Improving Human-Autonomous Car Interaction Through Gaze Following Behaviors of Driving Agents

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Summary ───

    Autonomous cars have been gaining attention as a future transportation option due to an envisioning of a reduction in human errors and achieving a safer, more energy efficient and more comfortable mode of transportation. However, eliminating human involvement may impact the usage of autonomous cars negatively because of the impairment of perceived safety and enjoyment of driving. In order to achieve a reliable interaction between an autonomous car and a human operator, the car should evince intersubjectivity, implying that it possesses the same intentions with as those of the human operator. One critical social cue for human to understand the intentions of others is eye gaze behaviours. This paper proposes an interaction method that utilizes the eye gazing behaviours of an in-car driving agent platform that reflects the intentions of a simulated autonomous car that holds a potential of enabling the human operators to perceive the autonomous car as a social entity. We conducted a preliminary experiment to investigate whether an autonomous car will be perceived as possessing the same intentions as a human operator through gaze following behaviors of the driving agents as compared to the conditions of random gazing as well as not using the driving agents at all. The results revealed that gaze-following behavior of the driving agents induces an increase in the perception of the intersubjectivity. Furthermore, a detailed eye gaze data analysis remarked that the gaze following behaviors of the robots received more attention from the driver. Finally, the proposed interaction method demonstrated that the autonomous system was perceived as safer and more enjoyable.

1. Introduction

Recently, a great deal of research has been conducted on highly autonomous vehicles which make their own driving decisions that minimize human interventions with the vision of decreasing human errors and achieving a safer, more energy efficient and more comfortable mode of transportation [Poczter 14, Vanderbilt 12]. However, eliminating human involvement from driving might threaten the trust and perceived safety, and suppress drivers' joy of driving and the desire to control the vehicle which in turn lead to a refusal to use autonomous cars.

Researches has demonstrated that an increase in perceived anthropomorphism affects positively the perceived trust in autonomous vehicles [Hock 16, Waytz 14]. However, in these studies, the interaction between the system and the human is still not natural nor intuitive due to the system lacks the exhibiting of continuous sociability. A

human operator should be able to understand the automation system, fully and intuitively. [Norman 13] discussed that a system's design model should be identical to the user's mental model. He also suggests that the communication can be more effective in a form of an appropriate metaphor. [Flemisch 03] introduced H-Metaphor as an interaction concept between an autonomous car and a human operator based on understanding the situational-intentions of each other based on the idea of continuous haptic interactions between a horse and a rider. We believe that through building a reciprocal interaction between a human operator and an autonomous car where the parties can perceive each other as social entities and understand each other's intentions (emerging intersubjectivity), in which they can find motivation to engage with each other [Tomasello 07] (i.e. situational-awareness towards the shared environment to react when an action is needed),
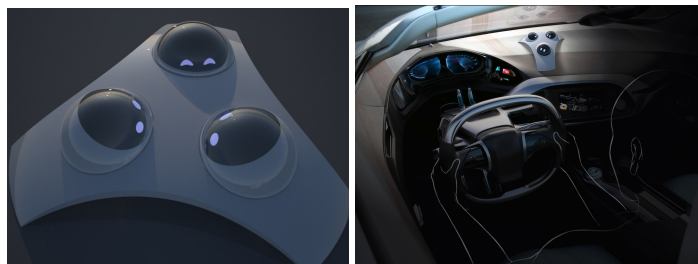
Figure1: A conceptual diagram of the NAMIDA platform. It consists of one base unit containing three movable heads with one degree of freedom each (*left*). The base unit of NAMIDA, which attaches to the dashboard of a car is within the peripheral vision of the driver (*right*).

a reliable interaction can be established.

Intentional stance is a strategy for understanding an entity's behaviour by treating it as a rational entity whose actions are governed by its beliefs and desires [Dennett 89]. Intentional stance is closely related to social presence, which defines the degree of awareness of the other entity in an interaction and the sense of access to the other's mind [Sallnas 00]. Intersubjectivity emerges as humans feel that others feel or act on as if they have the same intentions [Beebe 05]. This intersubjective sharing is critical, because it creates a shared space of common psychological ground that enables everything from collaborative activities with shared goals to human-like cooperative communication through comprehending each other's intentions. In this respect, when the autonomous system persuades the human operator that the system possesses the same intentions as the human operator as a social entity, the relationship between them will gain a more organic shape, which will enable the establishment of a constant reliable interaction.

Humans engage in a wide variety of social interactions using their ability to reason about others' intentional stance. One social interaction for humans is to adopt the intentional stance of others using the ability to interpret the eye gazing of others and then interpreting their actions [Baron-Cohen 95, Dennett 89]. Researchers in cognitive science and developmental psychology consider gaze following to be one of the essential components in social interaction and learning [Brooks 05]. It also contributes to understanding of what the others think, feel and intend to do [Baron-Cohen 99, Tomasello 07].

