU SJTU	SJTU SJTU
	Blind-blind	10 10	Blind Blind	YZSES YZSES	YZSES YZSES

[a] Abbreviations see Chapter 5.4.3.

The blind-sighted group consisted of 10 pairs with one blind person and one sighted person in each (M_{age} = 16.55, SD = .83, N = 8 females vs. 12 males). The blindfolded-sighted group consisted of 10 pairs with one blindfolded and one sighted in each (M_{age} = 23.45, SD = 2.67, N = 12 females vs. 8 males) and the blindfolded participant in each pair was selected randomly. The sighted-sighted group consisted of 10 pairs of the sighted participants (M_{age} = 22.05, SD = 2.24, N = 8 females vs. 12 males) and the blind-blind group consisted of 10 pairs of the blind participants (M_{age} = 16.85, SD = 1.39, N = 8 females vs. 12 males). Compensation for each participant was 100 CNY for approximately three hours for two experimental groups, and 50 CNY for approximately one hour for two control groups.

The information about the age, gender, and education of the participants is presented in Table 6.3, Table 6.4 and Table 6.5. We also documented the information regarding the dominant hands of the participants. All participants in China were right-handed. The possibility is that a combination of traditional values and practical considerations reduced the actual prevalence of left-handedness in China (Kushner, 2013).

Table 6.3 Participants' age.

Conversation Groups	N	M	SD	Minimum	Maximum
Blind-sighted	20	16.55	.83	15	18
Blindfolded-sighted	20	23.45	2.67	19	30
Blind-blind	20	16.85	1.39	15	20
Sighted-sighted	20	22.05	2.23	19	26
Total	80	19.73	3.61	15	30

Table 6.4 Participants' gender.

Conversation Groups	Gender	N
Blind-sighted	Male Female	12 8
Blindfolded-sighted	Male Female	8 12
Blind-blind	Male Female	12 8
Sighted-sighted	Male Female	12 8
Total	Male Female	44 36

Table 6.5 Participants' education.

Conversation Groups	Education	N
Blind-sighted	The third grade The eighth grade The tenth grade	1 9 10
Blindfolded-sighted	Bachelor Master PhD student	7 12 1
Blind-blind	The third grade The eighth grade The tenth grade The eleventh grade	1 10 6 3
Sighted-sighted	Bachelor Master PhD student	9 10 1

Vision Conditions. The blind participants provided their vision conditions based on CDPF (2013). We converted the vision conditions of blind participants in mainland China to the WHO standard (Table 6.6 and Table 6.7).

Table 6.6 Vision conditions of the blind participants in the blind-sighted group.

Gender	Age	Vision Conditions (WHO)	Congenital Blindness (Y/N)	Color perception (Y/N)	Light perception (Y/N)
M	16	Moderate visual impairment	N	Y	Y
M	18	Moderate visual impairment	Y	Y	Y
M	17	Moderate visual impairment	Y	Y	Y
F	16	Moderate visual impairment	N	Y	Y
F	15	Blindness 3	N	Y	Y
M	16	Blindness 4	N	N	Y
M	15	Blindness 5	N	N	N
M	17	Blindness 5	Y	N	N
F	16	Blindness 5	Y	N	N
F	16	Blindness 5	Y	N	N

Table 6.7 Vision conditions of the blind participants in the blind-blind group.

Gender	Age	Vision Conditions (WHO)	Congenital Blindness (Y/N)	Color perception (Y/N)	Light perception (Y/N)
M	16	Moderate visual impairment	Y	Y	Y
M	17	Moderate visual impairment	Y	Y	Y
M	16	Moderate visual impairment	N	Y	Y
M	20	Moderate visual impairment	Y	Y	Y
M	18	Moderate visual impairment	Y	Y	Y
F	16	Moderate visual impairment	N	Y	Y
F	16	Moderate visual impairment	N	Y	Y
F	19	Moderate visual impairment	Y	Y	Y
M	18	Severe visual impairment	N	Y	Y
M	19	Severe visual impairment	Y	Y	Y
M	17	Blindness 3	Y	Y	Y
F	15	Blindness 3	N	Y	Y
M	16	Blindness 4	N	N	Y
M	16	Blindness 4	N	Y	Y
M	17	Blindness 4	N	Y	Y
M	16	Blindness 5	Y	N	N
F	16	Blindness 5	Y	N	N
M	18	Blindness 5	N	N	N
M	15	Blindness 5	N	N	N
F	16	Blindness 5	Y	N	N

Familiarity. In 80 participants, 48 participants never knew each other; 6 participants knew each other, but never had conversations; 9 participants knew each other and sometimes had conversations; 17 participants knew each other and often had conversations (Table 6.8). In the blind-blind group, all participants knew each other. Among them, 6 participants knew each other but never had conversations. The students know or be familiar with others mainly came from Yang Zhou Special Education School. Since there was a small number of blind students (average 10 students) in each grade, they are easy to know each other.

Table 6.8 Familiarity among the participants in each group.

Conversation Groups	Initial Familiarity	N
Blind-sighted	Never know each other	20
Blindfolded-sighted	Never know each other	16
	Know each other, often speak	4
	Total	20
Blind-blind	Know each other, never speak	6
	Know each other, sometimes speak	7
	Know each other, often speak	7
	Total	20
Sighted-sighted	Never know each other	12
	Know each other, sometimes speak	2
	Know each other, often speak	6
	Total	20
Total	Never know each other	48
	Know each other, never speak	6
	Know each other, sometimes speak	9
	Know each other, often speak	17
	Total	80

6.3.4 Setup and Procedure

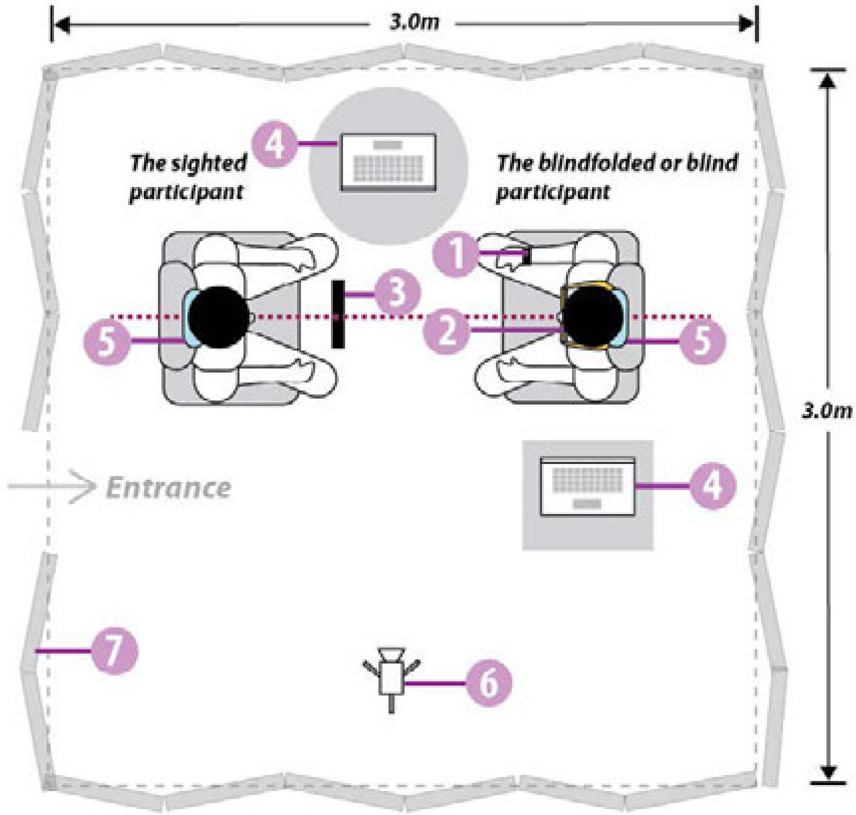


Figure 6.6 Overhead view of the experimental setup: (1) the tactile wristband, (2) the E-Gaze glasses, (3) Eye Tribe Tracker, (4) laptop, (5) the pillow to support the neck of the participant, (6) the observation camera, and (7) folding screens.

The experimental setup in this study was similar to that mentioned in Section 5.4.4. A blind participant wore the E-Gaze glasses and the tactile wristband in the user experiment (Figure 6.6). Figure 6.7 shows the picture taken from the observation camera during the experiment.

Figure 6.8 presents the experimental procedure of four conversation groups. The participants in each pair were matched with the same gender and similar age to avoid the heterosexual effect in conversations. In the experimental groups, four conversations were taken place under four test conditions (Table 6.1) of the E-Gaze system with a counterbalanced order to avoid carry-over effects. In the control groups, only one conversation was taken for each pair of participants in the TNIN condition (Table 6.1).

Figure 6.7 Picture taken from the observation camera during the experiment: (a) the E-Gaze glasses and (b) the tactile wristband.

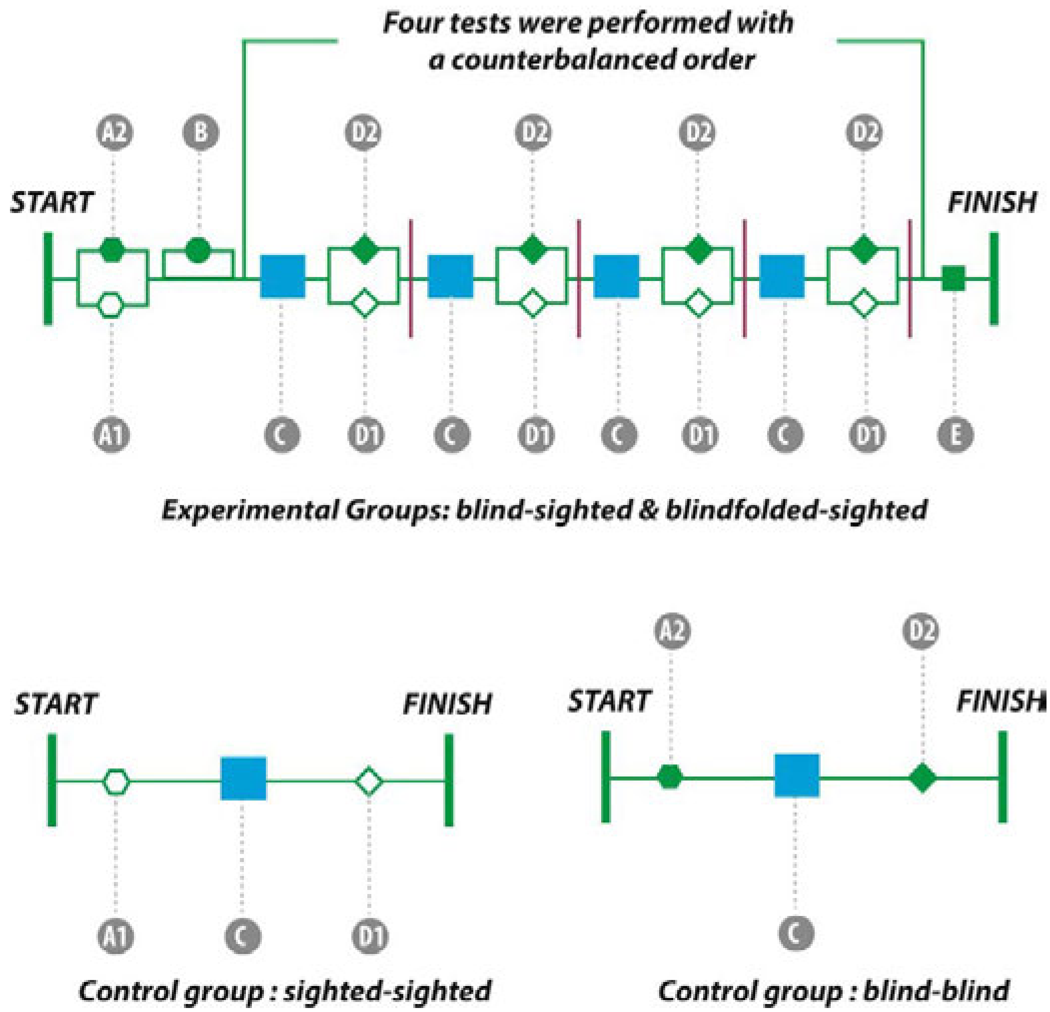


Figure 6.8 The experimental procedure of four conversation groups. The procedure of the experiment: (A1) read and sign consent forms; (A2) a volunteer helped in the consent process (only for the blind participants); (B) experience being blindfolded (only for the blindfolded participants); (C) test; (D1) complete the post-experimental questionnaire; (D2) the researcher orally presented the questionnaire to the blind or blindfolded participants and completed the questionnaires based on their oral answers; (E) the interview for the open questions.

6.3.5 Measurements

In Chapter 5, we measured the communication quality of the participants by using the subjective questionnaires. In this study, we use the same questionnaires regarding social presence and closeness which have been introduced in Chapter 5.4.6. Besides, we collect gaze data, analyze conversation videos and ask the participants' some open questions.

6.3.5.1 Gaze Data

We programmed the system to record gaze data of sighted participants. The system can calculate the fixation duration while the participant interacts with the E-Gaze glasses. We define the rectangle region of the E-Gaze glasses as the area of the interest (AOI). Based on the captured gaze data, we can further calculate the attention ratio (it has also been used in other HCI studies, e.g., Osawa et al., 2009) towards the E-Gaze glasses in each test, to illustrate the level of the sighted participants' engagement in conversations.

6.3.5.2 Video Analysis

Duck et al. (1991) suggested that control of the interaction is an important dimension in face-to-face communication or interaction. It includes three major aspects: (1) *who initiated the conversation*, (2) *who controlled the conversation*, and (3) *who ended the conversation*. In our experiment, we specifically analyze who initiates the conversation. It reflects whether a participant has an active attitude in face-to-face communication. We use the scoring of a "1" or a "0" in video analysis. "1" stands for the participant to initiate a conversation and "0" stands for not initiating.

6.3.5.3 Open Questions

We collect qualitative feedback with open questions and interviews. After four tests, we have a short interview to ask the participants some open questions, including the item: "Which aspects make you like or dislike this system?"

6.4 Results

6.4.1 Quantitative Results

The quantitative results included six parts: (1) analysis of the baseline condition, (2) analysis of group types, (3) analysis of interventions in the experimental groups, (4) analysis of interventions in the blind-sighted group, (5) gaze data and (6) video analysis.

6.4.1.1 Analysis of the Baseline Condition

A one-way between subjects ANOVA was conducted to compare the effect of conversation group types on the communication quality in blind-sighted, blindfolded-sighted, blind-blind, and sighted-sighted conversations under a baseline condition (TNIN) (Table 6.1). The results are presented in Table 6.9 and Table 6.10.

Co-presence. There was a significant effect of the conservation group type on the participants' co-presence, $F(3, 76) = 6.900$, $p < .001$, $r = .463$. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.95, SD = .54) was significantly higher than the blind-sighted conversation group (M = 5.09, SD = 1.09) and the blindfolded-sighted conversation group (M = 4.59, SD = 1.14).

Attention allocation. There was a significant effect of the conservation group type on the participants' attention allocation, F(3, 76) = 4.323, *p* = .007, *r* = .382. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.30, SD = .90) was significantly higher than the blindfolded-sighted conversation group (M = 4.24, SD = 1.11).

Perceived message understanding (PMU). There was a significant effect of the conservation group type on the participants' PMU, F(3, 76) = 3.915, *p* = .012, *r* = .366. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.80, SD = .53) was significantly higher than the blindfolded-sighted conversation group (M = 4.64, SD = 1.60), and the blind-blind conversation group (M = 4.69, SD = 1.36).

Perceived message understanding (PMU). There was a significant effect of the conservation group type on the participants' PAU, F(3, 76) = 4.110, *p* = .009, *r* = .374. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.19, SD = .60) was significantly higher than the blind-sighted conversation group (M = 4.08, SD = 1.35) and the blindfolded-sighted conversation group (M = 3.97, SD = 1.50).

Perceived emotional interdependence (PEI). There was a significant effect of the conservation group type on the participants' PEI, F(3, 76) = 4.352, *p* = .007, *r* = .383. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.48, SD = .86) was significantly higher than the blind-sighted conversation group (M = 4.12, SD = 1.33) and the blindfolded-sighted conversation group (M = 4.27, SD = 1.37).

Perceived behavioral interdependence (PBI). There was a significant effect of the conservation group type on the participants' PBI, F(3, 76) = 6.623, *p* < .001, *r* = .455. Post hoc Bonferroni test revealed that the mean score for the sighted-sighted conversation group (M = 5.66, SD = .72) was significantly higher than the blind-sighted conversation group (M = 4.39, SD = 1.01) and the blindfolded-sighted conversation group (M = 3.97, SD = 1.71).

Closeness. There was a non-significant effect of the conservation group type on the participants' closeness, F(3, 76) = .920, *p* = .435.

Summary. Under the baseline condition, except for the closeness of the participants, the conservation group type greatly affects the co-presence, attention allocation, PMU, PAU, PEI, and PBI of the participants (Figure 6.9). Post hoc Bonferroni test revealed that the mean score for the sighted-sighted group was much higher than the blind-blind group, the blind-sighted group, and the blindfolded-sighted group. Also, although not significant, the communication quality in the blind-blind group was better than the blind-sighted group and the blindfolded-sighted group.

Table 6.9 Means and standard deviations of the communication quality in four conversation groups under the baseline condition.

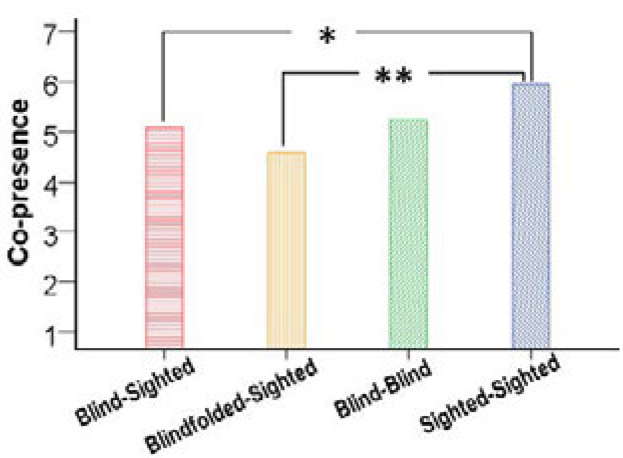
	Conversation Groups	N	Mean	Std. Deviation
Co-presence	Blind-sighted	20	5.09	1.09
	Blindfolded-sighted	20	4.59	1.14
	Blind-blind	20	5.24	.93
	Sighted-sighted	20	5.95	.54
	Total	80	5.22	1.06
Attention allocation	Blind-sighted	20	4.58	1.23
	Blindfolded-sighted	20	4.24	1.11
	Blind-blind	20	5.07	.83
	Sighted-sighted	20	5.30	.90
	Total	80	4.80	1.09
Perceived message understanding	Blind-sighted	20	4.77	1.24
	Blindfolded-sighted	20	4.64	1.60
	Blind-blind	20	4.69	1.36
	Sighted-sighted	20	5.80	.53
	Total	80	4.98	1.31
Perceived affective understanding	Blind-sighted	20	4.08	1.35
	Blindfolded-sighted	20	3.97	1.50
	Blind-blind	20	4.42	1.24
	Sighted-sighted	20	5.19	.60
	Total	80	4.41	1.29
Perceived emotional interdependence	Blind-sighted	20	4.12	1.33
	Blindfolded-sighted	20	4.27	1.37
	Blind-blind	20	4.47	1.58
	Sighted-sighted	20	5.48	.86
	Total	80	4.58	1.39
Perceived behavioral interdependence	Blind-sighted	20	4.39	1.01
	Blindfolded-sighted	20	3.97	1.71
	Blind-blind	20	4.76	1.32
	Sighted-sighted	20	5.66	.72
	Total	80	4.70	1.37
Closeness	Blind-sighted	20	4.85	1.63
	Blindfolded-sighted	20	4.10	1.62
	Blind-blind	20	4.90	2.27
	Sighted-sighted	20	4.55	1.15
	Total	80	4.60	1.71

Note. The mean score ranges from 1-7.

Table 6.10 ANOVA results summary of the conservation group type on the communication quality in a baseline condition.

		SS	*df*	*MS*	*F*	*p*
Co-presence	Between Groups	18.877	3	6.292	6.900	**.000****
	Within Groups	69.310	76	.912		
	Total	88.187	79			
Attention allocation	Between Group	13.737	3	4.579	4.323	**.007****
	Within Groups	80.499	76	1.059		
	Total	94.237	79			
Perceived message understanding	Between Groups	18.274	3	6.091	3.915	**.012***
	Within Groups	118.245	76	1.556		
	Total	136.520	79			
Perceived affective understanding	Between Groups	18.378	3	6.126	4.110	**.009****
	Within Groups	113.292	76	1.491		
	Total	131.670	79			
Perceived emotional interdependence	Between Groups	22.483	3	7.494	4.352	**.007****
	Within Groups	130.877	76	1.722		
	Total	153.359	79			
Perceived behavioral interdependence	Between Groups	30.877	3	10.292	6.623	**.000****
	Within Groups	118.113	76	1.554		
	Total	148.990	79			
Closeness	Between Groups	8.100	3	2.700	.920	.435
	Within Groups	223.100	76	2.936		
	Total	231.200	79			

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.



