Development Report:

Design and Evaluation of Attention Guidance Through Eye Gazing of "NAMIDA" Driving Agent

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The driving agents considered thus far have aimed at navigating the driver's attention while driving, for example, using interactions through linguistic conversations. Therefore, in this study, to investigate such a role in automatic driving from the perspective of nonverbal communication focusing on physicality (e.g., head movements and eye gaze), we constructed a driving agent called NAMIDA, along with its physical properties, as a research platform to investigate the role of nonverbal communication. We conducted a cognitive experiment on attention guidance, focusing on "gaze direction," i.e., the movement of the eyes of NAMIDA. As a result, we confirmed that the attention of the participants is attracted by such eye-gaze movements of "NAMIDA," which become a "cue" to exploring the surroundings.

Fig. 1. Dashboard-embedded driving agent NAMIDA, which functions as an interface between autonomous driving system and driver.

1. Introduction

To bring about the realization of connected cars and autonomous driving systems, along with autonomous-driving and driving-assist technologies, an interface that facilitates communication between the vehicle and driver is increasing in importance. In addition to display and operations by meters on the instrument panel and touch panels, display methods such as head-up displays (HUDs) and liquid crystal displays (LCDs) have recently been put to practical use. Moreover, studies are being carried out on driving agents, which serve as intermediaries of communication between the vehicle and driver as an extension of car navigational functions. As an extension of question-answering functions employed in smart speakers, these driving agents are designed to present road conditions or assist the driver and answer queries asked by the driver. They are also expected to be used to assist elderly or novice drivers.

We are also carrying out research and development of driving agents, of which there are two types: 1) NAMIDA[0], a standalone unit characterized by a multiparty conversation interaction approach with the driver, and 2) NAMIDA, a dashboard-embedded unit (**Fig. 1**), which functions as an interface between the autonomous driving system and the driver. The objective of this study is to verify and evaluate the gaze guidance function of the latter, which is expected to serve as the interface with an autonomous driving system.

Communication between the vehicle and driver is essential even when the autonomous driving system takes over driving tasks from the driver. As symbolized by a scene in which the driver's hands are cautiously removed from the steering wheel during a demonstration of an autonomous driving system, it is difficult for the driver to guess the internal state or intention of the system, or in other words, to know what state the autonomous driving system is in, or what it is going to do next. Furthermore, communication between the driver and vehicle is also essential for a collaborative action when the driver must respond to an emergency when a level-3 autonomous driving system [a] is used.

We developed the driving agent NAMIDA to address

these issues and it consists of three simple agents. These agents, which are capable of operating collaboratively, rotate their heads to point in certain directions, and can display the state of the vehicle by blinking or changing the colors of the LED lights. The agents are also capable of communicating information by spoken language, and depending on the application, can provide navigational functions to assist the driver. In this paper, we focus on the gaze movements of NAMIDA used to express its intention. We describe a gaze guidance verification experiment conducted to verify and evaluate the capacity of NAMIDA to transmit nonverbal information among its physical movements. Specifically, we verify whether the gaze movements of NAMIDA can induce the driver's gaze, and to what extent, using Posner's spatial cueing task.

The remainder of this paper is structured as follows. The next section outlines the background and relevance of this study, and Section 3 describes the concept and system configuration of NAMIDA, the driving agent used as the study platform. Section 4 describes the gaze guidance experiment and discusses the results. Finally, Section 5 presents some concluding remarks and future issues to be addressed.

2. Study Background

2.1. Driving Agent Connecting the Vehicle and Driver

Car navigation systems have been widely used to provide route guidance and road information to drivers. In connected cars, which maintain a constant connection with a network or allow collaboration with other vehicles, as well as provide road information, the possibility exists to present information on stores and tourist attractions in the surrounding area. Systems are also being studied that apply a question-answering function employed in smart speakers to respond to the driver's queries. Furthermore, studies are also being undertaken on driving agents that provide information through social interactions by integrating personal communication robots and advanced navigational functions.

Representative examples include PIVO2 [b], a concept car announced by Nissan Motor Co. in 2007; an Affective Intelligent Driving Agent [1, 2], proposed in 2009 by a group consisting of the Massachusetts Institute of Technology Media Lab and Volkswagen of America; and the recent KIROBO mini [c] developed by Toyota Motor Co., Ltd. In addition to simple navigation, these agents provide information suitable to the driver's condition or on the area currently being navigated, and serve as a driving companion.

