Affective Role of the Future Autonomous Vehicle Interior

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ABSTRACT
Recent advancements in autonomous technology allow for new opportunities in vehicle interior design. Such a shift in in-vehicle activity suggests vehicle interior spaces should provide an adequate manner by considering users’ affective desires. Therefore, this study aims to investigate the affective role of future vehicle interiors. Thirty-one participants in ten focus groups were interviewed about challenges they face regarding their current vehicle interior and expectations they have for future vehicles. Results from content analyses revealed the affective role of future vehicle interiors. Advanced exclusiveness and advanced convenience were two primary aspects identified. The identified affective roles of each aspect are a total of eight visceral levels, four visceral levels each, including focused, stimulating, amused, pleasant, safe, comfortable, accommodated, and organized. We expect the results from this study to lead to the development of affective vehicle interiors by providing the fundamental knowledge for developing conceptual direction and evaluating its impact on user experiences.

1 INTRODUCTION
The growth and refinement of autonomous technologies are driving vehicle innovation, expanding design possibilities from infotainment systems to the whole vehicle interior (Figure 1). Core advantage of autonomous driving is freeing drivers from driving tasks, enabling other activities such as leisure and entertainment [17]. It also enhances social interactions between driver and passengers [8]. In 2015, Nissan responded to these changes with a new autonomous vehicle interior design in their IDS concept car, featuring front-row seats that rotate in autonomous mode, blurring the boundary between driver and passengers. This evolution in autonomous technology is shifting user perceptions, providing fresh design opportunities for innovative vehicle interiors [16].

Vehicles manufacturers must now deeply consider user activities in their interior designs [1, 20]. For instance, Toyota showcased the e-palette concept at CES 2018, a flexible interior design platform tailored to customer needs, signaling a shift towards user-focused design. Similarly, Renault, at the 2018 Paris Motor Show, unveiled three concept vehicles based on users’ vehicle usage: the EZ-GO for daily routines, the EZ-PRO for moving heavy products, and the EZ-ULTIMO for premium mobility on special days. Future vehicle interiors are evolving beyond simple infotainment, moving towards intelligent spaces designed for specific purposes. To enhance user experience, vehicle design should align with its intended purpose.

Therefore, the devices composing the vehicle interior and the sensation of space must be unified in expressing the purpose provided by the vehicle. It is essential to define the affective role of the vehicle product in delivering cohesive feelings within the vehicle [11, 12]. The dictionary definition of ‘affect’ is “relating to, arising from, or influencing feelings or emotions,” which refers to things naturally aroused when seeing or using an object [5]. Similarly, well-designed affective vehicle interiors allow users to naturally immerse themselves in the provided experience and provide an emphatic impression from such emotional engagement [4]. Therefore, it is essential to define the affective role while designing a better vehicle interior.

To identify affective roles, studies typically expose users to a range of designs to stimulate diverse impressions, gathering and organizing adjectives to describe the experience. However, due to scale limitations, it’s challenging to offer a variety of vehicle interior stimuli. As a result, affective roles are often identified within specific components, like steering wheels, clusters [9, 10], infotainment displays [19], or human-machine interfaces [2]. Additionally, the industry is adopting affective solutions in vehicle design. For
instance, Benz’s AVTR concept car monitors the user’s emotional state to influence driving style. Similarly, KIA debuted a real-time emotion-adaptive driving system at CES 2019 that predicts driver preferences and tailors the seat and infotainment system accordingly.

Nevertheless, the current affective solutions provided by vehicle interiors focus on human emotions such as anger or excitement, which are intuitive and straightforward emotions and sensations expressed by users. However, there are limitations to studies that encompass users’ complicated feelings and define users’ affective sensations felt within the vehicle. For example, when users are provided with a welcome light after opening the door, the instant emotion aroused from it is surprise, while the affective sensation delivered to users is a thoughtful and considerable impression. Therefore, it is necessary to identify hidden sensations of users within the scope of future vehicles and define the affective role of future vehicle interiors by organizing observed sensations.

