Investigation of Basic Characteristics of Awareness Presentation Using Gaze of a Robot

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ABSTRACT

In our previous research, we proposed a voice call system with robots to initiate conversations between remote people by exchanging gaze information. In the proposed system, we implemented robots that can detect and present gaze as awareness information. When the mutual gaze is established via the robots, a voice call initiates. However, the basic characteristics (noticeability, comprehension, division of attention, telepresence) of the proposed system are not investigated. In order to investigate these basic characteristics, we conducted an experiment to compare the conditions using gaze, text, and light. In the experiment, the participants performed tasks on a PC and the awareness information is presented in the peripheral vision. The results showed that in the gaze and light conditions, the users needed less attention and easily understood the awareness information than in the text condition. In addition, in the gaze condition, users felt the presence of the remote worker more than in the text condition.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; *Collaborative and social computing devices*; *User studies.*

KEYWORDS

awareness, gaze interaction, communication robot, peripheral interaction

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1 INTRODUCTION

Initiating conversations, particularly informal communication, between remote people is difficult. Informal communication occurs incidentally, without a fixed schedule or agenda [1]. Previous research [4, 9, 10, 14] have proposed systems that provide awareness information for initiating conversations. Awareness is defined by Dourish et al. [2] as "an understanding of the activities of others, which provides a context for your own activity". By presenting awareness information, a worker can understand whether the remote person is available for conversations, and reducing the psychological burden of talking to the remote worker is expected. Previous systems for presenting awareness information can provide only availability (only responsive or unresponsive). In contrast, some systems can present detailed awareness information (e.g., degree of concentration of the remote person to tasks) as in face-to-face situations. Although these systems can provide detailed awareness information, privacy issues arise because of the use of a video [13]. In order to solve this problem, we proposed a system that presents detailed awareness information without using video.

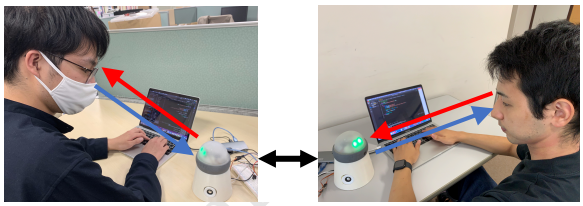

Figure 1: Using the proposed system in our previous research. Users' gazes are exchanged between remote locations using robots, and a voice call starts when the mutual gaze is established.

In our previous research [18], we implemented robots that can exchange gaze as awareness information between remote workers. The robots can detect and present the user's gaze. When the mutual gaze is established between remote workers via robots, a voice call initiates (Fig. 1). We intend to present awareness information implicitly using non-verbal information as in face-to-face communication. In addition, we expect improving the presence of the remote worker by the reproduction of face-to-face communication. However, we have not investigated the basic characteristics of the system, such as the noticeability and comprehension of the awareness information, and the division of attention to tasks when the awareness information is presented using non-verbal information. We have not investigated whether the presence of the remote worker improves as well. In this research, in order to investigate these basic characteristics, we conducted an experiment to compare methods of presenting awareness information using gaze, text, and light.

2 RELATED WORK

In this section, we describe our previous research that presents awareness information using the gaze of robots. Next, we describe

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related work on the basic characteristics for systems that present awareness information. At last, we describe basic characteristics in presenting awareness information using gaze.

2.1 The system that presents awareness information using the gaze of robots

We describe the proposed system in our previous research. The proposed system is fully described in [18]. This is just a summary of the proposed system. The proposed system aims to present detailed awareness information, which is presented in face-to-face communication, without using video. In initiating a conversation, gaze plays an important role and mutual gaze is a trigger for initiating a conversation [7, 8, 15]. Based on that, we have developed a system that reproduces the gaze exchange leading to the initiation of a conversation using robots (Fig. 1). We created two units of robots to place one robot on each desk with two remote workers. Users' gazes are exchanged with each other via the robots. Each remote worker sends his/her gaze to the robot, and when mutual gaze was established via the robots, a voice call starts. We conducted an experiment to investigate whether the proposed system is effective for initiating conversations. In the experiment, participants used the proposed system to initiate conversations in situations that assumed remote work. The result of the experiment suggested that the proposed system was partially effective in reducing the psychological burden of initiating conversations.