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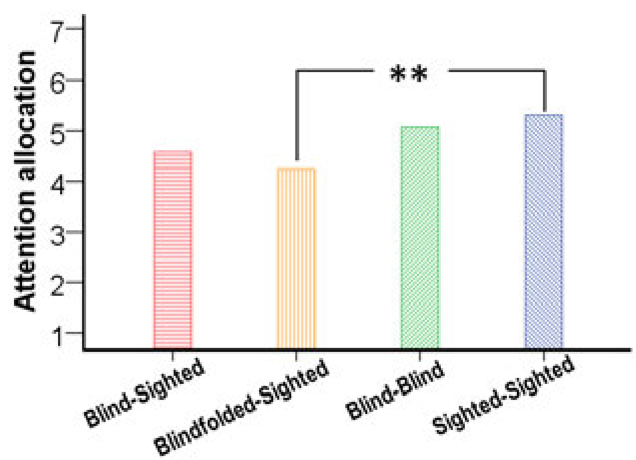

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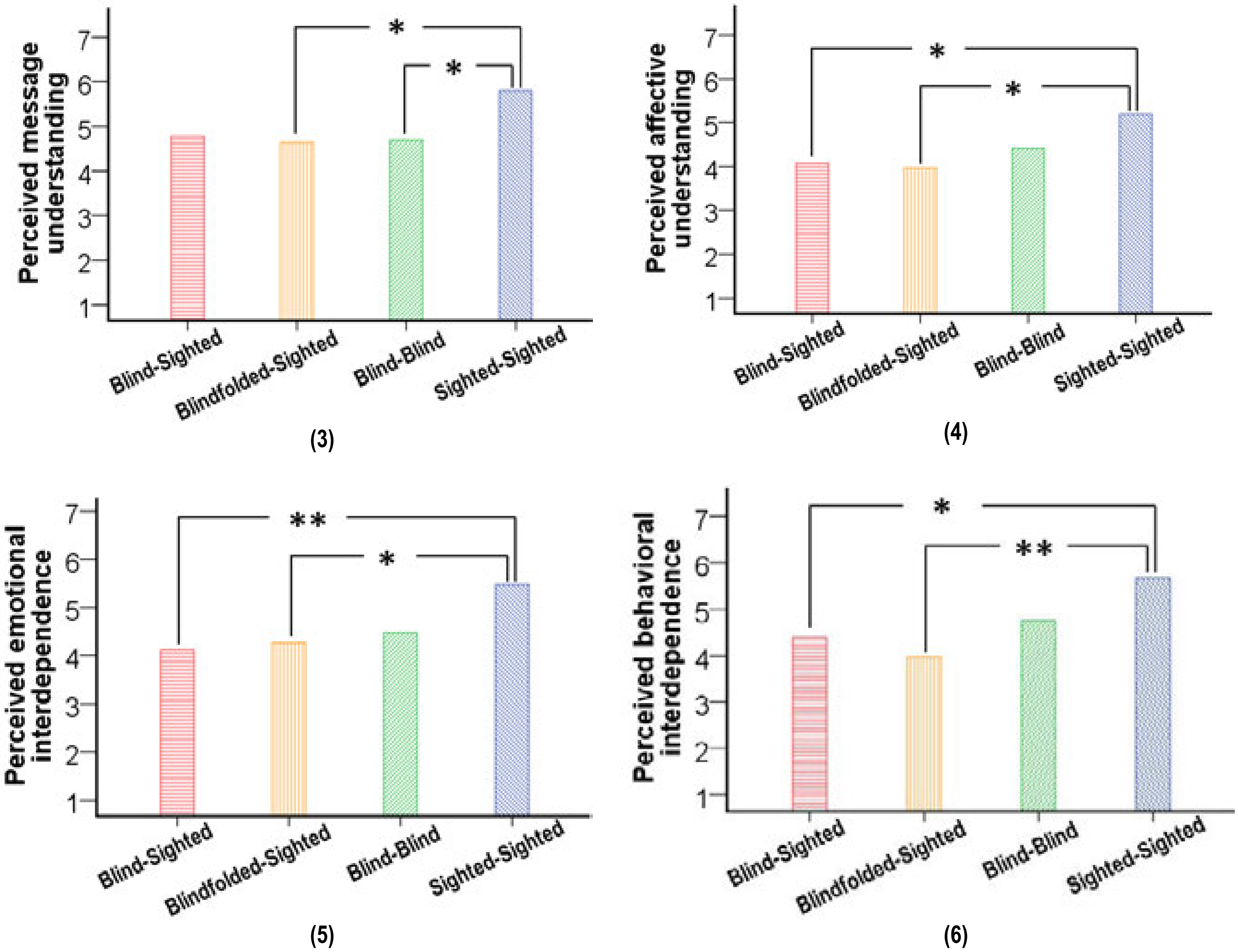


Figure 6.9 Means on the communication quality of four conversation groups under the baseline condition. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

6.4.1.2 Analysis of Group Types

A 2 × 2 × 2 × 2 mixed ANOVA was conducted, using the Tactile Feedback (active, non-active) and the Interactive Gaze (active, non-active) as the within-subjects factors, the conversation groups (blind-sighted, blindfolded-sighted) and the participant roles (the blind and blindfolded participants, the sighted participants) as the between-subjects factors.

Co-presence. Although the predicted main effect of the conversation groups was not significant [F(1, 36) = .624, p = .435], a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 8.490, p = .006, η_p^2 = .191]. The contrast revealed that the sighted participants in the blind-sighted group felt significantly higher co-present than in the blindfolded-sighted group. In addition, the interaction effect was not significant between the state of the Tactile Feedback and the conversation groups [F(1, 36) = .098, p = .756], while the interaction effect was significant between the state of the Interactive Gaze and the conversation groups [F(1, 36) = 28.514, p < .001, η_p^2 = .442]. It indicated that in the blind-sighted group, the participants' co-presence was generally the same whether the Interactive Gaze was active or not, but the participants in the blindfolded-sighted group felt significantly higher co-present when the Interactive Gaze was active than it was not. The results are presented in Table 6.11 and Table 6.12.

Attention allocation. Although the predicted main effect of the conversation groups was not significant [F(1, 36) = .250, p = .620], a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 6.987, p = .012, η_p^2 = .163]. The contrast indicated that the sighted participants in the blind-sighted group perceived significantly higher attention allocation than in the blindfolded-sighted group. In addition, the interaction effect between the state of the Tactile Feedback and the conversation groups was not significant [F(1, 36) = .555, p = .461], while the interaction effect between the state of the Interactive Gaze and the conversation groups was significant [F(1, 36) = 7.260, p = .011, η_p^2 = .168]. It indicated that in the blind-sighted group, the participants' attention allocation was generally the same whether the Interactive Gaze was active or not, but the participants in the blindfolded-sighted group perceived significantly higher attention allocation when the Interactive Gaze was active than it was not. The results are presented in Table 6.13 and Table 6.14.

Perceived message understanding (PMU). Although there was a non-significant main effect of the conversation groups [F(1, 36) = .060, p = .808], a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 18.323, p < .001, η_p^2 = .337]. The contrast indicated that the blindfolded participants experienced significantly higher PMU than the blind participants. This contrast also revealed that the sighted participants in the blind-sighted group perceived significantly higher PMU than in the blindfolded-sighted group. In addition, a non-significant interaction effect was observed between the state of the Tactile Feedback and the conversation groups [F(1, 36) = 1.128, p = .295], while a significant interaction effect was found between the state of the Interactive Gaze and the conversation groups [F(1, 36) = 5.894, p = .020, η_p^2 = .141]. It indicated that in the blind-sighted group, the participants' PMU was generally the same whether the Interactive Gaze was active or not, but the participants in the blindfolded-sighted group perceived significantly higher PMU when the Interactive Gaze was active than it was not. The results are presented in Table 6.15 and Table 6.16.

Perceived affective understanding (PAU). Although the predicted main effect of the conversation groups was not significant [F(1, 36) = .011, p = .917], a significant interaction effect was observed between the conversation groups and the participant roles, [F(1, 36) = 12.264, p = .001, η_p^2 = .254]. The contrast revealed that the blindfolded participants perceived significantly higher PAU than the blind participants. This contrast also revealed that the sighted participants in the blind-sighted group perceived significantly higher PAU than in the blindfolded-sighted group. In addition, the interaction effect between the state of the Tactile Feedback and the conversation groups was not significant [F(1, 36) = .305, p = .584], but the interaction effect between the state of the Interactive Gaze and the conversation groups was significant [F(1, 36) = 4.113, p = .050, η_p^2 = .103]. It indicated that in the blind-sighted group, the participants' PAU was generally the same whether the Interactive Gaze was active or not, while the participants in the blindfolded-sighted group perceived significantly higher PAU when the Interactive Gaze was active than it was not. The results are presented in Table 6.17 and Table 6.18.

Perceived emotional interdependence (PEI). The predicted main effect of the conversation groups was not significant [F(1, 36) = .668, p = .419]. In addition, a non-significant interaction effect was observed between conversation groups and participant roles [F(1, 36) = .225, p = .638]. The interaction effect between the state of the Tactile Feedback and the conversation groups was not significant [F(1, 36) = 2.546, p = .119], but the interaction effect between the state of the E-Gaze and the conversation groups was significant [F(1, 36) = 20.707, p < .001, η_p^2 = .365]. It revealed that in the blind-sighted group, the participants' PEI was generally the same whether the Interactive Gaze was active or not, while the participants in the blindfolded-sighted group perceived significantly higher PEI when the Interactive Gaze was active than it was not. The results are presented in Table 6.19 and Table 6.20.

Perceived behavioral interdependence (PBI). Although the predicted main effect of the conversation groups was not significant [F(1, 36) = .093, p = .762], a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 14.119, p = .001, η_p^2 = .282]. The contrast indicated that the blindfolded participants perceived significantly higher PBI than the blind participants. This contrast also revealed that the sighted participants in the blind-sighted group perceived significantly higher PBI than in the blindfolded-sighted group. In addition, the interaction effect between the state of the Tactile Feedback and the conversation groups was not significant [F(1, 36) = .338, p = .564], but the interaction effect between the state of the Interactive Gaze and the conversation groups was significant [F(1, 36) = 15.231, p < .001, η_p^2 = .297]. It indicated that in the blind-sighted group, the participants' PBI was generally the same whether the Interactive Gaze was active or not, while the participants in the blindfolded-sighted group perceived significantly higher PBI when the Interactive Gaze was active than it was not. The results are presented in Table 6.21 and Table 6.22.

Closeness. The predicted main effect of the conversation groups was not significant [$F(1, 36) = 2.910$, $p = .097$]. There was also a non-significant interaction effect between the conversation groups and the participant roles [$F(1, 36) = .474$, $p = .496$]. In addition, the interaction effect between the state of the Tactile Feedback and the conversation groups was not significant [$F(1, 36) = .619$, $p = .437$], and the interaction effect between the state of the Interactive Gaze and the conversation groups was not significant [$F(1, 36) = .169$, $p = .684$]. The results are presented in Table 6.23 and Table 6.24.

Table 6.11 Means and standard deviations on the participants' co-presence in the experimental groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Co-presence	
				Mean	Std. Deviation
TNIN	Blind-sighted	Blind	10	4.80	1.28
		Sighted	10	5.38	.82
		Total	20	5.09	1.09
	Blindfolded-sighted	Blindfolded	10	5.30	.74
		Sighted	10	3.88	1.05
		Total	20	4.59	1.14
	Total	Blind and Blindfolded	20	5.05	1.05
		Sighted	20	4.63	1.20
		Total	40	4.84	1.13
TNIY	Blind-sighted	Blind	10	4.85	1.42
		Sighted	10	5.78	.32
		Total	20	5.32	1.11
	Blindfolded-sighted	Blindfolded	10	5.37	.75
		Sighted	10	5.78	.52
		Total	20	5.58	.66
	Total	Blind and Blindfolded	20	5.11	1.14
		Sighted	20	5.78	.42
		Total	40	5.45	.91
TYIN	Blind-sighted	Blind	10	5.32	.75
		Sighted	10	5.55	.56
		Total	20	5.43	.65
	Blindfolded-sighted	Blindfolded	10	5.73	.88
		Sighted	10	3.93	.96
		Total	20	4.83	1.29
	Total	Blind and Blindfolded	20	5.52	.82
		Sighted	20	4.74	1.13
		Total	40	5.13	1.05
TYIY	Blind-sighted	Blind	10	5.47	.77
		Sighted	10	5.72	.85
		Total	20	5.59	.80
	Blindfolded-sighted	Blindfolded	10	5.78	.72
		Sighted	10	5.80	.63
		Total	20	5.79	.66
	Total	Blind and Blindfolded	20	5.63	.74
		Sighted	20	5.76	.73
		Total	40	5.69	.73

Note. The mean score ranges from 1-7.

Table 6.12 Mixed ANOVA results summary of main effects and interaction effects on the participants' co-presence in the experimental groups.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.262	1	.262	.624	.435
Conversation Group * Participant Role	3.566	1	3.566	8.490	**.006****
Error	15.120	36	.420		
Tactile Feedback * Conversation Group	.066	1	.066	.098	.756
Error(Tactile Feedback)	24.249	36	.674		
Interactive Gaze * Conversation Group	6.049	1	6.049	28.514	**.000****
Error(Interactive Gaze)	7.637	36	.212		

Significant group difference; * $p < .05$, ** $p < .01$.

Table 6.13 Means and standard deviations of the participants' attention allocation in the experimental groups across four test conditions.

Test Conditions	**Conversation Group**	**Participant Role**	**N**	**Score of Attention Allocation**	
				Mean	**Std. Deviation**
TNIN	Blind-sighted	Blind	10	4.30	1.36
		Sighted	10	4.85	1.09
		Total	20	4.57	1.23
	Blindfolded-sighted	Blindfolded	10	5.05	.76
		Sighted	10	3.43	.74
		Total	20	4.24	1.11
	Total	Blind and Blindfolded	20	4.67	1.14
		Sighted	20	4.14	1.16
		Total	40	4.41	1.17
TNIY	Blind-sighted	Blind	10	4.85	1.35
		Sighted	10	5.12	1.13
		Total	20	4.98	1.22
	Blindfolded-sighted	Blindfolded	10	5.42	.53
		Sighted	10	5.07	.91
		Total	20	5.24	.74
	Total	Blind and Blindfolded	20	5.13	1.04
		Sighted	20	5.09	1.00
		Total	40	5.11	1.01
TYIN	Blind-sighted	Blind	10	5.17	1.08
		Sighted	10	4.97	.88
		Total	20	5.07	.96
	Blindfolded-sighted	Blindfolded	10	5.47	.63
		Sighted	10	3.62	.87
		Total	20	4.54	1.21
	Total	Blind and Blindfolded	20	5.32	.87
		Sighted	20	4.29	1.10
		Total	40	4.80	1.11
TYIY	Blind-sighted	Blind	10	4.87	1.26
		Sighted	10	5.32	1.05
		Total	20	5.09	1.15
	Blindfolded-sighted	Blindfolded	10	5.43	.94
		Sighted	10	4.93	.88
		Total	20	5.18	.92
	Total	Blind and Blindfolded	20	5.15	1.12
		Sighted	20	5.13	.96
		Total	40	5.14	1.03

Note. The mean score ranges from 1-7.

Table 6.14 Mixed ANOVA results summary of main effects and interaction effects on attention allocation in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Conversation Group	.162	1	.162	.250	.620
Conversation Group * Participant Role	4.526	1	4.526	6.987	**.012***
Error	23.320	36	.648		
Tactile Feedback * Conversation Group	.322	1	.322	.555	.461
Error(Tactile Feedback)	20.891	36	.580		
Interactive Gaze * Conversation Group	3.648	1	3.648	7.260	**.011***
Error(Interactive Gaze)	18.091	36	.503		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.15 Means and standard deviations of the participants' perceived message understanding in the experimental groups across four test conditions.

Test Conditions	**Conversation Group**	**Participant Role**	**N**	**Score of Perceived Message Understanding**	
				Mean	**Std. Deviation**
TNIN	Blind-sighted	Blind	10	4.47	1.30
		Sighted	10	5.08	1.15
		Total	20	4.77	1.24
	Blindfolded-sighted	Blindfolded	10	5.87	.36
		Sighted	10	3.42	1.40
		Total	20	4.64	1.60
	Total	Blind and Blindfolded	20	5.17	1.17
		Sighted	20	4.25	1.51
		Total	40	4.71	1.41
TNIY	Blind-sighted	Blind	10	4.82	1.22
		Sighted	10	5.32	.94
		Total	20	5.07	1.09
	Blindfolded-sighted	Blindfolded	10	5.75	.80
		Sighted	10	4.48	1.46
		Total	20	5.12	1.32
	Total	Blind and Blindfolded	20	5.28	1.11
		Sighted	20	4.90	1.27
		Total	40	5.09	1.19
TYIN	Blind-sighted	Blind	10	4.85	1.40
		Sighted	10	5.27	.63
		Total	20	5.06	1.08
	Blindfolded-sighted	Blindfolded	10	5.95	.62
		Sighted	10	3.72	.99
		Total	20	4.83	1.40
	Total	Blind and Blindfolded	20	5.40	1.20
		Sighted	20	4.49	1.13
		Total	40	4.95	1.24
TYIY	Blind-sighted	Blind	10	4.42	1.46
		Sighted	10	5.52	.91
		Total	20	4.97	1.31
	Blindfolded-sighted	Blindfolded	10	6.23	.46
		Sighted	10	4.88	1.00
		Total	20	5.56	1.03
	Total	Blind and Blindfolded	20	5.33	1.41
		Sighted	20	5.20	.99
		Total	40	5.26	1.20

Note. The mean score ranges from 1-7.

Table 6.16 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived message understanding in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Conversation Group	.050	1	.050	.060	.808
Conversation Group * Participant Role	15.407	1	15.407	18.323	**.000****
Error	30.271	36	.841		
Tactile Feedback * Conversation Group	.504	1	.504	1.128	.295
Error(Tactile Feedback)	16.086	36	.447		
Interactive Gaze * Conversation Group	2.500	1	2.500	5.894	**.020***
Error(Interactive Gaze)	15.268	36	.424		

Significant group difference; * $p < .05$, ** $p < .01$.

Table 6.17 Means and standard deviations of the participants' perceived affective understanding in the experimental groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Affective Understanding	
				Mean	Std. Deviation
TNIN	Blind-sighted	Blind	10	3.85	1.54
		Sighted	10	4.30	1.16
		Total	20	4.08	1.35
	Blindfolded-sighted	Blindfolded	10	4.98	.97
		Sighted	10	2.95	1.22
		Total	20	3.97	1.50
	Total	Blind and Blindfolded	20	4.42	1.38
		Sighted	20	3.63	1.35
		Total	40	4.02	1.41
TNIY	Blind-sighted	Blind	10	4.18	1.44
		Sighted	10	4.50	1.35
		Total	20	4.34	1.37
	Blindfolded-sighted	Blindfolded	10	4.87	.98
		Sighted	10	3.67	1.36
		Total	20	4.27	1.31
	Total	Blind and Blindfolded	20	4.52	1.25
		Sighted	20	4.08	1.39
		Total	40	4.30	1.32
TYIN	Blind-sighted	Blind	10	4.07	1.53
		Sighted	10	4.93	.87
		Total	20	4.50	1.29
	Blindfolded-sighted	Blindfolded	10	5.33	.85
		Sighted	10	2.92	1.01
		Total	20	4.13	1.54
	Total	Blind and Blindfolded	20	4.70	1.37
		Sighted	20	3.93	1.38
		Total	40	4.31	1.41
TYIY	Blind-sighted	Blind	10	3.87	1.23
		Sighted	10	5.10	1.05
		Total	20	4.48	1.28
	Blindfolded-sighted	Blindfolded	10	5.37	.73
		Sighted	10	4.43	1.35
		Total	20	4.90	1.16
	Total	Blind and Blindfolded	20	4.62	1.25
		Sighted	20	4.77	1.23
		Total	40	4.69	1.23

Note. The mean score ranges from 1-7.