A number of studies in Human-Robot Interaction and Human-Agent Interaction have shown that with eye gazing behaviours, robots can gain the ability to give information to their interlocutors [Das 15, Karatas 17, Mutlu 09]. In situated human-machine interaction, the robot's or agent's gaze could be used as a cue to facilitate the user's comprehension of the robot's instructions [Skantze 14]. Expressive eye gaze is one behaviour (among many drawn

from animation principles) that can make intentions and desires more explicit [Takayama 11]. Even when users are unaware of the intended communication, robots can reveal their intentions implicitly through eye gazes and influence human behaviours [Mutlu 09]. Researches have demonstrated that robots can use gazes to establish joint attention in the attempts of learning from demonstrations, as well as in soliciting feedback when there is uncertainty [Lockerd 04]. When a robot responds to joint attention by following the human teacher's gaze, it better conveys its internal states which leads to more efficient teaching, including fewer errors, faster recovery from errors, and less repetition of learned information [Huang 11]. People also rate a robot as more natural and competent when it builds joint attention while performing a task [Huang 11].

In this study, we employ a robotic, driving agent platform, NAMIDA (**??**), to utilize eye gazing cues to reveal the intentions of the robots, correspondingly the social presence of an autonomous car. We analyzed whether the gaze following behaviours of the robots can facilitate the interaction between the human operator and the autonomous car.

1·1 Perceived Agency

Using a robotic driving agent as an interface for an autonomous car might create ambiguity for the humans' perceptions. The interface can either be perceived as a companion for the driver that is independent from the autonomous system (e.g., passenger), or as an authority who is directly connected to the system and responsible for the autonomous driving. We expect that when the robots' intentions (e.g., watching the road and being aware of surroundings by caring the driver's attention) synchronize with the autonomous car's actions (take an action according to the situations on the road, such as changing lane, etc.,), the human operator will infer the existence of dependency (authority) of the driving agents to the autonomous system, which we will define it as the "perceived agency" of the robots. Since, following gaze behaviors will bring a human-like trait to

the robots, drivers will perceive them as communicatable entities. Herein, we believe that by having a communicatable authority in an autonomous car where the human operator's control is limited, the perceived agency would lead to an increase in the perception of safety.

2. Method

In this study, we investigated whether the gaze following behaviors of a robotic driving agent platform was effective on increasing the perceived agency and intentional stance of the robots, social presence of the autonomous car, perceived safety and enjoyability of a human operator that they could feel during a simulated autonomous driving. We also expected that the latter two factors will be depended on the intentional stance and the perceived social presence of the system. In addition, we aimed to explore the relationship of the perceived agency with the other factors.

2·1 System Design

For this study, we employed NAMIDA platform [Karatas 16] that is consisting of three robots (**??**). The NAMIDA platform involves one base unit that attaches to the dashboard of a car, containing three movable heads with one degree of freedom each in the driver's peripheral vision. The round shaped head of each robot allows for the positioning of their eyes with full color LED light emission. The movement of the robots is enabled by three servomotors linked to the Arduino platform inside each head that is attached to the main board. NAMIDA has an utterance generation mechanism that allows the robots to generate verbal and non-verbal behaviors within each turn-taking. However, in the current study, we focused on the effectiveness of NAMIDA system's particular non-verbal behaviors (eye gaze behaviors), thus we did not employ the utterance generation mechanism. Because the robots' head consists of two discernible eyes, we believe that employing three robots with same design would amplify and make it more clear the sense of the eye gaze behaviors of the robots from the driver's perspective, which would fit to the objectives of this study.

2·2 Gaze Following Behaviors of NAMIDA

Joint attention is an active bilateral process which involves attention manipulation, but it can only be fully realized when the parties are aware of each other's attention [Kaplan 04]. Even though response and feedback behaviours are necessary to realize a joint attention that makes robots more competent and socially interactive within

a human-robot interaction, however, in this study, we only focused on the one aspect of the joint attention which is the gaze following behaviours that is the active unilateral process of simultaneous looking.

In order for the robots to realize the gaze following of the human, we used Tobii Pro Glasses 2[*1] tracker. From the tracker, two parameters of eye gazing data (i.e., points on x and y axes) were used to implement the gazing behaviours of the robots. In order to amplify the gaze following movements of the robots (to increase the human sense on the gaze following behaviors of the robots), the eye gaze data obtained from the tracker was multiplied by *3.5* on the x axis. We also put a 350 ms delay between the human gaze and the robots' gaze to make the gaze following more sensible by the human operator. For this study, when the human moves his/her eyes, all the three robots perform gaze following behaviours simultaneously within a cohesive manner.

2·3 Conditions

We conducted an experiment by employing our NAMIDA platform with three conditions in an autonomous driving environment:

(1) No NAMIDA (NN): the robots were not used. They were covered with a black piece of cloth.