In the experiment, we used the proposed system in situations of communication. However, basic characteristics such as the noticeability and comprehension of the awareness information was not investigated when the awareness information was presented using gaze. In this research, we conducted an experiment to investigate the basic characteristics of the proposed system.

2.2 Basic characteristics for presenting awareness information to the peripheral vision

The previous studies investigated basic characteristics for presenting information to peripheral vision. Maglio et al. [11] stated that the key to peripheral informing is to maximize the information presented while minimizing the presentation's impact on ongoing activities. McCrickard et al. [12] suggest a classification of peripheral informing system, according to three critical parameters – interruption, reaction (rapid and accurate response), and comprehension. These researches show that systems for the presenting awareness information should be noticeable and comprehensive, but not distracting.

Handberg et al. [5] investigated the effect of presence on the communication model in the workspace and identified that sense of presence affects the level of trust and co-existence. Robert et al. [3] proposed a video system that increases a sense of a shared space between remote coworkers and stated that people need to be at the same place at the same time for initiating informal communication and the essence of telecommunication is co-presence. These researches show that the presence of the remote worker is important for the presentation of awareness information that leads to the initiation of conversations.

We consider the above basic characteristics of the proposed system that uses gaze. In the proposed system, we intend users to present and recognize detailed awareness information implicitly by using gaze as in a face-to-face situation. Therefore, users are expected to notice and understand the awareness information implicitly. In this case, noticeability and comprehension of awareness information may be improved. If users can recognize awareness information implicitly, division of attention is considered to be low because users need not pay attention to the information explicitly. In addition, the presence of the remote worker is expected to improve by the reproduction of face-to-face communication. In this research, we investigate the basic characteristics for presenting awareness information by the proposed system: noticeability, comprehension, division of attention, and telepresence.

3 EXPERIMENT

In this research, we conducted an experiment to investigate the basic characteristics of the proposed system.

3.1 Basic characteristics of presenting awareness information

In this research, based on the design of basic characteristics for presenting awareness information described in Section 2.2, we defined basic characteristics as below:

- **R1.** Noticeability: the degree that noticing the change of awareness information
- **R2.** Comprehension: the degree that understanding the awareness information
- **R3.** Division of attention: the degree of distracting worker's attention by awareness information
- **R4.** Telepresence: the degree that presenting presence of remote worker

If the degrees of R1, R2, and R4 are high and the degree of R3 is low, the basic characteristics of the awareness information is considered to be positive. We conducted an experiment to investigate these basic characteristics of the proposed system.

3.2 Experimental design

In the experiment, the participants performed tasks on a PC and the awareness information is presented in the peripheral vision. For the tasks on a PC (primary task), participants clicked and deleted a specified figure from a large number of randomly presented figures, referring to [6]. While performing the primary task, participants pressed the button located on the left side of the PC as soon as possible when they noticed the change in the awareness information. We set three states of the presented awareness information: inactive, active, and receiving. The inactive state indicates that the remote worker is not present, and he/she cannot respond because he/she is busy or absent. The active state indicates that the remote worker is present and can respond. The receiving state indicates that the remote worker is requesting a response. The transitions of these awareness states are shown in Fig. 2. We asked the participants to press the button when awareness information changed from the active state to the receiving state. In this experiment, we did not

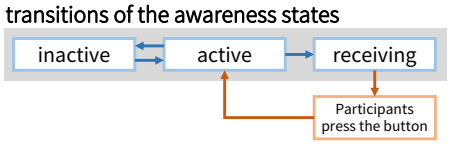


Figure 2: Awareness information changes during the experiment. The inactive, active, and receiving states are randomly changed, and the participant presses a button when he/she notices that the state has changed to receiving. If the button is pressed, the system returns to the active state.

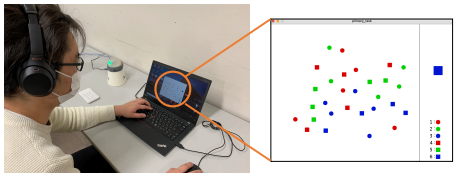


Figure 3: The experiment is in progress. Awareness information is presented at a 45-degree angle to the left while the participant is performing tasks on a PC. When the participant notices that the awareness state has changed to receiving, he/she presses the button located on the left side. In the primary task, participants clicked and deleted a specified figure from a large number of randomly presented figures

connect with the remote worker to present the awareness information but instead transitioned the state randomly to investigate the basic characteristics of the system, not its effect on communication. Participants played white noise using headphones to remove the effect from environmental noise.