This study aims to define the affective role of future vehicle interiors from users’ expectations for the innovative future autonomous vehicles. To gather the insights, we designed focus groups among people with similar vehicle usage purposes and gathered data on expected affective roles of future vehicle’s interior space through interviews. Then, we performed a content analysis of the gathered information to identify the affective role of the future vehicle interior. We expect this study to provide a framework for future research on automotive affective computing solutions in line with the current innovations in the automobile industry. Thus, the study results could provide a foundation of primary data for affective interior design and apply to an emotional evaluation scale in evaluating future design proposals. Lastly, the study is expected to support more satisfactory user experiences in developing an affective vehicle interior.

2 METHODS

2.1 Participants

As shown in Table 1, thirty-one participants were recruited through the institution’s mailing list and our final sample included ten focus groups of 14 males and 17 females. As the main focus of the study is to understand user perceptions and consumer demands for future vehicles, we recruited people in their 20s who were familiar with high technology devices and services (mean of all participants’ age = 28.23; standard deviation of all participants’ age = 3.59).

As user sensation changes significantly depending on vehicle ownership, we classified groups accordingly [13]. We recruited various college students who are interested in cars but have not yet owned a vehicle (G1), rented a car (G2), inherited (G3), and purchased and used a pre-owned car (G4). Furthermore, we included interviews with users with overseas driving experience (G5, G6). Since the user experience of vehicles is influenced by the culture, we expected to overcome the limitations of the study set up as this interview was conducted mainly with Korean participants [6]. Moreover, we recruited participants closely related to the automotive industry: graduate students working on car-related projects (G7) and project managers of the car industry (G8). Furthermore, we also invited experts from other industries (G9) to hear different opinions on the current trend of future vehicles. Lastly, we recruited users who mostly use a vehicle with their child (G10) to observe the purpose of using the vehicle while caring for other people.

• Ice breaking session (15min)
  – What kind of vehicle do you own (or can be purchased if you do not own it), and can you share some regrettable moments while driving the vehicle?
  – If you could attach new options to your current vehicle, which option would you want to add?
  – Or if you can buy a new vehicle which kind of car you want to purchase?

• Session 1. What if you were free to take your hands off the steering wheel? (30min)
  – Can you share if there was a moment when the driver had to keep their hand on the steering wheel?
  – If the advent of autonomous driving technology frees the hands of the driver, what kind of experience do you expect the vehicle to provide?

• Session 2. What if free communication becomes possible due to the blurring of the boundary between driver and passenger? (30min)
  – Can you share a moment that was disappointing in communication during the in-vehicle experience because the driver’s concentration on driving had to be considered first?
Table 1: Demographic data of focus groups (N=10) and its participants (N=31)

| Group | Description | Participants (gender: M for male, F for female, age) |
|-------|-------------|------------------------------------------------------|
| G1    | 20s college students have an interest in cars | P1.1 (M, 24), P1.2 (M, 23) |
| G2    | 20s office workers frequently using car-sharing service | P2.1 (F, 26), P2.2 (F, 25), P2.3 (M, 24), P2.4 (F, 29) |
| G3    | 20s students inherited their parents’ car | P3.1 (F, 27), P3.2 (F, 25), P3.3 (F, 29) |
| G4    | 20s students bought an used car | P4.1 (M, 29), P4.2 (F, 28) |
| G5    | 20s students have driving experience abroad (Kazakhstan and China) | P5.1 (F, 28), P5.2 (F, 28) |
| G6    | 20s students have driving experience in USA | P6.1 (F, 29), P6.2 (M, 29), P6.3 (M, 31) |
| G7    | 20s graduate students had project experience with car company | P7.1 (M, 32), P7.2 (F, 29), P7.3 (F, 29) |
| G8    | 20s office workers working in management team for car company | P8.1 (F, 29), P8.2 (M, 25), P8.3 (M, 29), P8.4 (M, 27) |
| G9    | 20s office workers working in management team (not car company) | P9.1 (M, 24), P9.2 (M, 27), P9.3 (M, 28), P9.4 (M, 30) |
| G10   | 30s working moms usually driving with their young toddler | P10.1 (F, 34), P10.2 (F, 38), P10.3 (F, 36), P10.4 (F, 35) |

- What kind of vehicle interior do you expect to be provided if it can be changed so that there is no problem with communicating inside the vehicle with the advent of autonomous driving technology?
- Session 3. What if the design restrictions on the interior of the vehicle were completely removed so that you could freely mount the options you want? (30min)
- Can you share a moment when it was inconvenient to have certain components attached to the vehicle in a certain space?
- Given that the interior components of a vehicle can be freely moved or changed, what kind of vehicle space do you think will be provided?
- Wrap-up session (15min)
  - (With showing the chat room with summarizing) The affective experiences that came out in today’s interview are as follows, could you tell me if there’s a topic that you’d like to discuss more?
  - Lastly, if you don’t have enough time or if there’s a topic you want to handle more don’t feel hesitate to share and after sharing final feedback, we’ll end the session.