(2) NAMIDA with Random gaze Behaviors (NRB): The robots were placed on the dashboard and were set to watch the front side of the road (as passengers) with the head movement of normally distributed from -15 to +15 degrees.

(3) NAMIDA with Following Behaviors (NFB): The robots were constantly following the eye gaze of the participants by using the eye gaze tracker.
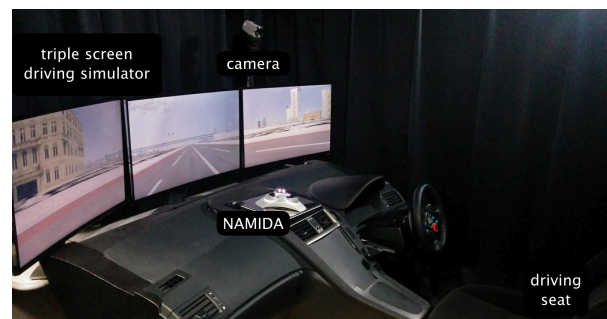
2·4 Experimental Setup

Figure2: The experiment room and experimental setup.

Our aim was to investigate the effects of the gaze following behaviors of NAMIDA on the perceptions of the

Figure3: Driver's point of view.

agency, intentional stance, social presence, perceived safety and enjoyment of the human operators. We set up our experiment in a simulated autonomous driving environment that consists of three monitors placed on the dashboard, an adjustable driver seat and a steering wheel (**??** and **??**). We used UC-win Road Ver.13[*2] as the simulation software. The experiment room was dimmed to enhance the reality of the driving task.

In the simulated road, we placed five situations (checkpoints) along the way (with the order of: (1) turn right, (2) underground passageway, (3) accident, (4) turn left, (5) turn right) where each one triggered an action for the autonomous system to take. Three of the checkpoints indicate turning actions (signaling, slowing down, changing lane and turning right or left), one checkpoint to indicate an underground passageway (signaling, slowing down, changing lane) and one to indicate an automobile accident in the underground passageway (signaling, slowing down and changing lane to pass by the automobile accident carefully). These situations were selected to force the participants to check their environment, also they were likely to be happen during an autonomous driving, and were remarkable incidents to draw attention from the drivers on a daily basis.The maximum speed of the car was set to 40km/h during the autonomous driving.

2·5　Procedure

22 participants (3 female, 19 male) from 19 to 40 years old (M=24.82, SD=6.31) took part in our experiment. We conducted a counterbalanced within-subject-study. All participants had a current driving license. Upon arrival, each participant was given an explanation about the experiment. Before starting the experiment, the participants were asked to fill out a demographic questionnaire. After each session, they were asked to fill out the subjective assessment questionnaire; the three questions for Perceived Agency

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*2　http://www.forum8.co.jp/product/ucwin/road/ucwin-road-1.htm

Table1: Subjective assessment questionnaire consists of Perceived Agency (PA), Perceived Enjoyment (PE), Perceived Safety (PS), Social Presence (SP), Intentional Stance of NAMIDA (ISN).

Code	Questions
PA1	I felt that Namida and the car were connected.
PA2	I felt that Namida was independent from the car.
PA3	I felt that Namida reflected the car's mind.
PE1	I think the driving was enjoyable.
PE2	I think the driving was fascinating.
PE3	I think,the driving was boring.
PS1	I think the driving was safe.
PS2	I think the driving was relaxing.
PS3	I think the driving was calm.
PS4	I think the driving was surprising.
SP1	I perceived that I was in the presence of the car.
SP2	I felt that the car was watching me and was aware of my presence.
SP3	The thought that the car is not a real person crosses my mind often.
SP4	The car appeared to be sentient (conscious and alive) to me.
SP5	I perceived the car as being only machine, not as living creature.
ISN1	I felt that the robots could understand my intention.
ISN2	I thought that the robots shared my feelings.
ISN3	The robots seemed to care about me.
ISN4	The robots was trying to get involved with me.
ISN5	I thought the attention of the robots depended on my attention.
ISN6	I felt a connection between me and the robots.

Table2: The table shows the t values for a paired t-test analysis (PA and ISN factors), F values for a one-way repeated ANOVA (PA, SP, ISN, PS and PE factors), and p values for the corresponding analysis for each factor (*p<0.05, **p<0.01, ***p<0.001).