2.2. Driving Agents NAMIDA^0 and NAMIDA

The interaction between the driving agent and driver is also an interesting subject from the viewpoint of human-robot interaction (HRI). Such interaction takes place in the vehicle compartment, which is a relatively quiet personal space, and the user is usually the same driver. Sensors, cameras, and CPUs do not necessarily have to be housed in the driving agent and can be embedded into various locations within the vehicle.

Conventional driver-agent interactions have often been premised on one-to-one communication, similar to the interaction mode of general communication robots, which has given rise to particular issues. For example, to maintain a dialogue with the agent, (a) the driver may be distracted from driving, or (b) the driver may become burdened by the need to respond to the agent's interactive dialogue, placing a constraint on the driver's behavior. To address such issues, we developed the driving agent NAMIDA^0 that consists of three agents and it is characterized by a multiparty conversational interaction with the driver. The conversation can be maintained among the three agents, which allows the driver to join the conversation when desiring to do so, or to ignore the conversation as a bystander when it is necessary to concentrate on driving. Previous studies have confirmed that this framework can reduce the driver's cognitive load and prevent the driver from becoming distracted through an interaction with the agent [3–6].

2.3. Communication Between Autonomous Driving System and Driver

Because autonomous driving systems use information from various sensors to autonomously control the actuators such as the engine or motor, they can be considered a type of autonomous robot. However, the internal state of an autonomous driving system is insufficiently displayed, and thus the driver and passengers have difficulty guessing "what it is thinking at the moment or what it is attempting to do," and can thus become needlessly concerned. Furthermore, with a level-3 autonomous driving system [a], a high level of communication must take place between the driver and vehicle to execute joint action in the case of an emergency.

Taking into account such considerations, we have been developing NAMIDA, a dashboard-embedded agent that functions as a social robot in unison with the autonomous driving system. Considering the three agents, as with NAMIDA^0, NAMIDA is designed to indicate its intention through gaze movements and the system's internal state using the blinking of LED lamps. For instance, if NAMIDA's gaze points to a red traffic light as the autonomous driving system decelerates, it should make the driver and passenger aware that "the autonomous driving system has recognized the red signal and is beginning to decelerate." If the system recognizes a pedestrian and applies the brakes, NAMIDA's gaze movements can call the driver's attention to the pedestrian. Furthermore, if NAMIDA can accurately convey to the driver the lowered reliability of the sensor functions of the autonomous driving system whenever it occurs, it may serve to draw out the driver's readiness [7]. To make such scenarios possible, we have been working to apply NAMIDA's gaze

Fig. 2. External appearance of NAMIDA, designed based on minimal design and characterized by three agents and their gaze movements.
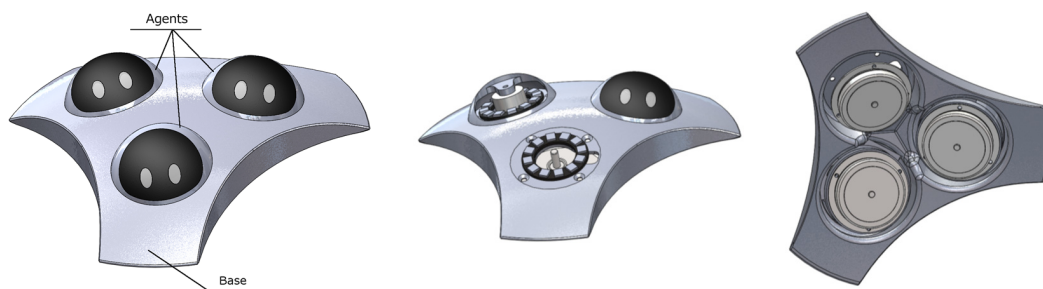

Fig. 3. Hardware configuration of NAMIDA. Three agents arranged on the base (left); housing of full-color LED ring arrays emitting light (center); the rotational angles of the agents are controlled by brushless motors mounted at the bottom (right).

movements to indicate the safety of an autonomous driving system [8], including its reliability and acceptability, and to evaluate and verify the effect of guidance provided to the driver's gaze. In this paper, we report on the latter aspect.

3. Research Platform, NAMIDA

This section describes the design concept and system configuration of NAMIDA. The multiparty interactive driving agent was developed as a platform to investigate the driver's communication with the driving agent during autonomous driving.