Table 6.18 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived affective understanding in the experimental groups.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.013	1	.013	.011	.917
Conversation Group * Participant Role	13.968	1	13.968	12.264	**.001****
Error	41.002	36	1.139		
Tactile Feedback * Conversation Group	.126	1	.126	.305	.584
Error(Tactile Feedback)	14.863	36	.413		
Interactive Gaze * Conversation Group	1.695	1	1.695	4.113	**.050***
Error(Interactive Gaze)	14.839	36	.412		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.19 Means and standard deviations of the participants' perceived emotional interdependence in the experimental groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived Emotional Interdependence	
				Mean	Std. Deviation
TNIN	Blind-sighted	Blind	10	4.52	1.52
		Sighted	10	3.72	1.03
		Total	20	4.12	1.33
	Blindfolded-sighted	Blindfolded	10	4.94	1.14
		Sighted	10	3.60	1.31
		Total	20	4.27	1.37
	Total	Blind and Blindfolded	20	4.73	1.33
		Sighted	20	3.66	1.15
		Total	40	4.19	1.34
TNIY	Blind-sighted	Blind	10	4.23	1.37
		Sighted	10	3.78	1.29
		Total	20	4.01	1.31
	Blindfolded-sighted	Blindfolded	10	4.87	1.03
		Sighted	10	4.53	1.18
		Total	20	4.70	1.09
	Total	Blind and Blindfolded	20	4.55	1.22
		Sighted	20	4.16	1.26
		Total	40	4.35	1.24
TYIN	Blind-sighted	Blind	10	4.57	1.45
		Sighted	10	4.13	.97
		Total	20	4.35	1.22
	Blindfolded-sighted	Blindfolded	10	4.87	.99
		Sighted	10	3.30	1.13
		Total	20	4.08	1.31
	Total	Blind and Blindfolded	20	4.72	1.22
		Sighted	20	3.72	1.11
		Total	40	4.22	1.26
TYIY	Blind-sighted	Blind	10	4.23	1.63
		Sighted	10	3.95	1.26
		Total	20	4.09	1.42
	Blindfolded-sighted	Blindfolded	10	4.77	1.11
		Sighted	10	4.65	1.33
		Total	20	4.71	1.19
	Total	Blind and Blindfolded	20	4.50	1.38
		Sighted	20	4.30	1.31
		Total	40	4.40	1.33

Note. The mean score ranges from 1-7.

Table 6.20 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived emotional interdependence in the experimental groups.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.891	1	.891	.668	.419
Conversation Group * Participant Role	.300	1	.300	.225	.638
Error	47.999	36	1.333		
Tactile Feedback * Conversation Group	.603	1	.603	2.546	.119
Error(Tactile Feedback)	8.524	36	.237		
Interactive Gaze * Conversation Group	5.084	1	5.084	20.707	**.000****
Error(Interactive Gaze)	8.838	36	.246		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.21 Means and standard deviations of the participants' perceived behavioral interdependence in the experimental groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Perceived behavioral Interdependence	
				Mean	Std. Deviation
TNIN	Blind-sighted	Blind	10	4.28	1.08
		Sighted	10	4.50	.98
		Total	20	4.39	1.01
	Blindfolded-sighted	Blindfolded	10	5.17	1.15
		Sighted	10	2.78	1.30
		Total	20	3.97	1.71
	Total	Blind and Blindfolded	20	4.72	1.18
		Sighted	20	3.64	1.42
		Total	40	4.18	1.40
TNIY	Blind-sighted	Blind	10	4.63	1.11
		Sighted	10	4.68	1.07
		Total	20	4.66	1.07
	Blindfolded-sighted	Blindfolded	10	5.30	.72
		Sighted	10	4.30	.98
		Total	20	4.80	.98
	Total	Blind and Blindfolded	20	4.97	.98
		Sighted	20	4.49	1.02
		Total	40	4.73	1.01
TYIN	Blind-sighted	Blind	10	4.28	1.07
		Sighted	10	4.83	.81
		Total	20	4.56	.96
	Blindfolded-sighted	Blindfolded	10	5.58	.72
		Sighted	10	2.80	.77
		Total	20	4.19	1.60
	Total	Blind and Blindfolded	20	4.93	1.11
		Sighted	20	3.82	1.30
		Total	40	4.37	1.32
TYIY	Blind-sighted	Blind	10	4.45	1.14
		Sighted	10	5.03	.99
		Total	20	4.74	1.08
	Blindfolded-sighted	Blindfolded	10	5.47	.82
		Sighted	10	4.62	1.08
		Total	20	5.04	1.03
	Total	Blind and Blindfolded	20	4.96	1.09
		Sighted	20	4.82	1.03
		Total	40	4.89	1.05

Note. The mean score ranges from 1-7.

Table 6.22 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived behavioral interdependence in the experimental groups.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Group	.073	1	.073	.093	.762
Conversation Group * Participant Role	11.062	1	11.062	14.119	**.001****
Error	28.205	36	.783		
Tactile Feedback * Conversation Group	.109	1	.109	.338	.564
Error(Tactile Feedback)	11.623	36	.323		
Interactive Gaze * Conversation Group	3.764	1	3.764	15.231	**.000****
Error(Interactive Gaze)	8.896	36	.247		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.23 Means and standard deviations of the participants' closeness in the experimental groups across four test conditions.

Test Conditions	Conversation Group	Participant Role	N	Score of Closeness	
				Mean	**Std. Deviation**
TNIN	Blind-sighted	Blind	10	5.20	1.62
		Sighted	10	4.50	1.65
		Total	20	4.85	1.63
	Blindfolded-sighted	Blindfolded	10	4.50	1.78
		Sighted	10	3.70	1.42
		Total	20	4.10	1.62
	Total	Blind and Blindfolded	20	4.85	1.69
		Sighted	20	4.10	1.55
		Total	40	4.48	1.65
TNIY	Blind-sighted	Blind	10	5.20	2.15
		Sighted	10	4.60	2.07
		Total	20	4.90	2.07
	Blindfolded-sighted	Blindfolded	10	4.30	1.49
		Sighted	10	3.60	1.58
		Total	20	3.95	1.54
	Total	Blind and Blindfolded	20	4.75	1.86
		Sighted	20	4.10	1.86
		Total	40	4.43	1.87
TYIN	Blind-sighted	Blind	10	4.60	2.01
		Sighted	10	4.90	1.66
		Total	20	4.75	1.80
	Blindfolded-sighted	Blindfolded	10	4.70	1.42
		Sighted	10	3.70	1.49
		Total	20	4.20	1.51
	Total	Blind and Blindfolded	20	4.65	1.69
		Sighted	20	4.30	1.66
		Total	40	4.48	1.66
TYIY	Blind-sighted	Blind	10	4.80	2.04
		Sighted	10	4.70	1.49
		Total	20	4.75	1.74
	Blindfolded-sighted	Blindfolded	10	4.60	.97
		Sighted	10	3.70	1.25
		Total	20	4.15	1.18
	Total	Blind and Blindfolded	20	4.70	1.56
		Sighted	20	4.20	1.44
		Total	40	4.45	1.50

Note. The mean score ranges from 1-7.

Table 6.24 Mixed ANOVA results summary of main effects and interaction effects on the participants' closeness in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Conversation Group	5.077	1	5.077	2.910	.097
Conversation Group * Participant Role	.827	1	.827	.474	.496
Error	62.794	36	1.744		
Tactile Feedback * Conversation Group	.756	1	.756	.619	.437
Error(Tactile Feedback)	43.975	36	1.222		
Interactive Gaze * Conversation Group	.156	1	.156	.169	.684
Error(Interactive Gaze)	33.375	36	.927		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Summary. Although the predicted main effect of the conversation groups was not significant, the interaction effect was observed between the conversation groups and the participants roles. The contrast revealed that the blindfolded participants perceived significantly higher PMU, PAU, and PBI than the blind participants (Figure 6.10 (3)(4)(5)). Meanwhile, the sighted participants in the blind-sighted group perceived significantly higher co-presence, attention allocation, PMU, PAU and PBI than in the blindfolded-sighted group (Figure 6.10).

Also, the interaction effect between the state of the Tactile Feedback and the conversation groups was not significant, but the interaction effect between the state of the Interactive Gaze and the conversation groups was significant. In the blind-sighted group, the participants' communication quality was generally the same whether the Interactive Gaze was active or not. However, the sighted participants in the blindfolded-sighted group experienced significantly higher co-presence, attention allocation, PMU, PAU, PEI and PBI when the Interactive Gaze was active than it was not (Figure 6.11).

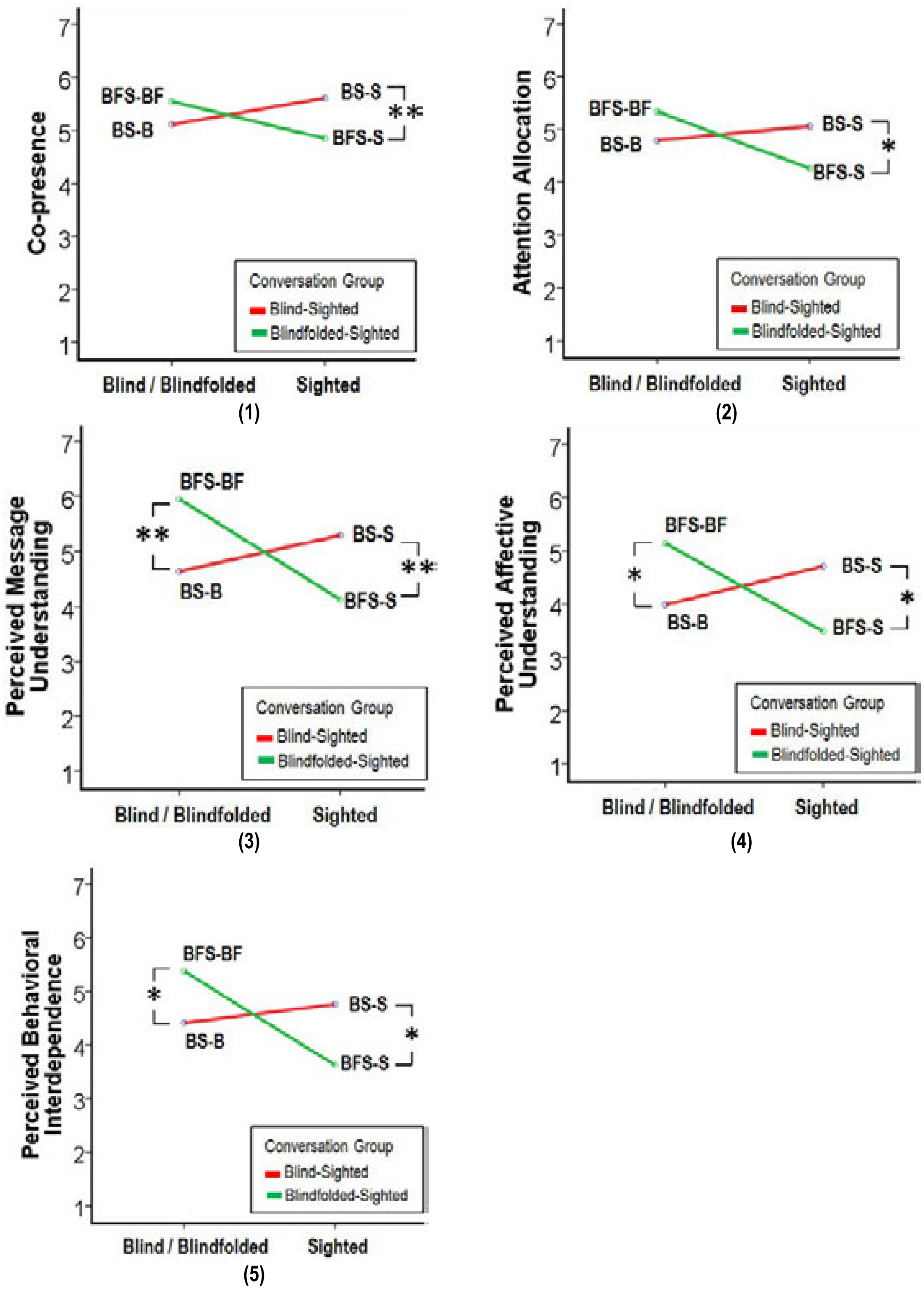


Figure 6.10 Interaction effects between the conversation groups and the participant roles on the participants' co-presence, attention allocation, PMU, PAU, and PBI. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

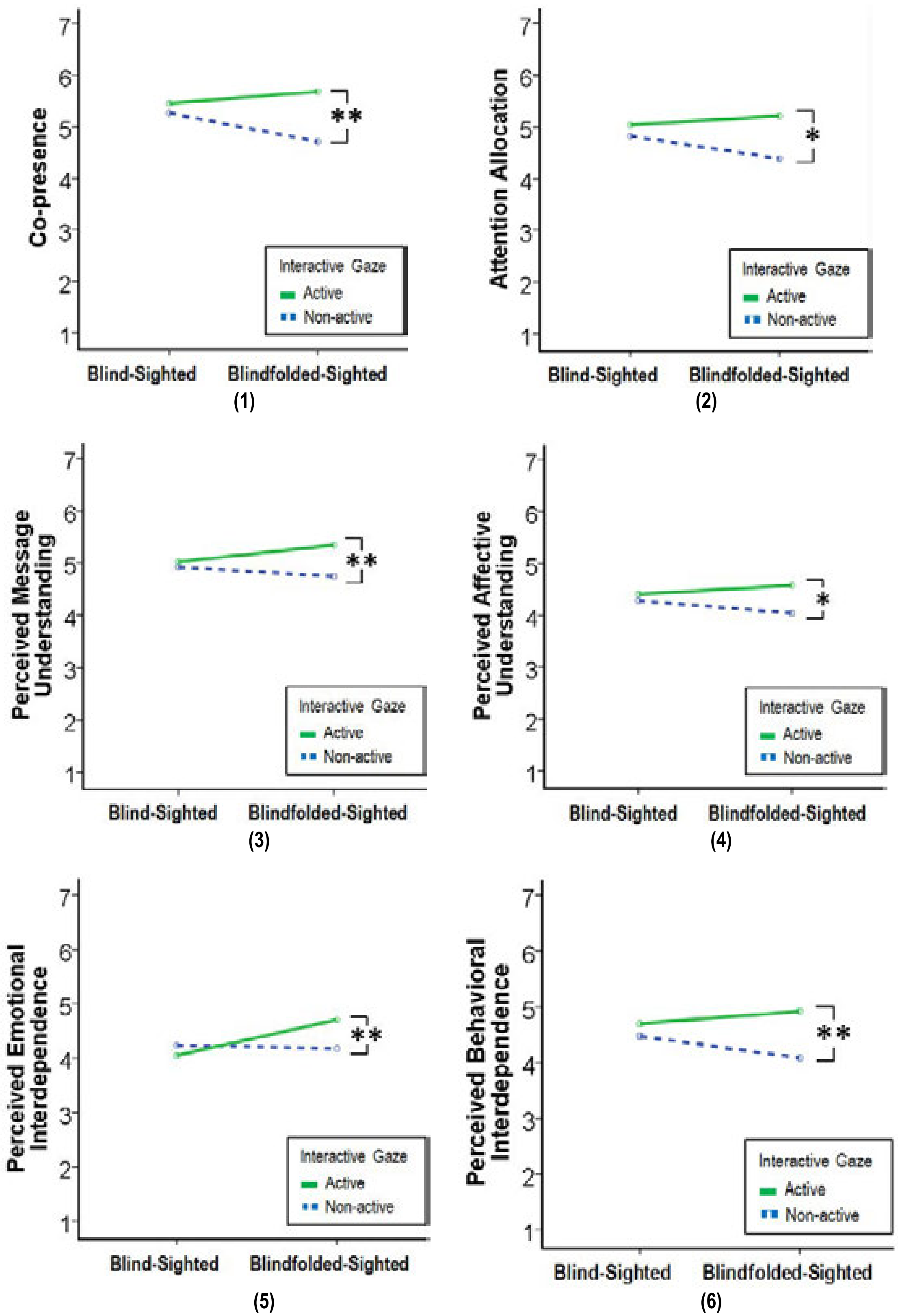


Figure 6.11 Interaction effects between the conversation groups and the Interactive Gaze on the participants' co-presence, attention allocation, PMU, PAU, PEI and PBI. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

6.4.1.3 Analysis of Interventions in the Experimental Groups

Co-presence. The predicted main effect of the Tactile Feedback was significant [F(1, 36) = 4.293, p = .045, η_p^2 = .107]. The contrast revealed that the participants felt significantly higher co-present when the Tactile Feedback was active (M = 5.41, SE = .11) than it was not (M = 5.14, SE = .13). In addition, the predicted main effect of the Interactive Gaze was significant [F(1, 36) = 63.730, p < .001, η_p^2 = .639]. The contrast revealed that the participants felt significantly higher co-present when the Interactive Gaze was active (M = 5.57, SE = .11) than it was not (M = 4.99, SE = .11).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 36) = 3.070, p = .088], but a significant interaction effect was observed between the state of the Interactive Gaze and the participant roles [F(1, 36) = 47.351, p < .001, η_p^2 = .568]. It indicated that the blind and blindfolded participants' co-presence was generally the same whether the Interactive Gaze was active or not, while the sighted participants felt significantly higher co-present when the Interactive Gaze was active than it was not. The results are presented in Table 6.25.

Attention allocation. Although the predicted main effect of the Tactile Feedback was not significant [F(1, 36) = 3.062, p = .089], the predicted main effect of the Interactive Gaze was significant [F(1, 36) = 21.441, p < .001, η_p^2 = .373]. The contrast revealed that the participants perceived significantly higher attention allocation when the Interactive Gaze was active (M = 5.13, SE = .15) than it was not (M = 4.61, SE = .13).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 36) = .980, p = .329]. However, a significant interaction effect was observed between the state of the Interactive Gaze and the participant roles [F(1, 36) = 11.045, p = .002, η_p^2 = .235]. It indicated that the blind and blindfolded participants' attention allocation was generally the same whether the Interactive Gaze was active or not, while the sighted participants perceived significantly higher attention allocation when the Interactive Gaze was active than it was not. The results are presented in Table 6.26.

Perceived message understanding (PMU). Although the predicted main effect of the Tactile Feedback was not significant [F(1, 36) = 3.744, p = .061], the significant main effect of the Interactive Gaze was observed [F(1, 36) = 11.603, p = .002, η_p^2 = .244]. The contrast revealed that the participants perceived significantly higher PMU when the Interactive Gaze was active (M = 5.18, SE = .16) than it was not (M = 4.83, SE = .15).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [$F(1, 36) = .399$, $p = .532$], but there was a significant interaction effect between the state of the Interactive Gaze and the participant roles [$F(1, 36) = 10.208$, $p = .003$, $\eta_p^2 = .221$]. It indicated that the blind and blindfolded participants' PMU was generally the same whether the Interactive Gaze was active or not. However, the sighted participants perceived significantly higher PMU when the Interactive Gaze was active than it was not. The results are presented in Table 6.27.

Perceived affective understanding (PAU). The predicted main effect of the Tactile Feedback was significant [$F(1, 36) = 11.208$, $p = .002$, $\eta_p^2 =$ 237]. The Contrast revealed that the participants perceived significantly higher PAU when the Tactile Feedback was active (M = 4.50, SE = .17) than it was not (M = 4.16, SE = .19). In addition, a significant main effect of the Interactive Gaze was observed [$F(1, 36) = 10.592$, $p = .002$, $\eta_p^2 = .227$]. The contrast revealed that the participants perceived significantly higher PAU when the Interactive Gaze was active (M = 4.50, SE = .18) than it was not (M = 4.17, SE = .18).

Although a non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [$F(1, 36) = 2.220$, $p = .145$], the interaction effect between the state of the Interactive Gaze and the participant roles was significant [$F(1, 36) = 9.883$, $p = .003$, $\eta_p^2 = .215$]. It indicated that the blind and blindfolded participants' PAU was generally the same whether the Interactive Gaze was active or not, while the sighted participants perceived significantly higher PAU when the Interactive Gaze was active than it was not. The results are presented in Table 6.28.

Perceived emotional interdependence (PEI). Although the predicted main effect of the Tactile Feedback was not significant [$F(1, 36) = .213$, $p = .647$], a significant main effect of the Interactive Gaze was observed [$F(1, 36) = 4.834$, $p = .034$, $\eta_p^2 = .118$]. The contrasts revealed that the participants perceived significantly higher PEI when the Interactive Gaze was active (M = 4.38, SE = .19) than it was not (M = 4.21, SE = .18).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [$F(1, 36) = .708$, $p = .406$], but there was a significant interaction effect between the state of the Interactive Gaze and the participant roles [$F(1, 36) = 22.124$, $p < .001$, $\eta_p^2 = .381$]. It indicated that the blind and blindfolded participants' PEI was generally the same whether the Interactive Gaze was active or not, while the sighted participants perceived significantly higher PEI when the Interactive Gaze was active than it was not. The results are presented in Table 6.29.

Perceived behavioral interdependence (PBI). The predicted main effect of the Tactile Feedback was not significant [$F(1, 36) = 3.881$, $p = .057$], but the main effect of the

Interactive Gaze was significant [F(1, 36) = 45.811, p < .001, η_p^2 = .560]. The contrast revealed that the participants perceived significantly higher PBI when the Interactive Gaze was active (M = 4.81, SE = .15) than it was not (M = 4.28, SE = .14).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 36) = .735, p = .397]. However, the interaction effect between the state of the Interactive Gaze and the participant roles was significant [F(1, 36) = 25.575, p < .001, η_p^2 = .415]. It indicated that the blind and blindfolded participants' PBI was generally the same whether the Interactive Gaze was active or not, while the sighted participants perceived significantly higher PBI when the Interactive Gaze was active than it was not. The results are presented in Table 6.30.

Closeness. The predicted main effect of the Tactile Feedback was not significant [F(1, 36) = .005, p = .943]. There was also a non-significant main effect of the Interactive Gaze [F(1, 36) = .061, p = .807].

In addition, a non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 36) = .619, p = .437]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles [F(1, 36) = .007, p = .935]. The results are presented in Table 6.31.