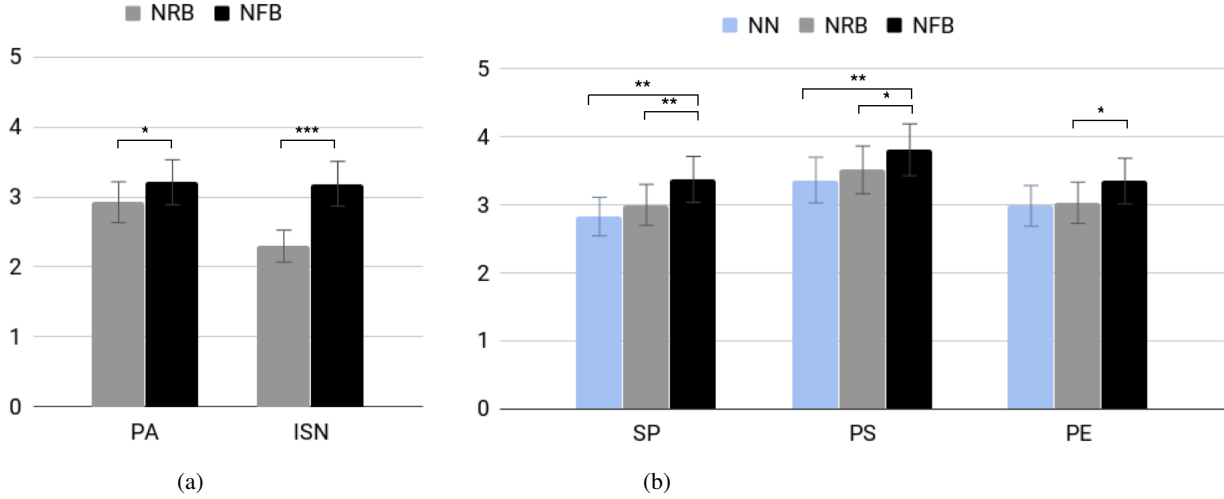|		t/F value	p-value
t-test	PA	-1.734	<0.048*
	ISN	-4.252	<0.001***
ANOVA	SP	9.872	<0.001***
	PS	6.408	0.004**
	PE	4.27	0.021*

(a)   (b)

Figure4: The graphs indicate the mean values of each subjective factor and the conditions where the factors are significantly different (*p <0.05, **p<0.01, ***p<0.001).

Table3: The table shows the Pearson's correlation analysis. The values on the correlation table represents the *r* values (*p<0.05, **p<0.01, ***p<0.001).

	PA	SP	ISN	PS	PE
PA	–				
SP	0.208	–			
ISN	0.344*	0.569***	–		
PS	0.488***	0.506***	0.423**	–	
PE	0.218	0.066	0.270	0.168	–

(PA) of NAMIDA, three questions for Perceived Enjoyment (PE), four questions for Perceived Safety (PS), five questions for Social Presence of the autonomous car (SP) and six questions for Intentional Stance of Namida (ISN) (**??**). Except for PA, the questionnaire items were prepared based on the work in [Bailenson 01, Heerink 08, Suzuki 03]. At the end of the experiment, we had a brief interview with the participants to understand their impression about the robots and the autonomous driving.

The participants were told that they had to go to a train station, and that the autonomous car would take them to there using the best route, so their task was to carefully watch the environment and interact the robots during the autonomous driving.

Before starting the experiment, the participants undertook a trial session for a few minutes in order for them to adapt to the environment. After the trial, the real sessions started. Each session took approximately five minutes. During all the three experimental conditions, the participants' eye gaze were recorded via Tobii Pro Glasses 2.

3. Results

Perceived Agency (PA) and Intentional Stance of NAMIDA (ISN) questions were given only after the NRB and NFB conditions. The validity of the questions were analyzed through conducting an internal reliability analysis. For the PA, the results showed that the Cronbach's alpha was greater than 0.68 under both NRB and NFB conditions ($\alpha=0.855$ and $\alpha=0.688$, respectively). The data passed the Shapiro-Wilk normality test at p=0.05 level for both conditions, therefore a paired t-test was conducted. A subsequent paired t-test revealed significant difference between two conditions *(t(21)=-1.734, *p<0.048)*. The NFB was rated significantly higher (M=3.189, SD=0.91) than the NRB condition (M=2.295, SD=1.032) (Fig. (**??**) and **??**). This result revealed that in the NFB condition, participants' feeling of connection between the robots and the autonomous car was higher.

The results for the validity of ISN questionnaire showed that the Cronbach's alpha was $\alpha=0.937$, $\alpha=0.907$ for the NRB and the NFB conditions, respectively. The data passed the Shapiro-Wilk normality test at p=0.05 level for both conditions, therefore a paired t-test was conducted to investigate whether the gaze behaviors of the robots had an effect on their perceived intentional stance. The results showed that under the NFB (M=3.114, SD=0.915) condition the participants rated the related questions significantly higher than under the NRB condition (M=2.205, SD=0.999), *(t(21)=-4.252 , ***p<0.001)* (Fig. 4(a) and **??**). The result showed that the gaze following behavior of the robots was effective to persuade the participants about the robots' intentions.

