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Reducing Workload in Remote Bus Operation Environments through Field-of-View Design

Naoki Furugohri[1)] **Toshiyuki Sugimachi**[2)] **Toshiaki Sakurai**[2)] **Syuichi Yahagi**[2)]

Masaaki Onuki[3)] **Kimihiko Nakano**[3)] **Jongseong Gwak**[4)]

1)Tokyo City University Graduate School (1-28-1 Tamazutsumi, Setagaya-ku, Tokyo)
2)Tokyo City University (1-28-1 Tamazutsumi, Setagaya-ku, Tokyo)
3)Institute of Industrial Science, The University of Tokyo (4-6-1 Komaba, Meguro-ku, Tokyo)
4)Takushoku University (3-4-14 Kohinata, Bunkyo-ku, Tokyo)

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In this study, we focused on remote control as a means of complementing autonomous driving, which is expected to address the shortage of public bus drivers. As autonomous driving requires the vehicle to stop outside the Operational Design Domain (ODD), the use of remote control is considered as a backup. However, remote control presents challenges, including increased driver workload due to the lack of tactile feedback and video latency, as well as the need to monitor numerous mirrors specific to buses. Therefore, in this study, we developed a single-screen human–machine interface (HMI) that displays the necessary images within the driver's effective field of view and evaluated its effectiveness.

For the remote-control environment, the six-screen configuration displayed the front view, left and right rear-view mirrors, left and right under-view mirrors, and wide-angle mirror views individually on six 24.5-inch monitors. The remote-control environment with the six-screen configuration is shown in Fig . 1. while the single-screen configuration integrated these six views into a single 32-inch monitor. The remote-control station with the single-screen configuration is shown in Fig . 2. In both setups, a 200 ms video delay was simulated by displaying the DS video via a webcam and an external PC. The single-screen system was designed to minimize eye movement, considering that the effective human field of view extends 35° to the left and right of the central field of view.

In the experiment, nine male participants aged 48–75 who held heavy vehicle licenses were asked to drive a course simulating urban conditions, including straight sections and left and right curves, under two conditions: the six-screen configuration and the single-screen configuration. The evaluation metrics used were Mean Lateral Position (MLP), Standard Deviation of Lateral Position (SDLP), composite jerk, subjective evaluation, NASA-TLX, and saccade occurrence rate.

The results exhibited that, with the single-screen condition, the absolute value of MLP decreased overall, with a significant reduction of 0.33 m observed particularly during right-hand curves. Furthermore, composite jerk decreased across all sections, confirming a trend towards smoother steering. On the other hand, SDLP increased in some sections, indicating a tendency for increased lateral fluctuation.

In the subjective evaluation, the single-screen layout exhibited a significant improvement in ease of driving, and a tendency towards increased relaxation. Furthermore, mental workload exhibited a downward trend. The results of mental workload are shown in Fig . 3.and the saccade rate decreased across all sections. These results suggest that the single-screen layout facilitates the acquisition of necessary information while suppressing the frequency of eye movements, thereby potentially contributing to a reduction in driving load and an improvement in ease of driving.

In summary, the single-screen layout based on the effective field of view was shown to be potentially effective compared to the six-screen layout in terms of ease of correcting driving position, smoothness of maneuvering, subjective ease of driving, reduction of workload, and reduction of eye movements. As a reduction in the absolute value of MLP and a decrease in composite jerk were confirmed, it indicates that the single-panel layout facilitates driving along the center of the lane, enabling smoother maneuvering. Furthermore, improvements in driving ease in the subjective evaluation, a downward trend in the NASA-TLX, and a decrease in the saccade occurrence rate suggest that the ability to efficiently acquire necessary information within the effective field of view may have led to a reduction in gaze movement frequency and a reduction in driving workload.

On the other hand, SDLP increased in some sections, and indicated greater variability in lane position with the single-screen layout. This may be attributed to an increase in minor corrective steering maneuvers, as it became easier to continuously monitor deviations in lane position within the effective field of view. Consequently, while the single-screen layout contributes to suppressing lane position deviation and ensuring smooth handling, further consideration is required from the perspective of steering stability. Future work should include validation in more complex traffic environments, including pedestrians and other vehicles, as well as under driving conditions where the frequency of checking the mirror image increases. Furthermore, through detailed analysis of gaze position and fixation targets, it is necessary to further clarify the impact of the single-screen layout on driving behaviors.

Fig .1 Six-screen type

Fig .2 Single-screen type

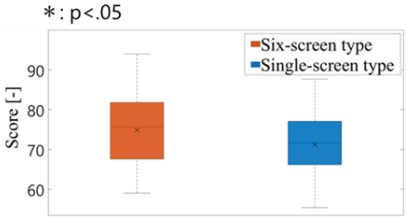

Fig .3 Results of NASA TLX