3.3 Experimental condition

The experiment was conducted in a within-subject design. 12 undergraduate or graduate students (11 males and 1 female, mean age = 23.0 years) participated in the experiment. We recruited the participants from our laboratory. We set three experimental conditions as follows.

- **C1. text condition** The awareness information is presented by text in the display (Fig. 4). We set this condition in order to compare the proposed method and the method of presenting the awareness information by text in the display. Another display is placed and the text is displayed in the center of the display. The size of the text was designed to be 10cm wide × 3cm height, which is the same size as the information presented area of the other conditions. Text in the display indicates the states ("inactive", "active", and "messaging") of the remote worker. The text "messaging" indicates receiving state.
- **C2. light condition** The awareness information is presented by turning on a physical light (Fig. 5). This condition was set to compare the proposed method and the method without non-verbal information. In the inactive state, the light is turned off, and in the active state, the light is turned on the green. In the receiving state, the light will blink.

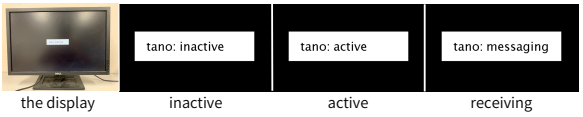


Figure 4: Awareness information presented in text condition.

Figure 5: Awareness information presented in the light condition.

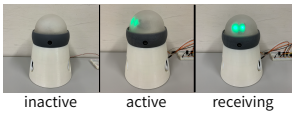


Figure 6: Awareness information presented in the gaze condition.

- **C3. gaze condition** The awareness information is presented by the gaze of the robot (Fig. 6). In the inactive state, the gaze is not presented (light off), and in the active state, the robot sends the gaze toward a different direction from the participant. In the receiving state, the robot sends the gaze toward the participant.

3.4 Evaluation items

The evaluation items in this experiment are described below.

Questionnaire

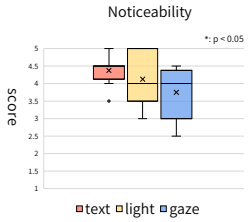
We used a questionnaire by Sadat [16] which evaluates methods of presenting information to the peripheral vision to evaluate R1, R2, and R3. We extracted three scales relevant to our experiment (*Noticeability*, *Comprehension*, *Division of attention*) from the questionnaire. For the evaluation of R1. Noticeability, we used the *Noticeability* scale, which consists of two questions (e.g. Did you notice the display). For the evaluation of R2. Comprehension, we used the *Comprehension* scale, which consists of two questions(e.g. Were you able to understand the information in the display). For the evaluation of R3. Division of attention, we used the *Division of attention* scale, which consists of three questions(e.g. Was the display located outside the focus of your attention). For the evaluation of R4. Telepresence, we used a questionnaire by Tanaka et al [17], which evaluated the presence of virtual avatars and physical avatars in communicative situations (*Telepresence*). *Telepresence* consists of a single question (Did you felt as if remote partner were in the same room). A five-point Likert scale was used to answer each questionnaire. After the completion of each condition, we conducted interviews with the participants.

Reaction time

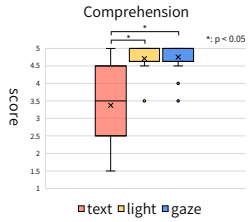
If the noticeability is high, the reaction time to the change of the awareness information is expected to be short. Therefore, to evaluate R1. Noticeability, we evaluated the reaction time. The minimum interval time of reaction time (= changes of awareness state) was 10 seconds.

Primary task grades

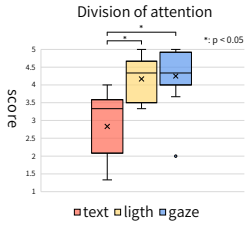
If the division of attention is lower, performance on the primary task is expected to be better. To evaluate R3, we evaluated the number of figures deleted in the primary task (primary task grades).



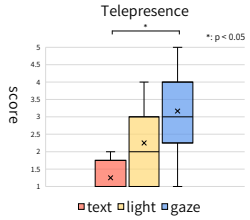
(a) The result of *Noticeability*.



(b) The result of *Comprehension*.



(c) The result of *Division of attention*.



(d) The result of *Telepresence*.

Figure 7: Results of the questionnaires.