The results of the validity analysis of the Social Pres-

Table4: The table shows the descriptive analysis of the eye gaze data (*%*) in NRB (*left*) and NRB (*right*) conditions, also the results of Wilcoxson signed-rank test. (*p<0.05, **p<0.01, ***p<0.001).

Minute	NRB			NFB			Wilcoxson signed-rank test (p-value)
	Namida Mean (STD)	Simulation Mean (STD)	Other Mean (STD)	Namida Mean (STD)	Simulation Mean (STD)	Other Mean (STD)	
1	13.172 (15.10)	86.25 (15.87)	0.5806 (1.245)	23.244 (21.75)	75.79 (21.97)	0.9615 (1.704)	Z=-2.343 (*p=0.019)
2	12.301 (17.27)	87.16 (17.64)	0.5428 (0.7691)	19.660 (22.55)	79.40 (22.92)	0.9396 (1.569)	Z=-2.011 (*p=0.044)
3	10.171 (14.42)	89.27 (15.33)	0.5557 (1.046)	23.860 (25.31)	75.10 (25.37)	1.043 (1.154)	Z=-1.869 (p=0.061)
4	5.664 (14.59)	93.74 (14.99)	0.5982 (1.469)	16.926 (23.62)	82.19 (23.77)	0.8838 (1.652)	Z=-2.480 (*p=0.013)
5	6.356 (13.16)	92.96 (14.44)	0.6867 (2.057)	15.523 (25.59)	83.95 (26.08)	0.5232 (1.476)	Z=-1.538 (p=0.123)

ence (SP) questions showed that the Cronbach's alpha was $\alpha=0.658$, $\alpha=0.785$, and $\alpha=0.811$ for NN, NRB and NFB conditions, respectively. Then we conducted a one-way within subject ANOVA to investigate whether the gaze following behaviors of NAMIDA affect the perceived social presence. The results showed a significant difference among the conditions *(F(2,42)=9.872, ***p<0.001)*. The Bonferroni correction revealed that the main score for the NFB (M=3.372, SD=0.458) condition was significantly higher than the NN (M=2.827, SD=0.701) condition; *t(21)= -3.552, **p= 0.006* and NRB (M=3, SD=0.436) condition; *t(21)=-3.355, **p=0.009* (Fig. 4(b) and **??**). These results indicated that the existence of the NAMIDA platform was effective on the perceived social presence of the autonomous. Moreover, the robots' following gaze behaviors invoked the sense of presence of the autonomous car, and the participants could attribute the social presence to the system better than the other two conditions.

The Cronbach's alpha for the Perceived Safety questionnaire (SP) was under *0.68* in three conditions ($\alpha=0.664$, $\alpha=0.57$ and $\alpha=0.667$ for NN, NRB and NFB conditions, respectively). However, when we excluded the PS4 question, the Cronbach's alpha for each condition became $\alpha=0.774$, $\alpha=0.693$ and $\alpha=0.757$ for NN, NRB and NFB conditions, respectively. After excluding the PS4, we conducted a one-way within subject ANOVA to investigate whether the gazing behaviors of the robots affected perceived safety. The results showed a significant difference among the conditions *(F(2,42)=6.408, **p=0.004)*. The Bonferroni correction revealed that the main score for the NFB (M=3.807, SD=0.436) condition was significantly

higher from the NN (M=3.364, SD=0.601) condition *(t(21)= -2.941, **p=0.008)*, and NRB (M=3.511, SD=0.52) condition *(t(21)= -2.784, *p=0.011)* (Fig. 4(b) and **??**). These results showed that the existence of NAMIDA platform was effective to make the participants feel safer, and following gaze behaviors of the robots increased the feeling of safety.

The validity test of the Perceived Enjoyment (PE) questionnaire showed that the Cronbach's alpha was $\alpha=0.841$, $\alpha=0.844$ and $\alpha=0.811$ for NN, NRB and NFB conditions, respectively. We then conducted a one-way within subject ANOVA to investigate whether the gaze following behavior of NAMIDA affected perceived enjoyment. The results showed a significant difference among the conditions *(F(2,42)=4.27, *p=0.021)*. The Bonferroni correction revealed that the main score for the NFB (M=3.348, SD=0.43) condition was significantly higher than the NRB (M=3.03, SD=0.435) condition *(t(21)=-2.672, *p=0.043)* (Fig. 4(b) and **??**). However, NFB condition did not show a significant difference with NRB condition on the perceived enjoyability.