Table 6.25 Mixed ANOVA results summary of main effects and interaction effects on the participants' co-presence for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	2.892	1	2.892	4.293	**.045***
Tactile Feedback * Participant Role	2.068	1	2.068	3.070	.088
Error(Tactile Feedback)	24.249	36	.674		
Interactive Gaze	13.520	1	13.520	63.730	**.000****
Interactive Gaze * Participant Role	10.045	1	10.045	47.351	**.000****
Error(Interactive Gaze)	7.637	36	.212		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 6.26 Mixed ANOVA results summary of main effects and interaction effects on the participants' attention allocation for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	1.777	1	1.777	3.062	.089
Tactile Feedback * Participant Role	.569	1	.569	.980	.329
Error(Tactile Feedback)	20.891	36	.580		
Interactive Gaze	10.774	1	10.774	21.441	**.000****
Interactive Gaze * Participant Role	5.550	1	5.550	11.045	**.002****
Error(Interactive Gaze)	18.091	36	.503		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 6.27 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived message understanding for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	1.673	1	1.673	3.744	.061
Tactile Feedback * Participant Role	.178	1	.178	.399	.532
Error(Tactile Feedback)	16.086	36	.447		
Interactive Gaze	4.921	1	4.921	11.603	**.002****
Interactive Gaze * Participant Role	4.330	1	4.330	10.208	**.003****
Error(Interactive Gaze)	15.268	36	.424		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.28 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived affective understanding for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	4.627	1	4.627	11.208	**.002****
Tactile Feedback * Participant Role	.917	1	.917	2.220	.145
Error(Tactile Feedback)	14.863	36	.413		
Interactive Gaze	4.366	1	4.366	10.592	**.002****
Interactive Gaze * Participant Role	4.074	1	4.074	9.883	**.003****
Error(Interactive Gaze)	14.839	36	.412		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.29 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived emotional interdependence for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	.050	1	.050	.213	.647
Tactile Feedback * Participant Role	.168	1	.168	.708	.406
Error(Tactile Feedback)	8.524	36	.237		
Interactive Gaze	1.187	1	1.187	4.834	**.034***
Interactive Gaze * Participant Role	5.432	1	5.432	22.124	**.000****
Error(Interactive Gaze)	8.838	36	.246		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.30 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived behavioral interdependence for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	***SS***	***df***	***MS***	***F***	***p***
Tactile Feedback	1.253	1	1.253	3.881	.057
Tactile Feedback * Participant Role	.237	1	.237	.735	.397
Error(Tactile Feedback)	11.623	36	.323		
Interactive Gaze	11.321	1	11.321	45.811	**.000****
Interactive Gaze * Participant Role	6.320	1	6.320	25.575	**.000****
Error(Interactive Gaze)	8.896	36	.247		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.31 Mixed ANOVA results summary of main effects and interaction effects on the participants' closeness for the Tactile Feedback and the Interactive Gaze in the experimental groups.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.006	1	.006	.005	.943
Tactile Feedback * Participant Role	.756	1	.756	.619	.437
Error(Tactile Feedback)	43.975	36	1.222		
Interactive Gaze	.056	1	.056	.061	.807
Interactive Gaze * Participant Role	.006	1	.006	.007	.935
Error(Interactive Gaze)	33.375	36	.927		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Summary. The participants perceived significantly higher co-presence and PAU when the Tactile Feedback was active than it was not (Figure 6.12). However, the interaction effect between the Tactile Feedback and the participant roles was not significant. Also, the Interactive Gaze positively affected the participants' co-presence, attention allocation, PMU, PAU, PEI and PBI in conversations (Figure 6.13). A significant interaction effect was also observed between the Interactive Gaze and the participant roles. It revealed that the sighted participants perceived significantly higher co-presence, attention allocation, PMU, PAU, PEI and PBI when the Interactive Gaze was active than it was not (Figure 6.14).

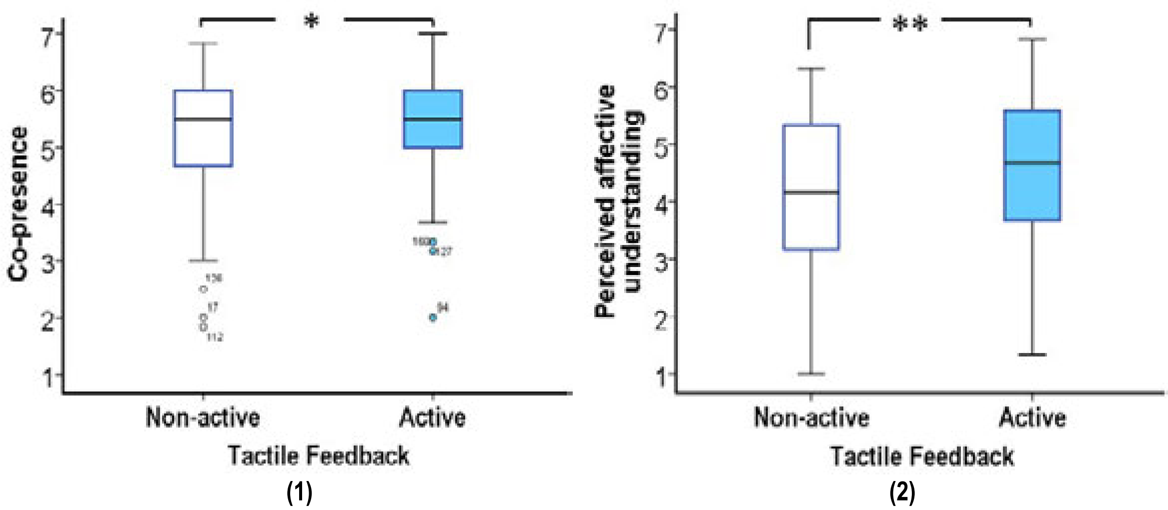


Figure 6.12 Boxplot of the main effect of the Tactile Feedback on the participants' co-presence and PAU. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

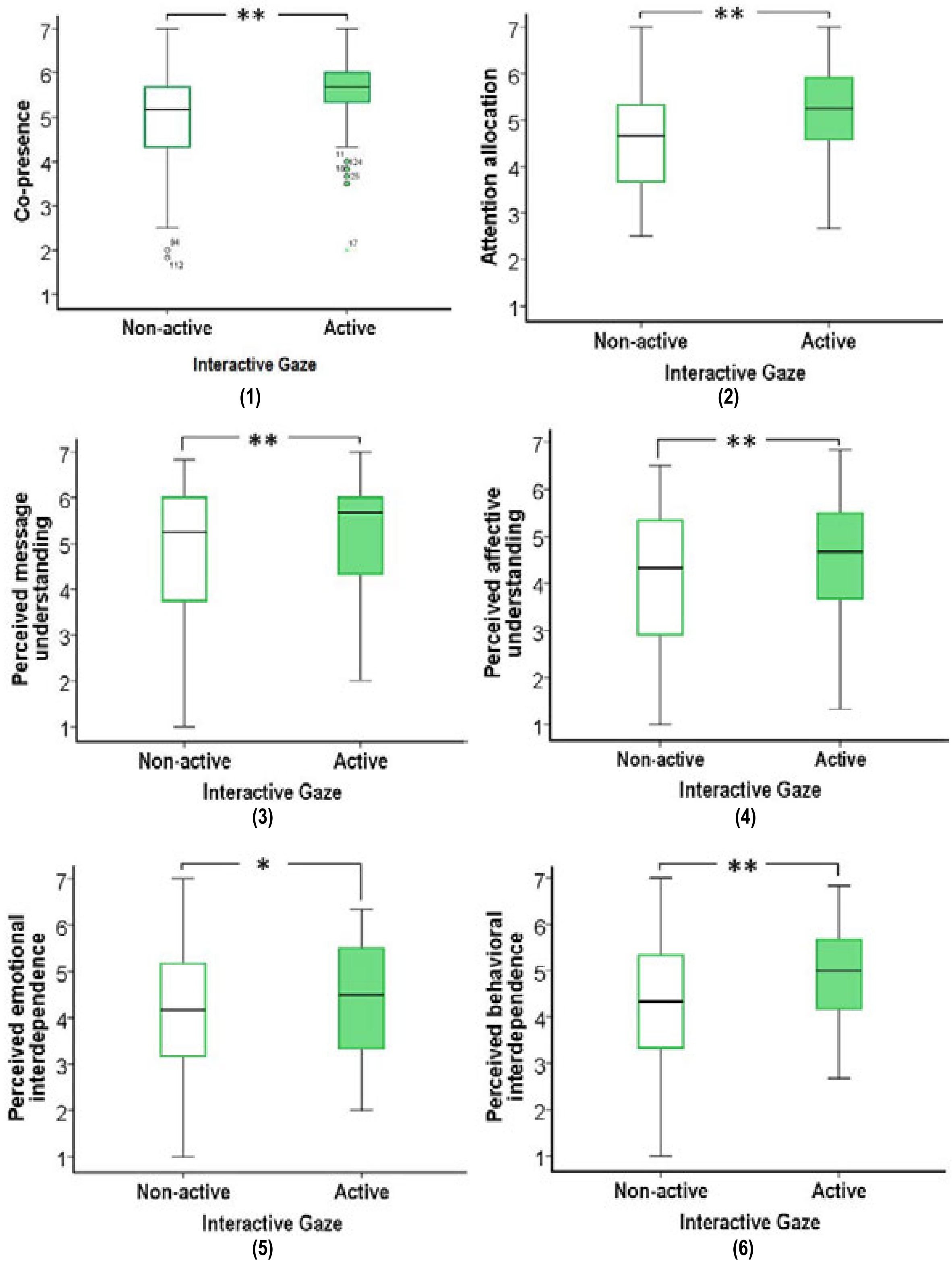


Figure 6.13 Boxplot of the main effect of the Interactive Gaze on the participants' co-presence, attention allocation, PMU, PAU, PEI and PBI. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

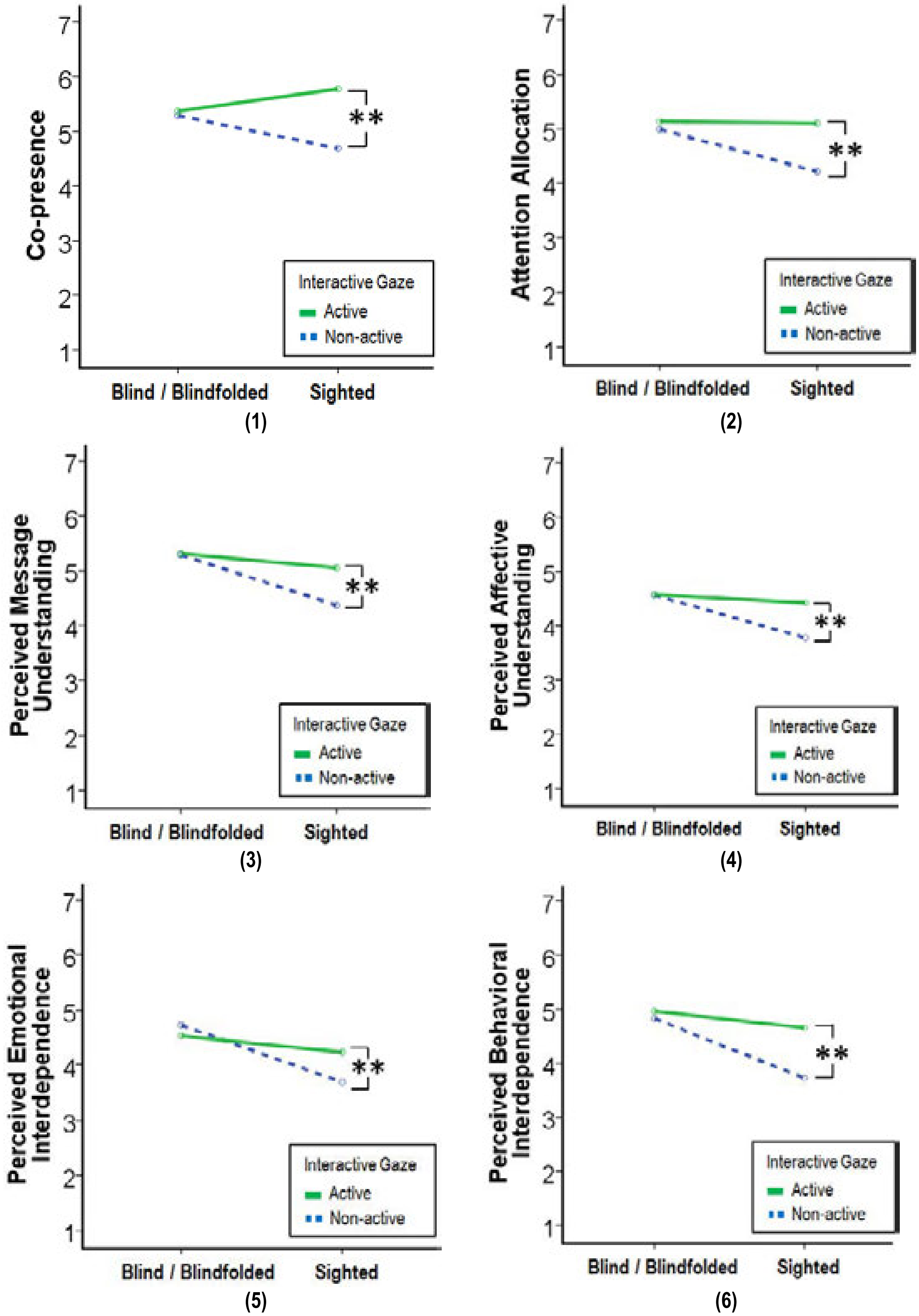


Figure 6.14 Interaction effects between the participant roles and the Interactive Gaze on the participants' co-presence, attention allocation, PMU, PAU, PEI and PBI. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

6.4.1.4 Analysis of Interventions in the Blind-Sighted Group

To further investigate the effect of the Tactile Feedback and the Interactive Gaze in blind-sighted conversations, we analyzed the experimental data only from the blind-sighted group. A 2 × 2 × 2 mixed ANOVA was conducted, using the Tactile Feedback (active, non-active) and the Interactive Gaze (active, non-active) as the within-subjects factors, and participant roles (the blind participants, sighted participants) as the between-subjects factor.

Co-presence. A non-significant main effect of the Tactile Feedback was observed [F(1, 18) = 1.854, p = .190]. Although not significant, the participants felt higher co-present when the Tactile Feedback was active (M = 5.52, SE = .16) than it was not (M = 5.21, SE = .21). The predicted main effect of the Interactive Gaze was significant [F(1, 18) = 4.960, p = .039, η_p^2 = .216]. The contrast revealed that the participants in the blind-sighted group felt significantly higher co-present when the Interactive Gaze was active (M = 5.456, SE = .16) than it was not (M = 5.26, SE = .15).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles, F(1, 18) = 1.308, p = .268. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles, F(1, 18) = 1.084, p = .312. The results are presented in Table 6.32 and Table 6.33.

Attention allocation. The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = 3.090, p = .096]. Although not significant, the participants perceived higher attention allocation when the Tactile Feedback was active (M = 5.08, SE = .23) than it was non-active (M = 4.78, SE = .26). The predicted main effect of the Interactive Gaze was also not significant [F(1, 18) = 2.673, p = .119].

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = .685, p = .419]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles [F(1, 18) = .470, p = .502]. The results are presented in Table 6.34 and Table 6.35.

Perceived message understanding (PMU). The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = .393, p = .539]. Although not significant, the participants perceived higher attention allocation when the Tactile Feedback was active (M = 5.01, SE = .25) than it was not (M = 4.92, SE = .25). The predicted main effect of the Interactive Gaze was also not significant [F(1, 18) = 2.561, p = .127].

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = .464, p = .504]. However, a significant interaction effect was observed between the state of the Interactive Gaze and the participant roles [F(1, 18) = 5.070, p = .037, η_p^2 = .220]. It indicated that the blind and blindfolded participants' PMU was generally the same whether the Interactive Gaze was active or not, while the sighted participants perceived significantly higher PMU when the Interactive Gaze was active than it was not. The results are presented in Table 6.36 and Table 6.37.

Perceived affective understanding (PAU). The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = 2.895, p = .106]. Although not significant, the participants perceived higher PAU when the Tactile Feedback was active (M = 4.49, SE = .26) than it was not (M = 4.21, SE = .30). The main effect of the Interactive Gaze was also not significant [F(1, 18) = 1.398, p = .252].

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = 3.969, p = .062]. There was also a non-significant interaction effect between the state of the Interactive Gaze and the participant roles [F(1, 18) = .314, p = .582]. The results are presented in Table 6.38 and Table 6.39.

Perceived emotional interdependence (PEI). The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = 2.080, p = .166]. Although not significant, the participants perceived higher PEI when the Tactile Feedback was active (M = 4.22, SE = .29) than it was not (M = 4.06, SE = .28). In addition, the main effect of the Interactive Gaze was also not significant [F(1, 18) = 3.148, p = .093].

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = 1.475, p = .240]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles [F(1, 18) = 1.420, p = .249]. The results are presented in Table 6.40 and Table 6.41.

Perceived behavioral interdependence (PBI). The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = 1.028, p = .324]. Although not significant, the participants perceived higher PBI when the Tactile Feedback was active (M = 4.65, SE = .21) than it was not (M = 4.53, SE = .23). However, the predicted main effect of the Interactive Gaze was significant [F(1, 18) = 9.875, p = .006, η_p^2 = .354]. The contrast revealed that the participants in the blind-sighted group perceived significantly higher PBI when the Interactive Gaze was active (M = 4.70, SE = .23) than it was not (M = 4.48, SE = .20).

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = 3.103, p = .095]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles [F(1, 18) = .222, p = .643]. The results are presented in Table 6.42 and Table 6.43.

Closeness. The predicted main effect of the Tactile Feedback was not significant [F(1, 18) = .228, p = .638]. There was also a non-significant main effect of the Interactive Gaze [F(1, 18) = .010, p = .923].

A non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 18) = 2.056, p = .169]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles [F(1, 18) = .086, p = .773]. The results are presented in Table 6.44 and Table 6.45.

Table 6.32 Means and standard deviations of the participants' co-presence in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Co-presence	
			Mean	**Std. Deviation**
TNIN	Blind	10	4.80	1.28
	Sighted	10	5.38	.82
	Total	20	5.09	1.09
TNIY	Blind	10	4.85	1.42
	Sighted	10	5.78	.32
	Total	20	5.32	1.11
TYIN	Blind	10	5.32	.75
	Sighted	10	5.55	.56
	Total	20	5.43	.65
TYIY	Blind	10	5.47	.77
	Sighted	10	5.72	.85
	Total	20	5.59	.80

Note. The mean score ranges from 1-7.

Table 6.33 Mixed ANOVA results summary of main effects and interaction effects on the participants' co-presence in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	1.916	1	1.916	1.854	.190
Tactile Feedback * Participant Role	1.352	1	1.352	1.308	.268
Error(Tactile Feedback)	18.599	18	1.033		
Interactive Gaze	.741	1	.741	4.960	**.039***
Interactive Gaze * Participant Role	.162	1	.162	1.084	.312
Error(Interactive Gaze)	2.690	18	.149		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.34 Means and standard deviations of the participants' attention allocation in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Attention Allocation	
			Mean	Std. Deviation
TNIN	Blind	10	4.30	1.36
	Sighted	10	4.85	1.09
	Total	20	4.57	1.23
TNIY	Blind	10	4.85	1.35
	Sighted	10	5.12	1.13
	Total	20	4.98	1.22
TYIN	Blind	10	5.17	1.08
	Sighted	10	4.97	.88
	Total	20	5.07	.96
TYIY	Blind	10	4.87	1.26
	Sighted	10	5.32	1.05
	Total	20	5.09	1.15

Note. The mean score ranges from 1-7.

Table 6.35 Mixed ANOVA results summary of main effects and interaction effects on the participants' attention allocation in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	1.806	1	1.806	3.090	.096
Tactile Feedback * Participant Role	.400	1	.400	.685	.419
Error(Tactile Feedback)	10.521	18	.585		
Interactive Gaze	.942	1	.942	2.673	.119
Interactive Gaze * Participant Role	.166	1	.166	.470	.502
Error(Interactive Gaze)	6.343	18	.352		

Significant group difference; * $p < .05$, ** $p < .01$.

Table 6.36 Means and standard deviations of the participants' perceived message understanding in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Message Understanding	
			Mean	Std. Deviation
TNIN	Blind	10	4.47	1.30
	Sighted	10	5.08	1.15
	Total	20	4.77	1.24
TNIY	Blind	10	4.82	1.22
	Sighted	10	5.32	.94
	Total	20	5.07	1.09
TYIN	Blind	10	4.85	1.40
	Sighted	10	5.27	.63
	Total	20	5.06	1.08
TYIY	Blind	10	4.42	1.46
	Sighted	10	5.52	.91
	Total	20	4.97	1.31

Note. The mean score ranges from 1-7.

Table 6.37 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived message understanding in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.170	1	.170	.393	.539
Tactile Feedback * Participant Role	.201	1	.201	.464	.504
Error(Tactile Feedback)	7.798	18	.433		
Interactive Gaze	.203	1	.203	2.561	.127
Interactive Gaze * Participant Role	.402	1	.402	5.070	**.037***
Error(Interactive Gaze)	1.427	18	.079		

Significant group difference; * $p < .05$, ** $p < .01$.

