Written evidence submitted by Dr Kyungjoo Cha,
Bournemouth University (SDV0005)

Dr Cha is submitting this evidence to emphasise the broader implications from psychological factors for smart infrastructure and safety to better cater to Connected and Autonomous Vehicles' (CAVs) development and deployment.

Dr Cha's research within future mobility follows a human-centred design approach and provides insight into design considerations alongside developing innovative product concepts for CAVs by utilising affective scenarios and speculative design.

Executive summary

- A deeper understanding of human behaviours and possible emotional responses in a multi-layered context can help develop smarter and safer infrastructure for CAVs.
- Enabling communication between CAVs and non-automated vehicles is the key, particularly in controlling a handover between automated driving systems and drivers.
- Planning for emotion-triggered situations of road violation, CAVs' system malfunction and/or human errors, and emergency and occupant interruptions to vehicle operations will lead to the safer deployment of CAVs.

Inquiry topic: potential implications for infrastructure, both physical and digital

1. **Understanding psychological factors influencing automotive contexts is crucial to successfully developing and deploying connected and autonomous vehicles (CAVs).** It is imperative to focus on what may trigger either positive or negative emotions regarding automobiles to get deeper insights into future infrastructure for CAVs, considering the close link between human emotions and people's significant concerns or goals in a multi-layered context[12]. Possible concerns and potential

implications for the future should be understood within the complex automotive environment:

– in the context of controlling a handover between automated driving systems and drivers[3];

– in a transition period when non-automated and connected and autonomous vehicles will share the same road.

The study[4] of a broader range of affective automotive contexts suggests four considerations for future infrastructure as follows below.

2. **First, there is a need for a smart infrastructure that manages data about non-automated vehicles effectively.** Road violation is one of the most frequently appeared contexts that trigger drivers' negative emotions. This includes overtaking, insulting behaviour, being forced to give way, arguments and tailgating. In road violation, non-automated vehicles could be enabled to interrupt CAVs moving on a narrow road. The considerations of how the infrastructure can allow communication between CAVs and non-automated vehicles to deal with the situation and how ethical issues in data management and informed consent of violated non-automated vehicles can be resolved would have to be addressed.

3. **Second, complementary road infrastructure can be effective in the situation of CAVs' system malfunction and/or human errors.** A driver's emotion is influenced negatively by external environment conditions including road infrastructure (i.e., road signs, traffic lights, street lights, poor road surface, and poor road design).

    - In the event that a CAV on level 4 automation failed to update road maps at a junction, a system that either stopped the car safely or returned control to the driver, again safely, would have to be in place. However:
        - could the car be suddenly stopped?;
        - would the occupant be alerted for control handover?

    Negative emotions are also triggered by car hardware system malfunction and alerts. Decisions about who would be contacted in the event of a CAV system suddenly breaking down due to system malfunction or cyber hacking would have to be resolved.

- A complementary road infrastructure would be beneficial for people who are less capable or less confident in driving, such as poor night vision or a first-time driver. If an occupant failed to read traffic signage by accident on level 3 automation how well can the data be automatically transmitted to the relevant digital infrastructure, such as data centres and operational security? Improved data management of infrastructure and improved machine to machine communication for path prediction/detours would be crucial.

- In the event that the entire software system of a CAV malfunctions, due to being outside of the networked boundary (e.g. moved to another country), safeguards need to be in place. Both physical and digital infrastructure such as telecommunication, transportation, operational security and data centre networks need to be considered for data transmissions and protection between countries.

4. **Third, emergency situations on the road need to be communicated with relevant infrastructure.** Assuming all CAVs traffic automatically gives way for emergency vehicles such as ambulances or police cars, the possibility of enabling private emergencies being dealt with similarly should be investigated. The context of showing *generous driving behaviour on the road* such as getting help, giving way, and helping others are typical causes of positive emotions. However, if the human decision to show generous driving behaviour to others is not allowed, issues regarding personal emergency situations on the road might be problematic:

    a. how would CAVs be communicated to the relevant networks?;

    b. how would personal emergency situations be prioritised?;

c. what if someone abuses this network? and how can potential abuse be prevented?

Advanced Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication would be essential to cope with these situations. Furthermore, improved situational awareness through physical and behavioural information in individuals and credits/benefits to an occupant for generous driving behaviour on the road could help the situation.

5. **Lastly, a smart infrastructure that manages lane changes and recognises stationary traffic in particular situations can resolve the potential issue of heavy congestion**. According to the study[5], *driving landscape* such as seeing beautiful scenery is one of the contexts that trigger positive emotions on the road. However:

   a. what if CAVs encounter unexpected long queues at touristic spots due to idling by many CAVs so occupants can view scenery?;

   b. could a CAV overtake the other CAVs?;

   c. how can non-automated vehicles safely overtake those vehicles idling by choice?

