

A HUMAN MACHINE INTERFACE SUGGESTED FROM NEUROSCIENTIFIC ANALYSIS OF HUMAN FACTOR

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ABSTRACT

Honda aims for zero traffic collision fatalities involving Honda motorcycles and automobiles globally by 2050. To realize a zero traffic-incident society, we need to minimize human driver errors. Improper processing of information should trigger human errors during driving, however, despite its importance for our society, neural mechanisms during driving that can lead to catastrophic traffic consequences remain unclear. To clarify these, we have researched the relationships among drivers' manipulation, gaze, and brain activation. In particular, we have focused on the human eye gaze because it is not only a passive input organ, but also reflects dynamic information processing in the brain. To investigate the human brain mechanisms involved in safe and secure driving, we scanned the human brain using functional magnetic resonance imaging (fMRI) while driving in an MRI-compatible driving-simulator. We introduce one of the experiments showing differential brain activation between safe drivers and control drivers manipulating a vehicle in ordinary traffic conditions. In this experiment, participants were healthy adults, and they manipulated the driving-simulator in the MRI scanner, while their

driving manipulation and gaze were monitored. The participants encountered risk factors in the driving scenarios. We extracted the difference in the brain activation at gazing some risks between the safe drivers and control drivers, then the differences in brain activity between safe drivers and others were found in the precuneus, V1, and SMA. Then we constructed a human-machine interface (HMI) that aimed to complement and enhance the cognitive processing which is necessary for safe driving. To verify the efficacy of our HMI, we conducted experiments by using driving-simulator composed of the front part of N-BOX(Honda) and 5 displays (65 inches), the original system. As a result, the suggested HMI could have effect on early noticing and avoiding high-risk object. It is possible, therefore, that general drivers began to drive more safely with a safe driver-inspired information processing assistance system. Our findings will help elaborate the specification of devices for ADAS and ADS.

INTRODUCTION

Traffic incidents are one of the critical causes of death worldwide approximately 1.3 million people lose their lives on the road. Traffic injuries lead to some serious losses not only to individuals and their families but also to nations as a whole. It is said that road traffic crashes cost most countries 3 % of their gross domestic product [1]. To serve people worldwide with the “joy of expanding their life’s potential”, Honda is having the effort to realize “zero traffic collision fatalities involving Honda motorcycles and automobiles globally by 2050.” That said, no matter how much we improve safety technologies for motorcycles and automobiles, these alone will not eliminate traffic collision fatalities completely. We need to work on making people’s driving behavior safe by eliminating human errors. Thus far, several studies examined the association between traffic collision fatalities and human errors and suggested that inattention such as failure to notice risky objects is a critical factor underlying them [2] [3] [4] [5]. In order to understand the underlying factors of human errors, the present study focused on the relationship between driving behaviors leading to human error and human brain activity. In previous studies, Oba et al. reported that frontoparietal control network activity positively correlated with better lane-keeping [6]. Schweizer et al. studied the tasks in which participants had to drive at simple or complex intersection. They found that in the complex condition, brain activation shifted from the posterior visuospatial attentional system to the frontal system related to multi-tasking and divided attention [7]. In this study, we focused on hard braking caused by the driver’s failure to notice high-risk as a human error. Our purpose is to propose a methodological instance for constructing a neuroscience-inspired driving support system while having two primary aims: 1) To investigate cognitive function related to safe and secure driving, especially noticing risky objects, from a neuroscientific point of view and 2) to ascertain the effects of prototyped HMI based on these neuroscientific findings.

NEUROSCIENTIFIC EXPERIMENT

Devices

In order to investigate the cognitive processes related to the safe and secure driving, a driving-simulator system (MRI compatible, shown in Figure 1) was used for experiment on fMRI (functional magnetic resonance imaging). The fMRI is the main non-invasive method used to research some cognition mechanisms from brain activation. All fMRI data were acquired with a Siemens Verio 3T MRI system (Siemens, Germany) located on the National Institutes for Quantum Science and Technology (QST). The manipulation part of the driving simulator consisted of an acceleration pedal and a braking pedal and a steering wheel (Driving System, CURRENT DESIGNS, USA) added two buttons input device (CURRENT DESIGNS, USA) as a turn signal. Participant's gaze was measured by the Live Track AV for fMRI (Cambridge Research Systems, UK).

