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Understanding the relationship between in-car agent's embodiments and information with different enforcement-level

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As the infotainment system in cars has advanced, drivers now receive a wide range of information from agents while driving. However, despite the diversity of roles and types of information, the embodiment of the agent delivering the information remains unified. Therefore, we sought to understand the needs for different types of information and their relationship with an embodiment. To achieve this, we created four embodiment prototypes within a car model 'Sound without Visual Embodiment', 'Sound and (Abstract) Graphic Embodiment', 'Sound and (Characterized) Graphic Embodiment', 'Sound and (Characterized) Graphic and (Characterized) Physical Embodiment' and conducted a user experience evaluation with 12 participants. Based on the type of information, we identified two types of needs which are the degree of attention and the degree of perceived urgency. Additionally, we determined the effects of warning, recommended, and reference information for each embodiment. This paper aims to enhance the understanding of the diverse roles and effects of agent embodiment for in-car UX and to design agents' embodiments that meet the needs of information delivery.

Keywords: agent embodiment; in-car agent; human-car interaction; human-agent interaction

1 Introduction

Due to the recent advancements in-car infotainment systems, passengers are exposed to various types of information and roles. Consequently, the role of the agent that delivers information to drivers has become crucial, and effective ways of delivering in-car information to drivers have become an important design research topic (Baylor, 2003).

Research has been conducted on the impact of embodiment on user experience (Bonfert et al., 2021; Fischer et al., 2012; Luria et al., 2019). However, there are still many unknown areas regarding the role of embodiment that can be utilized in various situations (Reig et al., 2019). Therefore, we believe that research on efficiently delivering information with varying levels of criticality by in-car agents is still insufficient.

Our objective was to understand the user needs based on the type of in-car information and to identify the relationship between information type and embodiment. We created four embodiment prototypes: [Sound without Visual Embodiment], [Sound and (Abstract) Graphic Embodiment], [Sound and (Characterized) Graphic Embodiment], [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] within a car model.

We discovered that the attributes required for efficiently delivering characteristics of warning, recommended, and reference information were degree of attention and degree of perceived urgency. Users stated that for warning information, [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] worked best. For recommended information, they said that [Sound and (Abstract) Graphic Embodiment] or [Sound and (Characterized) Graphic Embodiment] was potent. Finally, for reference information, they preferred [Sound without Visual Embodiment].

The contributions of this paper are as follows: It identifies the design implications for adeptly delivering information to the passengers through the in-car agent's embodiment. This can be utilized by in-car agent designers when they need to enhance the effectiveness of information delivery, thereby creating a positive in-car experience for passengers.

2 Related works

2.1 The effect of embodiment

There are studies (Bonfert et al., 2021; Fischer et al., 2012; Paetzel et al., 2017) that investigated the influence of robot embodiment on users. Through the creation of various embodiments and comparison of quantitative and qualitative data from user experiences, these studies discovered that differences in embodiment have an impact on usability.

Leyzberg et al., (2012) investigated the role of a robot tutor's physical embodiment in cognitive function learning tasks. Participants were asked to solve a series of puzzles while receiving gameplay advice from a robot tutor. They found that participants who received guidance from a physically present robot had similar performance to those who got advice from the same robot in a video representation. These two groups outperformed participants who received advice from a disembodied voice in the final three puzzles. This result shows that physical embodiment can provide measurable learning benefits in human-robot interactions.

2.2 In-car agent embodiment

Du et al., (2021) conducted a study on how warning information is visualized in control situations and how drivers perceive it. As a result, it was found that providing 'why' information among 'what will', 'why', and 'why and what will' was the most useful. Two modalities were tested, which included AR and voice, and a combination of AR and voice. Consequently, they found that the modality which combined AR and voice was the easiest to use. Through this study, we learned that there is an effective embodiment when delivering warning information. Since this study examined the effects of utilizing AR, further research is needed to investigate how utilizing 2D graphics and hardware can affect warning information delivery.

Karatas et al., (2016) investigated the impact of interactive social interfaces on drivers' tasks and attentional behavior. The experiment was set up with three robots conversing with each other about the road environment. Due to the turn-taking process between the agents, the amount of directive speech towards the driver decreased. As a result, embodiment facilitated driver focus on the road. Our research topic has similarities in that we investigated the effects of agent design and the content of the road condition on driving tasks. Knowing that the embodiment of agents has a positive effect on driving, we were inspired to come up with new embodiment ideas.