2.2 Procedure

The interview was conducted via the online conference program Zoom due to the COVID-19 outbreak. The interview was divided into five stages: an opening and ice-breaking session, three main sessions, and a warp-up session. The entire session lasted about 2 hours. The opening session was the ice-breaking session that induced active communication among the interviewees by sharing participants’ understanding of the autonomous vehicle and their perceptions. The main sessions were structured into three major sessions about significant changes expected with autonomous vehicles: 1) Allows the driver to take their hands off the steering wheel, 2) Blurs the boundary between the driver and passengers and enables communication within the vehicle, 3) The design freedom for the interior space of the vehicle is significantly increased. Main sessions were composed of two main questions; 15 minutes was spent on each question. According to each question, we requested that participants use their imagination (Imagine the moments and summarize on the chat room) for 5 minutes, and share (Sharing the moments and providing similar situations to others) for 10 minutes to encourage participants to describe the future vehicle’s expected sentiments and demands during the interview. Finally, we wrapped up with the final interview. The reward provided to each participant was 30$. The detailed structure of the interview questions is as follows.

2.3 Data Analysis

We performed content analysis for data analysis. For the preprocessing of the data, all interview data were transcribed and transferred into 437 quotes. Two researchers collected similar quotes and clustered them into 232 factual levels. Next, they conducted open coding and divided the collected facts into two categories for closed coding: overcoming pain and expecting new experiences. Finally, researchers clustering of the collected facts was to support researchers in extracting affective roles. The initial code table was designed after rounds of discussion of mismatching codes from the results of the closed coding session. Finally, we invited two other researchers for an intercoder evaluation of the initial code table. We finalized the code table with the final themes, as shown in Table 2.

3 RESULTS

Users anticipate autonomous vehicle interiors to serve two main affective roles: advanced exclusiveness and advanced convenience. For advanced exclusiveness, the prominent affective roles are focused, stimulating, amused, and pleasant. For advanced convenience, the key affective roles are safe, comfortable, accommodated, and organized.

3.1 Role of Advanced Exclusiveness of Future Vehicle

3.1.1 Focused. Users expect to have focused sensibility from future vehicle. Participants reflected that the current role of experiencing focused sensation was solely on driving the vehicle. For this reason,
they expected to have a more safe and comfortable time enjoying the daily activity on the road within the autonomous vehicle in a more considered environment. For example, G2 and G9 anticipated having an office-like space within the vehicle where they could check e-mails and do simple work while commuting. In addition, almost all female participants expected to have a convenient and comfortable place to put on makeup. We observed that users would like a convenient and thoughtful place for routine activities or focus. Participants explained that the vehicle should understand user activities and provide and convey relevant sensations within the future vehicles. For example, G2 expressed that “I think it is most important to know what I am trying to do and gently guide me to do that activity naturally. I do not do it because I am too lazy to do it. After all, it is annoying” about the office-like environment. In addition, participants stated that they expect to feel treated and served by the vehicle as they experience the interior that provides a tailored and focused atmosphere by understanding the circumstances of the environment.

3.1.2 Stimulating. Users are hoping to have a more stimulating and personalized interior environment. The current user experience of achieving stimulating sensation from the vehicle interior is to purchase additional options on the vehicle by modifying premium car seats or upgrading to Hi-Fi audio. However, user responses to such additional options were similar to what is provided by the automotive OEMs (G1) or after-market purchases as it is too expensive (G3, G4). They expect to be accommodated with more freedom to personalize interior components and decorative devices within the future vehicle interior. G1 and G3 proposed vehicles that could replace vehicle devices with expensive options in the future, while G8 proposed replaceable vehicle seats. G8 expressed in the interview that “I may be able to stylize the interior to my personal taste. For example, if I replace seats with different designs, interior devices, and displays that change their moods and colors accordingly.” It explains a need for accommodation within the future vehicle with more automated stimulating options to provide personalized and explicit interior space.

