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Design of a Gaze Behavior at a Small Mistake Moment for a Robot

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ABSTRACT

A change of gaze behavior at a small mistake moment is a natural response that reveals our own mistakes and suggests an apology to others with whom we are working or interacting. In this paper we investigate how robot gaze behaviors at small mistake moments change the impressions of others. To prepare gaze behaviors for a robot, first, we identified by questionnaires how human gaze behaviors change in such situations and extracted three kinds: looking at the other, looking down, and looking away. We prepared each gaze behavior, added a no-gaze behavior, and investigated how a robot's gaze behavior at a small mistake moment changes the impressions of the interacting people in a simple cooperative task. Experiment results show that the looking at the other gaze behavior outperforms the other gaze behaviors and indicates the degrees of perceived apologeticness and friendliness.

Key words: Communication robots, Gaze, Mistake, Mitigation

1. INTRODUCTION

Since human beings are fallible, completely preventing failures and mistakes is impossible. When we make mistakes, we have various strategies to mitigate them, such as apologizing or offering compensation. Even if the failure is minor, people do something to mitigate the unhappiness of others. Based on these considerations, we assume that since a robot will also experience failure and make mistakes, it will also need mitigation strategies. Because of the increasing development of robots that work with people [1~2], such a strategy for failures will become especially important.

How should a robot behave at the moment of a mistake? Even if current robots do not cause serious mistakes because of their limited uses, several researchers have started to investigate error recovery strategies from small mistake situations for robots [3~5]. For example, Lee et al. investigated appropriate robotic service recovery strategies using delivery robots: apologies, compensation, and user options [3]. Other research implemented an apology behavior for robots that interact with people at small mistakes during interaction [4, 5]

However, these research works only focused an error recovery during conversations, i.e., verbal behavior. In interactions between people, they often change their nonverbal behavior, e.g., looking at the other, looking down, and so on. Since nonverbal behavior is essential in interactions [6, 7], we believe that its design is also important for robot error recovery strategies that resemble those of humans.

Gaze is one essential nonverbal behavior to indicate a robot's intention [8]. In particular, eye-contact is an important social cue that positively improves impressions toward robots in various situations [9, 10]. These previous works show the significance of the gaze behavior of robots in human robot interaction, but they did not focus on the effects of gaze behaviors from the view of mitigation during mistake situations. It remains unknown how the robot's gaze behavior at mistake moments changes the impressions of others.

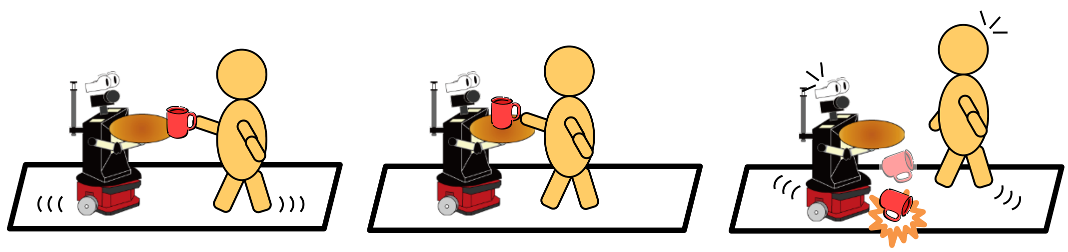

Fig. 1 Mistake: how should the robot change its gaze?

2. Data collection

Even though many works exist on gaze behavior in human-robot interaction [6-12], we found none that focused on the design of gaze behavior at a robot's mistake moment. So we investigated how people change their gaze behaviors at mistake moments by conducting a questionnaire-based data collection.

We can empirically imagine that people change their gaze behavior depending on two factors: social relationships and where the culpability lies. We asked participants to imagine a situation where they made a mistake in a cooperative task. They assumed that their social position is lower than the others (e.g., superiors, because people perceive robots as having

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relatively lower social positions [13, 14]) and that they are responsible for the mistake. They considered the following situation: "Describe how you change your gaze when you make a mistake in front of a superior."