Table 6.38 Means and standard deviations of the participants' perceived affective understanding in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Affective Understanding	
			Mean	Std. Deviation
TNIN	Blind	10	3.85	1.54
	Sighted	10	4.30	1.16
	Total	20	4.08	1.35
TNIY	Blind	10	4.18	1.44
	Sighted	10	4.50	1.35
	Total	20	4.34	1.37
TYIN	Blind	10	4.07	1.53
	Sighted	10	4.93	.87
	Total	20	4.50	1.29
TYIY	Blind	10	3.87	1.23
	Sighted	10	5.10	1.05
	Total	20	4.48	1.28

Note. The mean score ranges from 1-7.

Table 6.39 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived affective understanding in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	1.613	1	1.613	2.895	.106
Tactile Feedback * Participant Role	2.211	1	2.211	3.969	.062
Error(Tactile Feedback)	10.028	18	.557		
Interactive Gaze	.310	1	.310	1.398	.252
Interactive Gaze * Participant Role	.070	1	.070	.314	.582
Error(Interactive Gaze)	3.992	18	.222		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.40 Means and standard deviations of the participants' perceived emotional interdependence in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Emotional Interdependence	
			Mean	Std. Deviation
TNIN	Blind	10	4.52	1.52
	Sighted	10	3.72	1.03
	Total	20	4.12	1.33
TNIY	Blind	10	4.23	1.37
	Sighted	10	3.78	1.29
	Total	20	4.01	1.31
TYIN	Blind	10	4.57	1.45
	Sighted	10	4.13	.97
	Total	20	4.35	1.22
TYIY	Blind	10	4.23	1.63
	Sighted	10	3.95	1.26
	Total	20	4.09	1.42

Note. The mean score ranges from 1-7.

Table 6.41 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived emotional interdependence in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.501	1	.501	2.080	.166
Tactile Feedback * Participant Role	.355	1	.355	1.475	.240
Error(Tactile Feedback)	4.335	18	.241		
Interactive Gaze	.679	1	.679	3.148	.093
Interactive Gaze * Participant Role	.306	1	.306	1.420	.249
Error(Interactive Gaze)	3.882	18	.216		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Table 6.42 Means and standard deviations of the participants' perceived behavioral interdependence in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Perceived Behavioral Interdependence	
			Mean	**Std. Deviation**
TNIN	Blind	10	4.28	1.08
	Sighted	10	4.50	.98
	Total	20	4.39	1.01
TNIY	Blind	10	4.63	1.11
	Sighted	10	4.68	1.07
	Total	20	4.66	1.07
TYIN	Blind	10	4.28	1.07
	Sighted	10	4.83	.81
	Total	20	4.56	.96
TYIY	Blind	10	4.45	1.14
	Sighted	10	5.03	.99
	Total	20	4.74	1.08

Note. The mean score ranges from 1-7.

Table 6.43 Mixed ANOVA results summary of main effects and interaction effects on the participants' perceived behavioral interdependence in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.311	1	.311	1.028	.324
Tactile Feedback * Participant Role	.940	1	.940	3.103	.095
Error(Tactile Feedback)	5.451	18	.303		
Interactive Gaze	1.015	1	1.015	9.875	**.006****
Interactive Gaze * Participant Role	.023	1	.023	.222	.643
Error(Interactive Gaze)	1.850	18	.103		

Significant group difference; * *p < .05,* ** *p < .01.*

Table 6.44 Means and standard deviations of the participants' closeness in the blind-sighted group across four test conditions.

Test Conditions	Participant Role	N	Score of Closeness	
			Mean	**Std. Deviation**
TNIN	Blind	10	5.20	1.62
	Sighted	10	4.50	1.65
	Total	20	4.85	1.63
TNIY	Blind	10	5.20	2.15
	Sighted	10	4.60	2.07
	Total	20	4.90	2.07
TYIN	Blind	10	4.60	2.01
	Sighted	10	4.90	1.66
	Total	20	4.75	1.80
TYIY	Blind	10	4.80	2.04
	Sighted	10	4.70	1.49
	Total	20	4.75	1.74

Note. The mean score ranges from 1-7.

Table 6.45 Mixed ANOVA results summary of main effects and interaction effects on the participants' closeness in the blind-sighted group.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.313	1	.313	.228	.638
Tactile Feedback * Participant Role	2.813	1	2.813	2.056	.169
Error(Tactile Feedback)	24.625	18	1.368		
Interactive Gaze	.012	1	.012	.010	.923
Interactive Gaze * Participant Role	.113	1	.113	.086	.773
Error(Interactive Gaze)	23.625	18	1.313		

Significant group difference; * *p < .05,* ** *p < .01.*

Summary. The Tactile Feedback did not significantly affect the communication quality in the blind-sighted group. Besides, a non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles. However, in this group, the participants perceived significantly higher co-presence and PBI when the Interactive Gaze was active than it was not (Figure 6.15). The interaction effect further revealed that the sighted participants perceived significantly higher PMU when the Interactive Gaze was active than it was not (Figure 6.16).

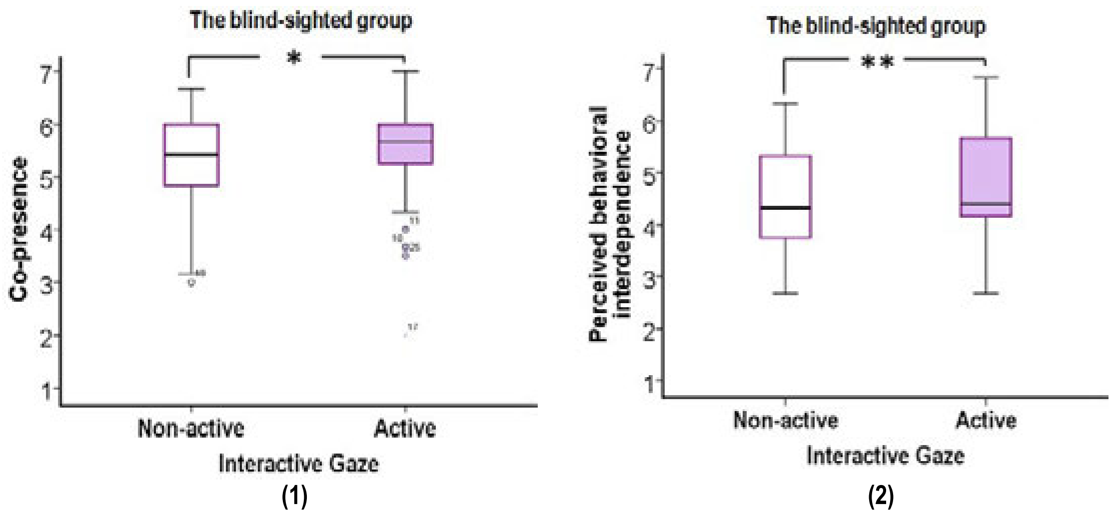


Figure 6.15 Boxplot of the main effect of the Interactive Gaze on the participants' co-presence and PBI in the blind-sighted group. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

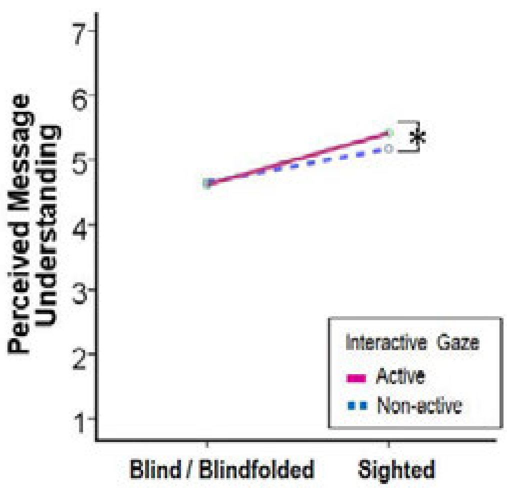


Figure 6.16 Interaction effects between the participant roles and the Interactive Gaze on the participants' perceived message understanding in the blind-sighted group. Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

6.4.1.5 Gaze Data

One participant's gaze data were excluded due to the partial data loss in the eye tracking system. To analyze gaze data, a 2 × 2 mixed-design ANOVA was conducted by using the Interactive Gaze (active, non-active) as the within-subjects factor and the conversation groups (blind-sighted, blindfolded-sighted) as the between-subjects factor. The results are presented in Table 6.46 and Table 6.47.

A non-significant main effect of the Interactive Gaze states was observed on the attention ratio [$F(1, 37) = 1.828$, $p = .185$]. Although not significant, the sighted participants looked more at the E-Gaze glasses when the Interactive Gaze was active (M = 45.50%, SE = .03) than it was not (M = 40.77%, SE = .03). However, the predicted main effect of the conversation groups on the attention ratio was significant [$F(1, 37) = 19.592$, $p < .001$, $\eta_p^2 = .346$]. The contrast revealed that the sighted participants in the blindfolded-sighted group (M = 53.64%, SE = .03) significantly looked more at the E-Gaze than in the blind-sighted group (M = 32.63%, SE = .03) (Figure 6.17).

Table 6.46 Means and standard deviations of the attention ratio in the experimental groups.

Interactive Gaze	**Conversation Groups**	**N**	**The attention ratio**[a]	
			Mean	**Std. Deviation**
Non-active	blind-sighted	20	30.45%	.14
	blindfolded-sighted	19	51.10%	.24
	Total	39	40.51%	.22
Active	blind-sighted	20	34.81%	.15
	blindfolded-sighted	19	56.18%	.19
	Total	39	45.22%	.20

[a] The attention ratio = Looking at the E-Gaze glasses /total looking (%)

Table 6.47 Mixed ANOVA results summary of main effects and interaction effects on the attention ratio.

Source	***SS***	***df***	***MS***	***F***	***p***
Conversation Group	.430	1	.430	19.592	**.000****
Error	.812	37	.022		
Interactive Gaze	.043	1	.043	1.828	.185
Interactive Gaze * Conversation Group	.000	1	.000	.011	.918
Error(Interactive Gaze)	.880	37	.024		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

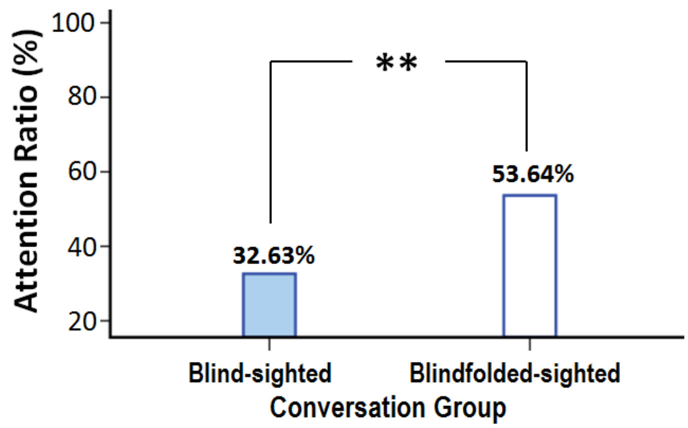


Figure 6.17 Bar chart of the main effect of the attention ratio in the experimental groups. Significant group difference; * $p < .05$, ** $p < .01$.

6.4.1.6 Video Analysis

We observed the experimental videos to record who initiated the conversation in each test. Based on the research questions, we reported video data from three aspects: (1) conversation group types, (2) interventions in the experimental groups, and (3) interventions in the blind-sighted group.

Conversation group types. In the video analysis, a 2 × 2 × 2 × 2 mixed-design ANOVA was conducted by using the Tactile Feedback (active, non-active) and the Interactive Gaze (active, non-active) as the within-subjects factors and the conversation groups (blind-sighted, blindfolded-sighted) and the participant roles (the blind and blindfolded participants, the sighted participants) as the between-subjects factors.

There was a non-significant main effect of the conversation groups on the average number of times to initiate a conversation ($\boldsymbol{T_a}$), F(1, 36) = .026, p = .872. However, a significant interaction effect was observed between the conversation groups and the participant roles [F(1, 36) = 32.331, $p < .001$, $\eta_p^2 = .473$]. The contrast revealed that the blindfolded participants had much bigger $\boldsymbol{T_a}$ than the blind participants. The contrast also indicated that the sighted participants in the blind-sighted group had much bigger $\boldsymbol{T_a}$ than in the blindfolded-sighted group. In addition, a non-significant interaction effect was observed between the state of the Tactile Feedback and the conversation groups [F(1, 36) = .062, p = .805]. A non-significant interaction effect was also observed between the state of the Interactive Gaze and the conversation groups [F(1, 36) = .039, p = .844]. The results are presented in Table 6.48 and Table 6.49.

Table 6.48 Means and standard deviations of T_a in the experimental groups across four test conditions.

Test Conditions	Conversation Groups	Participant Roles	N	T_a	
				Mean	Std. Deviation
TNIN	Blind-sighted	Blind	10	.00	.00
		Sighted	10	1.00	.00
		Total	20	.50	.51
	Blindfolded-sighted	Blindfolded	10	.50	.53
		Sighted	10	.50	.53
		Total	20	.50	.51
	Total	Blind and Blindfolded	20	.25	.44
		Sighted	20	.75	.44
		Total	40	.50	.51
TNIY	Blind-sighted	Blind	10	.10	.32
		Sighted	10	.90	.32
		Total	20	.50	.51
	Blindfolded-sighted	Blindfolded	10	.10	.32
		Sighted	10	.80	.42
		Total	20	.45	.51
	Total	Blind and Blindfolded	20	.10	.31
		Sighted	20	.85	.37
		Total	40	.47	.51
TYIN	Blind-sighted	Blind	10	.10	.32
		Sighted	10	.90	.32
		Total	20	.50	.51
	Blindfolded-sighted	Blindfolded	10	.70	.48
		Sighted	10	.30	.48
		Total	20	.50	.51
	Total	Blind and Blindfolded	20	.40	.50
		Sighted	20	.60	.50
		Total	40	.50	.51
TYIY	Blind-sighted	Blind	10	.00	.00
		Sighted	10	1.00	.00
		Total	20	.50	.51
	Blindfolded-sighted	Blindfolded	10	.60	.52
		Sighted	10	.40	.52
		Total	20	.50	.51
	Total	Blind and Blindfolded	20	.30	.47
		Sighted	20	.70	.47
		Total	40	.50	.51

Note. The mean score ranges from 0-1.

Table 6.49 Mixed ANOVA results summary of main effects and interaction effects on T_a.

Source	*SS*	*df*	*MS*	*F*	*p*
Conversation Groups	.002	1	.002	.026	.872
Conversation Groups * Participant Roles	1.914	1	1.914	32.331	$.000^{**}$
Error	2.131	36	.059		
Tactile Feedback * Conversation Groups	.006	1	.006	.062	.805
Error(Tactile Feedback)	3.625	36	.101		
Interactive Gaze * Conversation Groups	.006	1	.006	.039	.844
Error(Interactive Gaze)	5.725	36	.159		

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

Interventions in the experimental groups. There was a non-significant main effect of the Tactile Feedback on $\boldsymbol{T_a}$ [F(1, 36) = .062, *p* = .805]. The predicted main effect of the Interactive Gaze on $\boldsymbol{T_a}$ was also not significant [F(1, 36) = .039, *p* = .844].

A significant interaction effect was observed between the state of the Tactile Feedback and the participant roles [F(1, 36) = 10.490, *p* = .003, η_p^2 = .226]. The contrast revealed that the blind and blindfolded participants had much bigger $\boldsymbol{T_a}$ when the Tactile Feedback was active than it was not. Accordingly, the sighted participants had a significantly had much smaller $\boldsymbol{T_a}$ when the Tactile Feedback was active than it was not. A non-significant interaction effect was observes between the state of the Interactive Gaze and the participant roles [F(1, 36) = .039, *p* = .844]. The results are presented in Table 6.50.

Table 6.50 Mixed ANOVA results summary of main effects and interaction effects on T_a.

Source	*SS*	*df*	*MS*	*F*	*p*
Tactile Feedback	.006	1	.006	.062	.805
Tactile Feedback * Participant Roles	1.056	1	1.056	10.490	.003**
Error(Tactile Feedback)	3.625	36	.101		
Interactive Gaze	.006	1	.006	.039	.844
Interactive Gaze * Participant Roles	.506	1	.506	3.183	.083
Error(Interactive Gaze)	5.725	36	.159		

*Significant group difference; * $p < .05$, ** $p < .01$.*

Interventions in the blind-sighted group. A non-significant main effect of the Tactile Feedback was observed on $\boldsymbol{T_a}$ ($p > .05$). There was also a non-significant main effect of the Interactive Gaze on $\boldsymbol{T_a}$ ($p > .05$).

Also, a non-significant interaction effect was observed between the state of the Tactile Feedback and the participant roles ($p > .05$). A non-significant interaction effect was also observed between the state of the Interactive Gaze and the participant roles ($p > .05$). The results are presented in Table 6.51.

Table 6.51 Means and standard deviations of T_a in the blind-sighted group across four test conditions.

Test Conditions	Participant Roles	N	T_a Mean	T_a Std. Deviation
TNIN	Blind	10	.00	.00
	Sighted	10	1.00	.00
	Total	20	.50	.51
TNIY	Blind	10	.10	.32
	Sighted	10	.90	.32
	Total	20	.50	.51
TYIN	Blind	10	.10	.32
	Sighted	10	.90	.32
	Total	20	.50	.51
TYIY	Blind	10	.00	.00
	Sighted	10	1.00	.00
	Total	20	.50	.51

Note. The mean score ranges from 0-1.

Summary. The findings demonstrated that the blindfolded participants had much bigger T_a than the blind participants (Figure 6.18). Meanwhile, the sighted participants in the blind-sighted group had much bigger T_a than in the blindfolded-sighted group (Figure 6.18).

In the experimental groups, the blind and blindfolded participants had much bigger T_a when the Tactile Feedback was active than it was not (Figure 6.19). Accordingly, the sighted participants had a significantly had much smaller T_a when the Tactile Feedback was active than it was non-active (Figure 6.19). However, in the blind-sighted group, the interventions had no significant impact on T_a.

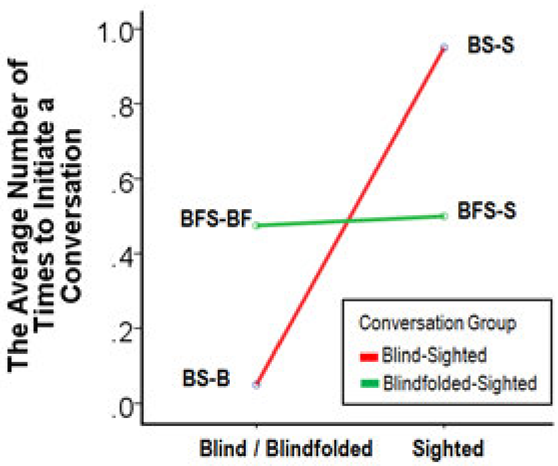


Figure 6.18 Interaction effects between the conversation groups and the participant roles on T_a.

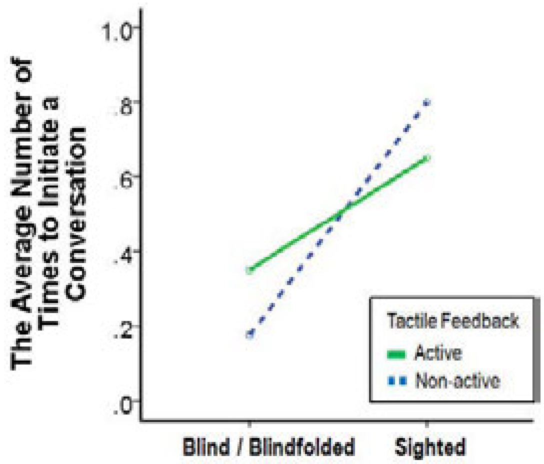


Figure 6.19 Interaction effects between the state of the tactile feedback and the participant roles on T_a.

6.4.2 Qualitative Results

In the qualitative analysis, we used the *conventional content analysis* approach (Hsieh and Shannon, 2005) to analyze the participants' comments from the open questions (Table 6.52). Total 342 quotes were examined to identify major categories and sub-categories related to users' motivation and attitudes towards the system, their perceptions towards the function of the system and design suggestions. The ID of the participants for exemplary quotes is presented in Table 6.53.

Table 6.52 Open questions for the participants.

No.	Open Questions
1	Do you have an interest in this system? If yes, why you are interested in the system?
2	Which aspects make you like or dislike this system?
3	What do you think the function of the system in the conversation?
4	Do you have any other suggestions for improving this system?

Table 6.53 Participants' ID of quotes.