3.1.3 Amused. Users expect the amusing role of vehicle interiors with greater customizability for its users. Participants mentioned that the entertainment experience of the current vehicle interior is limited to watching content or listening to music. On the other hand, G6 expected future vehicles to prove an immersive “theater-on-wheels” for long road trips. G10 hoped to have a shared video game studio with friends after giving children a ride to school. Especially when G10 explained about the video game studio, they stated that “After sending the children to school, there is a bit of time left, and in the meantime, it would be nice to invite other parents to play games together. So it is to provide a mingle place with fun activities or contents to enjoy.” Furthermore, it explains that the vehicle will be remembered as a unique space that allows users to share pleasant and enjoyable activities with others.

3.1.4 Pleasant. Users expect a more pleasant emotional experience with advanced technology from future vehicles. With autonomous driving technology, users can enjoy the scenery on the road; thus, interactivity with the the outside and the sensation of openness within the vehicle would be more critical. For example, G3 expected to see the night sky on a gloomy day. G7 hoped to see the sky on a rainy day while driving. Similarly, G5 and G6 suggested the interior space where they could observe aurora or star lights from the autonomous vehicle. Finally, G11 suggested a system to communicate easily with other vehicles on the road. Many participants collectively illustrated glass-like interiors or open spaces that assisted the openness sensation achieved from enjoying the scenery, which is a luxurious experience as it is similar to a chauffeured vehicle. They also described that enjoying swift moving on the autonomous vehicle would provide different sensations as users will enjoy different activities inside the vehicle rather than focusing on driving.

| Theme     | Code       | Description                                                                 |
|-----------|------------|-----------------------------------------------------------------------------|
| Exclusiveness | Focused (23) | Users would like a convenient and thoughtful place for routine activities or focus |
| Stimulating (21) |            | Users need for more personalized and explicit interior space                  |
| Amused (24) |            | Users recognize as a unique space that makes enjoyable and amenable to share pleasant activities with others |
| Pleasant (21) |            | Users expect experience to be akin to chauffeured vehicle                     |
| Convenience | Safe (11)  | Users expect safe and protected sensation inside future vehicle.              |
|           | Comfortable (46) | Users expect future vehicle interiors to deliver caring emotional, personalized services, and reliable solutions |
|           | Accommodated (33) | Users expect to have an accurate and immediate understanding of vehicle status and information |
|           | Organized (52) | Users expect to future vehicles to provide efficient and customizable space   |

Table 2: Final themes and affection codes
3.2 Role of Advanced Convenience of Future Vehicle

3.2.1 Safe. Users expect to have future vehicles communicate the feeling of safety within the autonomous vehicle. During the interview, many participants expressed that drivers and passengers would feel uncomfortable as they have less control and focus on driving with autonomous vehicles. As they feel more alerted and cautious with the actual driving situation from the current vehicle experiences, they would like to feel similarly secure within the future vehicle. G2 responded to feeling secure inside the future vehicle as “If you use an autonomous vehicle, you will hardly care about the road situation, but I think it will be essential to feel safe and secure in the future vehicle. Moreover, I would be more surprised if I am not prepared for accidental moments like sudden breaks or interruptions from other cars.” It implies that continuously delivering a safe and protected sensation inside the future vehicle is critical. G2 also discussed possible solutions for conveying a sense of safety in future vehicles. They explained, “So I think it will be very important for the vehicle to quickly and accurately judge the moment in advance and guide it immediately. Then I think I’ll be able to trust the car when I ride it, so I’ll always want to ride this car.” Their comments imply that accurate and advent notification of any accidental circumstances is critical. Delivering a continuous sensation of feeling safe and secure with responsive notification of any accidental circumstances would provide more trust in the vehicle system.

3.2.2 Comfortable. Users expect to have comfortable and convenient space in future vehicles. Current vehicles are designed with ergonomics and safety regulations tuned to driven cars. For future vehicles, users expect to have space for resting comfortably (G10) and sleeping while the vehicle is running on the road (G2). In addition, users highlighted that future vehicle interior space should provide necessary convenience and a pleasant place. Additionally, G2 added that comfortable mattress-like seats might be helpful while commuting. G10 stated that convenient devices should aid babysitting. We found out from the interview that a future vehicle interior should deliver caring emotion, personalized services, and reliable solutions to users.