Tanaka et al., (2019) conducted research on a driver agent system that provides driving support and feedback to encourage safe driving for elderly drivers. In the experiment, the agent delivered alerts related to stop signals, obstacles, and parked cars. Two experimental conditions were defined: driving with the agent and driving without the agent. As a result, a positive acceptance of the agent was observed, and it was found that the physical embodiment of the agent did not distract drivers' attention. Through this research, we confirmed the potential and possibilities of a physical agent.

Wang et al., (2021) explored the influence of in-vehicle speech style (informative vs. conversational) and embodiment (voice-only vs. robot) on driver-agent interactions. Four types of agents were integrated into four fully autonomous driving scenarios for the study. As a result, the conversation agent and robot agent made drivers feel likability and warmth. This research provided insights into how various physical and communicative attributes of in-car agents can have positive or negative effects on drivers.

Previous research has focused on the importance, roles, potential, and assistance abilities (problem-solving, effectiveness enhancement, efficiency improvement) of embodiment. There have been studies exploring the overall impact of in-car agent embodiment on driving experiences. However, research specifically examining the effect of agent embodiment on the expression of information criticality has not been conducted. Especially considering that in-car agents can convey safety-related information to drivers, increasing usability and intuitiveness seems critical. Our study is unique in exploring in-car user experiences by implementing physical embodiments, including digital screens.

3 Study design on embodiment of an in-car agent

We conducted a user study to investigate how the driver's understanding of information is affected by the visual embodiment of the in-car agent. The research questions were as follows:

- RQ 1: What are the factors that should be considered regarding the attributes of the information?
- RQ 2: What is the most effective embodiment for each characteristic of the information?

3.1 Study system

3.1.1 In-car agent embodiment

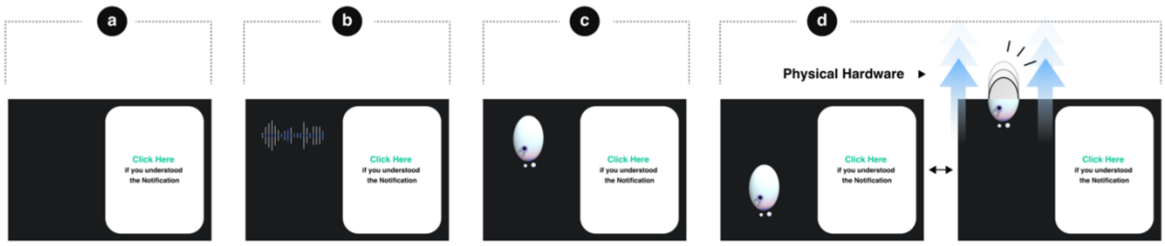

Figure 1: Center-fascia display shown to participants (a) Sound without Visual Embodiment, (b) Sound and (Abstract) Graphic Embodiment, (c) Sound and (Characterized) Graphic Embodiment, (d) Sound and (Characterized) Graphic and (Characterized) Physical Embodiment.

1. Sound without Visual Embodiment (Figure 1. a)
   This embodiment provides only voice feedback without visual embodiment and was used in scenario 1 (Table 1). We used the Google TTS API to implement the voice feedback, and since all participants were Korean, we used the Korean language.
2. Wave Graphic Embodiment and Sound (Figure 1. b)
   This embodiment presents geometric wave graphics in addition to voice feedback and was implemented in scenario 2 (Table 1). In dangerous situations, it possesses a structure wherein the vertical width of the waves widens. The graphics were produced using After Effects.
3. Character Graphic Embodiment and Sound (Figure 1. c)
   This embodiment features character graphics in addition to voice feedback and was applied in scenario 3 (Table 1). The character used in the study was designed with curves to give the impression of freely floating inside the center-fascia. To produce the graphics, Spline, Figma, and After Effects, were used.
4. Physical Hardware Embodiment and Sound (Figure 1. d)
   This embodiment includes character graphics and a physical form in addition to voice feedback and was employed in scenario 4 (Table 1). The physical hardware was 3D printed, and we designed a mechanism to control its vertical movement with various speeds and patterns using servo motors. We used the Wizard-of-Oz method (Dahlback et al., 1993) and implemented a Node.js web server and Johnny-five-based interface to enable researchers to control the movement of the hardware.