3.1. Minimal Design

The use of a minimal design is one approach for designing a robot's external appearance and interactions. This is a design guideline based on the idea that one can draw out the active involvement of the user by limiting the external appearance or functions of an artifact by engaging the human act of attaching meanings that reflects situational or contextual changes [9, 10].

In the case of interactions with a driving agent, the driver's interpretation of the intent behind the behavior of an agent robot with many modalities, such as verbal conversation, gestures, and eye gaze, will accompany a level of complexity. The aim of our system is to display the agent's intention, that is, the current target of the vehi-

cle's attention, and the vehicle's recognition of its current state. As the minimally required element to achieve this end, we felt that gaze-based interactions would suffice. Thus, this paper describes a driving agent design that focuses on gaze movements.

As shown in **Fig. 2**, NAMIDA is characterized by communication that takes place with three agent units. Because communication is achieved by the agents, which take turns in a multiparty interaction to assume the roles of "speaker," "listener," and "bystander," the driver's response load is reduced [3–6].

3.2. Hardware Configuration

The hardware configuration of NAMIDA is shown in **Fig. 3**. Designed to be installed on the dashboard of a vehicle, NAMIDA consists of three agents that simulate heads mounted on a robot base.

The robot base houses three maxon EC45 ϕ42.8 mm brushless motors to drive the agents. Their rotation is measured using Hall sensors mounted on the motors. The brushless motors are controlled using exclusive EPOS2 24/2 controllers. An EPOS2 is connected to the control PC, which is set up outside the robot, and transmits simplified control instructions to carry out optimum control by referring to the motor's state, which is monitored by the EPOS2.

Each agent's head houses a NeoPixel Ring-12, which is a full-color 12-LEDs ring array manufactured by Adafruit Industries (in the center of **Fig. 3**). The areas of the head

Fig. 4. NAMIDA operating in real time to deal with road conditions displayed by a driving simulator.

that correspond to the agent's eyes are fitted with milk-white, semi-transparent acrylic boards. The driver is able to readily recognize the agent's gaze direction by the LED light emanated from these sections. The LEDs were controlled using an Arduino Uno onboard microcontroller. In the same manner as with the motor drivers, the external PC transmits instructions to control the blinking. The agents' eye colors and blinking periods can be controlled in various ways according to the status of the driving agent.

3.3. Software Configuration

There are several modes for controlling the EPOS2 motor driver. We used profile position mode (point-to-point (PTP) control) to compute the accurate position control and acceleration/deceleration to achieve a trapezoidal profile control. The full-color LEDs were controlled using Arduino and a control library for AVR microcontrollers, both provided by Adafruit. Control signals transmitted from the PC to Arduino Uno are used to change the color (RGB value), brightness, period, and blinking pattern. Two blinking patterns were used, i.e., random blinking and blinking with a specific periodic function.

3.4. Connection with Driving Simulator

NAMIDA can be used with a driving simulator (**Fig. 4**). The simulated driving image is displayed on three monitors installed above the vehicle's dashboard. UC-win/Road by Forum8 was used as the simulation software. A data log output plugin is used to transmit the driving conditions to NAMIDA through UDP communication during the simulation in real time.

4. Experiment Conducted to Evaluate Gaze Guidance by NAMIDA

In this experiment, we focus on the display of intentionality, as expressed by NAMIDA's gaze movements. Herein, we describe the experiment to verify the gaze guidance, that is, to what extent NAMIDA's gaze movements are able to guide the driver's gaze (line of sight), as well as the results.

4.1. Objective

We employ Posner's spatial cueing task [11] to examine whether NAMIDA, with three agents, can provide gaze guidance to the driver.

Many studies have been conducted on eye-gaze capture by robots. As a method of drawing attention using physical expressions, Otsuki et al. [12] suggested that the gaze of an artificial "eye" can be used to guide a person's gaze direction. In addition, Sato and Takeuchi [13] found that the eye-gaze direction of a robot included in a multiparty interaction affects the turn-taking process among the participants. Furthermore, Stanton et al. [14] reported that a robot's gaze can affect human decision-making.

These studies on attention guidance have mainly dealt with situations in which the robotic agent and human user face each other. In a situation in which the robot and human user are positioned side by side facing the same direction, Kuno et al. [15] examined the percentage of subjects whose attention was induced by the robot's head movements, thus suggesting the possibility of attention guidance based on physical expressions. In the present study, which considers attention guidance in a vehicle, we assume a setting in which the driver and robot are positioned side by side to face the target, and examine the effect of attention guidance by considering the user's response time against the robot's cue instead of the probability of guidance.

