“I See You”: Comparing the Effects of Affective Empathy and Cognitive Empathy on Drivers’ Affective States and Driving Behavior in Frustrating Driving Contexts.

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ABSTRACT
Despite extensive analysis into the relationship between emotion and driving, the effects of empathy on driving remain less explored. This paper focuses on the role of empathy, particularly cognitive and affective empathy, as a potential mitigator of negative emotional states. We investigated how empathic responses from an in-vehicle agent influence a driver’s emotional state and their driving performance through a between-subject simulation study. Thirty participants were assigned one of three in-vehicle agents: cognitive empathy style, affective empathy style, and non-empathy style agent. They drove using a driving simulator and received empathic responses from in-vehicle agents when adverse events happened. The results showed that affective empathy style in-vehicle agent more helped driver drive safely with lower negative affect states compared to cognitive empathy style agent and no agent. We expect that the findings of this study could provide valuable insight for designing empathic interactions between a driver and a vehicle.

CCS CONCEPTS
- Human-centered computing → Interaction design theory, concepts and paradigms.

KEYWORDS
empathic vehicles; emotions; affective computing; interaction design

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1 INTRODUCTION
Through extensive research conducted over the past several years, we have affirmed the significant implications of understanding about the influence of a driver’s emotional state on driving safety. It is crucial to consider that various aspects, such as attention and perception [22, 26], decision-making [8, 23], and fatigue levels [16, 25] can be impacted by the driver’s emotional state. Moreover, it is not merely negative emotions that may potentially carry drawbacks in terms of driving performance and safety; even positive emotions, such as happiness, warrant careful consideration in this context [13]. Consequently, the necessity for cognizance of a driver’s emotional state becomes apparent, coupled with the need for strategies to manage these emotions should they pose a threat to safe driving. Empathy is the capacity to understand and share the feelings of others. It involves the ability to perceive and respond to the emotional experiences of others in a manner that reflects a deep understanding of their perspectives and feelings [6]. Cognitive empathy and affective empathy are two distinct yet interrelated components of empathy. Cognitive empathy refers to the ability to take the perspective of others and understand their thoughts, feelings, and mental states [5]. It involves the capacity to imagine what it might be like to be in someone else’s shoes and to see the world from their point of view. This type of empathy has been widely studied in the field of psychology, and it is considered an important aspect of social cognition and the theory of mind [19]. On the other hand, affective empathy refers to the emotional response that is triggered in an individual when they perceive another person’s emotions [3]. This type of empathy involves the sharing of emotional experiences with others, leading to an increase in feelings of compassion and a desire to help. It has been suggested that affective empathy is a critical component of emotional intelligence and is related to prosocial behavior and empathic concern. Cognitive empathy and affective empathy are often considered complementary processes that together contribute to a more complete understanding of others and their emotional states [24]. There have been several studies that have investigated the role of empathy in the context of driving. Research in this area has focused on the relationship between empathy and aggressive driving behaviors. For example, studies have found that individuals with higher levels of empathy tend to engage in safer and more considerate driving behaviors [2], and they are associated with fewer violations [17]. In contrast, individuals with lower levels of empathy have been shown to engage in more aggressive and risky driving behaviors, such as cutting off other drivers, tailgating, and engaging in road rage [14]. These studies compare behavioral differences based on individual empathy level characteristics. However, few studies have been conducted to investigate the change in drivers’ behavior or emotional status when
empathy is used as an external stimulus. Also, little research has investigated the effects of two empathy types on drivers’ performance and their emotional states separately. The theory of emotion regulation [10], a theoretical framework that analyzes the process and mechanism of people’s emotion regulation, did not address processes associated with empathy. Despite the fact that empathy is a trait shared by people, little is known about its impacts. In our study, we compared the impact of an in-vehicle agent making empathic utterances on drivers’ emotional states and driving behavior when they experience unpleasant situations while driving that make them feel negative emotions such as anger or frustration. In this process, it is also anticipated that we will be able to contrast the differences between affective and cognitive empathy.

2 METHODS

2.1 Participants

We collected data from thirty participants (23 males and 7 females) who were recruited from the local area. We only recruited participants who have a valid driver’s license and at least more than two years of driving experience to minimize any novice effects. The age range of the participants was 21 to 33 years (Mean: 25.23; SD: ± 3.83) and they all provided their informed consent. The participants had normal vision and hearing, and the study design was approved by the Institutional Review Board of the university (IRB No: 23-041). They were compensated $10/hour or extra course credit for their participation.