Conversation Groups	Participant Roles	ID
Blind-sighted	Blind	BS-B1, BS-B3, BS-B5, BS-B7, BS-B9, BS-B11, BSB-13, BSB-15, BSB-17, BSB-19
Blind-sighted	Sighted	BS-S2, BS-S4, BS-S6, BS-S8, BS-S10, BS-S12, BS-S14, BS-S16, BS-S18, BS-S20
Blindfolded-sighted	Blindfolded	BFS-BF5, BFS-BF5, BFS-BF7, BFS-BF9, BFS-BF11, BFS-BF13, BFS-BF17, BFS-BF19, BFS-BF21, BFS-BF23
Blindfolded-sighted	Sighted	BFS-S6, BFS-S8, BFS-S10, BFS-S12, BFS-S14, BFS-S16, BFS-S18, BFS-S20, BFS-S22, BFS-S24

6.4.2.1 Interest

We collected 65 quotes regarding the participants' interests towards the E-Gaze system. The results are presented in Table 6.54. The majority of the participants (57 quotes) expressed a great interest towards the E-Gaze system (e.g., "a good idea," "innovative," "funny" and "magic"). They explained the reasons for showing interests as below:

Tactile Feedback. Eighteen quotes mention the Tactile Feedback could benefit the blind and the blindfolded participants. The example quotes are: "Tactile feedback makes me feel less nervous to talk with sighted people" (BS-B15); "Help a blind person directly and exactly feel the attention from a sighted person" (BFS-BF9); "Let a blind person perceive the presence of the sighted conversation partner" (BFS-S12); "Tactile feedback makes me feel connected with the conversation partner" (BFS-BF13).

Interactive Gaze. Eleven quotes mention that the Interactive Gaze positively influenced sighted participants. The example quotes are: "I cannot help interacting with a person with Interactive Gaze, and I want to know what he is thinking about" (BFS-S24); "Interactive Gaze can influence my mood when I talk with a blind person" (BS-S8).

The system. Fourteen quotes mention that the system could positively affect face-to-face communication between blind and sighted people. BS-S16 said, “The system makes me feel closer to communicate with the conversation partner. It is helpful to establish eye-to-eye communication.”

Nevertheless, eight quotes mention that the participants were not interested in the system. Some reasons are given below:

“If sighted people know the conversation partner is blind, they do not care whether or not they have eye-to-eye communication” (BFS-BF19).

Some participants reported that they did not feel too much about the Tactile Feedback: “In the test, I do not pay much attention to the Tactile Feedback. I do not know how many times the wristband vibrates in conversations” (BFS-BF17).

Table 6.54 The participants’ interests in the system.

Categories	Sub-categories	Number of quotes
Interests	Tactile Feedback	18
	Interactive Gaze	11
	The E-Gaze system	14
	General comments	14
	Total	57
No interests	Not necessary	3
	The inadequacy of the Tactile Feedback	5
	Total	8
Total		65

6.4.2.2 Attitudes

We collected the participants’ positive and negative comments (115 quotes) towards the system. The results are presented in Table 6.55. The positive category consists of three sub-categories: (1) Tactile Feedback, (2) Interactive Gaze and (3) the system.

Tactile Feedback. Twelve quotes mention that the participants liked the Tactile Feedback. As stated by BFS-BF8, “It provides me with the feedback that I can understand my conversation partner is interested in my speaking or not.” “The tactile feedback can tell me know how many times my conversation partner looks at me” (BS-B13).

Interactive Gaze. Eight quotes mention that the participants liked the Interactive Gaze could simulate eye gestures of a blind person. Example quotes are: "I can see the eyes of a blind person" (BS-S8), and "Interactive Gaze guided me to have the eye contact with a blind person" (BFS-S10). Five quotes describe the eye gestures of the Interactive Gaze looked real, vivid and natural. Two quotes mention that the participants felt curious about the simulated eye gestures.

The system. Twenty-eight quotes mention the advantages of the system. The example quotes are: "The system benefits us to make friends with sighted people. (BS-B17)" "We could communicate efficiently by using this system" (BS-S6). "I can distinguish whether the conversation partner cares me through the system"(BFS-BF23).

Table 6.55 The participants' positive and negative attitudes towards the system.

Categories	Sub-categories	Further sub-categories	Number of quotes
Positive	Tactile Feedback	Let a blind person know someone is looking at her	10
		Like the vibration and the wristband	2
	Interactive Gaze	Simulating eyes and eye gestures for blind people	8
		Real, vivid and natural eyes and eye gestures	5
		Be curious about simulated eye gestures	2
		Others	3
	The system	Make communication efficient, interactive and natural	11
		Assist blind people	5
		Interesting and playful	7
		Simple, convenient and portable	3
		High-tech and innovative	2
	Total		58
Negative	Interactive Gaze	Inappropriate gaze animations	11
		Very large and attractive eyes	7
		Strange and fearsome eye appearance	5
	Wearability	Uncomfortable to wear	9
		Inconvenient to use and not portable	8
		Heavy	6
	Physical appearance	Too large and not beautiful	7
		Not suitable for the daily use	2
		Uncertain about the physical appearance	2
	Total		57
Total			115

The negative category has three sub-categories: (1) Interactive Gaze, (2) wearability and (3) physical appearance.

Interactive Gaze. Twenty-three quotes describe the disadvantages of the Interactive Gaze. For example, "The size of the simulated eyes are too large, so I am easily distracted" (BFS-S24), and "I do not think the Interactive Gaze can express the blind person's mood. It only simulates the eye appearance" (BFS-S12).

Wearability. Twenty three quotes mention the E-Gaze was heavy, non-portable and uncomfortable to wear. As stated by BS-B13, "My eyes feel uncomfortable when I wear the E-Gaze glasses. I need a long time to adjust to it."

Physical Appearance. Eleven quotes mention the participants disliked the physical appearance of the E-Gaze glasses. The example quotes are: "The shape of the E-Gaze glasses is not suitable for the daily use" (BFS-BF5); "I feel uncertain about the shape of the E-Gaze glasses in the eyes of sighted people, so I am not confident in wearing the E-Gaze" (BFS-BF13).

6.4.2.3 Functions

Sixty-five quotes claimed the function of the E-Gaze system was very useful, while 14 quotes expressed the opposite idea. The results are presented in Table 6.56. The useful category consists of three sub-categories: Interactive Gaze, Tactile Feedback, and general comments.

Interactive Gaze. The majority of the participants praised the Interactive Gaze for its ability to simulate eye gestures of blind people, enhancing their feelings and personalities in conversations. The example quotes are: "In conversations, I feel that I talk with a normally sighted person. I can see the eyes of my conversation partner clearly" (BFS-S8); "Interactive Gaze promotes us to have an equal communication" (BFS-S18); "You can discern whether a blind person is interested in your speaking through the eye contact" (BFS-S16).

Tactile Feedback. The majority of the participants claimed that the Tactile Feedback was an indicator of the engagement in conversations. Besides, it provided the participants with a sense of security. The example quotes are:

"When I feel the vibration, I know the conversation partner is looking at me. I am more willing to speak to him. If there is no vibration, I guess he is distracted. At that moment, I am not willing to speak anymore" (BFS-BF21).

"I feel I speak more than usual" (BS-B5).

"Without the Tactile Feedback, I feel the conversation partner is far away from me. I cannot see, so I am eager to have a sense of safety. The vibration makes me feel safe. I feel the psychological distance of us becomes shorter" (BFS-BF13).

General Comments. Example quotes are: "overcome communication barriers," "express a friendly attitude," "enliven the atmosphere of face-to-face communication" and "enhance the mutual presence."

Fourteen quotes mention that the participants did not think the E-Gaze was useful. The example reasons are: "helpfulness for the conversation," "worried about the appearance of the E-Gaze glasses," and "distract the attention." BS-B13 also emphasized, "I do not perceive too much of vibrations during my speaking. I feel the vibration intensity is a little weak. For example, if I am moving the body or become engaged in an exciting topic, I will ignore such tiny signals."

Table 6.56 The participants' perceptions of the functions of the system.

Categories	Sub-categories	Further sub-categories	Number of quotes
Useful	Interactive Gaze	Seeing the eyes and eye gestures of a blind person	16
		Show feelings and personality	9
		Become engaged in conversations	5
		Attract the attention	5
		Provide the visual feedback	4
	Tactile Feedback	An indicator for the engagement	10
		Perceiving the gaze from the sighted	5
	General comments		11
	Total		65
Not useful			14
Total			79

6.4.2.4 Design Suggestions

We collected 83 quotes regarding design suggestions. The results are presented in Table 6.57. Design suggestions consist of five sub-categories: (1) gaze simulation, (2) vibration and others, (3) sensing multiple nonverbal signals, (4) the physical appearance and (5) additional functions.

Gaze Simulation. The majority of the participants required realistic and natural gaze simulation, to provide customized eyes and diverse eye gestures. The example quotes are:

“I wish the E-Gaze glasses can display diverse eye gestures to match different facial expressions” (BFS-S8). “The simulated eyes can be customized based on the personality and the facial appearance of blind people”(BFS-S20).

Vibration and Others. Twelve participants suggested improving the vibration of the wristband. Ten participants presented converting gaze signals to other types of signals, such as auditory signals, color, light, or temperature. The example quotes are given below:

“The vibration intensity should be more gentle (e.g., a ring device for the finger is better than a tactile wristband). A tiny vibration can make me feel relieved” (BFS-BF21).

“Different vibration patterns can match different eye gestures. For example, the vibration of the rolling eyes and a general look should be different. If someone is looking at me, the wristband will vibrate only once; if someone is staring at me, the wristband will keep vibrating. I do not think the continuous vibration bothers me” (BS-B15).

“The growing darker color displayed on the E-Gaze glasses can indicate an increase of the intimacy between two interlocutors” (BFS-BF9).

“If someone is approaching me, the E-Gaze glasses should become warm” (BFS-BF13).

Sensing Multiple Nonverbal Signals. The participants expected the system to sense multiple nonverbal signals, including facial expressions, body gestures, distance and eye movements. Some participants also mentioned to expand the sensing area of the system, rather than limited to the region of the E-Gaze glasses. The example quotes are:

“I want to perceive facial expressions and the mood of my conversation partner (e.g., four to five typical facial expressions)” (BS-B7).

“I want to know body gestures of the conversation partner. For example, does she lean forward or back during my speaking? If receiving such information, I can infer that whether she is interested in my speaking or not” (BFS-BF13).

“The expanded sensing area includes the face, foot, or any place of the body, so I can realize that someone is looking at a certain part of my body” (BS-B13).

Physical Appearance. The participants presented several expected features of the system, including the invisible design, portability, mobile device, and wearability. The examples are: “The physical appearance of the E-Gaze glasses is expected to be similar to the object seen in daily lives. For example, it looks like a pair of black glasses” (BFS-BF19); “E-Gaze glasses and the tactile wristband are separate two parts, which are inconvenient to wear. The system should combine the glasses with the tactile feedback” (BS-B13).

Additional Functions. The participants suggested that new functions could be added to this system such as voice navigation, voice photography and color recognition. The examples are: “I wish the system can take photos and videos at all times and places” (BS-S16); “Different vibration patterns can stand for different colors. A long and strong vibration can stand for the bright color, while a short and weak vibration for the dark color” (BS-B15).

Table 6.57 Design suggestions.

Categories	**Sub-categories**	**Further sub-categories**	**Number of quotes**
Gaze simulation	Improve the eye appearance	Resizing the eye image	3
		Providing details of the eye appearance	2
	Be more realistic and natural		5
	Providing diverse eye gestures		5
	Gaze timing		4
	Total		19
Vibration and others	Improving vibration	Intensity	5
		Location	4
		Using different vibration patterns to express eye gestures	3
	Others	The auditory feedback	5
		Color and light	3
		Temperature	1
		Directly stimulating optic nerves	1
	Total		22
Sensing multiple nonverbal signals	Facial expressions		7
	Body gestures and the distance		5
	Accurate eye movements		2
	Expanding the sensing area		2
	Total		16
Physical appearance	Like ordinary glasses		4
	Portability	Simple and convenient	9
		Smaller	4
		Mobile device	3
	Wearability		6
	Total		26
Additional functions	Voice navigation, voice photography and color expression		5
Total			88

6.5 Discussion and Conclusion

In this study, we implemented the E-Gaze Version 3 to perform the user experiment. We investigated whether the Tactile Feedback and Interactive Gaze could motivate face-to-face communication between blind and sighted people. Our findings were discussed from the following parts:

- **Baseline Condition.** We compared the communication quality in four groups when both Tactile Feedback and Interactive Gaze were not active.

- **Group Types.** We examined whether the perceptions of the participants differed in the blind-sighted group and the blindfolded-sighted group.

- **Tactile Feedback and Interactive Gaze.** We investigated how the participants perceived the Tactile Feedback and Interactive Gaze in face-to-face communication and specifically discussed the experimental results for the blind-sighted group.

- **Design Implication.** We presented several design implications based on the comments of the participants.

6.5.1 Baseline Condition

Hypothesis 1. In the baseline analysis, we found that without any intervention, the sighted-sighted group performed significantly better communication quality than the blind-blind group, the blind-sight group, and the blindfolded-sighted group. As stated by Kemp and Rutter (1986), blind people are limited in social cues (e.g., gaze signals, facial expressions and gestures) that they can send and receive, the same as sighted people's conversations over the telephone. Among four conversation groups, the sighted-sighted group has the largest amount of social cues, naturally leading to the highest communication quality in four types of conversations. Kemp and Rutter (1986) suggested that based on the amount of the social cues, the communication quality of the blind-sighted should be between the blind-blind and the sighted-sighted. However, the findings in our experiment did not support this assumption.

Although not significant, the communication quality of the blind-blind was better than the blind-sighted and the blindfolded-sighted. The possibility is that although blind people lack visual social cues, they have a sensitive awareness of hearing and smelling to perceive nonverbal signals. In conversations, it is easier for a blind person to understand another blind person rather than a sighted person. Blind people share similarities in life experiences, easily triggering empathy in mutual discussions. For example, a teacher in Yangzhou Special Education School reported that some blind students preferred to stay at school to communicate with blind classmates rather than go back home to communicate with their sighted parents. The reason was the sighted parents could not well understand their children on many things. In the same vein, it is easier for two sighted people to communicate with each other and create empathy. Overall, the baseline analysis tells us that it needs to provide certain interventions to increase the communication quality between blind and sighted people since they may lack empathy with each other.

6.5.2 Group Types

In Section 5.6.1, we found that the communication quality differed between blind-sighted and blindfolded-sighted conversations. We concluded that it could not substitute the blind participants with the blind participants in the user experiments, especially in a dyadic-conversation scenario. In this chapter, the findings further strengthened our confidence that the communication quality of the blind-sighted conversations was different from the blindfolded-sighted conversations.

Hypothesis 2.1 A significant interaction effect was observed between the conversation groups and the participant roles. The blindfolded participants perceived significantly better communication quality than the blind participants. The findings were aligned with the results of the video analysis regarding who initiated the conversation. In the tests, the blindfolded participants initiated more conversations than the blind participants. It revealed that the blindfolded participants performed more actively than the blind participants in face-to-face communication. The sighted participants in the blind-sighted group demonstrated significantly better communication quality than in the blindfolded-sighted group. Such findings were also consistent with the results of the video analysis. The sighted participants in the blind-sighted group initiated more conversations than in the blindfolded-sighted group.

Hypothesis 2.3 A significant interaction effect was observed between the state of the Interactive Gaze and the conversation groups. In the blind-sighted group, the communication quality was generally the same whether the Interactive Gaze was active or not. However, in the blindfolded-sighted group, the sighted participants perceived significantly better communication quality when the Interactive Gaze was active than it was not. The findings were aligned with gaze data from the sighted participants in two conversation groups. We found that the sighted participants looked at the blindfolded participants much more than the blind participants (Figure 6.17). The possibility is that the facial expressions of a blind person look stiff and unnatural from a sighted person's eyes. Bellack and Hersen (1979) stated that although many types of social training attempt to improve the performance of nonverbal responses of blind people, many visual nonverbal signals such as facial expressions are still impossible for them to intimate. According to Valente et al. (2017), children can intimate their parents by directly replicating the facial expression linked to each emotion. If children are born blind, they will lose the opportunity to learn any facial expression directly. It is very difficult for them to pose emotional expressions. In our experiments, the blindfolded participants were very familiar with facial expressions and other social signals. Even they could not see anything in conversations, they still unconsciously used natural facial expressions and gestures to react to their sighted conversation partners. The Interactive Gaze looked more harmonious with the facial expressions of the blindfolded participants than the blind participants. It also explained why the sighted participants looked more at the blindfolded participants than the blind participants with the Interactive Gaze.

6.5.3 The Effect of Tactile Feedback and Interactive Gaze

6.5.3.1 The Experimental Groups

Hypothesis 3 The quantitative results demonstrated that the Tactile Feedback was effective to increase the communication quality, which performed a significantly positive effect on the participants' co-presence and PAU. The qualitative results also supported this hypothesis (Section 6.4.2). The majority of the participants held the positive attitudes of the Tactile Feedback. For example, BS-B15 stated that the Tactile Feedback could make her feel less nervous when talked with a sighted person. Another important reason is the Tactile Feedback provided a sense of safety for the blind and blindfolded participants. As stated by BFS-BF13, the Tactile Feedback decreased her anxiety in darkness and shortened the psychological distance between two people.

Hypothesis 3.1 The quantitative results from the questionnaires demonstrated a non-significant interaction effect between the state of the Tactile Feedback and the participant roles. However, the video analysis revealed that the blind and blindfolded participants initiated more conversations when the Tactile Feedback was active than it was not (Section 6.4.1.6). The findings showed that the Tactile Feedback effectively promoted the blind and blindfolded participants to be more active in conversations. Accordingly, the sighted participants had fewer times to initiate conversations when the Tactile Feedback was active than it was non-active.

Hypothesis 4 The quantitative results strengthened our confidence that the Interactive Gaze positively affected the communication quality. Gaze data also supported the findings. The sighted participants looked more at the E-Gaze glasses when the Interactive Gaze was active than it was not (Section 6.4.1.5). In the qualitative findings (Section

6.4.2), the majority of the participants thought that the Interactive Gaze provided the visual feedback that motivated them fully engaged in conversations. It helped sighted people overcome possible negative feelings to the unattractive eye appearance of blind people. Vinciarelli et al. (2009) suggested that the physical appearance is one of the social signals, which associates with the attractiveness. The Interactive Gaze improved the physical appearance of blind people. As stated by a sighted participant (BFS-S8): "[…] I feel I talk with a normally sighted person."

Hypothesis 4.1 The quantitative results well supported this hypothesis. A significant interaction effect was observed between the state of the Interactive Gaze and the participant roles. The sighted participants perceived significantly better communication quality when the Interactive Gaze was active than it was not.

In the experimental groups, we found that the intervention of the Interactive Gaze had a greater impact on the communication quality than the Tactile Feedback (Table 6.58). We concluded the reasons as below:

Table 6.58 *p*-value and the effect size (η_p^2) of two interventions: the Interactive Gaze and the Tactile Feedback.

	Interactive Gaze		**Tactile Feedback**	
	p	$\boldsymbol{\eta_p^2}$	***p***	$\boldsymbol{\eta_p^2}$
Co-presence	**.000****	.639	**.045***	.107
Attention allocation	**.000****	.373	.089	.078
Perceived message understanding	**.002****	.244	.061	.094
Perceived affective understanding	**.002****	.227	**.002****	.237
Perceived emotional interdependence	**.034***	.118	.647	.006
Perceived behavioral interdependence	**.000****	.560	.057	.097

Significant group difference; $^{*}p < .05$, $^{**}p < .01$.

- The Interactive Gaze has a positive impact on the sighted participants due to they are very familiar with the gaze and eye contact in daily livings. They well understand the importance of the gaze and eye contact in face-to-face communication. In the experiments, they can directly see the Interactive Gaze displayed on the E-Gaze glasses. Since the sight is often viewed as the dominant modality in five senses (Howes, 2005), the visual feedback of the Interactive Gaze is very effective and straightforward for all sighted participants.

- Compared with the Interactive Gaze, the Tactile Feedback has a weaker impact on the communication quality for both blind and blindfolded participants. The possibility is blind people have a fuzzy understanding of gaze behaviors (Section 3.4.3). For the blindfolded participants, although they well understand the gaze and eye contact, they still need some time to be familiar with the relationship between the gaze and the tactile signal.

6.5.3.2 The Blind-Sighted Group

In this section, we discuss the findings of the blind-sighted group. Our findings did not support Hypothesis 5 and 5.1, but supported Hypothesis 6 and 6.1. In the blind-sighted group, the participants perceived significantly higher co-presence and PBI when the Interactive Gaze was active than it was not. More precisely, the sighted participants perceived significantly higher PMU when the Interactive Gaze was active than it was not. Based on the analysis for the experimental groups, we found that the blindfolded-sighted group demonstrated to be more sensitive to the interventions of the Interactive Gaze and Tactile feedback than the blind-sighted group. The Interactive Gaze has a positive impact on the communication quality of the blind-sighted group, but it has a smaller impact on the blindfolded-sighted group. Some factors may influence the communication quality of the blind-sighted group. For instance, the level of the blind participants' spoken language and their passive strategies in conversations. We observed that the spoken language of some blind participants was not very good, causing the impatience from the sighted conversation partners (Section 5.6.3). Besides, most blind participants adopted a passive strategy (such as listening) in conversations. The possibility is that they were uncertain about initiating a conversation. Based on the Uncertainty Reduction theory of Griffin (2006), blind people have the uncertainty about attitudes of sighted people due to a lack of visual information. They are uncertain about the consequences such as how a sighted person will react to them.