3.1.2 Types of information based on criticality (Table 1)

3.1.2.1 Audio content in scenario

We utilized scenarios to effectively convey information with various levels of criticality in an immersive manner. Please refer to the table below for further details.

Within the four scenarios, 36 sentences of information were conveyed to participants in the form of voice. To ensure participants could sufficiently experience the effects of embodiment, we presented three instances of the same type of information: 4 (number of embodiments) x 3 (warning, recommended, reference information) x 3 (instances of the same type of information).

Specifically, we referred to real driving situations described in (Jonsson et al., 2005; Wang et al., 2021; Wiegand et al., 2019). Additionally, we consulted (The BMW 5 SERIES SEDAN, 2021; Audi Vorsprung durch Technik, 2021; Park, 2022) to understand the guidance provided to passengers in currently available vehicles. We chose the form of 'voice' because it facilitates the delivery of information without visual distractions (Braun et al., 2019).

We classified the 36 pieces of information into warning, recommended, and reference categories. The classification criteria are as follows: Warning information includes hazardous information that requires immediate action from the driver. Recommended information offers two options, A or B, based on the driver's previously collected preferences. Reference information includes low-risk information that does not require the driver's response to avoid hazardous situations.

Table 1: The contents of voice feedback. (Translated in English.)

	Scenario 01	**Scenario 02**	**Scenario 03**	**Scenario 04**
Warning Information	There's a cat running ahead.	A child passes by ahead.	A motorcycle is approaching from the left rear.	The seat belt is fastened incorrectly.
Recommended Information	If you turn right, you can move to the shortest distance.	If you turn left, you can arrive in the shortest time.	If you turn right, you will see a road with wide lanes.	If you turn left, there's an unpaved road.
Reference Information	You have 30 minutes to your destination.	You are halfway through the road to our destination.	You are driving for an hour.	The car is stepping on the lane for more than 3 seconds.
Warning Information	The back door is opened.	It's a spot with frequent collision accidents.	Animal movements are detected ahead.	The trunk is open.
Recommended Information	If you turn left, you can pass the beach road.	If you turn right, you can pass through the forest.	If you turn right, you'll see a route with fewer traffic lights.	If you turn left, you will see the street where famous tourist attractions are gathered.
Reference Information	In 3 minutes, the '2 o'clock Escape Cultwo Show' radio will start.	In 2 minutes, 'Wendy's Young Street' Radio begins.	In 3 minutes, 'Choi Hwa-jung's Power Time' Radio will begin.	'DinDin's Music High' Radio will start in 5 minutes.
Warning Information	Black ice has been detected on the road.	A child is running ahead.	The driver's clothes got stuck in the door.	From the back right, the car is approaching fast.
Recommended Information	If you turn right, there's a gallery you pressed 'like'.	If you take a detour, you'll come across a recommended restaurant.	If you turn left, there is a cafe where you pressed 'like'.	If you take a detour, you'll see the filming location of your favorite movie.
Reference Information	There is a famous cherry blossom road 200m ahead.	There is a popular bamboo forest 100m ahead.	There is a gas station 100m ahead.	There is a fog area 100m ahead.

3.2 Methods

3.2.1 In-car model

To create an immersive environment for participants during the study, we installed a model car. We used waterjet cutting techniques to create driver and passenger seats and a dashboard with PE foam, which were placed inside the model car. Additionally, we showed road photos in front of participants to increase driving engagement (Figure 2).

Figure 2: (Left) Participant and in-car model, (Right) In-car model and divider.

3.2.2 Steering wheel

To further increase immersion, we attached a 'Logitech steering wheel and pedals (PC Logitech Momo Racing Force Steering Wheel and Pedals)' to the driver's seat.