The Pearson correlation coefficients results among the five subjective assessment factors are shown in **??**. The results showed that there was a moderate positive correlation between ISN and PA *(r=0.344, *p=0.022)*, PS and PA *(r=0.488, ***p<0.001)*, PS and ISN *(r=0.423, **p=0.002)*. On the other hand, there was a strong positive correlation between the ISN and SP *(r=0.569, ***p<0.001)*, SP and PS *(r=0.506, p***p<0.001)* (**??**). These results remarked that comprehending the intentions of the robots induces the social presence of the autonomous car; and, attributing

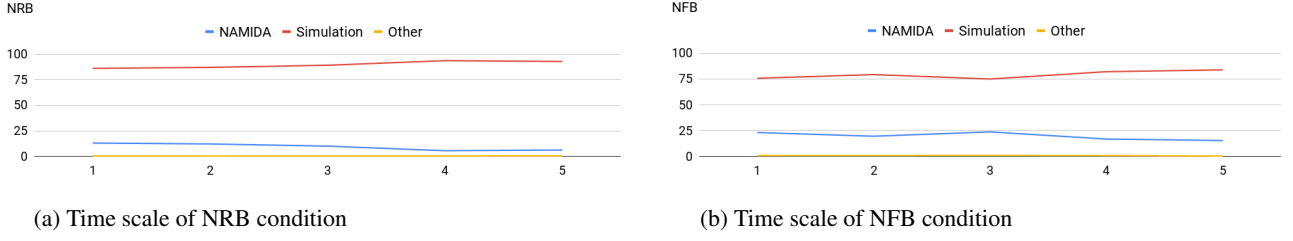(a) Time scale of NRB condition

(b) Time scale of NFB condition

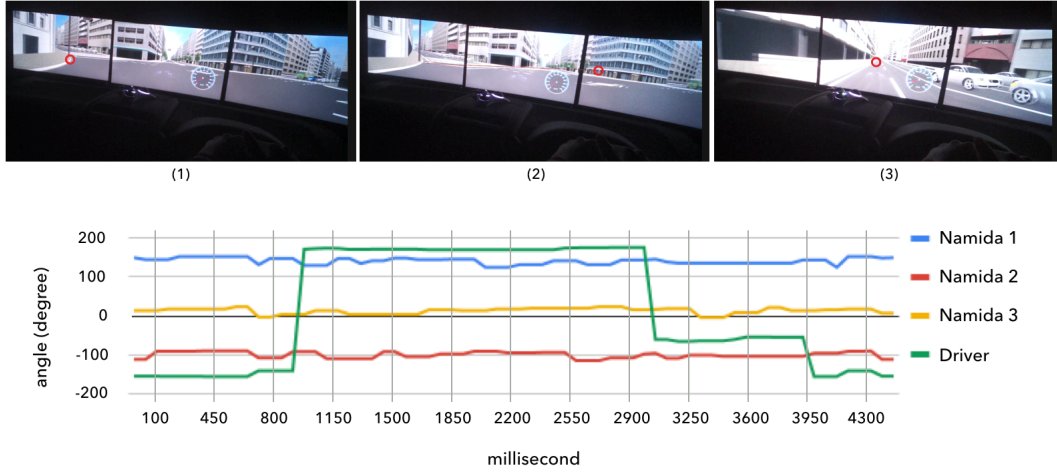Figure5: Time scales of the two conditions demonstrate the average eye gaze trend of the participants.

Figure6: In the NRB condition, the robots moved left and right with a random Gaussian distribution of +-15 degrees as it was precoded.
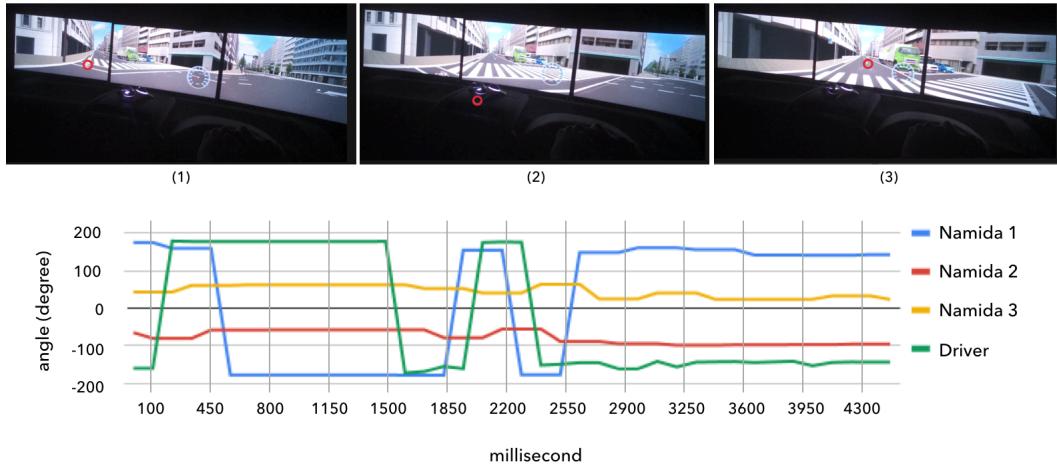

Figure7: In the NFB condition, the robots followed the eye gaze of the participant with 350 millisecond latency.

social presence to the of the autonomous car fostered the perceived safety. The results also showed that when the participants conceived the intentions of the robots, they attributed stronger connection between the robots and the autonomous car, therefore their perception of safety increased.