Overall, we demonstrate that our system positively affects the communication quality in dyadic conversations, especially for the blindfolded-sighted group. We might consider extending our target users to "blindfolded people." Such people do not have the sight, but they experience and well understand the gaze and eye contact. For example, older adults gradually lost their sight due to the growing age.

6.5.4 Design Implications

In the interviews, we asked the participants' to present their ideas and suggestions to the E-Gaze system. Here we summarize the findings and present design implications.

6.5.4.1 Invisible Design

Weiser (1999) presented the vision of the calm technology: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it " (p.1). This notion informs the design trend regarding the physical appearance of the system. In this study, the participants required the thickness of the E-Gaze glasses was the same as the ordinary glasses, and the appearance of the tactile wristband was like a real sports bracelet. To make the E-Gaze thinner, lighter and "invisible" to people, soft OLED screens may provide an option for our future design.

6.5.4.2 The "Uncanny Valley" Effect

The Uncanny Valley effect was presented by Mori (1970). It describes the negative emotional reaction of a human towards a humanlike robot or prosthesis. The more humanlike characteristics a prosthesis has, the more likely it will be accepted by humans. However, if the similarity to humans reaches a certain point, the affinity will quickly become a strong disgust. In this study, we directly used videos of the realistic human's eyes for the Interactive Gaze design. Some participants reported that the eye appearance displayed on the E-Gaze glasses was too realistic and even let them feel horrible. The Uncanny Valley effect may help explain their perceptions. In our future design, we attempt to use less humanlike eye appearance to improve the E-Gaze glasses (e.g., the suitable animated eyes).

6.5.4.3 Increasing the Vibration Intensity

In this study, we found a difference of perceiving vibration intensity between blind and blindfolded participants. Due to sensory compensation, blind people developed enhanced tactile acuity for their lack of vision (Goldreich and Kanics, 2003). Initially, we predicted that because of being more sensitive to the tactile feedback, the blind participants would need the lower vibration intensity than the blindfolded participants. However, we were surprised to find that most blind participants liked the strong tactile feedback to perceive the "eye contact." As stated by BS-B17, she thought the vibration feedback from the tactile wristband was too tiny to perceive, especially in a conversation scenario. She did not think increasing the vibration intensity could disturb her. Otherwise, strong vibrations enabled her to increase the confidence in speaking. Some participants also reported that strong vibrations helped increase a sense of security. Since blind people cannot see anything in the darkness, they particularly concern about their security. It was also found in our previous investigation in Hong Kong (Qiu et al., 2015).

6.5.4.4 Expanding the Sensing Area

The majority of the blind participants wished to expand the sensing area rather than restrict in the glasses region of the E-Gaze. They envisioned the system to provide them with the tactile feedback when the sighted was looking at their face or body. In our study, most blind participants reported that they were born blind or became blind at a very young age. They did not have an explicit understanding of eye contact. In their opinions, the eye contact was similar to eye-to-face or eye-to-body communication. Also, the tactile feedback enabled them to keep alert if the sighted was looking at their face or body.

6.5.4.5 Sensing Multiple Nonverbal Signals

In addition to perceiving the gaze, the blind participants wished to know more nonverbal signals from conversation partners. Such nonverbal signals included facial expressions (e.g., smile or frown), body gestures (e.g., nod or shake the head), hand gestures (e.g., thumbs up) and the distance towards the conversation partner. For instance, one participant mentioned that if a teacher's voice pretended to be calm as usual, she was uncertain about his intention. If she could perceive his facial expressions and small gestures, she might easily realize his real intention. The envisioned system is expected to capture the multiple sensory inputs in face-to-face communication. It can extract many social features of sighted conversation partners (e.g., facial expressions, age, gender, body gestures, head pose, distances, and orientation). The system will select and convert necessary social features to blind people. Besides the tactile feedback, we may consider using the auditory feedback to deliver more accurate information to blind people.

6.5.5 Limitations

In this study, there are several limitations. Most of them are similar to the limitations introduced in Section 5.6.4. First, we did not well balance the participants' age, educational background and the level of spoken language for the between-group test. Second, the blind participants might not well understand the image questionnaire, so we did not get any significant results from an adapted Inclusion of Other in the Self (IOS) Scale (Aron et al., 1992). Third, due to a limited number of available blind participants, 10 orders of treatments for each group was a compromise in our study. Fourth, the participants in the sighted-sighted group and the blind-blind group did not wear anything in the TNIN condition. However, the participants in the blind-sighted group and the blindfolded-sighted group wore both E-Gaze glasses and the tactile wristband in the TNIN condition. The physical entity of the E-Gaze glasses and the tactile wristband might have an impact on the results in the analysis of the baseline condition (TNIN).

In summary, this study has the following contributions:

- The tactile wristband was added to the E-Gaze system, which helped the blind person to feel the "eye contact" with the sighted.

- It confirms the findings in Chapter 5 that the communication quality of the blind-sighted group is different from the blindfolded-sighted group.

- It presents the evidence that the Tactile Feedback has a positive impact on the communication quality in a dyadic-conversation scenario.

- The Interactive Gaze has a greater impact on the communication quality than the Tactile Feedback.

- The blindfolded-sighted group is more sensitive towards the intervention of the Interactive Gaze and Tactile feedback than the blind-sighted group.

This chapter concludes with design suggestions, considerations, and opportunities relevant to smart glasses technology.

7

Conclusions, Limitations, and Future Work

In this final chapter, we summarize the key contributions and respond to the research questions in Chapter 1. We also present the limitations and suggestions for future work.

7.1 Contributions

We started this research by reviewing assistive technologies for blind people. We then focused on the studies of assistive technologies for social interactions, which area is getting increased attention. The objective of our research was twofold: first to evaluate how emerging assistive technologies improved the communication quality between blind and sighted people, and second to inform the further accessible design. In our research, we integrated theoretical analysis, design practices, prototype implementations, and experimental studies. A system of simulating gaze behaviors for blind people was designed. It was inspired by the insights gained from research areas such as social psychology theories of the gaze and eye contact, human-computer and human-agent interaction and the recent development in sensing technologies. To our knowledge, this research is the first attempt of using the eye-tracking technology to simulate gaze behaviors for blind people. Our experimental findings can provide an input for the development of gaze-simulation systems in the accessible computing area. The main contributions of this dissertation are：

- Understanding blind people’s capabilities and limitations of the nonverbal signal perception in face-to-face communication, which provides the research basis for designing and simulating the gaze.
- Based on the user requirements, a functional interactive prototype for the gaze simulation was built, aiming at enabling a blind person to perceive the gaze from the sighted and to send the “gaze” as a visual reaction.
- An interactive gaze model for the prototype was created based on the eye-contact mechanism and a turn-taking strategy, which improves the communication quality between a sighted person and a blind person.
- It was found in user experiments that, simulating the gaze by integrating visual and tactile modalities can significantly increase the communication quality between blind and sighted people in face-to-face dyadic conversations.
- It was found in user experiments that, the communication quality of the blind-sighted group is different from the blindfolded-sighted group, indicating that blind participants cannot be substituted by blindfolded participants in evaluations, especially in a conversation scenario.

- Findings from these studies have design implications that can be used as general design guidelines for more effective assistive technologies for blind people in social interactions.

7.2 Answers to the research questions

RQ1: How do blind people perceive nonverbal signals in face-to-face communication and which problems they may have due to a lack of visual information?

The user study (chapter 3) suggests that hearing, touch, and sight are three major modalities for blind people to perceive nonverbal signals in face-to-face communication.

- Hearing is viewed as a dominant way (e.g., vocal behaviors, postures).
- Touch is another important modality (e.g., body touch).
- Low-vision people still rely on the sight to perceive rough postures and gestures (e.g., as P9 said, "if you still have a certain vision, you will rather rely on it.").

Blind people shared more experiences of their capabilities than limitations in our study. We identify their major problems as below:

- Blind people cannot perceive subtle information in nonverbal signals (e.g., gaze, facial expressions, and finger gestures).
- They received less positive signals in a conversation due to a lack of perceiving subtle gestures and facial expressions from their conversation partners.
- They have an indirect and fuzzy understanding of the eyes and eye gestures.

Based on their capabilities and limitations, we identify design opportunities to support the nonverbal signal perception of blind people. Specifically, we aim to help them perceive subtle information in nonverbal signals (e.g., gaze).

RQ2: To which extent does the tactile feedback help a blind person feel the gaze (attention) from the sighted in face-to-face communication?

We presented a study with 30 participants (chapter 4). They were grouped in pairs. Each pair included one sighted participant and one blindfolded participant. The objective of this study was to examine the hypothesis that the Tactile Band enabled a blind person to feel attention (gaze) from the sighted. We expected that the tactile feedback could enhance the level of engagement of the participants in face-to-face communication.

The quantitative findings did not provide us with the strong evidence that the tactile feedback could significantly enhance the engagement in dyadic conversations. But the comments from the blindfolded participants revealed that at the beginning of the conversation, the vibration was effective to help them concentrate on the sighted conversation partner.

RQ3: To which extent does the "eye contact" simulation help a sighted person feel the visual reaction from the blind conversation partner in face-to-face communication?

Eye contact has been viewed as a "social glue," binding people together and creating harmonious relationships (Lakin et al., 2003). To simulate the "eye contact," we implemented the Interactive Gaze displayed on the E-Gaze glasses (chapter 5). A blind person wears the E-Gaze when communicating with a sighed conversation partner.

It is evident from the findings that the Interactive Gaze helps a sighted person feel the visual reaction from the blind or blindfolded conversation partner. Such intervention has a positive impact on the communication quality in both blind-sighted and blindfolded-sighted groups. However, the positive impact in the blind-sighted group is smaller than in the blindfolded-sighted group. One possible reason is that the perceptions and behaviors of the blind participants are different from the blindfolded participants in conversations. For instance, the blindfolded participants focused on listening, and they became not sensitive to other nonverbal signals such as ignoring the conversation partner' perfume scent. They wished to get the vocal feedback immediately from conversation partners, and they were more enthusiastic to speak in conversations than usual. In the experiment, blind participants did not have such a behavior change. It shows that we cannot simply substitute the blind participants with the blindfolded participants in the user experiment, especially in a dyadic-conversation scenario, even if it is common to use the blindfolded participants for the evaluations in HCI (Moll et al., 2010).

RQ4: To which extent does the "eye contact" simulation integrating visual and tactile feedback improve the quality of face-to-face communication between sighted and blind people in dyadic conversations?

The findings in chapter 6 provide the strong evidence that the Interactive Gaze and Tactile Feedback positively affect the communication quality. The Tactile Feedback not only allows blind people to perceive someone is looking at them but also let them feel connected with conversation partners, to shorten the psychological distance between each other. For the blindfolded participants, it also decreases their anxiety in darkness and provides them with a sense of safety.

The Interactive Gaze shows a greater impact on the communication quality than the Tactile Feedback. The sighted participants can directly see the Interactive Gaze, however, mapping the "eye contact" with the tactile feedback is still a new knowledge for the blind and blindfolded participants, which is likely to require more time for practicing.

Furthermore, the blindfolded-sighted group was more sensitive towards the intervention of the Interactive Gaze and Tactile feedback than the blind-sighted group. It confirms the findings in Chapter 5 that the communication quality of the blind-sighted group is different from the blindfolded-sighted group.

7.3 Limitations

Studies conducted in this dissertation have several limitations:

Lab-based Experiments. Each conversation for the participants took 10 minutes in the controlled lab-based experiments. The short duration of each conversation may influence communication quality. A long-term intervention is still needed. We hope to conduct a long-term study in natural settings (e.g., family environments, classrooms).

Data collection. Our research used an eye-tracking system to collect gaze data to measure the engagement of sighted participants in conversations. We also gathered quantitative data of the communication quality from subjective questionnaires. Moreover, qualitative research methods such as *conventional content analysis* were used to analyze the results. Nevertheless, there is no quantitative data gathered to analyze the participants' emotion. We can try to evaluate the system using facial expression recognition, head pose recognition, and relevant bio-signals such as heart rate variability (HRV).

Sampling Methods. In our research, the blind participants were young students, and we recruited them from mainland China and Hong Kong. Considering that they are not a homogeneous group, the findings may have limitations to be generalized to the population of all blind individuals as they differ in age, visual impairments, educational background, personalities, etc.

7.4 Future Work

Scenario. In sociology, a dyad is a group of two people, regarded as the smallest social group (Charon, 1996). Hagad et al. (2011) suggested that dyadic conversations are "ideal for studying social behaviors since not only are they easier to observe, it is also easier to develop a social connection between participants" (p.614). Thus, a dyadic-conversation scenario has been used in our user experiments. In the future work, we will explore the effect of the simulated gaze in multi-party conversations that engage more than two people. As Sato and Takeuchi (2014) stated, people take various positions in multi-party conversations, such as being actively involved or being a good listener. In such conversations, simulating the gaze will be more challenging than in dyadic conversations, but also more interesting as a next step.

Sensing Positive Nonverbal Signals. Blind people are not active in the blind-sighted conversations, and they are often acted as listeners (chapter 6). One of the possibilities is they have the uncertainty about the attitudes of the sighted conversation partners due to a lack of visual information. It is helpful for blind people to perceive positive nonverbal signals from sighted people, to decrease their uncertainty in conversations. Such positive signals include facial expressions (e.g., smile or frown), body gestures (e.g., nod or shake the head) and hand gestures (e.g., thumbs up). Positive signals can encourage them to feel more confident in conversations.

Improving the Eye Animations. The eye animations of the E-Gaze glasses is based on the video clips of the realistic human-eye movements. The realistic eyes convey gaze information directly, and every sighted person can understand such information. However, some participants felt the realistic eyes looked horrible (Section 6.5.4.2). It is consistent with the "Uncanny Valley" Effect (Mori, 1970): if the similarity to humans' eyes has reached a certain point, the affinity may quickly become a disgust. It seems that no perfect solution can satisfy all users' needs. We may provide realistic eyes and the animated eyes according to users' requirements in different scenarios. For instance, a blind person can use a mobile phone to select the most suitable eye appearance for a certain scenario (Figure 7.1). The animated eyes can be used for the entertainment (e.g., cosplay), while the realistic eyes for a formal occasion (e.g., the meeting or presentation).

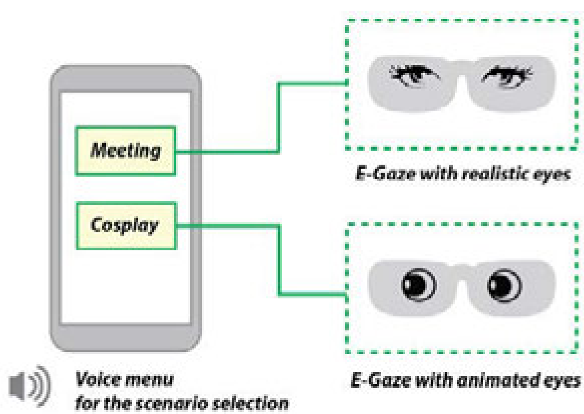


Figure 7.1 Scenario selection.

Feedback Consideration. In the user experiments, some blind participants described the tactile feedback was comfortable, to make them feel connected with the conversation partner. However, the tactile feedback still has some limitations. For example, "If being looked at by many people, what will be the vibration feedback of the E-Gaze?" (chapter

4). In a multi-person scenario, the auditory feedback may provide blind people with more precise information. It can directly tell a blind person that three people are now looking at him or her. We could explore other types of feedback used for the nonverbal signal perception of blind people, such as the sound, color, light, and temperature. For instance, if someone is approaching a blind person, the E-Gaze glasses will become warm.

Security Concerns. The investigation of Qiu et al. (2015a) showed that blind people concerned about the security when they made online friends in social media. One participant stated a blind person was easier to be cheated or involved in a dangerous situation than a sighted person. Blind people are less able to effectively monitor for privacy, security and safety risks (Ahmed et al., 2016). In Chapter 6, blind participants required strong tactile feedback, which could provide them with a sense of security. They also wished to expand the sensing area to their face or entire body, allowing them to keep alert if being looked. Overall, we should take this into design considerations for the future smart glasses system that can enhance their sense of safety in face-to-face communication.

Culture Influences. In our studies, most participants (chapter 3,5,6) are from mainland China and Hong Kong, and they did not have many cultural differences. Thus, we do not explore how culture affects gaze behaviors. Many researchers have studied gaze behaviors between eastern and western cultures (LaFrance and Mayo, 1976; Bond and Goodman, 1980; Argyle et al., 1986; Senju et al., 2013). Argyle et al. (1986) found that the rule "Should look the other person in the eye during conversation" was highly appreciated by English and Italian but not by Japanese and Hong Kong. Senju et al. (2013) investigated gaze behaviours of British and Japanese people when they looked at another person's face. The results supported "the Western cultural norms that value the maintenance of eye contact, and the Eastern cultural norms that require flexible use of eye contact and gaze aversion" (p.131). In our future work, we can try to implement the gaze model that is aware of cultural distinctions.

Appendix A

Questionnaires in Chapter 3, 4

Name (姓名):	Gender (性别):	Age (年龄):
Education (教育):	Occupation (职业):	Residence (居住地):

Part 1: Vision Conditions

1. Describe your vision condition.
   请描述一下您的视力情况。

   ____

   For instance: totally blind or low vision, with/without the light perception. Please provide descriptions of the medical diagnosis from the doctor.
   例如：完全失明或低视，是否有光感，请尽可能提供来自医院的诊断说明。

2. What is your cause of blindness?
   您的视力障碍是由于什么原因造成的？

   ____

   For instance: congenital blindness or any illness.
   例如：先天失明，后天疾病。

Part 2: Nonverbal Signals in Face-to-Face Communication

Nonverbal signals include body languages, facial orientation, facial expressions, eye contacts etc.
非语言信号包括手势、触碰、身体姿势、面部朝向、面部表情和眼神接触等。

1. Which nonverbal signal do you perceive in face-to-face communication (e.g., gestures, postures, face behaviors, facial expressions, gaze) and how do you perceive such nonverbal signals? Please give examples.

   您在与他人交谈中能察觉到哪些非语言信号 (比如：手势，身体姿势，面部行为，面部表情，眼神)？您是如何感知到的？请举例说明。

   ____

2. Can you perceive the moods of sighted conversation partners (e.g., happiness, anger or impatience) by nonverbal signals in face-to-face communication? If yes, how do you perceive? Please give examples.

   在谈话中您能通过非语言信号感知对方情绪吗（如: 高兴、生气、不耐烦）？如何感知？请举例说明。

   ____

3. Which problems do you meet in face-to-face communication due to a lack of visual cues? Please give examples.

   缺乏视觉的非语言信号可能会使您在交谈中遇到哪些问题？请举例说明。

   ____

4. Do you think eyes are important in face-to-face communication?

   您是否认为眼睛在双方交谈时起到重要作用？

   O Yes (是)

   O No (否)

5. Based on question 4, does anyone tell you or is it your opinion?

   基于问题 4， 这是别人告诉您还是您自己认为？

   O Someone told you (别人告知)

   O My opinion (自己认为)

   If it is your opinion, please give an explanation.

如果是自己认为，请解释说明。

____

6. How do people (e.g., your parents and teachers) explain the “eye” to you in your childhood?

   在您小的时候，其他人（比如你的父母和老师）是怎么跟您解释“眼睛”这个词的？

   ____

7. What do you think of the appearance of the eyes? What are the eye functions in conversations?

   您认为“眼睛”长什么样子？在交谈中起到什么作用？

   ____

8. “One person looks at the other person.” Can you explain “look at” based on your understanding?

   “一个人看着另外一个人。” 您基于自己的理解说明一下“看着”是什么意思吗？

   ____

Part 3: Design Proposals for Enhancing Nonverbal Communication

Xiao Ming is sixteen. He studies in a high school. He is visually impaired. His uncle gave him E-Gaze glasses as a Christmas gift last year. Xiao Ming wears the E-Gaze and starts a new experience.

小明十六岁，视障人士。目前在一所高中念书。小明的叔叔在去年圣诞节时送了一件礼物给他。礼物的名字叫做“E-Gaze”，可以戴在头上。自从佩戴了“E-Gaze”，小明开始体验了一种新的生活。

Scenario 1

Xiao Ming feels a slight vibration at the right side of his forehead from the E-Gaze. His head turns right and he wants to know who is looking at him. The artificial eyes of the E-Gaze start searching. After a short while, his sighted classmate Wang Wang comes, saying that: "I see you see me, and it reminds me to ask you a question." In this scenario, two features of the E-Gaze concept are presented: (C1) A slight vibration of the E-Gaze indicates the gaze from Wang Wang. (C2) When Wang Wang looks at the E-Gaze, it also looks back to establish the "eye contact."