4.2. Spatial Cueing Task

Attention plays a major role in the processing of visual information in a human's recognition of the environment. Posner's spatial cueing task [11] is a method for quantifying the effect of spatial attention. Under an experimental setting, the subject is instructed to gaze at the screen, and press the button in front as quickly as possible when a target is displayed in one of the boxes located on the left and right sides of the screen.

The subject is given a cue regarding the target's position before it is displayed. During each trial, the cue may be correct or incorrect, may not be given, or if given, may be meaningless as a cue. Such a trial is termed congruent, incongruent, or neutral, respectively. When the cue is indeed guiding the subject's attention, the response time in a congruent trial is known to be shorter than that in a neutral trial, whereas that in an incongruent trial is known to be longer than that in a neutral trial. We consider the difference in response time to be the attention effect.

To examine the effect of cueing, Driver et al. conducted an experiment that demonstrates the validity of a person's gaze used as the cue in a spatial cueing task [16]. Whereas this involves the gaze of a person (photographed), the present study examines whether similar effects can be achieved by the gaze of a minimum-designed low-anthropomorphic robot. This is important for evaluating NAMIDA's capacity to transmit nonverbal information and its social characteristics.
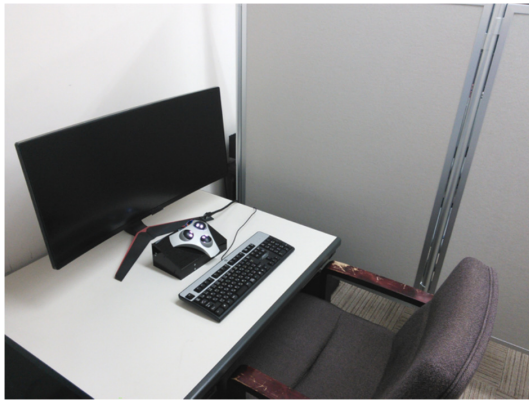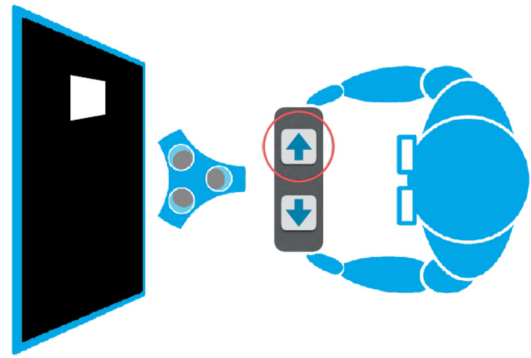
Fig. 5. Experiment setting.

Fig. 6. Experiment task: the subject is instructed to press the direction key (left or right) on the keyboard as soon as the subject notices the white square (target) on the screen.

Fig. 7. Experiment conditions: congruent clue, in which all three NAMIDA agents gaze in the direction of the target that will be displayed (left); incongruent clue, in which all agents gaze in the direction in which the target will not be displayed (center); neutral clue, in which the agents gaze in three different directions (right).

4.3. Experiment Setting

During the present experiment, NAMIDA's gaze shift was used as the cue in a spatial cueing task. The objective here is to verify whether NAMIDA's behavior is capable of drawing the subject's attention.

To carry out the task, the subject sat in front of a desk upon which a PC monitor and keyboard were placed (**Fig. 5**). The monitor displayed a black background when the experiment began. NAMIDA, which was placed between the subject and monitor, then began to display cues based on the conditions described below, after which the target, which was a white square, was displayed on either the right or left side of the monitor. The subject was instructed to press one of the direction keys (left or right) as soon as the subject noticed the target on the screen (**Fig. 6**). A single trial consisted of the time NAMIDA displayed a cue to the time the subject pressed a key. Each subject undertook a total of 400 trials, divided into two sets of 200 trials each.

In addition to the above trials, we added catch trials, in which no target was displayed on the screen following NAMIDA's cue. This was done to prevent the subject's concentration from deteriorating. The subject was instructed not to press the key if no target was displayed. The catch trials made up 10% of the trials conducted. The

neutral trials also made up 10%. The remaining 80% consisted of congruent and incongruent trials. The former, which is important for verifying NAMIDA's gaze guidance, made up 80%, and the latter made up the remaining 20%. The trials are described in the following section.

4.4. Experiment Conditions (Trials)

The experiment involved two factors: the type of cue employed in the spatial cueing task (three conditions) and the stimulus onset asynchrony (SOA), that is, the time lag until the target was displayed (three conditions).

