
The Design of Gaze Behavior for Embodied Social Interfaces

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Abstract

Non-verbal behavior, particularly gaze, is a crucial part of human communication. To interact with humans in a rich, natural way, social interfaces need to use this communicative channel effectively. While the role and mechanics of human gaze are extensively studied, how gaze might be used effectively by embodied interfaces is not well explored. The goal of my dissertation is to gain a deeper understanding of how gaze behavior affects people's interactions with embodied social interfaces and how we can design gaze for effective communication. This research focuses on four main social functions of gaze: *Regulation*, *Expression*, *Establishing Joint Attention*, and *Initiating/Avoiding of Social Encounters* and four sets of design variables: *Temporal*, *Spatial*, *Physiological*, and *Contextual*. A systematic study of how these functions and design variables affect each other is conducted through a series of empirical studies.

Keywords

Gaze, social gaze, embodied social interfaces, robots, modeling behavior, interaction design, user studies

ACM Classification Keywords

H.1.2 [Models and Principles]: User/Machine Systems – Human factors. H.5.2 [Information Interfaces and Presentation]: User Interfaces - User-Centered Design, Evaluation/methodology.

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Introduction and Background

Gaze—that is, the behavior of looking at sources of information such as another person—is considered, in humans and other primates, to be the strongest non-verbal communicative cue. We use our gaze to attend to others, show them what we are interested in, and likewise, evaluate others' gaze to interpret their direction of attention and intentions.

Kendon showed that people use their gaze to regulate conversations, particularly speaking and listening, signal turn-taking, and establish roles in social exchanges [5]. Gaze is also shown to communicate affect. Kleck and Nuesse found that people who look more are perceived as friendly, mature, and sincere, while people who look less are perceived as cold and submissive [6]. Gaze plays an important role in establishing joint attention and is found to be

correlated with language learning, even in infancy [2]. In public places, gaze is used to initiate or avoid social encounters by establishing or avoiding eye-contact [4].

The communicative functions of gaze make it an important element for the design of embodied social interfaces. For instance, Bailenson and others showed that when people interact in a virtual environment through avatars, they like each other more and feel more co-presence when the avatars employ gaze behavior than when the avatars do not [1]. Sidner and others showed that users engage with a social robot more when it employs appropriate gaze behavior [8].

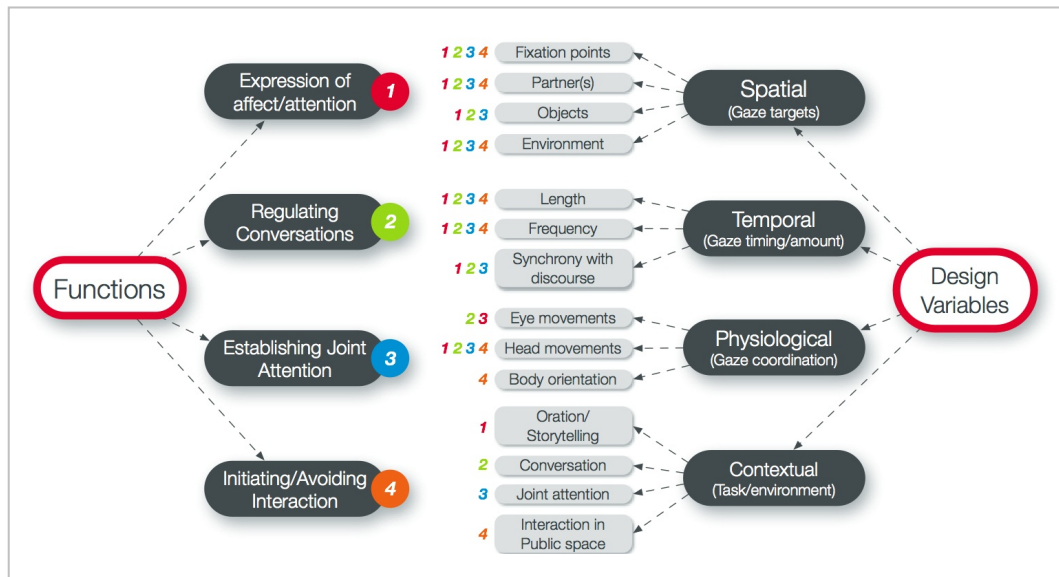
While these studies provide strong evidence for the importance of gaze behavior in the design of virtual and embodied social interfaces, a systematic study of how to design social gaze behavior is lacking. What are the design variables for social gaze behavior? How can we design effective social gaze behavior for robots? How do these variables affect human-robot interaction? My dissertation seeks answers to these questions in order to establish a deeper theoretical understanding of the role of gaze behavior in embodied social interfaces and to extract design variables and guidelines to inform the design of social gaze.