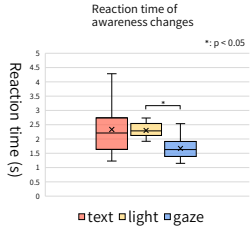


Figure 8: The result of reaction time.

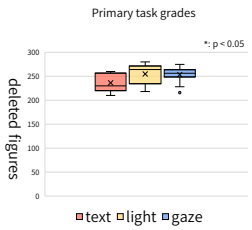


Figure 9: The result of primary task grades.

4 RESULTS

In this section, we describe the results for each evaluation item of the experiment. For each test in this study, a p value of less than 0.05 was considered statistically significant. In the analysis of the questionnaire, the mean value of each scale for each participant was used as the score for each scale.

4.1 Questionnaire

A higher score on *Noticeability* scale of the questionnaire means positive noticeability. The result of the *Noticeability* scale is shown in Fig. 7a. Shapiro-Wilk test showed no normality. Friedman's test showed significant difference ($p = 0.012 < 0.05$). Wilcoxon signed-rank test with Bonferroni correction showed no significant difference.

A higher score on *Comprehension* scale of the questionnaire means positive comprehension. The results of *Comprehension* scale is shown in Fig. 7b. Shapiro-Wilk test showed no normality. Friedman's test showed significant difference ($p < 0.001$). Wilcoxon signed-rank test with Bonferroni correction showed that score in *Comprehension* in the light and gaze conditions was significantly higher than in the text condition($p = 0.037 < 0.05, d = 0.74$ between light and text, $p = 0.011 < 0.05, d = 0.75$ between gaze and text).

A higher score on *Division of attention* scale of the questionnaire means lower Distractibility, that is, the awareness information does not distract the worker's attention. The result of *Division of attention* scale is shown in Fig. 7c. Shapiro-Wilk test showed no normality. Friedman's test showed significant difference ($p < 0.001$). Wilcoxon signed-rank test with Bonferroni correction showed that score in *Division of attention* in the light and gaze conditions was significantly higher than in the text condition($p = 0.016 < 0.05, d = 0.78$ between light and text, $p = 0.012 < 0.05, d = 0.83$ between gaze and text).

A higher score on *Telepresence* scale of the questionnaire means a positive effect of conveying presence. The result of *Telepresence* scale of questionnaire is shown in Fig. 7d. Shapiro-Wilk test showed no normality. Friedman's test showed significant difference ($p < 0.001$). Wilcoxon signed-rank test with Bonferroni correction showed that score in *Telepresence* in the gaze conditions was significantly higher than in the text condition($p = 0.016 < 0.05, d = 0.77$).

4.2 Reaction time

If the Noticeability is high, the reaction time is expected to be short. The results of reaction time is shown in Fig. 8. Shapiro-Wilk test showed no normality. Friedman's test showed significant difference ($p = 0.013 < 0.05$). Wilcoxon signed-rank test with Bonferroni correction showed that reaction time in gaze condition was significantly shorter than in the light condition ($p = 0.013 < 0.05, d = 0.85$).

4.3 Primary task grades

If the division of attention is lower, performance on the primary task is expected to be better. To evaluate the performance on the primary task, we used the number of figures deleted in the primary task (primary task grades). The result of the primary task grades is shown in Fig. 9. Shapiro-Wilk test showed no normality. Friedman's test showed no significant difference ($p = 0.067$).

5 DISCUSSION

5.1 R1. Noticeability

In the results of *Noticeability* scale of the questionnaire, no significant difference was shown. We initially thought that noticeability in the gaze condition would be better than in other conditions because of the use of light and motion, presented physically. However, the score of *Noticeability* in the gaze condition was not higher. Furthermore, Fig. 7a showed that the score in the text condition was higher. This result may reflect the degree of attention that participants paid to the awareness information. In the interview, we found that some participants interpreted the questionnaire as "needing to keep attention on the display". In other words, the results may reflect the ease of noticing by always paying attention to the display and becoming more sensitive to responses. We also considered that people present and understand gaze implicitly in face-to-face situation, so that participants might not notice change of awareness states.