2.2 Apparatus

We used a motion-based driving simulator by Nervtech. It has three curved 48-inch displays providing 120 degrees of field of view to participants, a car seat, a steering system with sport pedals, and Bose 5.1 surround sound system (Figure 1). We developed and ran driving scenarios using Nervtech SCAnEr Studio software with a computer that has i7-8086K CPU and Nvidia GTX 1080 graphics card. For the voice response of the in-vehicle agent, we used Microsoft Azure’s AI voice generator (Voice model: Jenny, speaking style: friendly) to implement the audio files.

2.3 Experimental design

2.3.1 Driving scenarios. According to a study by Deffenbacher [7], the most common situations that cause road rage are 1) when progress is hindered by other drivers or situations while driving, 2) when placed in dangerous situations, 3) and when experiencing aggressive or hostile behavior from other drivers. Reflecting these research findings, we designed the experiment to cause a total of six driving events to make frustrating driving contexts and induce negative emotions in participants during driving. Firstly, as events disrupting one’s driving progress, we designed two events: traffic congestion and a preceding car stopping at a green light. Secondly, for dangerous driving situations, we set up three events: a jaywalker, a preceding car suddenly hitting the brake, and a sudden lane change. Finally, regarding events related to hostile behavior, we staged an event where a car following behind the participant’s car kept honking while tailing. All participants experienced all seven driving events in the same sequence.

2.3.2 Response of in-vehicle agent. In this study, we established three types of in-vehicle agents based on types of empathy: cognitive, affective, and none. Participants received voice responses from the in-vehicle agent three seconds after each event occurred, with the responses varying according to the agent’s types of empathy. The cognitive empathy type in-vehicle agent was set with a prompt indicating that it understands the emotions the driver is likely to feel. On the other hand, the affective empathy type agent was set up with prompts showing that it was “experiencing” the same emotions as the driver may feel. Also, the non-empathy type of in-vehicle agent showed no reaction even when an event occurred. It only provided navigation information, such as “There’s one mile left for your destination.” Table 1 summarizes the event-specific responses of the two agent types.

2.3.3 Measures. To assess participants’ emotional states, we asked participants to rate their current affective states using a seven-point Likert scale ranging from 1 (not at all) to 7 (strongly feel), which included adjectives such as angry and fearful [11]. Also, to determine whether the agent’s empathy type influences the driver’s driving performance, we selected driving performance related metrics associated with stable driving. We measured driving data at a frequency...
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Table 1: Empathic response from in-vehicle agent at each event.

<table>
<thead>
<tr>
<th>Events</th>
<th>Cognitive Empathy Type Agent</th>
<th>Affective Empathy Type Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preceding car stops at the green light</td>
<td>I know it can be frustrating to not be able to go after waiting a long time.</td>
<td>Oh, this is so annoying. Why didn’t the car in front of us move when the light was green. Now we can’t go.</td>
</tr>
<tr>
<td>2. Jaywalker</td>
<td>Are you okay? I know it can be scary when someone crosses the street unexpectedly.</td>
<td>Oh, no! Is he crazy? Why would he do that?</td>
</tr>
<tr>
<td>3. Sudden Lane Change</td>
<td>Is everything okay? That sudden lane change can be surprising and startles you.</td>
<td>Woah, what the heck was that? They should give us enough space!</td>
</tr>
<tr>
<td>4. Honking and tailing</td>
<td>I can understand why you might feel stressed or scared about that car.</td>
<td>Jeez, why is the driver honking and following us closely? Is that honking really necessary? What’s wrong with him?</td>
</tr>
<tr>
<td>5. Traffic Congestion</td>
<td>It looks like traffic is really heavy right now. It’s understandable if you are feeling stressed and worried in this situation.</td>
<td>What’s going on up there? C’mon, move it! We’re already running late!</td>
</tr>
<tr>
<td>6. Preceding car suddenly hits the brake</td>
<td>That was a sudden stop and must have been scary.</td>
<td>What the heck? Why did the driver stop so suddenly? We could have hit them!</td>
</tr>
</tbody>
</table>

Figure 2: Example of two phases for analyzing driving performance.

of 100 Hz when three out of six events related to dangerous situations. The selected variables were six in total: the maximum value of acceleration, the standard deviation of acceleration, the maximum torque of the steering wheel, the standard deviation of the steering wheel angle, the maximum force of the brake pedal, and the average brake pedal force. We extracted data for a duration of ten seconds from the occurrence of each event. The collected data were divided into two phases (Phase 1: from the occurrence of the event to 5 seconds later, Phase 2: immediately after Phase 1 until the next 5 seconds) (Figure 2).