4.4.1. Cue

Referencing a previous study [16], we set up three conditions for the cue.

- Condition 1: congruent trial

  The three NAMIDA agents all directed their gaze in the direction of the target to be displayed (**Fig. 7**, left).

- Condition 2: incongruent trial

  The three NAMIDA agents all directed their gaze in a direction where the target would not be displayed (**Fig. 7**, center).
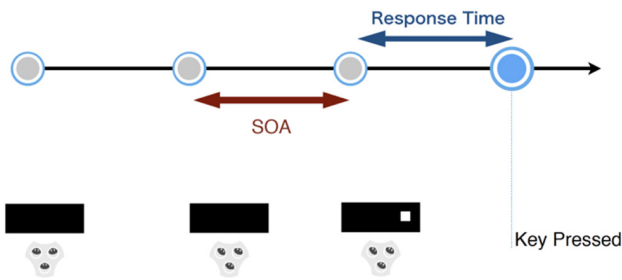
Fig. 8. Time between ending of NAMIDA cue and target appearance on screen (SOA) is set at 200, 400, and 800 ms. The target is displayed at the end of the SOA, and the response time between the target appearance and pressing of the key by the subject is measured (response time for a single trial).

Fig. 9. Average response time [ms].

- Condition 3: neutral trial

  The three NAMIDA agents directed their gazes in three different directions (**Fig. 7**, right).

4.4.2. Stimulus Onset Asynchrony (SOA)

Based on a previous study [16], the stimulus onset asynchrony (SOA, **Fig. 8**), that is, the period between the time when the NAMIDA's cue ends and the time when the target first appears on the screen, was set to 200, 400, and 800 ms.

4.5. Subjects

A total of 15 subjects (11 men, 4 women; average age of 25.5; standard deviation of 8.7; age range of 20–40 years) participated in the experiment.

4.6. Results

The response time of all subjects, that is, the time between the target's appearance and the subject's pressing of the key, was calculated for the different conditions. Trials with incorrect responses, trials in which the response time was 100 ms or less, and trials in which no response was given for 2500 ms or more were omitted from the analysis as erroneous responses. The results were as follows.

When the SOA was 200 ms, the average response times of the congruent, neutral, and incongruent trials were 420.6, 458.1, and 475.0 ms, respectively. Thus, the response was quickest in the congruent trials, followed by the neutral and incongruent trials. When the SOA was 400 ms, the respective response times were 425.5, 445.6, and 461.7 ms. The response was quicker in order of congruent, neutral, and incongruent trials, as before. When the SOA was 800 ms, the respective response times were 416.0, 439.4, and 431.5 ms. Although the response of the congruent trials was the quickest, this was followed in order by the incongruent and neutral trials, unlike with the other SOAs. To summarize, the response time of the congruent trials was lower than that of either the neutral or incongruent trials regardless of the SOA, whereas the pattern of the response time was different for long and short SOAs.
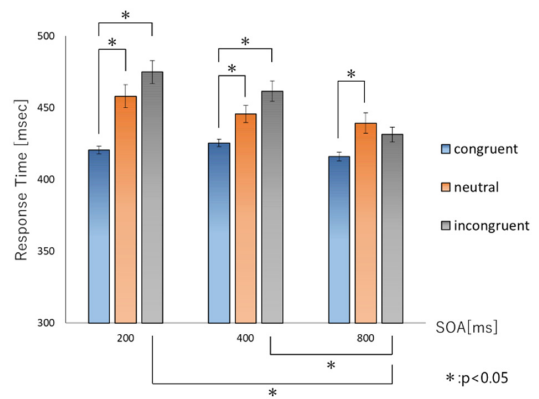
Next, we carried out an analysis of variance (ANOVA) to examine the effects of the cues and SOAs on the response time. The results showed that the interaction between cues and SOA was significant ($F(4, 5332) = 4.685$, $p < 0.05$). This indicates that the two factors, cue and SOA, mutually affect each other to produce the response time.

Because an interaction was observed, we carried out a simple main effect analysis. Specifically, we conducted multiple comparisons using a Bonferroni correction. The results showed that the simple main effect of the cues was significant for all SOAs ($p < 0.05$). Meanwhile, the simple main effect of the SOA was found to be significant in the case of incongruent cues ($p < 0.05$). The detailed results are shown in **Fig. 9**.