Figure 1 illustrates my proposed framework that summarizes the main communicative functions of gaze and design variables for creating humanlike gaze behavior, and highlights what my research has explored to date.

Research Design

The research described here addresses the lack of a systematic study of the design of social gaze behavior through a series of experiments that will allow us to gain a deeper understanding of the role of gaze in people's interactions with embodied interface agents

Figure 1. Functions and design variables of social gaze. The numbers **1, 2, 3,** and **4** represent conducted and planned empirical studies and indicate which design variables and functions are explored in these studies.



and create guidelines for the design of natural, effective gaze behavior. This exploration involves three major components:

- 1) The development of a framework (as illustrated in Figure 1) that encapsulates the main functions and design variables of social gaze derived from human communication research that sets the basis for research on designing gaze for embodied social interfaces,
- 2) The development of a methodology for designing and implementing human-like social gaze behavior using these design variables and models of human behavior derived from empirical data,
- 3) The evaluation of how different design variables shape the effectiveness and perception of the designed gaze behavior through manipulating these variables in a series of empirical studies.

Empirical studies involve the following process: An extensive literature review is followed by modeling of human behavior to design humanlike gaze behavior for the particular social context of my exploration. The underlying motivation for conducting this step is that in order to study the role of gaze in human-computer interaction, gaze behavior that is natural, sophisticated, and in synchrony with verbal behavior needs to be attained. The developed model is then implemented on an embodied interface platform using artificial intelligence and Wizard-of-Oz techniques. This is followed by an evaluation of the model through testing theoretical aspects of social gaze. The goal of this evaluation is to gain a theoretical understanding of how different design variables and their manipulation shape the effectiveness and perception of the designed gaze behavior and to evaluate the effectiveness of my gaze model.

Progress to Date

To date, I have conducted the first study and started developing two additional studies. The first study is concerned with the expression of attention in an oratory setting through adjusting the amount of gaze a robot exerts on people. The second study will be concerned with how gaze could be used to regulate conversations in a multi-party conversation. In the third study, I plan to look at how gaze could be used to establish joint attention with people. In this study, I also plan to explore aspects of eye and head coordination. A fourth study on designing gaze behavior for and understanding the role of gaze in initiating/avoiding social encounters is in the planning stage. Detailed descriptions of the first three studies are provided below.

Study I: Communicating Attention

In the first study, I explored how attention can be expressed through manipulating the amount of gaze. Research on the effects of gaze in educational settings shows that students learn better when they are looked at more [7]. Therefore, I created an interactive experience where I used a social robot to tell stories to an audience. I developed a gaze model that combined data collected from a human storyteller and an existing model of gaze behavior during speaking developed by [3]. The model was algorithmically implemented on the robot. In the experiment, the robot told stories to two participants. I manipulated how much each participant was gazed at to be 80% for one person and 20% for the other. The results showed that people who were looked at more performed significantly better in recalling the story ($F[1:16]=5.15, p=0.03$). The first experiment showed more gaze by an embodied social interface communicates attention and results in better learning in those who receive the gaze.