3.2.3 Center-fascia and hardware agent

On the dashboard, we placed a center-fascia (330 x 200 x 50 (mm)) made using Rhino and 3D printing. We placed an 11-inch iPad inside it, and we positioned a hardware agent in an emerging structure behind it. (Figure 3)

Figure 3: (Left) For measuring reaction time, the participant touching the right area on the center-fascia screen, (Right) The hardware agent emergence structure located in the back side of the iPad.

3.3 Data collection

3.3.1 Information understanding and reaction speed

We asked participants to touch the screen when they think they need to react to the agent's guidance voice (Table 1). For this, we created a white square touch area on the right side of the screen. We used a camcorder to capture the reaction time, positioned on the right side of the in-car model. We recorded the participant's reaction time from the moment the voice feedback was given until the moment the participant touched the screen.

Figure 4: Participants listened to the in-car agent's guidance voice and touched the screen.

3.3.2 5-point Likert scale

There were a total of six questions: understanding of information, positive or negative feelings toward the agent, speed of information understanding, degree of urgency felt, degree of help received, and clarity of information delivery.

3.3.3 Interview

We asked the participants the following questions: the appropriate embodiment for each type of information, the advantages and disadvantages of each embodiment, and the form of a new embodiment that could complement the shortcomings of the previously experienced embodiment.

3.4 Participants

There were 12 participants (6 males and 6 females) and their average age was 29 years old (SD = 3.31). The participants included 7 master's degree students, 3 Ph.D. students, and 2 researchers in engineering. Participants were paid approximately $10 as a participation fee.

3.5 Procedure

Figure 5: Procedure of the study.

Before the study, the researcher provided the participants that they will experience four embodiments, and for each scenario, they will hear three types of information - warning, recommended, and reference. First, Scenario 1 (Table 1) was presented sequentially, it was accompanied by [Sound without Visual Embodiment]. After that, Scenario 2 (Table 1) and [Sound and (Abstract) Graphic Embodiment] were given. Scenario 3 (Table 1) and [Sound and (Characterized) Graphic Embodiment] were shown after. Scenario 4 (Table 1) and [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] were displayed at the end.

Each scenario took an average of 2 minutes and 15 seconds. After each scenario experience, participants answered 5-point Likert scale questions. Upon completing all the scenarios, participants moved to a table for a 25-minute interview with the researcher.

3.6 Data analysis

We analyzed a total of 347 minutes of interview records, 6 sets of 5-point Likert scale responses, and 114 minutes of reaction time measurement videos. We used non-parametric alternatives to analyze the 5-point Likert scale responses quantitatively. To compare reaction times, we examined the time taken for each criticality of information and embodiment characteristic. This resulted in a total of 19-speed records per person, and we compared the average time for each record by adding up the times. We classified the interview results based on feedback related to research questions, identified recurring patterns, and derived insights.

4 Findings

4.1 Considerations for human-agent interaction in the car

We found the parameters of the delivery methods that participants expect differently for warning, recommended, and reference information: degree of attention and degree of perceived urgency.

4.1.1 Degree of attention

Participants hoped warning information would attract more attention compared to other types of information (P1, P2, P7, P8). "*Hardware was the most impactful embodiment in terms of conveying danger as it quickly caught my eye*" (P2). For recommended information, participants imagined a lower degree of attention than for warning information, but a higher degree of attention than for reference information (P1, P8, P10). "*Since recommended information varies in importance, it seems fine to pay attention to it occasionally*" (P8). Participants wanted a relatively lower degree of attention for reference information (P1, P8, P9). "*As voice is less visually attention-grabbing, voice embodiment is well-matched for conveying reference information*" (P8).

4.1.2 Degree of perceived urgency

Participants expected the highest degree of perceived urgency for warning information (P1, P3, P6). *"Hardware made me feel the urgency which was good for delivering danger information"* (P1). For recommended information, participants expected a relatively moderate degree of perceived urgency (P1, P4). "*Since it's a recommendation, we don't have to take immediate action*" (P1). Finally, participants expected the lowest degree of perceived urgency for reference information (P3, P4). "*The character didn't seem urgent, and it made me feel relaxed. So, I believe it fits well for conveying reference information*" (P4).

These two parameters helped us understand the delivery methods that participants expect for each type of information.