From **Fig. 9**, it can be seen that the average response times for SOAs of 200 and 400 ms display a different pattern from that for an SOA of 800 ms. In the former cases, the response time increases as the cue (trial) changes from congruent to neutral to incongruent. For an SOA of 800 ms, however, the response times of the neutral trials were greater than those of the incongruent trials. Thus, the response times of the congruent trials were lower than those of the incongruent and neutral trials for SOAs of 200 and 400 ms, respectively, but the differences in response times between the congruent and incongruent trials were smaller in the case of an SOA of 800 ms. In other words, the response times of the congruent trials are clearly lower than those of the incongruent and neutral trials when the SOA is short (e.g., 200 and 400 ms), whereas the incongruent cue has a weaker effect in the case of a long SOA (e.g., 800 ms).

4.7. Discussion

The results of the experiment show that the response times of the congruent trials are substantially lower than those of the neutral trials for all SOAs. This indicates that the behavior by which all three NAMIDA agents gaze in the direction of a target that will soon appear (congruent trials) has a positive effect on lowering the subject's response time when the target is presented. We can conclude that the behavior of NAMIDA in congruent trials

attracts a person's attention and successfully guides the person's gaze.

When the SOA was 800 ms, the response time of the incongruent trials was lower than those for other SOAs. This trend was confirmed in a previous study [16] and is thought to occur because the drawing of attention based on gaze is effective only when the target is displayed quickly after the cue, and then only for an extremely short duration. Therefore, gaze guidance has a reduced effect when the target is not quickly displayed (e.g., when the SOA is 800 ms), which creates extra time for the subject to search over the entire screen, allowing the subject to pay greater attention to the entire screen without having to resort to the gaze guidance provided by NAMIDA, as a result of which the display of an incorrect cue (incongruent cue) has a weaker effect.

4.8. Design Guidelines for Gaze Movements of Driving Agent

The objective of the present experiment was to confirm NAMIDA's capacity to capture the driver's attention based on its gaze direction. The spatial cueing task is thought to measure the promotional effect of the cue's display position, which is called attention capture. The experimental results indicate that NAMIDA's gaze directing behavior captures the subject's gaze (visual) attention when the SOA is 200 and 400 ms. It is interesting to note that the gaze movements of the simple, three-agent, and low-anthropomorphic NAMIDA are effective in guiding the subject's gaze, just as in a previous study that employed photographs of the human eye gaze [16]. This is because human beings tend to impart social meaning, even to movements of a simple robot, and personify such meaning [17, 18].

The validity of attention capture was also confirmed when the SOA was 800 ms, although the incongruent cue produced a different pattern than that for the other SOAs, as stated earlier in Section 4.7. Such findings can be important when drawing up design guidelines for gaze guidance by driving agents.

The use of three agents for gaze guidance should make it possible to display the internal state of the autonomous driving system in more detail. For instance, when the driving agent is able to accurately detect the direction in which the target appears, it is desirable to point the driving agent's gaze in the target's direction regardless of the length of time before the target appears. In particular, if the system is highly reliable, the three agents should gaze in the same direction. This raises the likelihood of capturing the driver's attention. Furthermore, the ratio of agents displaying a certain behavior can be used to express the reliability of the autonomous driving system. An example is when two agents gaze in the same direction while the third agent gazes in a different direction. Such behavior can provide a cue to the driver regarding the reliability of the system. Meanwhile, the gazes of multiple driving agents should not point in the same direction when the system is unable to accurately predict the direction in

which the target will appear. When there is some time (for example, about 800 ms) before the target is expected to appear, in particular, it may be desirable to exhibit such movements as pointing the three agents' gazes in different directions and entrust judgment to and incite the attention of the driver, since dispersing the agents' gaze is likely to draw the driver's attention. It is possible to draw up such guidelines on the gaze movements of the driving agent by incorporating the results of the present experiment. It will still be necessary, however, to verify in detail the effect of the number of agents on the guidance of the user's gaze in future studies.

4.9. Contribution and Limitations of Present Experiment

In this paper, we described our efforts to verify and evaluate the effects of gaze guidance as a part of the nonverbal information transmission capacity associated with NAMIDA's bodily movements. Specifically, focusing on NAMIDA's display of its intention based on its gaze movements, we described our investigation into the effect of the driving agents' gaze directions on the attention capture. The findings are relevant to the design of attention capture functions, including the movements and behavior of driving agents. They should also contribute to the design of driving agents that assist drivers in level-0 vehicles [19–21]. The use of a simple three-agent unit to verify the effect on human gaze guidance can be considered unique in the HRI field.