3·1 Eye Gazing Behaviours Of the Participants

We analyzed the overall ratio of the eye gaze data of the participants in three categories: gaze on the simulation screen, driving agents and other points in the vision

of the participants by considering the gazing behaviors of the robots in NRB and NFB conditions. We used the gaze data gathered from the eye gaze tracker. Three participants were omitted from the data set due to the insufficient amount of data caused by some technical issues related to the tracker. The gathered data could not pass the Shapiro-Wilk normality test in three categories for both conditions at p=0.1 level, therefore we used the Wilcoxon signed-rank test to compare the conditions using the gaze data from 19 participants. The results indicated that in the NFB condition, the participants looked at the robots
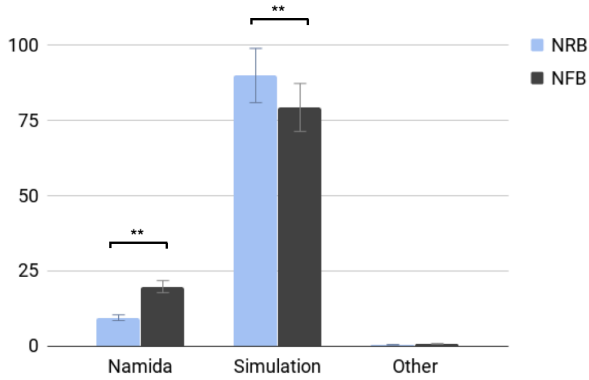
Figure8: The graph shows the result of Wilcoxon signed-rank test between NRB and NFB conditions on the gaze fixation count (%) (*p<0.05, **p<0.01, ***p<0.001).

significantly more times compared to NRB condition *(Z=-2.627, **p=0.008)*. The results also showed that in the NRB condition, the participants looked at the simulation screen more times compared to NFB condition *(Z=-2.678, **p=0.007)* (**??**).

We also analyzed the trend of the participants' eye gaze data amount (%) on the simulation screen and NAMIDA by dividing the eye gaze data into the minute of the each session. Then we applied Wilcoxon signed-rank test to compare eye gaze data on the robots and on the simulated screen in NRB and NFB conditions. The analysis showed that in the NFB condition, in the first, second and fourth minutes, the participants looked at the robots significantly more times compared to the NRB condition (**??** and **??**). The first and fourth minutes of the experiment included an intersection which required an action for the autonomous car to turn right and left, respectively. It is a habit for a driver to check the road within a wide range (looking at left and right) to assure the safety of the turning. In our case, even though the autonomous car drove itself, the participants performed their habit unconciously. While their gaze pointed to a wide left and a wide right (170≤angle≤200, -170≥angle≥-200), they realized the robots' gazing behaviors which synchronised with the participants' gaze. This behavior of the robots in the NFB condition paved the way for receiving more attention from the participants compared to robots in the NRB condition. **??** and **??** show an example of the coordination between the eye gaze behaviors of the robots and a participant for both conditions. **??** demonstrates that while the participant was looking at the right (**??** (1)), left (**??** (2)) and then front side (**??** (3)) for checking the road, the robots' movement remained the same (looking at the front). Thus the participant was not interested to look at the robots. On the other hand, in the NFB condition (**??**), when the car was crossing through an intersection, the participant first looked at the at the left (**??** (1)), after 350ms, the robots shifted their gaze towards the fixation point of the participant. After this behavior; because the robots were in the peripheral area of the participants, the attention of the participants shifted toward the robots (**??** (2)). Then he/she looked at the front (**??** (3)) and continued.

Furthermore, the second minute of the experiment included an action of entering to an underground passageway. We realized that along the road, particularly before arriving to the entrance, the road was calm, and the participants were trying to discover the responsive behaviors of the robots by looking at them. These behaviors of the participants can be associated to the continuity of their behaviors from the previous part (during the first minute). On the other hand, we did not observe a significant difference on the third (included an accident) and the fifth (included an action of turning right) minutes of the experiment. The reason for this might be that during the third minute, the participants' attention shifted on the accident where it was visible on the middle screen except the last a few seconds before the autonomous car passed that area. During the third minute, the robots' gazing behavior did not differ mainly between the conditions because the robots in the NRB were looking only forward while they gazed right or left screen only in the case of the drivers shifted their gaze on these points. As for the fifth minute, it was the last minute of the experiment, thus, the participants might get used to the behaviors of the robots which were not perceived as interesting as before.