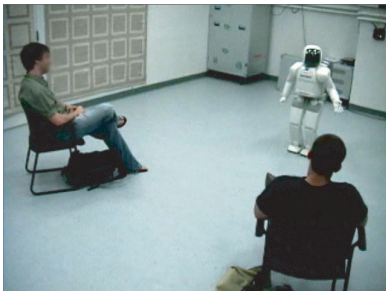
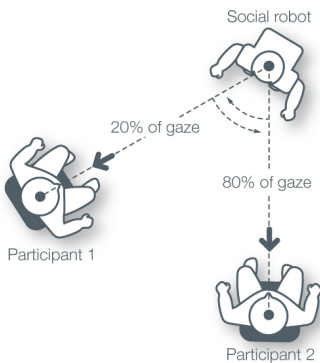


Figure 2. Experimental conditions, setup, and outline of Study I.

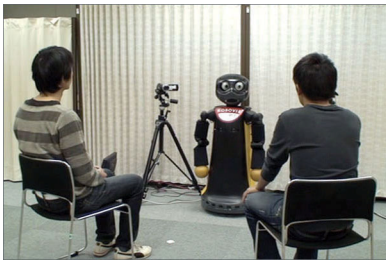
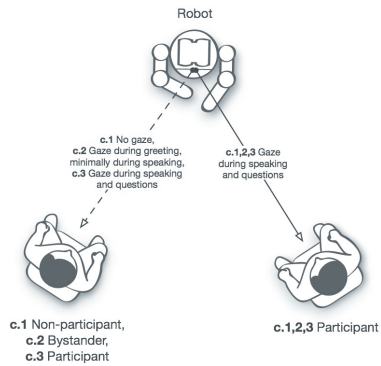


Figure 3. Experimental conditions, (pretest) setup, and outline of Study II.

Study II: Regulating Conversations

In the second study, I plan to explore how gaze can be used to regulate conversations, more specifically encourage non-participants of a multi-party conversation to be involved in the conversation or remain a non-participant. I am currently in the process of modeling conversational gaze behavior. I plan to create a three-party conversational situation where the robot will lead the conversation. I will manipulate the gaze behavior to follow (1) a two party-conversation model, (2) a two-party conversation model with a bystander, and (3) a three-party conversation model. I hypothesize that subjects who receive gaze as a bystander will feel more welcomed than those who do not receive any gaze and subjects who receive gaze as a participant will engage in the conversation more than those who receive gaze as a bystander.

Study III: Establishing Joint Attention

The third study will consist of two parts. In the first part, I will develop a gaze model involving both eye and head movements and implement this model on a more sophisticated social robot that can accommodate these movements. I plan to evaluate the effectiveness of using both eyes and the head over using just the head or just the eyes. In the second part, I will explore how my gaze model can be used to establish joint attention with people. I plan to create an experimental situation where the robot talks to a participant about an object that is not familiar to the participant. The gaze will be manipulated to be directed at the participant 80% of the time and at the object 20% of the time or vice versa. I hypothesize that when the object receives more gaze, participants will have better recall of the information presented to them, but when the participant receives more gaze, they will rate the robot as more sociable.

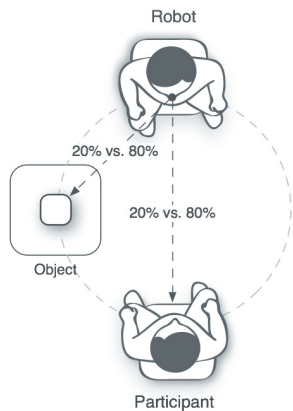


Figure 4. Experimental conditions and the outline of the second part of Study III.

Contribution to HCI

This research will contribute to knowledge in HCI in two ways. First, it will deepen our understanding of the role of gaze in our interactions with embodied social interfaces. Second, it will provide researchers and designers with design variables and guidelines for the design of gaze behavior for these interfaces.

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