The gaze movements of NAMIDA can be expected to be useful in the following scenarios. Consider, for instance, a scenario in which the autonomous driving system suddenly begins to slow down when the vehicle is traveling on an empty road where no other cars exist. Following NAMIDA's gaze, the driver may notice that a child is crossing the road ahead. As another scenario, when traveling on a road in a commercial district crowded with pedestrians, the NAMIDA agents may restlessly shift their gazes toward the people or objects within the vicinity. Thus, the driver can judge that autonomous driving will be difficult under such circumstances and take over the driving duties.

The results of the present experiment do not by themselves verify whether NAMIDA's gaze guidance is effective when the driver is riding in a vehicle being driven by an actual autonomous driving system; therefore, it will be necessary in the future to conduct navigation experiments with actual vehicles and investigate the results.

5. Conclusion

With the objective of discussing the communication and ideal relationship between an autonomous driving vehicle and driver, and focusing on the physical expression of a driving agent, this paper describes NAMIDA, which was developed as a driving agent with the characteristics of expressing the autonomous driving system's inten-

tion. We verified the behavior of NAMIDA, which employs eye gaze movements, which are nonverbal interaction modes that do not depend on phonetic or phonemic information, to communicate with the driving agent during autonomous driving.

We described an experiment in which a spatial cueing task was used to verify the effect of NAMIDA's gaze movements on capturing the driver's attention. Specifically, the results verified that NAMIDA's behavior is recognized as a cue in the driver's attention searching process, and that the gaze movements of a simple three-unit agent can induce guidance of the subject's gaze. These findings are of interest as they have bearing on the discussion of the social nature of minimally designed robots. Based on the experimental results, we discussed the design guidelines for gaze guidance by a driving agent.

As a follow up to this study, we plan to carry out verification experiments on the effect of NAMIDA's gaze movements on inducing the driver's attention in a simulated driving environment, as a part of experiments targeting its practical use in the real world.

References:

[1] K. Williams and C. Breazeal, "Reducing Driver Task Load and Promoting Sociability through an Affective Intelligent Driving Agent (AIDA)," P. Kotz, G. Marsden, G. Lindgaard, J. Wesson, and M. Winckler (Eds.), "Human-Computer Interaction – INTERACT 2013," Springer, Vol.8120, pp. 619-626, 2013.

[2] K. Williams, J. C. Peters, and C. Breazeal, "Towards leveraging the driver's mobile device for an intelligent, sociable in-car robotic assistant," 2013 IEEE Intelligent Vehicles Symp. (IV), pp. 369-376, 2013.

[3] N. Karatas, S. Yoshikawa, P. Ravindra S. De Silva, and M. Okada, "How Multi-Party Conversation Can Become an Effective Interface While Driving," J. of Human Interface, Vol.20, No.3, pp. 83-100, 2018.

[4] N. Karatas, S. Tamura, M. Fushiki, and M. Okada, "Multi-party Conversation of Driving Agents: The Effects of Overhearing Information on Lifelikeness and Distraction," Proc. of the 6th Int. Conf. on Human-Agent Interaction (HAI '18), pp. 84-91, 2018.

[5] N. Karatas, S. Yoshikawa, P. Ravindra S. De Silva, and M. Okada, "NAMIDA: Multiparty Conversation Based Driving Agents in Futuristic Vehicle," Proc. of the 17th Int. Conf. on Human-Computer Interaction (HCII 2014), pp. 198-207, 2015.

[6] Y. Yoshiike, P. Ravindra S. De Silva, and M. Okada, "MAWARI: A Social Interface to Reduce the Workload of the Conversation," Proc. of Int. Conf. on Social Robotics (ICSR 2011), pp. 11-20, 2011.

[7] N. Karatas, S. Yoshikawa, S. Tamura, S. Otaki, R. Funayama, and M. Okada, "Sociable Driving Agents to Maintain Driver's Attention in Autonomous Driving," Proc. of 26th IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN), pp. 143-149, 2017.

[8] N. Karatas, S. Tamura, M. Fushiki, and M. Okada, "Improving Human-Autonomous Car Interaction through Gaze Following Behaviors of Driving Agents," Trans. of the Japanese Society for Artificial Intelligence, Vol.34, No.2, pp. 1-11, 2019.