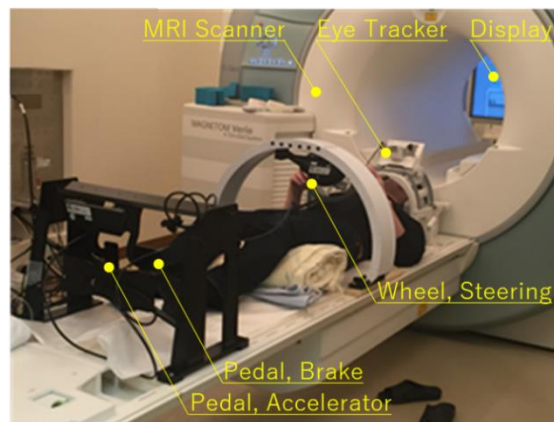


Figure 1. Overview of experimental driving-simulator composed of MRI-compatible manipulations and eye tracking device.

Procedure

The runs presented on the driving simulator were made by UC-win/Road (FORUM8 Co., Ltd., Japan). A run had some "blocks" composed of the preparing part that took about 5 seconds and the driving part that took about 30 seconds. In the preparing part, an instruction for changing lane such as "Right", "Left" or "Straight" was displayed and participant would be asked to follow the message shown in Figure 2(a). In the running part, participant drove at 40 km/h as initial velocity in some scenes which were modeled after some frequently road-accident areas in Japan. Figure 2(b) shows some samples of the scene used in this experiment. A traffic light located in the latter half of block was designed. There were three conditions about blocks in this experiment. First, in the target condition, participants were asked to change lane for right and stop at the traffic light. Second, in the dummy condition, they were required to change lane for left or right or go straight, sometimes not to stop at the traffic light. Third, the baseline condition which participants drove on no others in the scene was prepared.

A run had 8 target blocks, 6 dummy blocks and 3 baseline blocks that shown on the display randomly. In the target and dummy blocks, risky traffic objects were shown with slight difference (body color, velocity, type of car, etc.) in each block. Four runs were conducted per a participant, it took about 45 minutes totally including rest time as shown in Figure 3. Prior to commencing this experiment, all participants had a practical driving during about

5 minutes for getting used to manipulate this driving simulator in the MRI system.

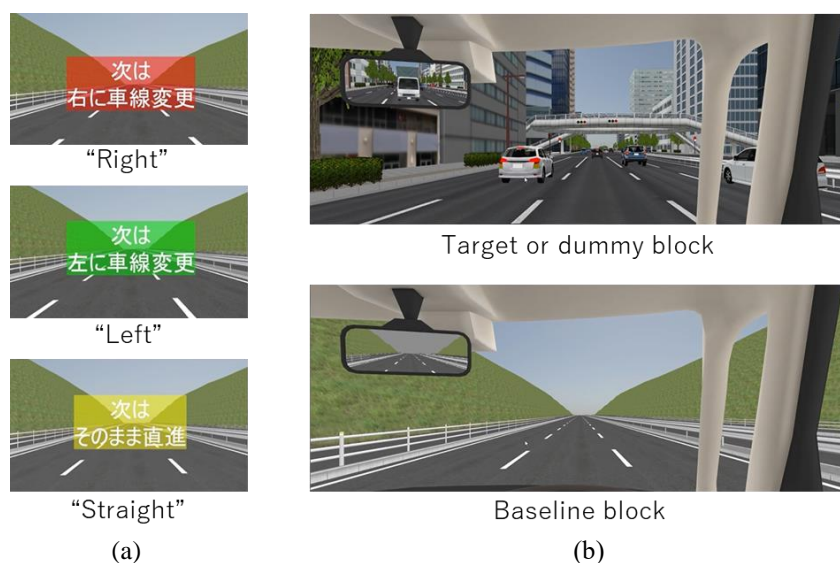


Figure 2. Contents used in the MRI experiment. (a) indication in the preparing part, (b) scenes shown in the driving part.