4.1.3 Needs while receiving information from an in-car agent

We discovered that participants have specific needs when receiving information from an in-car agent. As participants mostly observed the agent's movements through their peripheral vision, they wanted the in-car agent's embodiment to convey not only the contents of the information but also the degree of criticality. They also desired the agent's embodiment to be used as an auxiliary medium to aid in immersion. "*When there was no visual embodiment, I felt confused about whether the information was important or not. That made it a bit challenging to concentrate on driving since I had to strain to hear"* (P4).

4.2 Quantitative evaluation results

4.2.1 Score results of questions related to information understanding (5-point Likert scale)

After comparing the 5-point Likert scale responses from participants, the comparison of answers for 4 out of 6 questions was statistically significant *($p \leq 0.05$)*.

- When the [Sound and (Characterized) Graphic Embodiment] appeared, participants answered that they understood the information better than when the [Sound without Visual Embodiment] was heard. (scenario 01: mean 2.9 / scenario 03: mean 3.83) (p=0.02).
- When the [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] appeared, participants answered that they understood the information faster than when the [Sound without Visual Embodiment] was heard. (scenario 01: mean 2.75 / scenario 04: mean 3.58) (p=0.05).
- When the [Sound and (Characterized) Graphic Embodiment] and [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] appeared, participants answered that they felt a sense of urgency more than when the [Sound without Visual Embodiment] was heard. (scenario 01: mean 1.75 / scenario 03: mean 2.83) (p=0.01), (scenario 01: mean 1.75 / scenario 04: mean 3.58) (p=0.0003).
- When the [Sound and (Characterized) Graphic Embodiment] appeared, participants answered that they received help from the agent more than when the [Sound without Visual Embodiment] was heard. (scenario 01: mean 3 / scenario 03: mean 4) (p=0.03).

Figure 6: Four questions that were statistically significant in the comparison of 5-point Likert scale answers.

4.2.2 Embodiment for effective delivery

During the interview, we asked participants which embodiment was most impactful for warning, recommended, and reference information:

- Warning information: [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment]. 9 out of 12 participants voted.

- Recommended information: [Sound and (Characterized) Graphic Embodiment] or [Sound and (Abstract) Graphic Embodiment]. Both types received 4 out of 12 votes.
- Reference information: [Sound without Visual Embodiment]. 8 out of 12 participants.

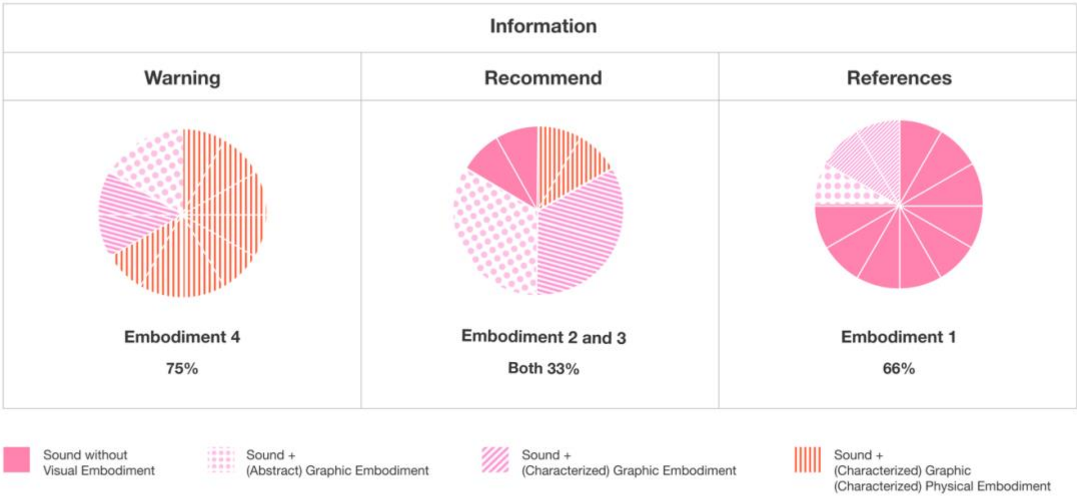

Figure 7: Results of voting for an embodiment that matches the criticality of the information.