[9] N. Matsumoto, H. Fujii, M. Goan, and M. Okada, "Minimal communication design of embodied interface," Proc. of the 2005 Int. Conf. on Active Media Technology (AMT 2005), pp. 225-230, 2005.

[10] N. Matsumoto, H. Fujii, and M. Okada, "Minimal design for human-agent Communication," Artificial Life and Robotics, Vol.10, No.1, pp. 49-54, 2006.

[11] M. I. Posner, "Orienting of attention," Quarterly J. of Psychology, Vol.32, Issue 1, pp. 3-25, 1980.

[12] M. Otsuki, K. Maruyama, H. Kuzuoka, and Y. Suzuki, "Effects of Enhanced Gaze Presentation on Gaze Leading in Remote Collaborative Physical Tasks," Proc. of the 2018 CHI Conf. on Human Factors in Computing Systems (CHI '18), No.368, pp. 1-11, 2018.

[13] R. Sato and Y. Takeuchi, "Coordinating turn-taking and talking in multi-party conversations by controlling robot's eye-gaze," Proc. of the 23rd IEEE Int. Symp. on Robot and Human Interactive Communication (ROMAN 2014), pp. 280-285, 2014.

[14] C. Stanton and C. J. Stevens, "Robot Pressure: The Impact of Robot Eye Gaze and Lifelike Bodily Movements upon Decision-Making and Trust," Proc. of Int. Conf. on Social Robotics (ICSR) 2014, M. Beetz, B. Johnston, and M. A. Williams (Eds.), "Social Robotics," Lecture Notes in Computer Science, Vol.8755, pp. 330-339, 2014.

[15] Y. Kuno, H. Sekiguchi, T. Tsubota, S. Moriyama, K. Yamazaki, and A. Yamazaki, "Museum Guide Robot with Communicative Head Motion," Proc. of the 15th IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN06), pp. 33-38, 2006.

[16] J. Driver IV, G. Davis, P. Ricciardelli, P. Kidd, E. Maxwell, and S. Baron-Cohen, "Gaze perception triggers reflexive visuospatial orienting," Visual Cognition, Vol.6, No.5, pp. 509-540, 1999.

[17] R. A. Barton and R. I. M. Dunbar, "Evolution of the social brain," A. Whiten and R. W. Byrne (Eds.), "Machiavellian intelligence II: Extensions and evaluations," Cambridge University Press, pp. 240-263, 1997.

[18] B. Reeves and C. Nass, "The media equation: How people treat computers, television, and new media like real people and places," The University of Chicago Press, 1996.

[19] T. Tanaka, K. Fujikake, Y. Yoshihara, T. Yonekawa, M. Inagami, H. Aoki, and H. Kanamori, "Driving Behavior Improvement through Driving Support and Review Support from Driver Agent," Proc. of the 6th Int. Conf. on Human-Agent Interaction (HAI '18), pp. 36-44, 2018.

[20] T. Tanaka, K. Fujikake, T. Yonekawa, M. Yamagishi, M. Inagami, F. Kinoshita, H. Aoki, and H. Kanamori, "Driver Agent for Encouraging Safe Driving Behavior for the Elderly," Proc. of the 5th Int. Conf. on Human Agent Interaction (HAI '17), pp. 71-79, 2017.

[21] D. Katagami, M. Hongo, and T. Tanaka, "Agent design for the construction of new relationship between a car and a driver," Proc. of the 30th Fuzzy System Symp. (Fuzzy System Symp. 2014), Vol.30, pp. 356-357, 2015.

Supporting Online Materials:

[a] Society of Automotive Engineers (SAE) Int.: SAEJ3016TM Levels of Driving Automation. https://www.sae.org/standards/content/j3016_201401/ [Accessed September 16, 2018]

[b] PIVO2. https://www.nissan-global.com/EN/ZEROEMISSION/HISTORY/PIVO2/ [Accessed September 16, 2018]

[c] KIROBO Mini. https://toyota.jp/kirobo_mini/ [Accessed September 16, 2018]

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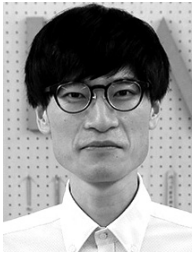
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● "STB: Child-dependent sociable trash box," Int. J. of Social Robotics, Vol.3, No.4, pp. 359-370, 2011.
● "Muu: Artificial creatures as an embodied interface," 27th Int. Conf. on Computer Graphics and Interactive Techniques (SIGGRAPH 2000), the Emerging Technologies: Point of Departure, Vol.91, 2000.
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