Ten Japanese people (five women and five men whose average age was 20.5 years, standard deviation (S.D) was 2.0) participated in our data collection. They freely described the changes of their gaze behaviors at mistake moments when they themselves are responsible for the mistake.

We gathered 20 sentences from the data collection (ten sentences for both assumptions about responsibility). Two coders analyzed and classified the transcribed results. Cohen's kappa coefficient from their classifications was 0.964 and yielded the following classifications:

(a) Looking at the other: they looked at the face of the person with whom they were working

(b) Looking down: they looked down because they could not face the other

(c) Looking away: they looked away to avoid eye contact with the other

Table 1 shows each category for each assumption. The results indicated that people look down when they themselves feel responsible for the mistake; on the other hand, people look at the other when they blame that person for the mistake. Based on these results, we used four kinds of gaze behavior (three gaze behaviors and a no-gaze behavior) in our experiments.

Table 1 Number of each category in different assumptions

	Responsibility	
	on myself	on the other
Looking at other	1	8
Looking down	9	1
Looking away	0	1

3. Experiments

3.1 Hypotheses and predictions about apologies

An apology signals the admission of one's own mistake and suggests remorse and regret for the action. For example, people who fail in cooperative tasks provide such signals. In fact, our data collection suggests that people change their gaze behaviors at such moments. This strategy is used not only in daily situations but also in medical malpractice litigation, political contexts, and corporate culture [16].

A robot that works with people, e.g., doing a cooperative task, must be able to admit its own mistakes and offer apologies at appropriate moments. Past research also reported the importance of apologies from robots [3, 15]. To admit mistakes and apologize to others, gaze behavior at mistake moments would be useful. Based on these considerations, we made the following hypothesis:

Prediction 1 Gaze behavior at a small mistake moment will increase the degree of perceived apologeticness.

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3.2 Hypotheses and prediction for friendliness and dissatisfaction

Indicating an apology increases the degree of perceived friendliness and decreases the dissatisfaction toward the robot. However, as observed in the data collection, people change their gaze behavior depending on their feelings about the cause of the mistake. Since phenomena related to gaze behaviors at small mistake moments remain basically unexplored, we established two contradictory hypotheses toward friendliness and dissatisfaction.

3.2.1 Hypothesis that assumes advantages of looking down

Based on the trend from the data collection, we assume that when a person accepts responsibility for a mistake, he uses looking down behaviors to signal such intentions as "I'm sorry." This attitude increases the degree of perceived friendliness and decreases dissatisfaction. From these considerations, we made the following hypothesis:

Prediction 2-a: Looking down during small mistake moments will increase the degree of perceived friendliness toward the robot more than other gaze behaviors.

Prediction 3-a: Looking down during small mistake moments will decrease dissatisfaction toward the robot more than other gaze behaviors.

3.2.2 Hypothesis that assumes advantages of looking at the other

We also have an opposite assumption: looking at others is friendlier than other gaze behaviors, because past research on gaze behaviors suggested that eye-contact improves

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impressions toward robots [8-10]. Since looking down and looking away might be more ambiguous for displaying intentions than looking at others, we made the following hypotheses:

Prediction 2-b: Looking at the other at small mistake moments will increase the degree of perceived friendliness toward the robot more than other gaze behaviors.

Prediction 3-b: Looking at the other at small mistake moments will decrease dissatisfaction toward the robot more than other gaze behaviors.

3.3 Participants

Sixteen university students (eight women and eight men, whose age averaged 20.5, S.D. is 2.13) participated.

3.4 Tasks

To investigate the effects of the gaze behaviors, we adopted a simple cooperation task in which the robot first asked the participant to put an object into its hand. After taking it from the participant, the robot put it into a box, rotated its body and released its arms. This task was conducted twice in each condition. The robot successfully does the first trial, but in the second trial, it fails to put the object into the box.