   An advanced infrastructure can both manage potential heavy traffic at touristic spots and provide accurate arrival time to a destination to road users.

Inquiry topic: safety and perceptions of safety, including the relationship with other road users such as pedestrians, cyclists and conventionally driven vehicles;

6. Automotive context is deeply associated with social relationships between cars, other drivers, families and friends[6]. Fear and anger are typical emotions that relate to safety concerns. Thus, looking at contexts where other road users are involved and where emotional responses frequently occur could improve the safety of CAVs.

7. **First, considering how CAVs can monitor and manage inconsiderate behaviours of other road users is worthwhile.** Any behaviour that may be antisocial or anti-community, such as insulting behaviour, being forced to give way or tailgating, has a significant impact on driver's safety and the perception of the safety of people by triggering their negative emotions[7]. Moreover, safety is heavily related to unexpected and dangerous situations. One example would be related to the abrupt manoeuvring of the driver. In the context of CAVs, there could be major issues regarding how quickly an occupant in a CAV on level 3 automation could respond to a non-automated vehicle changing lanes suddenly. Support for an occupant's vehicle control with AI and deep learning systems to automatically adapt to changes can be beneficial to improve road safety.

8. **Second, the contexts of car accidents with CAVs in a transition period are expected to be thoroughly investigated to improve the safety of CAVs.** It has been confirmed by many studies[8] that CAVs are safer than conventionally driven cars as CAVs reduce the possibility of car accidents by eliminating human errors that can happened on the road. However, a car accident is still one of the leading causes that trigger negative emotions on the road. Assuming a transition period where vehicles with different levels of automation[9] share the same road, user safety should be considered with more caution. The relative responsibility, for example, in a situation where a CAV hits a pedestrian immediately after transitioning to the driver's control on level 3 automation, would have to be established. Object or pedestrian detection and controls must be improved and tested during the transition (V2V, V2I, V2P[10] etc.).

9. **Lastly, younger occupants' possible interruptions in control of CAVs need to be carefully investigated.** One context that triggers positive emotions is driving with a loved one, such as driving with family and friends. This may be the same within CAVs. When a CAV is on level 4, which does not require any human vehicle operation, it would be dangerous if a child accidentally pressed a control button, such as

changing the automation to level 3 while the adult occupant's attention was elsewhere or was asleep. Protocols must be in place when developing CAVs to improve occupants' safety. Highly advanced and personalised security by the primary occupant (i.e., fingerprint) could stop control error by accident, so it minimises potential risk in vehicle operations and improves occupant's safety.

Conclusion

We don't know precisely how the self-driving era will unfold nor how it will change our society until we experience it. So, potential implications must be understood from various humanistic reference points to address peoples' safety, risks and the influence of negative experiences - to provide a much safer and more pleasurable experience for CAVs.

August 2022

Endnotes

[1] Dewey, J. (1980). Art as experience. New York: G. P. Putnam's Sons.

[2] Desmet, P. & Hekkert, P. (2007). Framework of Product Experience. International Journal of Design, 1(1), 13-23.

[3] Miller, D., Sun, A., Johns, M., Ive, H., Sirkin, D., Aich, S. & Ju, W. (2015). Distraction Becomes Engagement in Automated Driving. Proceedings of the Human Factors and Ergonomics Society 59th Annual Meeting, 59 (1), 1676-1680.

[4] Cha, K. (2019) "Affective scenarios in automotive design: a human-centred approach towards understanding of emotional experience". PhD Thesis. Brunel University London, Department of Design.

[5] Cha, K. (2019) "Affective scenarios in automotive design: a human-centred approach towards understanding of emotional experience". PhD Thesis. Brunel University London, Department of Design.

[6] Sheller, M. (2004). Automotive Emotions. Theory, Culture & Society, 21(4-5), 221-242.

[7] Cha, K., Giacomin, J., Skrypchuk, L., Choi, Y. and Dyer, B. (2022) "What situations trigger intense emotions in automobiles?", in T. Ahram and R. Taiar (eds.), Human Interaction & Emerging Technologies: Artificial Intelligence & Future Applications, AHFE International. DOI: 10.54941/ahfe100862

[8] Nidhi, K., & Paddock, S. M. (2016). Driving to safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability? Santa Monica, CA: RAND Corp.

[9] SAE international. (2016). Taxonomy and definitions for terms related to driving automation systems for on road motor vehicles. SAE International,(J3016).

[10] Vehicle-to-Pedestrian (V2P)