3.2.3 Accommodated. It is essential to have accommodated spatial experiences that are more personalized and tailored to users. During the interview, G6 described that “It feels like a future autonomous vehicle would be a personal salon with a private secretary as it provides necessary assistance tailored to my schedule, emotions, and driving style. Moreover, it would be more reliable and thoughtful if the vehicle provided personalized services from when I hop into the vehicle until I get out of it.” It points out that a caring and personalized vehicle experience is essential for future vehicles. Based on the interview results, users expect to have an accurate and immediate understanding of their status and information from future vehicle interiors. Furthermore, such an understanding of users implies that users hope to be served by the vehicle with more reliable and tailored services.

3.2.4 Organized. Users expect to have a space that provides convenience and easily manipulable aspects. Users feel that the vehicle’s space is limited compared with other personal living spaces or transportation systems. Current vehicles are packed with necessary components that their users manipulate, and such components are an inevitable necessity in the interior space. Users expect to have more space with the future vehicle as electrification and the autonomous driving system eliminates the required components previously required. This change will provide more organizable space for users and supports various purposes. In addition, users expect more compatibility of the vehicle interior space for their usage. From the interview, G3 responded, “I bought an electric car because it was roomier and taller than other vehicles. Frequently, I am packed with many things in my car. Then, if the car is not tall enough, it looks stuffed and squashed. I cannot even check cars behind me. For this reason, I would consider more room provided inside the vehicle and the efficiency of the interior space.” Providing efficient and manipulable space for users from future vehicles is essential even though the ultimate space is limited. In addition, conveying the sensation that users are in control of the space in its organization would be considered.

4 DISCUSSION

In this study, we defined the affective roles of autonomous vehicle interiors by collecting users’ emotional expectations from focus group interviews. This research has defined future autonomous vehicle interior space with four affective roles of exclusiveness and four affective roles of convenience.

Our study found two critical aspects - exclusiveness and convenience - similar to past research on future vehicle interior perceptions. William et al. argued that devices in future vehicles enhance interior acceptability and improve safe driving [18]. Their findings parallel our research, linking device perception with exclusiveness and convenience. More specifically, our study’s focused, stimulating, amusing, safe, comfortable, and accommodated roles were similar to previous studies. Previous research figured out the detailed factors such as intention, influence, fun, trust, facilitation, and expectancy are crucial in understanding autonomous vehicles’ acceptance [7, 15]. These resemblances in factors imply that people’s perception of the autonomous vehicle will likely affect their emotional response to the autonomous vehicle interior.

Previous studies found factors that shape users’ emotional experiences of autonomous vehicle interiors. Cha et al. identified six emotional perceptions tied to mobile device integration in vehicles [3]. Our research added two more factors, amusing and accommodating. These eight roles represent the emotional context of vehicle interiors, emphasizing spatial atmosphere of vehicle interior on device integration. Petterson’s study explored emotional experiences in autonomous vehicle interiors, listing nine roles: care, new-era, novel, social, free, relaxed, safe, comfortable, and efficient [14]. His roles mostly overlap with ours, the results of our study imply that accommodated aspects of autonomous driving should be considered when defining the emotional experiences caused by the future vehicle interior.

The affective roles we’ve identified can inform future vehicle interior design and vehicle concept direction. These roles can clarify the emotional appeal of a vehicle concept for specific target user groups. Moreover, they provide a metric for assessing the emotional value of existing products and discussing potential improvements,
enhancing the emotional experience in future vehicle interiors. By mapping current interiors against these eight affective roles, we can pinpoint areas of deficiency or needed improvement, guiding the direction of future design development.

5 CONCLUSION

This study uncovers the affective role of future vehicle interiors equipped with autonomous driving technology and advanced infotainment. Focus group interviews with 31 participants across 10 groups revealed novel affective roles rooted in the advanced exclusiveness and convenience of future vehicles. Eight affective roles were identified at the visceral level: focused, stimulating, amused, pleasant, safe, comfortable, accommodated, and organized. These findings enhance our understanding of future vehicle interior design, pinpointing elements that users value for a more enriching affective experience. We believe this study contributes to discussions on the affective design of autonomous vehicles, particularly regarding the development of concept directions focusing on affective aspects and their impact on user experience.

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