场景一

小明感觉到来自“E-Gaze”的轻微震动，在右侧的前额上。他的头部转向了右侧想知道谁正在看着他。安装在“E-Gaze”上的人造眼开始启动搜寻。过了一会，小明的同学旺旺过来说道：“我有个问题想问你。看见你正好注意到我，就想起来了。”在这个场景中，“E-Gaze”包含两个设计概念。设计概念一：“E-Gaze”的轻微震动代表别人注视你的目光。设计概念二：当旺旺看着“E-Gaze”上的人造眼睛时，人造眼睛也正注视着旺旺,可以追随旺旺的目光。

Questions (问题):

1. Imagine that you are Xiao Ming in this scenario. What do you think of Concept 1 (gaze detection)?
您觉得眼神识别这个设计概念怎样？想像一下在这个场景中您是小明,请告诉我您的想法。

____

2. I find this idea useful. 我觉得这个设计概念很有用。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

3. This idea makes communication more efficient. 这个设计概念让交谈变得更有效。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

4. This is an interesting idea. 这是个有趣的设计概念。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

5. Imagine that you are Xiao Ming in this scenario. What do you think of Concept 2 (eye contact simulation)?
您觉得追随目光这个设计概念怎样？ 想像一下在这个场景中您是小明,请告诉我您的想法。

___

6. I find this idea useful. 我觉得这个设计概念很有用。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

7. This idea makes communication more efficient. 这个设计概念让交谈变得更有效。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

8. This is an interesting idea. 这是个有趣的设计概念。

O Strongly Disagree 完全不同意 O Disagree 不同意 O Neutral 中立 O Agree 同意 O Strongly Agree 非常同意

Scenario 2

Wang Wang looks at Xiao Ming all the time and seems very talkative about his study plan. Xiao Ming looks at him to show the politeness. After a short while, he feels bored for this endless talk. Wang Wang realizes and asks: “Are you still interested in my plan? I see you are sleepy now. Let’s change to your favourite topic. I find a beautiful girl in Class 3 […]” Xiao Ming’s eyes open bigger to indicate attention. In this scenario, the E-Gaze has two features: (C3) If the sighted gazes long enough, the E-Gaze closes the eyes to avoid the long gaze. (C4) The simulated eyes on the E-Gaze open bigger when the heart rate of Xiao Ming increases, indicating an “attention state.”

场景二

旺旺兴致勃勃和小明聊起了自己的学习计划。小明脸面向他试图保持礼貌，但厌烦了他的喋喋不休。过了一会，旺旺说：“小明, 你对学习计划感兴趣吗？ 你看上去昏昏欲睡啊，换个你喜欢的话题吧。三班来了一个漂亮的女生......” 小明睁开了眼睛，他的眼睛变大了，显得聚精会神。在这个场景中，“E-Gaze” 的人造眼睛包含两个设计概念. 设计概念三：如果别人注视人造眼睛时间很长，人造眼睛会自己进入“回避状态”，会自动中断长时间的注视。设计概念四：如果自己的心跳加速的话，人造眼睛会进入“兴奋状态”， 它会变大。

Questions (问题):

9. Imagine that you are Xiao Ming in this scenario. What do you think of Concept 3 (avoiding state)?
您觉得回避注视这个设计概念怎样？ 想像一下在这个场景中您是小明,请告诉我您的想法。

---

10. I find this idea useful. 我觉得这个设计概念很有用。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

11. This idea makes communication more efficient. 这个设计概念让交谈变得更有效。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

12. This is an interesting idea. 这是个有趣的设计概念。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

13. Imagine that you are Xiao Ming in this scenario. What do you think of Concept 4 (attention state) ?
您觉得兴奋状态这个设计概念怎样？ 想像一下在这个场景中您是小明,请告诉我您的想法。

---

14. I find this idea useful. 我觉得这个设计概念很有用。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

15. This idea makes communication more efficient. 这个设计概念让交谈变得更有效。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

16. This is an interesting idea. 这是个有趣的设计概念。

O Strongly Disagree 完全不同意　O Disagree 不同意　O Neutral 中立　O Agree 同意　O Strongly Agree 非常同意

Appendix **B**

Questionnaires in Chapter 5, 6

Name (姓名):	Gender (性别):	Age (年龄):
Education (教育):	Vision Conditions (视力情况):	
The dominant hand: O Right O Left O Right or left 您一般用哪只手来使用筷子及写字: O右手 O左手 O左手或右手		

The relationship with your conversation partner:
与您的对话伙伴的关系

- O We are familiar with each other and often speak.
  我们彼此熟悉，经常讲话。
- O We know each other and sometimes speak.
  我们彼此认识，有时会讲话。
- O We only know each other, but never speak.
  我们仅仅彼此知道，但从来没有讲过话。
- O We never meet each other.
  我们从来没有见过。

This questionnaire aims to investigate how you perceive in conversations. It includes 36 statements. For each of the following statements, please indicate how true it is for you, using the following scale: 1. Strongly Disagree, 2. Disagree, 3. Disagree somewhat, 4. Neutral, 5. Agree somewhat, 6. Agree, and 7. Strongly Agree.

该问卷旨在调查您在谈话中的感受。一共有 36 个陈述。请您判断与自己实际情况的符合程度。每个陈述后面有从 1 到 7 七个数字，分别对应表示“极反对”，“反对”，“有些反对”，“中立”，“有些同意”，“同意”和“极同意”这七种情况。请您在每个陈述后选择其中的一种情况。

1. I noticed (my partner).
我注意到（我的同伴）。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

2. (My partner) was easily distracted from me when other things were going on.
当其他事情发生的时候，（我的同伴）很容易分心，不再关注我。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

3.(My partner's) presence was obvious to me.
（我的同伴）的存在对我来说显而易见。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

4. (My partner) found it easy to understand me.
（我的同伴）很容易理解我。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

5. My presence was obvious to (my partner).
我的存在对（我的同伴）来说显而易见。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

6. I caught (my partner's) attention.
我吸引了（我的同伴）的注意力。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

7. I was easily distracted from (my partner) when other things were going on.
当其他事情发生的时候，我很容易分心，不再关注（我的同伴）。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

8. It was easy to understand (my partner).
我理解（我的同伴）很容易。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

9. I remained focused on (my partner) throughout our interaction.
在交流中，我依然聚焦在（我的同伴）身上。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

10. (My partner) remained focused on me throughout our interaction.
在交流中，（我的同伴）依然聚焦在我身上。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

11. Understanding (my partner) was difficult.
我理解（我的同伴）很困难。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

12. (My partner) did not receive my full attention.
（我的同伴）没有得到我全部的关注。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

13. (My partner) noticed me.
（我的同伴）注意到我。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

14. I did not receive (my partner's) full attention.
我没有收到（我的同伴）的全部关注。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

15. My thoughts were clear to (my partner).
我的想法对（我的同伴）而言很清楚。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

16. (My partner's) thoughts were clear to me.
（我的同伴）的想法对我而言很清楚。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

17. (My partner) had difficulty understanding me.
（我的同伴）很难理解我。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

18. I could tell how (my partner) felt.
我可以分辨出（我的同伴）的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

19. (My partner) could tell how I felt.
（我的同伴）可以分辨出我的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

20. (My partner's) emotions were not clear to me.
我不清楚（我的同伴）的情绪。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

21. (My partner's) behavior was closely tied to my behavior.
（我的同伴）的行为与我的行为紧密联系。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

22. (My partner) could describe my feelings accurately.
（我的同伴）可以非常准确地描述我的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

23. I was sometimes influenced by (my partner's) moods.
我有时候被（我的同伴）的情绪影响。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

24. (My partner) was sometimes influenced by my moods.
（我的同伴）有时候被我的情绪所影响。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

25. I could describe (my partner’s) feelings accurately.
我可以非常准确地描述（我的同伴）的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

26. (My partner’s) feelings influenced the mood of our interaction.
我的同伴的心情影响我们交流的气氛。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

27. My feelings influenced the mood of our interaction.
我的心情影响我们交流的气氛。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

28. My behavior was closely tied to (my partner’s) behavior.
我的行为与（我的同伴）的行为紧密联系。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

29. (My partner) caught my attention.
（我的同伴）吸引了我的注意力。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

30. (My partner’s) attitudes influenced how I felt.
我的同伴的态度影响我的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

31. My attitudes influenced how (my partner) felt.
我的态度影响（我的同伴）的感受。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

32. My behavior was often in direct response to (my partner’s) behavior.
我的行为常常根据（我的同伴）的行为做出直接反馈。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

33. The behavior of (my partner) was often in direct response to my behavior.
（我的同伴）的行为常常根据我的行为做出直接的反馈。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

34. My emotions were not clear to (my partner).
（我的同伴）不清楚我的情绪。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

35. I reciprocated (my partner's) actions.
我与（我的同伴）有互动。

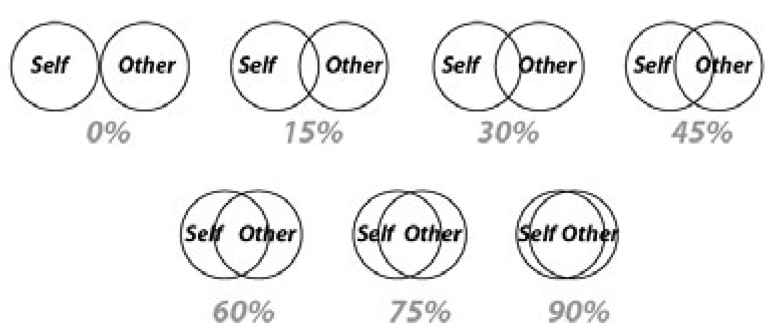
1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

36. (My partner) reciprocated my actions.
（我的同伴）与我有互动。

1	2	3	4	5	6	7
极反对	反对	有些反对	中立	有些同意	同意	极同意

IOS Scale was used to measure the closeness. It includes seven increasingly overlapping circle pairs. One circle stands for you and the other circle stands for your conversation partner. A growing overlap of the circle pairs illustrates an increasing closeness between two people. The overlap of two circles increases from 1 to 7. For instance: Option 1 stands for the overlap is 0%. Option 7 stands for the overlap is 90%. Please select the appropriate number that best describes your current relationship with your conversation partner.

图形问卷由两个圆形组成。一个圆形代表自己，另外一个圆形代表你的谈话伙伴。两个圆形的重合度逐渐递增，代表你和你的谈话伙伴的关系逐渐紧密。两个圆形相交重叠程度（即你和你的谈话伙伴的关系）由 1 到 7 逐步递增。例如：1 代表两个圆形相切，重叠 0%。7 代表两圆基本重合，重叠 90%。请选择合适的数字代表此时你和你的谈话伙伴之间的关系。



Appendix **C**

Qualitative Results in Chapter 5

We collected qualitative data of the participants from a questionnaire with six open questions: (Q1) interests towards the E-Gaze, (Q2) the perception towards the E-Gaze, (Q3) functions of the E-Gaze, (Q4) preference in the future design, (Q5) design suggestions, and (Q6) user experience of being blindfolded. The findings from Q2 and Q6 have been reported in Chapter 5. Here we report the findings from the other four questions.

Interests. Total 41 quotes were collected from the participants. Among them, 33 quotes mention interests and 8 quotes mention no interests (Table D.2). Example quotes are given below:

Table D.1 Interests towards the E-Gaze.

Participant Roles	Conversation Groups	Interests	Number of quotes
		Yes	6
Blind	Blind-sighted	No	6
		Total	12
Sighted	Blind-sighted	Yes	10
		Yes	8
Blindfolded	Blindfolded-sighted	No	1
		Total	9
		Yes	9
Sighted	Blindfolded-sighted	No	1
		Total	10
		Yes	33
Total	-	No	8
		Total	41

Category: interests

"Although the E-Gaze cannot convey emotions the same as the real eye contact, it is still useful to express my sincerity to the sighted." — BFS-BF15

"I will be distracted if there is no gaze or eye contact in conversations. Sometimes, there is a short silence in conversations, which makes me feel quite nervous and awkward. At that time, the E-Gaze can motivate nonverbal communication during the silence and effectively relieve my stress." — BFS-BF17

"I feel interested in the E-Gaze. In my school, the eyeballs of some blind classmates are removed by the surgery. Their eye appearance looks horrible. The E-Gaze can improve the eye and facial appearance of blind people."— BS-B17

Category: no interests

"It looks weird if the E-Gaze cannot match the face of a blind person well, which might have a negative impact on face-to-face communication."— BFS-BF9

The blind participants presented reasons to explain why they did not express the interest towards the E-Gaze. First, they could not realize the importance of the gaze and eye contact. Second, they did not know gaze functions in face-to-face communication. Third, they did not perceive any feedback when the E-Gaze reacted to sighted people.

Functions. Twenty-nine quotes mention the E-Gaze functions. Table D.2 presents four categories that emerged from the quotes: attention and engagement (10 quotes), attitudes (9 quotes), moods (8 quotes), and others (2 quotes). Example quotes are given below:

Table D.2 Functions of the E-Gaze.

Category	**Number of quotes**
Attention and engagement	10
Attitude	9
Mood	8
Others	2
Total	29

Category: attention and engagement

"It helps establish eye-to-eye communication between blind and sighted people, to promote the engagement in conversations."— BFS-S16

Category: attitude

"Let a sighted person realize that a blind person is paying attention to her. The sighted could feel being respected in face-to-face communication, to motivate equally communication between each other." — BFS-S20

Category: mood

"Be more open-minded and feel less nervous in conversations. The E-Gaze could provide a mental comfort for blind people." — BS-S6

Category: others

"I am blindfolded in conversations, and I do not think the E-Gaze has a direct impact on me."— BFS-BF7

Preference in Future Design. Thirty-nine quotes show the preference of the participants towards animated eyes (13 quotes) and realistic human's eyes (26 quotes) (Table D.3). The example quotes are given below:

Table D.3 Preference in eye appearance design of the E-Gaze.

Participant Roles	Conversation Groups	Preference in Eye Appearance	Number of quotes
Blind	Blind-sighted	Animated eyes	4
		Realistic human's eyes	6
		Total	10
Sighted	Blind-sighted	Animated eyes	4
		Realistic human's eyes	6
		Total	10
Blindfolded	Blindfolded-sighted	Animated eyes	3
		Realistic human's eyes	8
		Total	11
Sighted	Blindfolded-sighted	Animated eyes	2
		Realistic human's eyes	6
		Total	8
Total		Animated eyes	13
		Realistic human's eyes	26
		Total	39

Category: animated eyes

"I like anime. The animated eyes are cute and vivid (e.g., big eyes of the cartoon cats), which could make me feel pleasant. The realistic eyes seem a little bit horrible to display on the E-Gaze glasses." — BFS-BF19

"I love watching animated cartoons, but I cannot see their eyes. In my mind, their eyes are cute, beautiful, exaggerated and a little weird." — BS-B9

"I prefer the animated eyes. Compared with the realistic human's eyes, they are more cute and attractive to sighted people. If I wear the E-Gaze with the animated eyes, my sighted conversation partner could feel relaxed to communicate with me. Sighted people could easily overcome the possible discomfort when they confront blind people." — BFS-BF13

Category: realistic human's eyes

"The realistic human's eyes can express the gaze information directly, and every sighted person understand such information. The animated eyes look funny, but it may take some time for sighted people to understand which information they want to convey." — BFS-BF11

"The animated eyes may be lively, but not realistic. If a blind person wears the E-Gaze with the animated eyes, I feel she wears a mask to interact with me. The realistic eyes could express sincerity to me."— BFS-BF15

"I prefer to interact with the realistic eyes, providing me with the feelings of intimacy. The animated eyes may be used in a special scenario. " — BS-S12

Design Suggestions. Fifty-eight quotes describe design suggestions. Table D.5 presents four categories emerged from the quotes: (1) simulating the gaze, (2) providing the feedback, (3) sensing multiple signals, and (4) the physical appearance. The example quotes are given below:

Category: simulating the gaze

Sub-category: natural and realistic

"The simulated eyes of the E-Gaze should be more realistic […]" — BFS-BF5

Sub-category: synchronizing with facial expressions

"The simulated eye gestures could be synchronized with the facial expressions of blind people." — BS-S14

Sub-category: personalization

"I expect to select the eye appearance of the E-Gaze freely (e.g., single or double-edged eyelid, small or big eyes), which should match the face of a person." — BFS-S2

"I wish the E-Gaze has some personalized options such as simulating gaze behaviors based on different genders and personalities. " — BFS-BF15

Sub-category: self-controlled gaze

"I expect the E-Gaze can convey the feelings of blind people. They can use a certain hand gesture to control the specific eye gesture (e.g., looking down)." — BFS-BF9

Sub-category: 3D effect

"I expect an enhanced three-dimensional effect of the simulated eyes." — BFS-S4

Table D.4 Design suggestions.

Category	Sub-category	Number of quotes
Simulating the gaze	Natural and realistic	6
	Synchronize with facial expressions	3
	Personalization	3
	Self-controlled gaze	2
	3D effect	2
	Total	16
Providing the feedback	Vibration prompt	4
	Voice prompt	3
	Total	7
Sensing multiple signals	Signals from a blind person	8
	Signals from a sighted person	7
	Semantic analysis	5
	Distance towards the obstacle	2
	Total	22
Improving the physical appearance	Light and thin	6
	Portability	3
	Invisible design	2
	Wearability	2
	Total	13

Category: providing the feedback

Sub-category: vibration prompt

"I think voice prompt is not suitable. The auditory feedback may be annoying in conversations. The voice prompts interrupts the speaking of a teacher and the track of thought. Vibration feedback should be more feasible than voice prompts in a conversation scenario." — BS-B19

"I think a totally-blind person is more likely to demand the vibration feedback when being looked. Sometimes blind people feel scared about the surroundings because they cannot see anything. If they perceive the vibration feedback, they will feel relieved. We can use the mobile phone to provide vibration feedback. For example, if a sighted person is looking at me, my mobile phone will vibrate once." — BS-B11

Sub-category: voice prompt

“Voice prompt can be used when someone is looking at a blind person. It can directly say ‘a person is looking at you.’ It can also provide the information of gaze duration and gaze shifts.” — BS-B15

Category: sensing multiple signals

Sub-category: signals from a blind person

“I think it is impossible to express the mood of a blind person if only using eye gestures. Synchronizing facial muscles can enhance the effect of feelings. For example, a smile with cured eyes often shows happiness.” — BFS-BF17

“E-Gaze can be designed based on the heart rate (HR) of a blind person. If HR increases, the E-Gaze blinks more times than usual to show the nervousness of the blind person. Thus, the sighted conversation partner can immediately understand she is nervous, and change to another topic.” — BS-S2

“If the E-Gaze detects the physiological signals of a blind person and expresses such signals to a sighted person, it will cause a negative impact on the privacy. For example, a blind person may hate someone, but he can still pretend to like her. If the brain waves are recognized, he cannot hide the disgust.” — BFS-BF7

Sub-category: signals from a sighted person

“I expect the E-Gaze can provide me with the feedback of the gaze and facial expressions from the sighted. For example, let me know the sighted has a friendly smile or a cold smile. The cold smile indicates that the sighted is insincere and hostile to me.” — BS-B19

“I want to know the facial expressions of a sighted person (e.g., the smile).” — BS-B9

Sub-category: semantic analysis

“I expect the E-Gaze can display gaze behaviors based on the semantic analysis in conversations. Some given words in conversations can express particular emotions. If a blind person wants to ask some questions, the E-Gaze can use gaze behaviors to show his bewilderment. A sighted person may notice the E-Gaze suddenly light up when talking about some delicious food.” — BFS-BF1

“Gaze behaviors of the E-Gaze should be changed based on the conversation contents. If a blind person wants to stop talking and think for a while, he may look down rather than keep looking around.” — BFS-S10

Sub-category: distance towards the obstacle

“I expect the E-Gaze can detect the obstacle in front of me and provide the corresponding vibration prompt. I usually use a cane to find obstacles in surroundings, but it is less convenient than the glasses device.” — BS-B13

Category: improving physical appearance

“I suggest improving the wearability of the E-Gaze and making the glasses device more convenient to wear.” — BS-S18

“The physical appearance of the E-Gaze should be the same as the ordinary glasses.” — BS-S14

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Publications

Publications related to this dissertation:

Qiu, **S.**, Han, T., Rauterberg, M., & Hu, J. (2018). Impact of Simulated Gaze Gestures on Social Interaction for People with Visual Impairments. In *Proceedings of the 25th International Conference on Transdisciplinary Engineering* (pp. 249 - 258). Amsterdam: IOS press.

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Biography

Shi Qiu received a Bachelor of Arts (BA) in Industrial Design (2006) from East China University of Science and Technology (ECUST), a Master of Arts (MA) in Industrial Design (2009) from Shanghai Jiao Tong University (SJTU), and a Master of Design (MD) in Interaction Design (2012) from Hong Kong Polytechnic University (HKPU).

She has been a Ph.D. candidate at Department of Industrial Design, Eindhoven University of Technology since 2014, on the research topic "Social Glasses: Designing Gaze Behaviors for Visually Impaired People." She has been actively involved in scientific researches and has published 14 papers (first author: 12; second author: 2). Besides, she has been active in contributing to scientific events, such as being a publicity chair for the NGHAI workshop in 4th and 5th ACM International Conference on Human-Agent Interaction; serving as a reviewer for the ACM/IEEE International Conference on Human-Robot Interaction (HRI 2018); and demonstrating her work in public events (e.g., Dutch Design Week 2016).

Before starting her Ph.D. project, she had over five-year working experience in leading Internet companies in China: an interaction design expert in Ctrip.com (2013-2014), an interaction designer in Baidu.com (2011), and a UX designer in Alipay.com (2009-2011). She worked as an intern in Microsoft Research Asia (2008) and Shanghai Motor Group (2007-2008).