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Fig. 2 Success

(a) Looking down **(b) Looking away** **(c) Looking at the other**

Fig. 3 Gaze behaviors during a mistake

3.5 Robot

In the experiment, we used Robovie-mR2, an interactive humanoid robot. To conduct a cooperation task with participants, we prepared four kinds of motions: 1) taking an object from a participant, 2) putting it into a box, 3) dropping it, and 4) changing gaze behaviors.

Fig. 2 shows both motions used in the first trial in each task. In the third motion, the robot also turns to its right as the second motion, but it slightly spreads its arms in the middle of the turn. The object falls without going into the box (left side of Fig. 3). The robot changes its gaze behavior depending on the conditions from the mistake moment; it waited one second after the mistake moment based on research of robot response times [17].

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3.6 Conditions

We used a within-participant experiment design to evaluate and compare the effects of the three gaze behaviors from our data collection and the no-gaze behavior. Note that the participants reported that in the down/avoid/look conditions, the robot looked appropriately at the mistake moments.

- No-gaze: when the robot fails, it does not change its gaze.

- Down: when the robot fails, it looks down (Fig. 3-a).

- Avoid: when the robot fails, it looks away (Fig. 3-b).

- Look: when the robot fails, it looks at the participant (Fig. 3-c).

3.7 Procedure

Robovie-mR2 was placed on a low table, and a cube was placed diagonally in front of it as a stand (Fig. 4). The box in which to drop the object was placed on the robot’s right. Participants sat in front of the robot. In the interaction, the robot asks for the object twice. The signal to start the trial was sent by the operator.

Before the first session, the participants were given a brief description of the experiment’s purpose and procedure. Each participant participated in four sessions. They filled out questionnaires after each session. The order of these conditions was counterbalanced.

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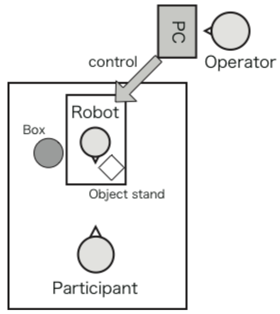

Fig. 4 Experiment environment

3.8 Measurement

To measure the subjective impressions, we prepared a questionnaire that addressed the apologeticness (the robot seemed to apologize), friendliness (I felt that the robot was friendly), and dissatisfaction (I felt dissatisfaction when the robot failed). After each session, participants answered on a 1-to-7 point scale, where "7" is the most positive and "1" is the most negative. They could freely describe their impressions of each gaze behavior.

4. Results

4.1 Verification of prediction 1

We analyzed the apologeticness (Fig. 5) by conducting a one-factor within subject ANOVA. Since Mauchly's test indicated that the assumption of sphericity was violated (chi-square=16.174, p=.007), we corrected the degrees of freedom using the Huynh-Feldt estimates of sphericity (epsilon=0.863). We found a significant difference among the conditions (F (2.589, 38.838) = 7.265, p =.001). Multiple comparisons with the Scheffe method revealed significant differences: look > no-gaze (p = .001), down > no-gaze (p = .003), and avoid > no-gaze (p < .001). Prediction 1 was supported.

4.2 Verification of prediction 2

We analyzed the perceived friendliness toward the robot (Fig. 6) by conducting a one-factor within subject ANOVA. We found a significant difference among the conditions (F (3, 45) = 15.496, p < .001). Multiple comparisons with the Scheffe method revealed significant differences: look > no-gaze (p < .001) look > down (p = .004), look > avoid (p = .005), down > no-gaze (p = .011), and avoid > no-gaze (p = .001). Prediction 2-b was supported, but not prediction 2-a.

4.3 Verification of prediction 3

We analyzed dissatisfaction with the robot (Fig. 7) by conducting a one-factor within subject ANOVA. Since Mauchly’s test indicated that the assumption of sphericity was violated (chi-square=15.083, p=.010), we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity (epsilon=0.604). We found no significant differences among the conditions (F (1.811, 27.164) = 2.853, p =.080). Neither predictions 3-a nor 3-b were supported.