In the result of reaction time, reaction time in the gaze condition was significantly earlier than in the light condition. On the other hand, in the interview of the gaze condition, the participant stated that "I sometimes noticed the changes by the sound of gaze turning". This interview suggests that not only visual information but also the sound of the motor to present gaze may have improved the reaction time of noticing awareness changes. This result is not appropriate for evaluation because the investigation of the noticeability by visual stimulus, not auditory stimulus was the purpose of our research. However, as shown in the result of the *Division of attention* scale, there was no effect on the division of attention. The participants wore headphones and the motor sound was reduced so that there may be no effect on the division of attention. This result suggests that in actual use, sounds that do not distract the worker's attention may improve the noticeability. These results suggest that presenting awareness information using gaze is unlikely to improve noticeability.

5.2 Comprehension

In the result of *Comprehension* scale, the light and gaze conditions have significantly improved the comprehension of the awareness information than the text condition. This result may have been because the information could be captured only in the peripheral vision. In the interview of the text condition, the participant stated that "I could immediately notice that the message content had changed, but could not understand the content unless I looked at it with their central vision". In contrast, in the interview of the light condition, the participant stated that "I was able to keep the display at the edge of my vision while performing the primary task". These comments suggest that the awareness information was comprehensive in the light and gaze conditions because the changes could be understood only in the peripheral vision. In addition, the average score in the gaze condition was 4.83 out of 5. These results suggest that R2. Comprehensibility is sufficient in the proposed system.

5.3 Divison of attention

In the result of *Division of attention* scale, the light and gaze conditions showed significantly less division of attention to the primary task than the text condition. This result can be attributed to R2. Comprehension. We thought that this is because the changes in the awareness information can be fully understood in the peripheral vision so that the participants can notice the changes while focusing on the primary task. In the interview of the text condition, the participants stated that "I had to keep paying attention to the display all the time" and "I had to check whether the display was active or not while doing primary task". In other words, when they cannot fully understand the changes of awareness information in the peripheral vision, they need to pay attention to the awareness information. On the other hand, in the interview of the light condition, the participants stated that "I did not have to worry that I might have missed changes," and in the gaze condition, "I was able to prepare to press the button because understanding active and inactive was easy. These comments suggest that when awareness information is comprehensive in the peripheral vision, there was no need to pay excessive attention to it.

In the result of the primary task grades, there was no significant difference. This result can be attributed to the fact that the task contents and the task time were limited. These results suggest that R3. Distractibility is low in the proposed system.

5.4 Telepresence

In the results of *Telepresence* scale, the gaze condition was significantly more effective in conveying the presence of the remote worker than the text condition. In the interview of the gaze condition, the participant stated that "I felt a strong sense of presence in the robot". This result showed that the proposed system is effective to present awareness information that leads to the initiation of conversations. This result suggests that R4. Telepresence is high in the proposed system.

5.5 Summary of results and discussion

In this experiment, we investigated the four basic characteristics of R1-R4. We considered that R1. Noticeability is not high. R2. Comprehension is considered to be sufficient. For R3. Division of attention, it was suggested that the proposed system has less distraction to the primary task. For R4. Telepresence, it is suggested that the proposed system conveys a high degree of presence of the remote person.

The results of R1-R4 suggest that when the gaze is presented as awareness information, the awareness information is sufficiently comprehensive and the distraction to the task is low. In addition, the degree of conveying a sense of presence was high. It was suggested that the basic characteristics of the proposed system for presenting awareness information were sufficient.

From these results, we think that the proposed system is useful for communication during remote work. In remote work, we need to focus on the primary task. In the proposed system, we may be able to convey the awareness information for initiating conversations while focusing on the primary task because the division of attention is low. In addition, the proposed system may create a sense of co-presence by conveying the presence of a remote worker. Robert et al. [3] stated that the essence of telecommunication for initiating informal communication is co-presence. The proposed system is considered to be effective to initiate conversations because of conveying the presence. In this research, we focused on initiating conversation. We would like to investigate the effect of the robots' presence during conversations (e.g. contents of conversations, how users feel).

6 CONCLUSIONS AND FUTURE WORK

In this study, we investigated the basic characteristics of the system that presents awareness information using the gaze of the robot, which we proposed in our previous research. The following results were obtained from the experiment.

- The awareness information presented by using gaze is considered to be sufficiently comprehensive.
- It was suggested that the awareness information presented by using gaze was less distracting to the primary task.
- It was suggested that the awareness information presented by using gaze conveyed a high degree of presence of the remote worker.

The results suggest that the basic characteristics of the proposed system for presenting awareness information may be sufficient. This experiment was conducted in an environment where the task contents and task time were limited. In the future, we plan to investigate the basic characteristics of the proposed system when it is used in a real environment.

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