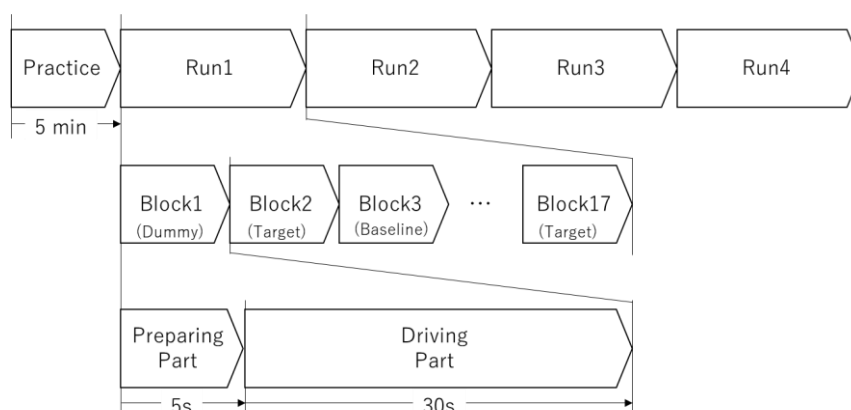


Figure 3. Schema of the MRI experiment protocol showing the timing and duration.

The MRI system was used to obtain T2*-weighted echo-planar imaging (repetition time [TR] = 1000 ms, echo time [TE] = 30 ms, slice number = 42 (interleaved), slice thickness = 4.0 mm, matrixes = 64 × 64, 600 volumes) with bold oxygen level-dependent (BOLD) contrasts and structural T1 image (TR = 2300 ms, TE = 1.98 ms, slice number = 176, slice thickness = 1 mm, matrixes = 512 × 512)

Participants

Fourteen healthy participants (mean age ± standard deviation, 37 ± 6 years) in this study were recruited from public and HONDA’s test drivers. All participants had no history of neurological and psychiatric disorders and were not taking any medication, had a driver’s license and were driving on a daily basis. Prior to the start of the experiment, all participants received an explanation of the contents and the risk of the experiment, their rights,

and voluntarily signed a participation agreement. This study was approved by the Ethical Committee of HONDA MOTOR CO., LTD., Japan and QST.

Analysis

The participants were divided into two groups based on their performance on the maximum magnitude of deceleration for stopping at the traffic light in the target blocks. The participants, who decelerated more moderately than the average, were assigned to the gentle braking group, and all others were assigned to the hard braking group. The mean maximum deceleration of the gentle braking group (mean age \pm standard deviation, 37 ± 6 years) was 2.5 ± 0.5 m/s² (mean \pm standard deviation), and 4.0 ± 0.4 m/s² for the hard braking group (37 ± 8 years).

We used SPM12 (The Wellcome Centre for Human Neuroimaging, UCL Queen Square Institute of Neurology, UK) software implemented in MATLAB (R2018b, Mathworks, USA) for preprocessing and statistical parametric mapping analysis. The preprocessing pipeline included realignment of the functional volumes, spatial normalization of the images to the Montreal Neurological Institute (MNI) space, and spatial smoothing using a 3D 8 mm full width at half maximum Gaussian kernel. We performed subject-level denoising using a regression model with the six motion parameters to eliminate head motion artifacts from the time course of the blood oxygenation level-dependent (BOLD) signal.

To extract cognitive process associated with attention for risk, we focused on brain activation at the moment to gaze the vehicle closing behind via right sideview mirror was adopted as the behavioral feature associated with attention for risk.

Result & Discussion

Figure 4 shows the differences between the gentle and hard braking groups in brain activity at the moment of gazing at risky object at the thresholds of uncorrected $p < .001$ at voxel level. The gentle braking group showed greater activations in the precuneus, SMA, and V1 than in the hard braking group. Several reports have shown that the precuneus is associated with cognitive functions such as episodic memory, visual imaging [8], and spatial judgement [9]. We speculate that these functions may play a role in linking cognition activities such as noticing risk objects, with motor execution, such as avoiding risky objects with smooth braking.