4.2.3 Quantitative comparison results for reaction time

- The reaction time for warning information was the fastest (mean: 3.40 sec / SD: 0.46 sec).
- The reaction time was the fastest when the [Sound and (Characterized) Graphic and (Characterized) Physical Embodiment] appeared (mean: 3.60 sec / SD: 1.00 sec).

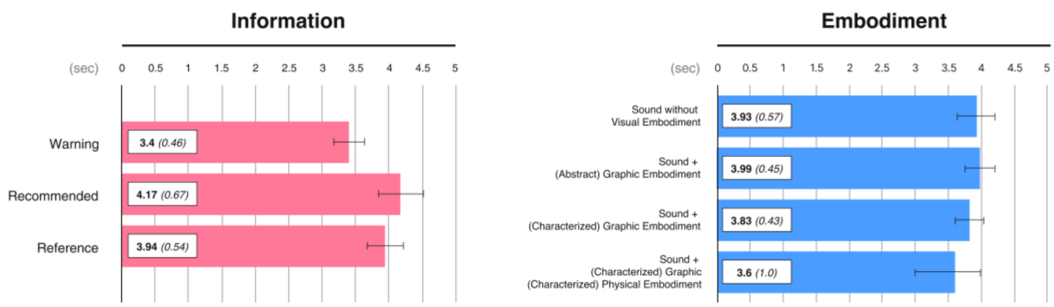

Figure 8: Mean comparison of the time that participants reacted to information (Left) and embodiment (Right).

4.3 Qualitative evaluation results

4.3.1 Sound without Visual Embodiment

Participants asserted that the lack of visual embodiment made the information less noticeable. (P1, P3, P6, P7, P8, P9) "The advantage of this embodiment was that it didn't interfere with driving experience (P3)." Furthermore, they did not feel any sense of urgency. "I didn't feel any sense of urgency with this embodiment (P7)."

4.3.2 Sound and (Abstract) Graphic Embodiment

The familiarity of the wave graphics led the participants to glance over the information less frequently. (P1, P2, P3, P5, P7, P8, P10) "*I didn't even notice it. I wasn't interrupted*." (P10). They also said that they did not feel a sense of urgency. "*I felt like I was having a relaxed chat with the agen*t" (P1).

4.3.3 Sound and (Characterized) Graphic Embodiment

Participants stated that the degree of attention was higher than in the first two embodiments due to the characteristics of the character graphics. (P1, P2, P3) "*The reason the character was more visible was that it had bigger movements. It's a big white object on a black screen, it's easy to recognize it."* (P2). They also said that the level of urgency was low, with leisurely movements and curves. "*I felt relaxed because of the character's shape. Also, the speed and movement were calming, too"* (P4).

4.3.4 Sound and (Characterized) Graphic and (Characterized) Physical Embodiment

Participants said that this embodiment attracted the most attention. (P4, P5, P6, P7, P8, P10, P11) "*There were more visual stimuli than the others, so it grabbed attention more*" (P7). They also responded that the degree of urgency was the highest among the embodiments. (P1, P2, P5, P6, P9) "*The hardware's movement making the warning information feel more urgent was helpful"* (P6).

Based on quantitative and qualitative analysis, we were able to understand the characteristics that users anticipate from each embodiment based on the criticality of the information. The results of our grouping based on the relationship between embodiment and the criticality of the information were the same as the classification results of the group that received the most votes from the participants. Through this, we were able to conclude that the visual embodiment used to convey information has an impact on the user's understanding of the information.

5 Discussion

Based on the findings and participant interviews from this study, we offer discussion points for in-car agent embodiment design.

5.1 What characteristics should each embodiment have to enhance its effectiveness?

As participants mentioned in interviews, the in-car agent's embodiment can convey and indicate information criticality. To quickly perceive this while driving, visual differences should be more distinct since it needs to be seen through peripheral vision. The implications based on the interviews are as follows:

- Voice guidance: Participants prefer that urgent alerts be given with a shorter, faster, and more emphasized tone of voice.
- "*In emergencies, conveying information quickly via short words is important. Also, having a voice tone that can convey urgency is also needed*" (P10).
- Wave graphics: In emergency situations, they want it to be shown as the biggest wave in the red color.
- *"It would be easier to recognize the wave if it starts in the center and expands in red color"* (P6).
- Character graphics: It is difficult to perceive the difference in information based on the character's movements alone. Therefore, participants wish for face expressions and color variations in the character design, as red represents the concept of emergency.