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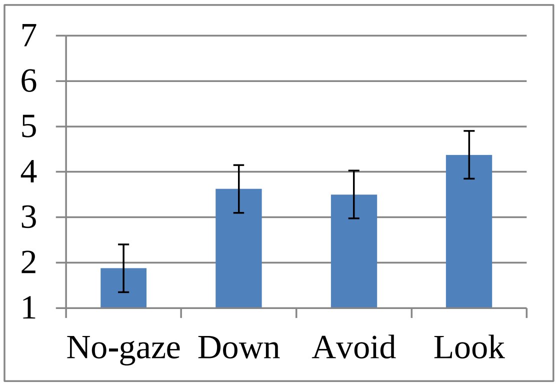

Fig. 5 Perceived apologeticness

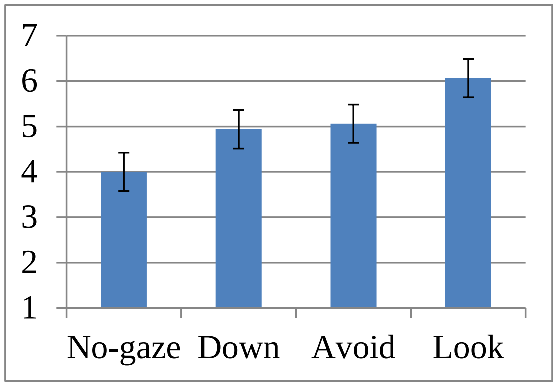

Fig. 6 Perceived friendliness

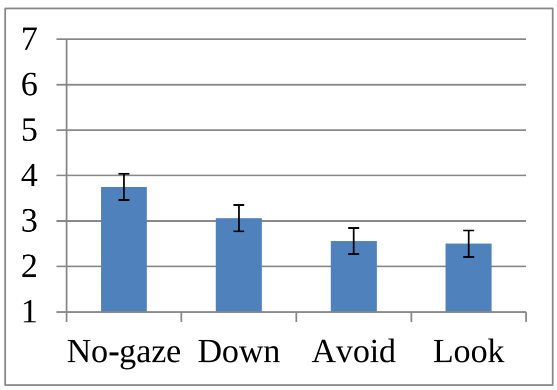

Fig. 7 Perceived dissatisfaction

5. Discussion

5.1 Analysis of free descriptions

Our results showed that the looking at the other condition outperformed looking down. Since this phenomenon is contrary to the results suggested by the data collection, we analyzed the free comments from the participants to determine why.

In our experiment, we gathered 64 sentences (16 for each gaze behavior). Two coders analyzed and classified the transcribed results from them. Cohen’s kappa coefficient from the coder classifications was 0.625, which showed moderate agreement. They yielded the following classifications:

(a) The robot seemed to notice and to reflect on its own mistake.

(b) The robot seemed to notice without reflecting on its own mistake.

(c) The robot didn’t seem to notice its own mistake.

Table 2 shows each category for each gaze behavior. The results indicate that the participants felt that the looking at the other condition provides more reflection.

Table 2 Number of each category of gaze impressions

	a	b	c
No-gaze	2	7	7
Down	6	6	4
Avoid	6	8	2
Look	11	5	0

5.2 Responsiveness to mistakes

In this study, we situated the responsibility for the robot's mistake in the cooperative task. However, in cooperative tasks in real situations, a person might fail even if the robots worked correctly, i.e., placing responsibility for the mistake on the person. In such situations, the gaze behaviors of the robot at mistake moments might have different impressions, e.g., blaming a person. Groom et al. investigated the effects of blame from a robot in cooperation situations and argued that blame negatively affected impressions of it [15]. Therefore, designing a gaze behavior at the mistake moments of people who engage in cooperative tasks with robots is fruitful future work.

6. CONCLUSION

We conducted an experiment during small mistake moments on four gaze behaviors: looking at the other, looking down, looking away, and no-gaze. Experimental results revealed that participants perceived apologies from the gaze behaviors at mistake moments and reported that the looking at the other condition increased the perceived friendliness more than the other conditions. This study provides useful knowledge for designing social robots that work with people.

7. ACKNOWLEDGEMENTS

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