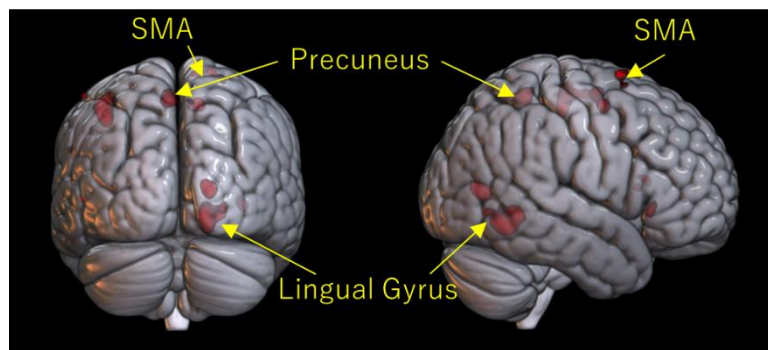


Figure 4. Significant brain activation on the contrast of the gentle braking group > the hard braking group at the threshold of uncorrected $p < .001$ at the voxel level.

A SUGGESTION OF HMI

According to this neuroscientific finding, we considered a specification of a head up display (HUD) as Human Machine Interface (HMI) for supporting the spatial cognition for early noticing then urging to avoid some risky objects as shown in Figure 5. Its outline was designed to assist the spatial cognition that was one of the precuneus' main function by showing overhead view centered on ego-car. Not to distract the participants' perception, ego-car and other running objects were represented by simple symbolic icons.

To establish whether this HMI's effectiveness that had a driver notice and then avoid risky objects on a road, the validation experiment was conducted by using a driving simulator. The experimental HUD (size: 116 mm x 49 mm) was created by the software (UC-win/Road) controlling the simulator and drawn on an area where a mass-produced HUD would be projected on an actual vehicle.

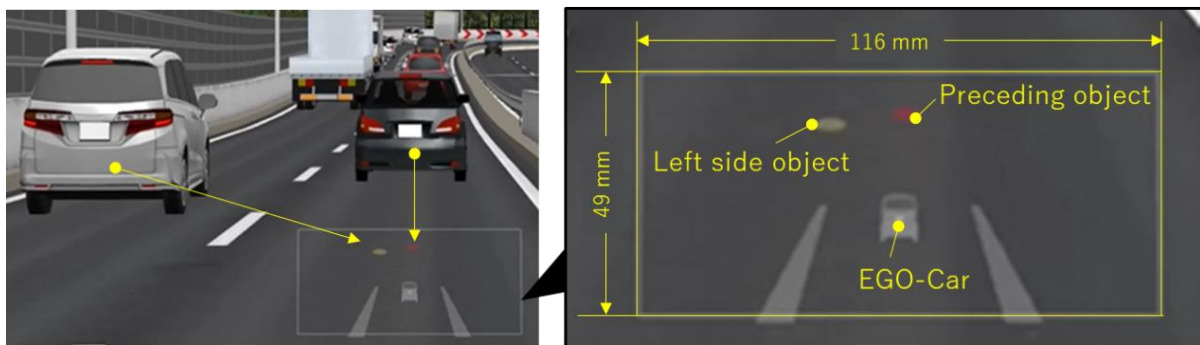


Figure 5. The experimental HUD drawn on the front display of the driving simulator.

HMI VERIFICATION EXPERIMENT

Devices

The driving simulator shown in Figure 6 used in this experiment to validate the suggested HMI was constructed originally based on a front half of an actual vehicle (N-BOX, Honda) with the driving simulator for training for safety driving [10] and the eye tracking system (Seeing Machines).

