EEG gamma-band synchrony predicts driving performance

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The performance of vehicle driving, especially that under the critical conditions, is affected by individual differences in various cognitive components such as visuospatial processing ability, working memory capacity or multitask/task-switching capabilities. In the current study, we focused on the relationship between general mental visuospatial processing ability and the driving performance under such condition where driver's view is severely limited, the one we experience during driving in a heavy rain.

The results from our previous study indicate that the event-related changes in the gamma-band (30 Hz) power (event-related synchronization: ERS) in the parietal and the frontal area as measured by EEG recording during the mental rotation task are significantly correlated with the behavioral performance of the task (Nishimura et al., 2020). In this study, we tested whether ERS measures recorded during the mental rotation task, which reflects individual performance in manipulating mental imagery in the 3-D space, can be used for an indicator to predict driving performance while driving in the simulated environment where driver's view is parametrically controlled.

Nineteen subjects participated in the study. Each subject performed both the Shepard & Metzler type mental rotation task in the EEG lab and the driving task using the driving simulator. During the driving task, the visual occlusion method (Senders et al, 1967), in which subject's view was periodically blanked out (occlusion) to control the demands required to perform the driving by parametrically changing the duration of the occlusion, was used to mimic the real world driving under poor visibility condition. In the current experiment, occlusion rate was set to either 0 (no occlusion), 20, 40, 60, or 80 % (most difficult). The driving performance was measured by the standard deviation of lateral position (SDLP) which indicates robustness in lane keeping while driving.

Figure 1 shows the individual driving performance. The subjects' performance in lane keeping rapidly degraded as the occlusion rate exceeds 40 %.

The results of the correlation analyses at the occlusion rate of 40 % are shown in Figure 2. The results showed that there was significant negative correlation between 30 Hz gamma-band power measured at the superior parietal and the frontal EEG electrodes during the mental rotation task in the EEG lab and the SDLP measured during the driving simulation under low visibility condition (Figure 1).

Since the gamma-band ERS in the fronto-parietal regions during the mental rotation task is often interpreted as a successful visuospatial processing in the mental image manipulation, the current results suggest that the ability to process mental imagery in the 3-D space plays an important role in keeping adequate driving performance under lower visibility conditions. The results also imply that the EEG measures obtained during the offline cognitive task could be used to predict individual differences in driving performance in realistic situations.

Acknowledgments

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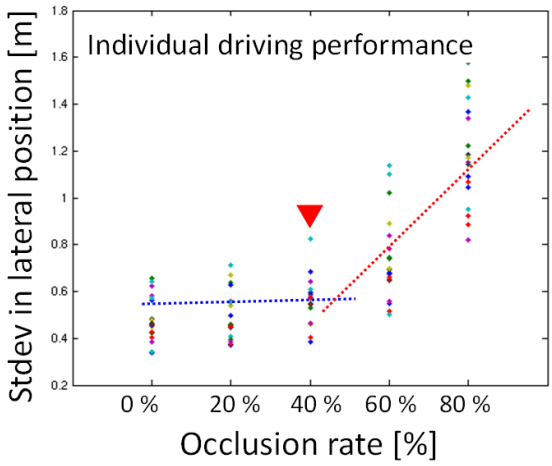

Fig. 1 The individual driving performance as measured by the standard deviation of lateral position (SDLP). The performance degraded rapidly as the occlusion rate exceeds 40 %.

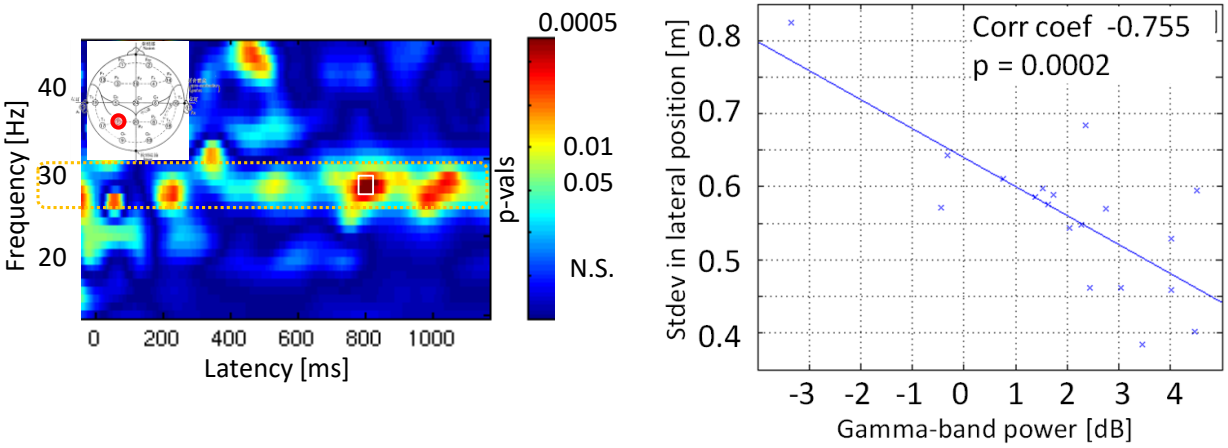

Fig. 2 The results of the correlation analyses between event-related gamma-band power recorded at the parietal electrode and the SDLP at the occlusion rate of 40 %.

References:

Nishimura K., Aoki T., Inagawa M., Tobinaga Y., Iwaki S. (2020) Mental rotation ability and spontaneous brain activity: a magnetoencephalography study, Neuroreport, 31: 999-1005.

Senders J.W., Kristofferson A.B., Levison W.H., Dietrich C.W., Ward J.L. (1967) The attentional demand of automobile driving, Highway Research Record, 195: 15-32.