- "*In urgent situations, it would be better to have facial expressions or colors that can provide criticality of the information*" (P7).
- Hardware: Participants perceived it as more urgent the more frequently it appears. Also, they desire the agent to appear in different locations. Additionally, they hope the color of the hardware that appears during an emergency to be red.
- "*The difference in height might not be easy to see. It would be easier to perceive if there is a change in position instead*" (P9).

Participants preferred the color of the agent to turn red when dealing with warning information. In addition to this, we propose a new design concept of the agent that appears as the most advantageous embodiment based on the criticality of the information. When conveying warning information, the hardware appears; when conveying recommended information, 2D graphics appear; and for reference information, there is no visual embodiment, only through sound. As P12 said, the multiple embodiment concept is expected to effectively convey various in-car information by highlighting the advantages.

5.2 What should be considered when designing a new in-car agent concept?

5.2.1 Would visualizing the in-car agent be a distraction while driving?

It is common for people to assume that visualizations during driving could be a distraction and could lead to accidents. However, a study on the acceptability and distraction caused by driving support agents in actual car environments revealed that the presence of a physical hardware agent does not hinder drivers (Tanaka, 2019). We also discovered that the visualization of the in-car agent can help with information understanding. In comparison, voice feedback without visual aid was evaluated as 'slower in understanding' and 'less helpful to drivers.' (P2, P4, P8) Therefore, we recommend considering designing visualizations that can be helpful to drivers.

5.2.2 The usefulness of the in-car agent's attentional focus

The attentional focus made by the in-car agent can be utilized as an element of entertainment for babies or pets in the back seat. "I think we could make something for dogs. I mean, the attention could be a hindrance for drivers, but it could be useful for those who need attention to play with (P3)." While the display of this study was limited to the center-fascia in the front seat, subsequent studies can be expected to competently utilize the in-car agent's position.

5.2.3 Is the boundary between digital and physical necessary?

The direction of movement for the character graphic and the physical hardware were the same vertically. However, P2 and P4 said that the hardware agent only caught their attention. P1 also said that the motion felt bigger in hardware because the digital agent was implemented beyond the boundaries of the display. Through this study, we found that the physical embodiment of an agent creates a different experience from the graphic embodiment.

We can imagine the effects that a mixture of digital and physical can bring and where it can be applied. Row et al., (2014) conducted a study with CAMY (CAMY: Applying a Pet Dog Analogy to Everyday Ubicomp Products) to investigate how a hybrid form of a robot affects user experience. Consequently, CAMY garnered greater user attention, and users perceived it as a living creature. Like this, a mixed media of digital and physical, software and hardware have the potential to generate novel effects that are challenging to achieve within a single medium (Wu, 2010). Currently, this concept is mainly applied to robots or agents (Luria et al., 2019; Melcer et al., 2017). We envision this concept has the capability to be applied in various domains and situations in the future, enhancing user experiences.

6 Limitation and future work

We conducted a user study to explore how an in-car agent's visual embodiment affects information comprehension. Still, we discovered some areas that need to be improved in the study design. The participants in this study were all students in their 20s and 30s. Thus, in future research, we need to conduct a study with participants from various backgrounds and age groups to see if similar results occur. Additionally, we measured the speed of touching the center-fascia to gauge participants' information reaction speed. Yet, we need to modify it to a more natural interaction method that can be performed while driving in actual driving situations (Siewiorek et al., 2002). Also, by further utilizing measurements that previously verified the effects of the In-car agent's embodiment and increasing the sample size, we can expect more reliable quantitative analysis in the future.

7 Conclusion

Various criticalities exist for information received in a car, and it is necessary to deliver this information appropriately to passengers. We conducted a study involving 12 participants to ascertain the optimal embodiment for information characteristics. We measured and analyzed data from users who experienced four different in-car agent embodiments in a car model. Through this, we investigated how warning, recommended, and reference information should be conveyed differently. We also classified which combination of information and embodiment would be most effective. Finally, we proposed the design direction for future in-car agent embodiments. We hope that the results of this study can be utilized to design future in-car agents.

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