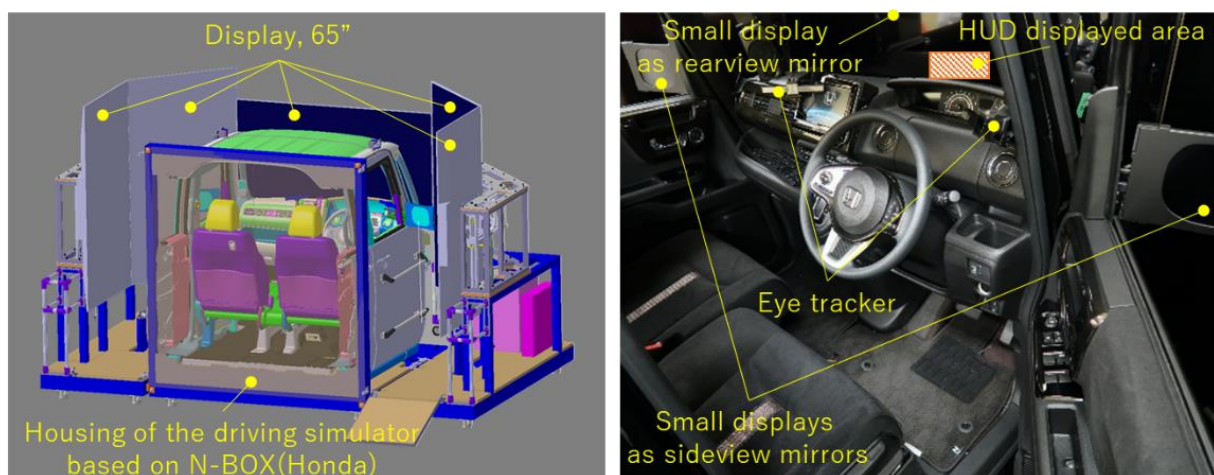


Figure 6. Overview of the prototyped driving simulator used in this experiment

Procedure

The Runs executed in this experiment were made by UC-win/Road. A run had 20 blocks, and each composed of the preparing part that took about 3 seconds and the driving part that took about 30 seconds. In the preparing part, two messages were set for, one was specifying direction of driving lane and the other was described “Follow the voice guidance” and either was displayed in the preparing part. In the case of former, an instruction for changing lane such as “Stay the lane” or “Change lane to right” was shown. In the other cases, a voice guidance message was spoken in the middle of the driving part such like “please stay the lane”. In any cases, participant would be asked to follow them. In the driving part, participant drove at 65 km/h as initial velocity in some scenes which were modeled after some parts of the Metropolitan Expressway in Japan.

In the target blocks, the vehicle overtaking on left lane intended to cut in the front of the car ahead was set as the risky object to notice and the car ahead was set as the risky to avoid.

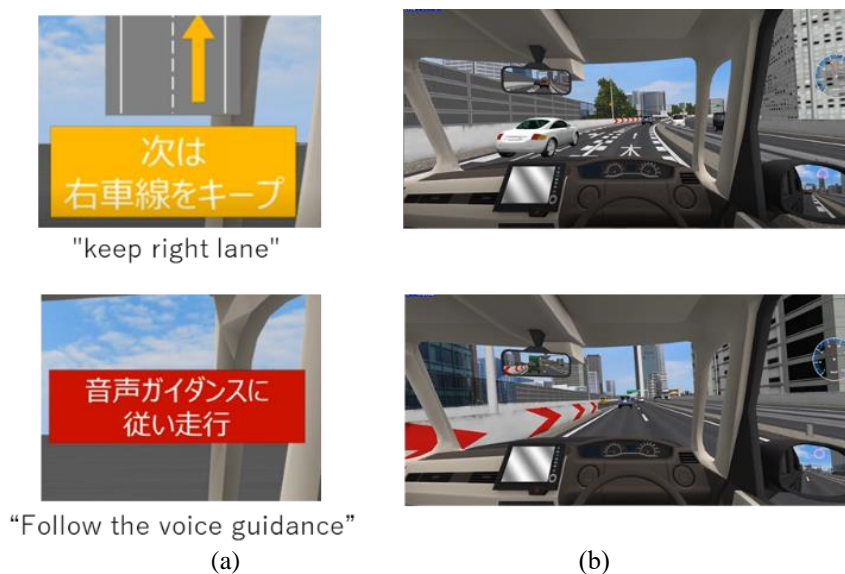


Figure 7. Contents used in the experiment for validation of the suggested HMI.
(a) indication in the preparing part, (b) sample of scenes shown in the driving part.

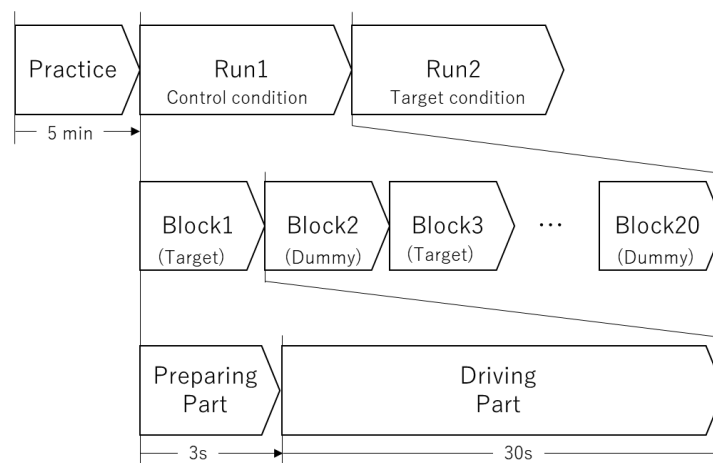


Figure 8. Schema of the experiment protocol for verification of HMI showing the timing and duration.
 A run had 7 target blocks and 13 dummy blocks shown on the display randomly and it took about 12 minutes.