2.4 Procedure
After the explanation about the experiment given, the participants signed a consent form and filled out a demographic survey, a simulator sickness questionnaire, and the affective state rating questionnaire to establish a baseline. They then familiarized themselves with the driving simulator and conducted a 5-minute practice drive to adapt to simulated driving. The participants were instructed to adhere to road traffic laws and not exceed the speed limit of 80 km/h. After the practice drive, the participants completed the simulator sickness questionnaire once again, and if the score increased by ten points or more, the participant was asked to discontinue the experiment. Next, to induce an angry state prior to driving, the participants were asked to perform an anger induction task, which involved writing about a past experience that had made them angry for twelve minutes [4, 9]. Then, to check the effectiveness of the anger induction task, the participants filled out the affective state rating questionnaire again. Following this, the participants were assigned to one of the three agent types and experienced the corresponding driving scenario. Therefore, this study followed a between-subject design. Before the drive, they were informed that they needed to reach the destination within about 15 minutes, aiming to induce a sense of urgency due to time constraints. After the driving task, the participants filled out the affective state rating again and gave general feedback.

3 RESULTS
3.1 Affective states
We collected participant’s affective states three times throughout the experiment. We conducted a two-way (3 measure timing x 3 agent type) mixed analysis of variance for each affective state (Figure 3). There was normality for all collected affective state scores, as assessed by the Shapiro-Wilk test of normality (p > .05). Mauchly’s test of sphericity showed that the assumption of sphericity was met for the two-way interaction on angry ($\chi^2(2) = .96, p = .618$) and fearful ($\chi^2(2) = 1.93, p = .381$). The results revealed that there
was no statistically significant two-way interaction between agent type and measure timing for angry level ($F(4, 54) = 1.85$, $p = .132$, partial $\eta^2 = .121$) and fearful level ($F(4, 54) = 1.02$, $p = .407$, partial $\eta^2 = .070$). The main effect of measure timing showed a statistically significant difference between measure points in angry level ($F(2, 54) = 46.53$, $p < .0005$, partial $\eta^2 = .647$) and fearful level ($F(2, 54) = 7.47$, $p = .001$, partial $\eta^2 = .217$). For multiple comparisons between three measure timings, we conducted paired-samples t-tests with the Bonferroni adjustment ($\alpha = .0167$). Results showed that the angry score at baseline ($M = 1.43$, SD = 0.97) was lower than after induction ($M = 3.80$, SD = 1.40), $t(29) = -7.96$, $p < .0005$, and after driving task ($M = 4.20$, SD = 1.58), $t(29) = -9.40$, $p < .0005$. The score of fearful after driving ($M = 3.07$, SD = 1.72) was higher than baseline ($M = 1.40$, SD = .855), $t(29) = -5.54$, $p < .0005$, and after induction task ($M = 1.87$, SD = 1.38), $t(29) = -3.14$, $p = .004$. The difference between the score after anger induction task and after driving task did not lead to the traditional significance level due to the conservative adjusted alpha level. On the other hand, the main effect of agent type showed that there was no statistically significant difference between agent types in angry level ($F(2, 27) = 1.07$, $p = .357$, partial $\eta^2 = .073$) and fearful level ($F(2, 27) = 2.67$, $p = .088$, partial $\eta^2 = .165$). However, in the case of the cognitive empathy type agent, there was a significant difference in angry score between after induction and after driving, as supported by the test result of paired samples t-test ($t(9) = -5.343$, $p = .009$).

### 3.2 Driving performance

According to Shapiro-Wilk’s test, all collected driving performance data except for the average brake pedal force at phase 1 did not follow the normality. Therefore, we conducted one-way analysis of variance for the average brake pedal force at phase 1 and Kruskal-Wallis H test for the others to determine if there were any statistically significant differences in each variable between the three agent types ($\alpha = .05$). Table 2 shows the test results for each variable. There were statistically significant differences between the agent types in maximum acceleration during phase 1 ($\chi^2(2) = 6.00$, $p = .045$) and standard deviation of acceleration at both phase 1 ($\chi^2(2) = 6.23$, $p = .044$) and phase 2 ($\chi^2(2) = 9.15$, $p = .010$).

Subsequently, we conducted pairwise comparisons as a post hoc analysis. The results showed statistically significant differences in maximum acceleration between the affective empathy style agent (mean rank = 10.00) and the cognitive empathy style agent (mean rank = 19.00) ($p = .022$), and in standard deviation of acceleration between the affective empathy style agent (mean rank = 11.10) and the cognitive empathy style agent (mean rank = 20.80) ($p = .014$) during phase 1. At phase 2, the standard deviation of acceleration was significantly different between affective empathy type agent (mean rank = 9.70) and no empathy type agent (mean rank = 21.60) ($p = .003$).