4.　Discussion

In this study, we investigated the effectiveness of gaze following behaviors of a robotic driving agent platform to enhance human-autonomous car interaction. The proposed interaction method was expected to increase the perceived agency and comprehending the intentional stance of the robots; and social presence of the autonomous car. In addition, we expected there to be an increase in perceived safety and enjoyability with the autonomous driving system.

The results verified that under the NFB condition, the participants attributed the robots a higher level of agency which means the gaze following behaviors were associated better with the actions of the simulated autonomous car by the participants. Consequently, the gaze following behaviors were an influence in the robots being perceived as the authority of the car rather than a passenger. Also,

at the end of the experiment, some participants reported that they could aware that the robots were following their eye gaze in the NFB condition. The result of the perceived the intentional stance of the robots in the NFB condition was significantly better than the NRB condition which led us to infer that the gaze following behaviors of the robots hold the potential of building intersubjectivity with the human operator. Gergely & Unoka [Gergely 08] assert that attachment and intersubjective mentalizing abilities are functionally and developmentally distinct but interrelated systems. From this point of view, it can be said that the intersubjectivity which implicitly indicates the shared focus of the robots and the human operator, can consolidate the empathy and attachment toward the system in long term.

The results also showed that under the NFB condition, through the gaze following behaviors of the robots, the participants' sense of social presence of the autonomous system was recorded higher compared to the NN and NRB conditions. The relatively strong correlation between the intentional stance of the robots and the social presence of the autonomous car indicated that realizing the intentions of robots contributed to perceiving the autonomous car as being a social entity.

Perceived safety was found significantly higher under the NFB condition compared to the NN and NRB conditions as it is expected. It can be inferred that the robots' gaze following behaviors persuaded the participants. Lichtenthäler, et al. [Lichtenthäler 12] have shown that when a robot's behavior was legible, perceived safety of humans increased. In this respect, the positive correlation between the intentional stance of the robots and the perceived safety was consistent. Weiten [Weiten 07] claims that humans feel safer when they sense the existence of social others rather than being alone. In this respect, the relatively strong positive correlation between the social presence of the autonomous car and the perceived safety of the human operators was relevant. Also, the moderate correlation between PS and ISN remarked the effectiveness of the the intentional stance of the robots, exhibiting through following gaze behaviors, on the social presence of the autonomous car and the perceived safety. Furthermore, the moderate correlations between PS and PA , PA and ISN, PS and ISN indicated that perceiving the robots as an authority was related to comprehending the intentions of the robots, and has a potential to ameliorate the perception of the system as a social entity that might affect the perceived safety.

Perceived enjoyment was found significantly higher under the NFB condition compared to the NRB condition

as it is expected; however, it was not significantly higher compared to the NN condition. It can be said that, without the robots, the participants could also enjoy the autonomous driving by observing and reasoning the car's actions. However, in the case of employing the robots, it was significantly more enjoyable when the robots were responsive to gazing of the participants. Kim, et al. [Kim 13] argued that the feeling of social presence is ameliorated by robots ' social cues (i.e., anthropomorphic traits) that will led to greater enjoyment, attachment, and satisfaction. Technology users who experience strong feelings of social presence are more likely to perceive that they are interacting with an embodied social actor rather than a mere machine. In this sense, through the gaze following behaviors, the robots gained anthropomorphic traits which paved of the participants enjoyed the autonomous driving significantly better in the NFB condition.

The eye gazing analysis in **??** showed that the participants looked at the robots in the NFB condition significantly more often compared to the times in the NRB condition. The responsive gaze following behaviors of the robots attracted the participants especially when they directed their gaze to left and right screen where the gaze following behaviors of the robots were the most apparent. Since the attention of the participants shifted to the robots more often in the NFB condition, and the rating of the perceived enjoyment was higher in the NFB rather than the NRB condition, it can be concluded that the responsive gazing behaviors were perceived as positively. Also, at the end of the experiment, some of the participants reported that in the NFB condition, the robots were watching the road better than the robots in NRB, thus they felt safer in the NFB condition. We can conclude that while the participants were carefully watching out the simulated road, especially on the intersections, they could recognise the robots' intentions, consequently, an intersubjectivity emerged between the robots and the human operators. The subjective evaluation of the intentional stance and the perceived safety supports our hypothesis on this topic.

5. CONCLUSION

In this study, we proposed an autonomous car-human operator interaction paradigm in order to achieve a reliable interaction with an autonomous car, such that the autonomous system and the human could sense each other's intentions and be aware of each other's presence. The results of this pilot study showed that perceiving an autonomous car as a social entity through the gaze following behaviors of a driving agent platform was possible and has

the potential to improve the perceived safety and enjoyment of the autonomous driving system. Future studies will investigate methods to improve the relationship between an autonomous car and human operator in terms of increasing the perceived safety, trust and the pleasure of autonomous driving.

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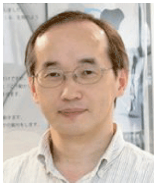
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