Traffic objects were shown with slight difference (body color, velocity, type of car, etc.) in each block. Participants asked to drive with no assistant tools as the control condition, then with the HMI as the target condition. In order to familiarize participants with this simulator, they were asked to drive practically for about five minutes before the experiment began.

Participants

In this study, 16 healthy participants were recruited from public apart from MRI experiment, consisted of 4 from each 20's, 50's, 60's and 2 from each 20's, 40's, and the gender ratio was even. 13 individuals were cited for the analysis because of their gaze data availability. Prior to the start of the experiment, all participants received an explanation of the contents and the risk of the experiment, their rights, and voluntarily signed a participation agreement. This study was approved by the Ethical Committee of HONDA MOTOR CO., LTD., Japan.

Analysis

The performance of the early noticing the risky was measured by a time from the moment when the left running vehicle that would be the risky on side by side to when the driver's gazed the vehicle. The index of avoidance of the risky was set as an appearance probability of behaviors such as releasing the acceleration pedal or putting on the braking pedal, to avoid the risky before the ahead vehicle became too close. Wilcoxon signed-rank test was used to compare these values between the control condition and target condition. Data management and analysis were performed using the Statistics and Machine Learning Toolbox of MATLAB (2018b).

Result & Discussion

Figure 9 (a) shows a data of the average of latency gazing risky object, the median \pm standard deviation were 2.5 ± 0.3 seconds in the control, 2.3 ± 0.1 seconds in the target condition.

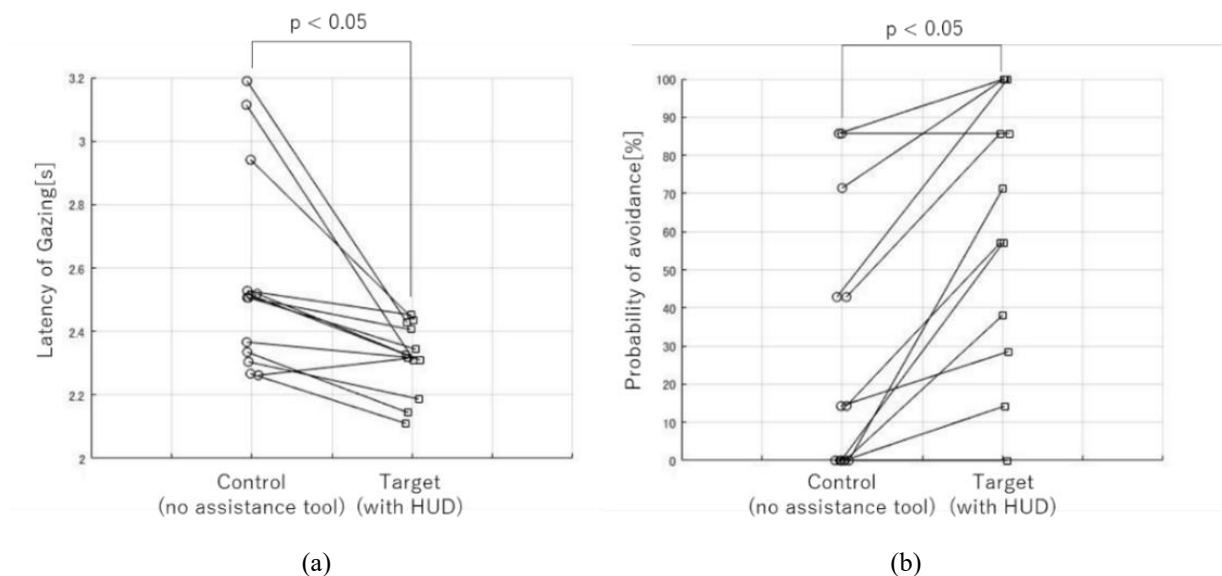


Figure 9. Results of verification on HMI suggested in this study

The difference between two conditions was significant ($p < .05$). The 12 participants out of 13 declined the

latency, we thought that the suggested HMI could have effect on early noticing risky objects. Figure 9 (b) indicates the probability of avoidance, 14.3 ± 34.2 % in the control and 56.8 ± 37.5 % in the target condition then there was a significant difference ($p < .05$). This result implies the HMI could have effect on avoiding risky objects. But three participants would not increase the probability unfortunately, especially the two were zero to zero despite of their latency improved. It seems that the two participants could notice the risky but could not come up with what action they did next by using information that displayed on the HUD.