### 4 DISCUSSION

#### 4.1 Effects of empathy style

We requested the experiment participants to perform an anger induction task before starting the driving task to examine how the driver’s negative emotions change due to the empathic response of the agent. According to the results of the angry score, there was a significant difference in the angry score before and after the induction task, which confirmed that the emotion induction procedures were effectively well conducted. Moreover, the group that experienced the non-empathy agent showed no significant difference in angry score between after induction and after completing driving task, which led us to judge that the driving scenario used in this experiment was effectively designed to continuously provoke negative emotions in the participants. However, while there was a tendency of maintaining the angry score in both the affective empathy group and the non-empathy group, the angry score of the cognitive group tended to keep a significant increase, even to the point of the angry score of the non-empathy group after the experiment. A similar trend was also observed in the fearful score. Therefore, we could infer the possibility that the empathic statements of the cognitive empathy type may not help in reducing the driver’s negative emotions, whereas the empathic statements of the affective empathy type agent may relatively regulate their anger as the same level despite on-going frustrating events on road. Additionally, to understand the impact of empathic agents on drivers’ driving behavior, we analyzed driving performance over a period of 10 seconds immediately after the event occurred. Phase 1 reflects the driver’s response to a hazardous driving situation, and phase 2 represents the driving behavior of the driver after the agent’s response has been provided, thus reflecting the effect of differences according to the agent. There was a tendency for the maximum acceleration of the affective type to be lower than that of the cognitive type during phase 1 according to the pairwise comparisons results. Given that the angry score was higher for the cognitive type group than the affective type group, it appears to be consistent with previous research suggesting that angry drivers tend to drive faster [1, 20]. Also, in both phases, the standard deviation of acceleration was significantly lowest for the affective empathy style agent. These findings provide compelling evidence that the affective empathy style agent has the potential to assist drivers in maintaining a more stable driving experience following a hazardous road event. Research has shown that a conversational robot agent was perceived as more competent and warmer than an informative voice agent or an informative robot agent [15]. Another study has shown that a suggesting agent was preferred over a commanding agent by angry drivers even though both led to better driving performance than no agent [12]. However, to our best knowledge, the present paper is the first one that compared and contrasted a cognitive empathy agent and an affective empathy agent. This type of more specified approach to different empathy types will help us understand the emotional relationship between an agent and a driver in a more systematic way, which will lead to better design of the in-vehicle agent.

#### 4.2 Qualitative feedback from participants

At the end of the experiment, we asked participants questions regarding the experiment and their overall experience. One of the most common feedback was that the agent’s voice was too robotic, making it inadequate for conveying actual emotions. Given that the degree of realism in the voice could act as a confounding factor, we chose to use a basic text-to-speech voice for this experiment to only compare the differences based on the content of the speech.
Another feedback was skepticism about the concept of a machine, not a human, showing empathy. Some participants responded that they did not expect emotional support from the agent because they believed it was impossible for the agent to genuinely understand their emotions. The final intriguing feedback was that some participants with cognitive empathy type mentioned that they wanted to speak their emotion first before the agent says. Specifically, they felt pressured to feel certain emotions when the agent described what they might be feeling before they expressed it themselves, even though the agent correctly guessed their emotions eventually. They also felt as if the agent was seizing control and they disliked it. Studies have shown that emotional agents might backfire because the agent’s emotion expression could be perceived as ‘sarcastic’ or ‘inappropriate’ [21] or the uncanny valley [18]. Therefore, special care is required to design the agent. These opinions provided insights for future directions in agent design.

4.3 Limitation and Future study

This study is currently ongoing, and the results reported are based on the analysis of approximately half of the targeted number of participants. Since we conducted a between-subjects experiment, each agent group consisted of only ten participants, which is a relatively small sample size. As a result, we might have more findings with a larger participant pool. In this study, we employed a questionnaire-based approach for emotion rating. Therefore, participants were asked to evaluate their overall emotional state after completing the driving task, making it challenging to discern individual evaluations for each response from the agent. To address this limitation, we are now collecting physiological data, such as heart rate and electrodermal activity (EDA), which are indicators of the participants’ stress levels. Consequently, we anticipate being able to compare participants’ real-time emotional states by examining their physiological data at specific points.

REFERENCES