LIMITATIONS

There were some limitations to this research. In particular, the MRI experiment required participants to lie down on the bed of MRI machine instead of sitting in a seat, an environment different from real-life driving. However, even with this limitation, it may be possible to examine some aspects of visual cognitive functions for traffic risk. The specification of the suggested HMI has contained only neuroscientific findings, but also other views of well-known knowledges. To evaluate only neuroscientific effects, well-targeted experiments are needed. There are some kinds of human errors, then just one of them such as “failure of noticing” was picked up in this study. For realizing our vision, other human errors should be dealt with, and further neuroscientific, psychophysics and praxeological validation would be needed for future.

CONCLUSION

This study investigated differences in brain activation between the gentle and hard braking groups at the moment of gazing at a risky object while driving. The results showed significantly increased precuneus, SMA, and V1 response in the gentle braking group (uncorrected $p < .001$). Then, an experimental HUD for supporting safe and secure driving designed according to these neuroscientific findings, especially precuneus’ main function of spatial cognition, by showing overhead view centered on ego-car. The suggested HMI was validated by participants recruited publicly, the risk detection time was significantly reduced ($p < .05$) and the probability of behavior for safety was increased ($p < .05$). These results might indicate that some drivers’ abilities for noticing and avoiding the risky object during driving were improved by showing the environment centered on ego-car on the suggested HMI which was made by utilizing neuroscientific findings. These findings were expected to be applied to consider and consolidate devices development for mass production.

REFERENCES

- [1] Road Traffic Injuries. (2022). World Health Organization.
<https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
- [2] Chen, C., Yiik, D.W., and Xuesong, W. (2017). Safety evaluation of driver cognitive failures and driving errors on right-turn filtering movement at signalized road intersections based on Fuzzy Cellular Automata (FCA) model.

Accident; Analysis and Prevention, 104(8):156-164

- [3] Thomas, A. (2008). *Driver Distraction: A Review of the Current State-of-Knowledge*. Washington, DC: National Highway Traffic Safety Administration.
- [4] Ruben, D. L., Silvana, A. M., Fernando, M. P., and Maria, F. L. (2010). Individual Differences in Driver Inattention: The Attention-Related Driving Errors Scale. *Traffic Injury Prevention*, 11:142–150
- [5] Klauer, S.G., Dingus, T. A., Neale, V. L., Sudweeks, J.D., and Ramsey, D.J. (2006) *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*. Washington, DC: National Highway Traffic Safety Administration.
- [6] Oba, K., Hamad, K., Tanabe-Ishibashi, A., Murase, F., Hirose, M., Kawashima, R., and Sugiura M. (2022). Neural Correlates Predicting Lane-Keeping and Hazard Detection: An fMRI Study Featuring a Pedestrian-Rich Simulator Environment. *Frontiers in Human Neuroscience*, Volume 16, Article 754379
- [7] Tom, A. S., Karen, K., Yuwen, H., Fred, T., Gary, N., and Simon, J.G. (2013). Brain activity during driving with distraction: an immersive fMRI study. *Frontiers in Human Neuroscience*, Volume 7, Article 53
- [8] Andrea, E. C., and Michel, R. T. (2006). The precuneus: a review of its functional anatomy and behavioural correlates. *Brain*, 129, 564-583
- [9] Chadwick, J. M., Jolly, E., Amos, P. D., Hassabis, D. and Spiers, J. H. (2015). A Goal Direction Signal in the Human Entorhinal/Subicular Region. *Current Biology*, 25, 87-92
- [10] Honda Begins Sales of All-new Automobile Driving Simulator Developed for Traffic Safety Education, (2010). <https://global.honda/newsroom/news/2010/c100302eng.html>